23 January 2014

DOCUMENT
AC/326-D(2014)0001

CNAD AMMUNITION SAFETY GROUP (AC/326)

Request for Approval

STANAG 4675/1

AOP-62 Ed(A) V1, -63 Ed(A) V1 and -64 Ed(A) V1

Note by the Secretary

References: (a) AC/326(SG/B)DS(2013)0002 (PFP), dated 2 December 2013
AC/326(SG/A)DS(2013)0002 (PFP), dated 2 December 2013
(b) AC/326-N(2013)0002, dated 20 December 2013

1. With the notice at Reference (b) and in accordance with the Sub-group A and Sub-group B members' decision (Ref (a)), STANAG 4675, AOP-62, -63 and -64 were submitted for approval by the AC/326. These publications, which are available on the DI portal, are enclosed for your convenience.

2. As per Reference (b), unless I hear by AC/326 delegates by 31 January 2014, the documents will be considered approved and will be processed further with the NSA.

(Signed) I. ROUFFIGNON-DRISCOLL

Action Officer: Isabelle Rouffignon-Driscoll, x3942
Original: English

STANDARDIZATION AGREEMENT

ACCORD DE NORMALISATION

STANAG 4675

IN-SERVICE SURVEILLANCE (ISS) OF NON NUCLEAR MUNITIONS

SUIVI EN SERVICE DES MUNITIONS NON NUCLÉAIRES

EDITION 1/ÉDITION 1

October/Octobre 2012

NORTH ATLANTIC TREATY ORGANIZATION

ORGANISATION DU TRAITÉ DE L'ATLANTIQUE NORD

Published by
THE NATO STANDARDIZATION AGENCY (NSA)

Publié par
L'AGENCE OTAN DE NORMALISATION (AON)

Date xxx

STANAG 4675
Edition/Édition 1

LETTER OF PROMULGATION

STATEMENT

The enclosed NATO Standardization Agreement (STANAG), which has been ratified by member Nations, as reflected in the NATO Standardization Documentation Database (NSDD), is promulgated herewith.

IMPLEMENTATION

This STANAG is effective upon receipt and ready to be used by the implementing Nations and NATO bodies.

The partner Nations are invited to adopt this STANAG.

SUPERSEDED DOCUMENTS

None

ACTIONS BY NATIONS

Nations are invited to examine their ratification of the STANAG and, if they have not already done so, advise the NSA of their intention regarding its implementation.

Nations are requested to provide to the NSA their actual STANAG implementation details.

SECURITY CLASSIFICATION

This STANAG is a non-classified NATO publication.

RESTRICTION TO REPRODUCTION

LETTRE DE PROMULGATION

DÉCLARATION

L'accord de normalisation OTAN (STANAG) ci-joint, qui a été ratifié par les pays membres dans les conditions figurant dans la Base de données des documents de normalisation OTAN (NSDD), est promulgué par la présente.

MISE EN APPLICATION

Ce STANAG entre en vigueur dès réception et est prêt à être mis en application par les pays et les organismes OTAN d'exécution.

Les pays partenaires sont invités à adopter ce STANAG.

DOCUMENTS ANNULÉS ET REMPLACÉS

Néant

MESURES À PRENDRE PAR LES PAYS

Les pays sont invités à examiner l'état d'avancement de la ratification du STANAG et d'informer, s'ils ne l'ont pas encore fait, l'AON de leur intention concernant sa mise en application.

Les pays sont priés de fournir à l'AON des informations détaillées sur la mise en application effective de ce STANAG.

CLASSIFICATION DE SÉCURITÉ

Ce STANAG est un document OTAN non classifié.

RESTRICTION CONCERNANT LA REPRODUCTION

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Cihangir AKSIT, TUR Civ

Director, NATO Standardization Agency

Cihangir AKSIT, TUR Civ.

Directeur de l'Agence OTAN de normalisation

Signature

STANAG 4675 Edition/Édition 1

IN-SERVICE SURVEILLANCE (ISS) OF NON NUCLEAR MUNITIONS

AIM

The aim of this agreement is to standardize the methods for in service surveillance of non-nuclear munitions. This standard will cover test and assessment methods, selection of surveillance assets and methods for determining life. Although reliability and performance are discussed this standard assumes that the primary criterion for limiting munitions life is safety.

INTEROPERABILITY REQUIREMENTS

To enable nations to conduct joint in-service surveillance programmes of munitions.

AGREEMENT

Ratifying nations agree to follow the guidance given in AOP62, AOP63 and AOP64, when assessing the safety and reliability of munitions in service. Ratifying nations also agree to provide on demand the relevant safety and reliability information indicated in AOP62, AOP63 and AOP64 when transferring munitions to other NATO nations.

Participating Nations agree to implement the following standards.

SUIVI EN SERVICE (ISS) DES MUNITIONS NON NUCLÉAIRES

BUT

Le présent accord de normalisation OTAN (STANAG) a pour but de normaliser les méthodes de suivi en service des munitions non nucléaires. Cette norme porte sur les méthodes d'essai et d'évaluation, le choix des moyens de suivi et les méthodes permettant de déterminer la durée de vie. Bien que les critères de fiabilité et de performance soient abordés, la présente norme part du principe que le critère essentiel pour limiter la durée de vie des munitions est celui de la sécurité.

EXIGENCES D'INTEROPERABILITÉ

Permettre aux pays de mener des programmes communs de suivi en service des munitions.

ACCORD

Les pays qui ratifient conviennent de suivre les directives données dans l'AOP-62, l'AOP-63 et l'AOP-64 pour ce qui est d'évaluer la sécurité et la fiabilité des munitions en service. Ils conviennent également de communiquer sur demande les informations pertinentes relatives à la sécurité et à la fiabilité dont il est question dans les AOP-62, AOP-63 et AOP-64 lors du transfert de munitions à d'autres pays de l'OTAN.

Les pays participants conviennent de mettre en application les normes suivantes.

STANDARDS

AOP 62 – In Service Surveillance of Non-nuclear Munitions - General Guidance

AOP 63 – In Service Surveillance of Non-nuclear Munitions - Sampling and Test Procedures

AOP 64 – In Service Surveillance of Non-nuclear Munitions - Condition Monitoring of Energetic Materials

NORMES

AOP-62 – Surveillance des munitions non nucléaires en cours d'utilisation opérationnelle – Directives générales

AOP-63 – Surveillance des munitions non nucléaires en cours d'utilisation opérationnelle – Procédures de prélèvement et d'essai

AOP-64 – Surveillance des munitions non nucléaires en cours d'utilisation opérationnelle – Contrôle de l'état de fonctionnement des matériaux énergétiques

OTHER RELATED DOCUMENTS

AOP 38 – Specialist Glossary of Terms and Definitions on Ammunition Safety

AUTRES DOCUMENTS CONNEXES

AOP-38 - Glossaire de termes et définitions sur la sécurité et l'aptitude au service des munitions, matières explosives et produits associés.

NATIONAL DECISIONS

The national decisions regarding the ratification and implementation of this STANAG are provided to the NSA.

The national responses are recorded in the NATO Standardization Document Database (NSDD).

DÉCISIONS NATIONALES

Les décisions nationales concernant la ratification et la mise en application du présent STANAG sont communiquées à l'AON.

Les réponses nationales sont consignées dans la Base de données des documents de normalisation OTAN (NSDD).

IMPLEMENTATION OF THE AGREEMENT

Implicit in a discussion of the acceptability of a safety level is an understanding of risk. Risk may be assessed as the combined result of the likelihood of occurrence of a hazardous condition, the subsequent likelihood of occurrence of a mishap (given that the hazard exists), and the severity of the repercussions of the mishap on personnel, materiel, and the environment.

The AOPs covered by this STANAG are as follows:

AOP 62 – In Service Surveillance of Non-nuclear Munitions - General Guidance
AOP 63 – In Service Surveillance of Non-nuclear Munitions - Sampling and Test Procedures
AOP 64 – In Service Surveillance of Non-nuclear Munitions - Condition Monitoring of Energetic Materials.

AOP 62, In Service Surveillance of Non-Nuclear Munitions - General Guidance

This AOP and its annexes provide basic guidance on ISS including, why it is necessary, when it should be implemented and the key personnel and documentation required. This AOP will also cover the association between ISS and maintenance, the different requirements for safety and reliability and will also provide basic guidance regarding the use of environmental data loggers.

Operational Imperative statement: This document is relevant to programme managers and service personnel who require information on surveillance and need basic guidance on planning a surveillance programme.

MISE EN APPLICATION DE L’ACCORD

Dans toute discussion sur l'acceptabilité d'un niveau de sécurité, la notion de risque est implicite. Le risque peut être évalué comme étant le résultat combiné de la probabilité d'occurrence d'une situation dangereuse, de la probabilité d'occurrence d'un accident qui peut en découler (si on considère que le danger existe) et de la gravité des conséquences de l'accident sur le personnel, les équipements, et l'environnement.

Les AOP couvertes par le présent STANAG sont les suivantes :

AOP-62 – Surveillance des munitions non nucléaires en cours d’utilisation opérationnelle – Directives générales
AOP-63 – Surveillance des munitions non nucléaires en cours d’utilisation opérationnelle – Procédures de prélèvement et d’essai
AOP-64 – Surveillance des munitions non nucléaires en cours d’utilisation opérationnelle – Contrôle de l’état de fonctionnement des matériaux énergétiques

AOP-62 – Surveillance des munitions non nucléaires en cours d’utilisation opérationnelle – Directives générales

Cette AOP et ses annexes donnent des directives de base concernant le suivi en service et expliquent notamment pourquoi il est nécessaire, quand il devrait être mis en œuvre, et quels sont les éléments clés nécessaires au niveau du personnel et de la documentation. Cette AOP porte également sur le lien entre ISS et maintenance, les différentes exigences relatives à la sécurité et à la fiabilité, et elle donne aussi des directives de base pour l’utilisation d’enregistreurs de données environnementales.

Énoncé de l’impératif opérationnel : ce document est destiné aux gestionnaires de programmes et aux militaires qui ont besoin d’informations concernant la surveillance et de directives de base sur la planification d’un programme de suivi.

AOP 63, In Service Surveillance of Non-Nuclear Munitions - Sampling and Test Procedures

This AOP provides guidance for selecting test items that adequately represent the whole population to be assessed. The document discusses the relative merits of probabilistic and non-probabilistic sample selection and suggests how to determine when to remove samples for testing. This part also indicates where predictive testing shall be required and how the testing requirements can be determined.

Operational Imperative statement: This document is relevant to anyone wishing to define the sampling techniques for surveillance or estimate the resources required for a surveillance program.

AOP 64, In Service Surveillance of Non-Nuclear Munitions - Condition Monitoring

This AOP provides guidance for the procedures required to assess continued or extended service use of an item. This includes the essential chemical and mechanical degradation modes of energetic materials that should be measured; this also includes examples of ISS condition monitoring programmes performed by different nations.

Operational Imperative Statement: This document is relevant to scientists or engineers looking for guidance on test procedures and for program managers wishing guidance on defining minimum inspection standards for service munitions.

Nations are invited to report on their effective implementation of the STANAG using the form at Annex H to AAP-03(J).

Partner Nations are invited to report on the adoption of the STANAG using the form at Annex G to AAP-03(J).

AOP-63 – Surveillance des munitions non nucléaires en cours d'utilisation opérationnelle – Procédures de prélèvement et d'essai

Cette AOP donne des directives concernant la sélection d'éléments bien représentatifs de l'ensemble de la population à évaluer. Elle examine les avantages relatifs d'une sélection probabiliste et non probabiliste d'échantillons et suggère des méthodes permettant de déterminer quand prélever des échantillons à tester. Cette partie précise aussi quand des essais prédictifs seront nécessaires et comment déterminer les exigences en matière d'essais.

Énoncé de l'impératif opérationnel : ce document est destiné aux personnes souhaitant définir les techniques de prélèvement pour le suivi ou évaluer les ressources nécessaires pour un programme de suivi.

AOP-64 – Surveillance des munitions non nucléaires en cours d'utilisation opérationnelle – Contrôle de l'état de fonctionnement des matériaux énergétiques

Cette AOP donne des directives concernant les procédures requises pour évaluer l'utilisation continue ou prolongée d'un élément en service. Il s'agit notamment des principaux modes de mesure de la dégradation chimique et mécanique des matériaux énergétiques. On y trouve aussi des exemples de programmes de contrôle de l'état de fonctionnement menés par différents pays au titre de l'ISS.

Énoncé de l'impératif opérationnel : ce document est destiné aux scientifiques ou aux ingénieurs ayant besoin de directives concernant les procédures d'essai et aux gestionnaires de programmes souhaitant obtenir des directives sur la définition de normes d'inspection minimum pour les munitions en service.

Les pays sont invités à rendre compte de la mise en application effective du présent accord au moyen du formulaire figurant à l'Annexe H à l'AAP-03(J).

Les pays partenaires sont invités à rendre compte de l'adoption du présent STANAG au moyen du formulaire figurant à l'Annexe G à l'AAP-03(J).

REVIEW

This STANAG is to be reviewed at least once every three years. The result of the review is recorded within the NSDD.

Nations and NATO Bodies may propose changes, at any time, through a standardization proposal to the tasking authority (TA), where the changes will be processed during the review of the STANAG.

RÉEXAMEN

Le présent STANAG doit être réexaminé au moins une fois tous les trois ans. Le résultat de ce réexamen est consigné dans la NSDD.

Les pays et les organismes OTAN peuvent, à tout moment, proposer des modifications en soumettant une proposition de normalisation à l'autorité de tutelle (TA), qui traitera ces modifications lors du réexamen du STANAG.

TASKING AUTHORITY

This STANAG is supervised under the authority of:

AUTORITÉ DE TUTELLE

Le présent STANAG est sous la responsabilité de :

Conference of National Armaments Directors (CNAD)/
CNAD Ammunition Safety Group (AC/326)
Conférence des directeurs nationaux des armements (CDNA)/
Groupe de la CDNA sur la sécurité des munitions (AC/326)
AC/326 point of contact/Point de contact de l'AC/326
AC/326 Secretary/Secrétaire de l'AC/326 : Mrs/Mme Isabelle Rouffignon-Driscoll
e-mail : rouffignon-driscoll.isabelle@hq.nato.int
Tel. : +32 2 707 3942 / Fax : +32 2 707.4103

CUSTODIAN

The custodian of this STANAG is:

PILOTE

Le pilote du présent STANAG est :

Royaume-Uni
AC/326-SG B Point of Contact/Point de contact de l'AC/326(SG/B)
AC/326 Secretary/Secrétaire de l'AC/326 : Mrs/Mme Isabelle Rouffignon-Driscoll
e-mail : rouffignon-driscoll.isabelle@hq.nato.int
Tel. : +32 2 707 3942 / Fax : +32 2 707.4103

FEEDBACK

Any comments concerning this STANAG shall be directed to:

NATO Standardization Agency
(NSA)

INFORMATIONS EN RETOUR

Tous les commentaires concernant le présent STANAG doivent être adressés à :

Agence OTAN de normalisation
(AON)

Boulevard Léopold III
1110 BRUXELLES – Belgique

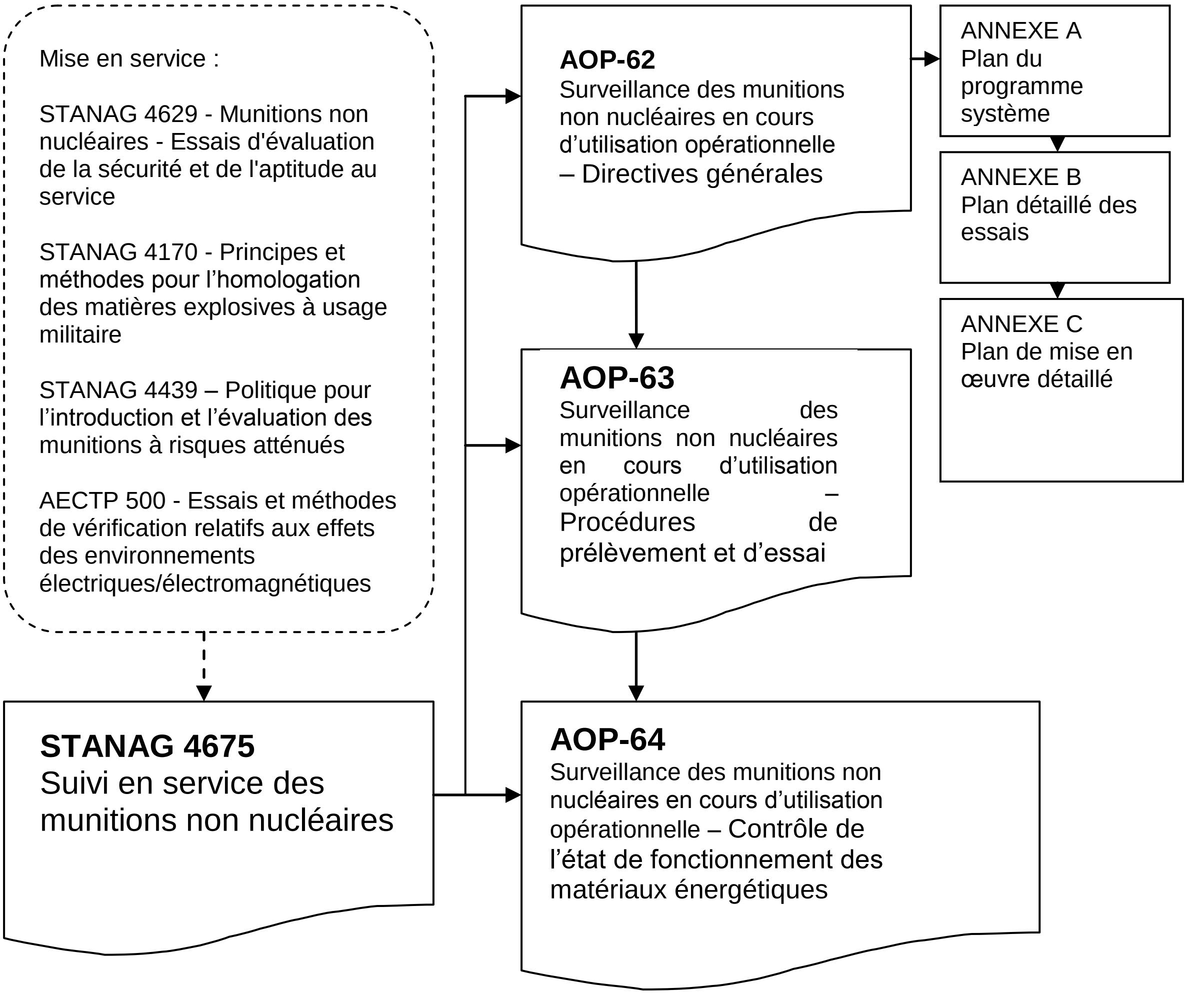

Figure 1 – Structure du STANAG 4675

NATO STANDARD

AOP-62
IN-SERVICE SURVELLIANCE OF MUNITIONS
GENERAL GUIDANCE

Edition A Version 1

NOVEMBER 2012

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED ORDNANCE PUBLICATION

Published by the
NATO STANDARDIZATION AGENCY (NSA)

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION AGENCY (NSA)

NATO LETTER OF PROMULGATION

[Date]

1. The enclosed Allied Ordnance Publication AOP-62, In-Service Surveillance of Munitions General Guidance has been approved by the nations in the AC/326 CNAD Ammunition Safety Group, is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 4675.

2. AOP-62 is effective upon receipt.

(*For a NON-CLASSIFIED (NO CLASSIFICATION MARKING) or NATO UNCLASSIFIED document*)

4. This publication shall be handled in accordance with C-M(2002)60.

(*For a document classified NATO RESTRICTED or higher*)

5. This publication shall be handled in accordance with C-M(2002)49. In particular, information contained herein requires approval of Member nations prior to its release to a nation outside of NATO.

Cihangir Aksit, TUR Civ
Director NATO Standardization Agency

DNSA VISA

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RESERVED FOR NATIONAL LETTER OF PROMULGATION

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Database for the complete list of existing reservations.	

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RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Database for the complete list of existing reservations.	

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CHAPTER 1 IN-SERVICE SURVEILLANCE OF MUNITIONS – GENERAL GUIDANCE

1.1. ABBREVIATION

1.1.1. List of Abbreviations and Acronyms

ALARP	As Low as Reasonably Practicable
AOP	Allied Ordnance Publication
APM	Acquisition Programme Manager
AUR	All Up Round
BTCA	Breakdown Test and Critical Analysis
CM	Condition Monitoring
ECP	Engineering Change Proposal
EDL	Environmental Data Logger
EM	Environmental Monitoring
EMD	Engineering and Manufacture Development
EMP	Environmental Monitoring Plan
EOSL	End Of Service Life
FSE	Field Support Engineer
IIP	Item Implementation Plan
FMECA	Failure Modes Effects Criticality Analysis
ISE	In Service Experience
ISM	In Service Monitoring
ISP	In Service Proof
ISS	In Service Surveillance
ITP	Item Test Plan
LAT	Lot Acceptance Tests
LCEP	Life Cycle Environmental Profile
PM	Project Manager
PT	Predictive Testing
RCM	Reliability Centred Maintenance
SOP	Standard Operating Procedures
SOW	Statement of Work
SPP	System Programme Plan
SRP	Safety, Reliability and Performance
SSE	System Support Engineer
S3	Safety and Suitability for Service
TLPM	Through Life Programme Manager
TOC	Total Ownership Cost
TP	Test Plan
WLA	Whole Life Assessment

1.2. SCOPE

1. This AOP and its annexes provide basic guidance on ISS including, why it is necessary, when it should be implemented and the key personnel and documentation required. This AOP will also cover the association between ISS and maintenance, the different requirements for safety and reliability and will also provide basic guidance regarding the use of environmental data loggers.

2. **Operational Imperative statement:** This document is relevant to program managers and service personnel who require information on surveillance and need basic guidance on planning a surveillance program.

1.3. RELATED DOCUMENTS

AECTP-100	Environmental Guidelines for Defence Material
AECTP-200	Environmental Conditions
AECTP-300	Climatic Environmental Tests
AECTP-400	Mechanical Environmental Tests
AECTP-600	The Ten Step Method for Evaluating the Ability of Material to meet Extended Life Requirements
AOP-7	Manual of Tests for the Qualification of Explosive Materials for Military Use
AOP-15	Guidance on the Assessment of the Safety and Suitability for Service of Munitions for NATO Armed Forces
AOP-46	The Scientific Basis for the Whole Life Assessment of Munitions
AOP-48	Explosives, Nitrocellulose based Propellants, Stability Test Procedures and Requirements using Stabilizer Depletion
AOP-56	Compendium of Chemical and Physical Tests for Analysis of Energetic Materials against their applicable NATO STANAG
AOP-63	In-service Surveillance of Munitions, Sampling and Test Procedures
AOP-64	In-service Surveillance of Munitions, Condition Monitoring
STANAG 4110	Definition of Pressure Terms and Their Interrelationship for Use in the Design and Proof of Cannons and Ammunition
STANAG 4115	Definition and Determination of Ballistic Properties of Gun Propellants Definition of Pressure Terms and Their Interrelationship for Use in the Design and Proof of Cannons and Ammunition
STANAG 4123	Methods to Determine and Classify the Hazards of Ammunition
STANAG 4147	Explosives: Chemical Compatibility of Ammunition Components with Explosives and Propellants (Non-Nuclear Applications)
STANAG 4157	Fuzing Systems: Test Requirements for Assessment for Safety and Suitability for Service
STANAG 4170	Principles and Methodology for the Qualification of Explosive Materials for Military Use

STANAG 4178	Test procedures for assessing the quality of deliveries of nitrocellulose from one NATO Nation to another
STANAG 4324	Electromagnetic Radiation (Radio Frequency) Test Information to Determine the Safety and Suitability for Service of EEDs and Associated Electronic Systems in Munitions and Weapon Systems
STANAG 4370	Environmental Testing
STANAG 4487	Explosives, friction sensitivity tests
STANAG 4488	Explosives, shock sensitivity tests
STANAG 4489	Explosives, impact sensitivity tests
STANAG 4490	Explosives, electrostatic discharge sensitivity
STANAG 4491	Explosives, Thermal Sensitiveness and Explosiveness Tests
STANAG 4506	Explosive Materials, Physical/Mechanical Properties Uniaxial Tensile Test
STANAG 4515	Explosives, Thermal Characterization by Differential Thermal Analysis, Differential Scanning Calorimetric and Thermo Gravimetric Analysis
STANAG 4525	Explosives, Physical/Mechanical Properties, Thermomechanical Analysis (TMA) for Determining the Coefficient of Linear Thermal Expansion
STANAG 4540	Explosives, Procedures for Dynamic Mechanical Analysis (DMA) and Determination of Glass Transition Temperature
STANAG 4556	Explosives, Vacuum Stability Test
STANAG 4581	Explosives, Assessment of Ageing Characteristics of Composite Propellant containing an Inert Binder
STANAG 4582	Explosives, Nitrocellulose based Propellants, Stability Test Procedure and Requirements using Heat Flow Calorimetry
STANAG 4666	Explosives, Assessment of Ageing of Polymer Bonded Explosives (PBXs) Cast-Cured Compositions using Inert or Energetic Binders
STANAG 4675	In-Service Surveillance (ISS) of Non-Nuclear Munitions

1.4. GENERAL

1.4.1. Introduction

1. It is almost impossible to keep munitions in an environment where they will not degrade. It is therefore generally accepted that almost all munitions have a finite life. Nations which implement AOP15 have agreed that before being accepted for service use, munitions must demonstrate Safety and Suitability for Service (S3). In assessing S3 it is necessary to assign some form of service life to the item. This is a prediction of the amount of environmental stress the item can take before it degrades to an unreliable or unsafe state. These predictions are less likely to be valid the longer an item stays outside of a controlled storage environment as the environment becomes more variable. In Service Surveillance (ISS) provides the means by which initial service life estimations can be confirmed, or even extended, to ensure safe and reliable use throughout the required service life. ISS can also be used to assess the continued safety of unserviceable items, during storage and transportation, pending disposal.

2. The through life implementation of S3 and ISS techniques is often referred to as Whole Life Assessment (WLA).

1.4.2. Purpose

1. Nearly all materials can degrade in some way over time and at an increased rate when exposed to increasingly harsh environments. Casings and canisters can be eroded; protective surfaces can be attacked by mould or other biological species; seals and energetic materials can react chemically with moisture, light or heat changing their chemical or physical make up; or structures can crack and break apart through vibration and shock induced stress. If these changes cannot be tolerated then it is essential to monitor and test for them.

2. Initial Qualification and Safety and Suitability for Service testing will identify the degradation that is most likely for the chosen design. They may even give some indication of the possible rate of degradation. It is unlikely that it will have been practical to test for all eventualities and combinations of environments. By inspecting items periodically, or following a particular deployment or training programme, it is possible to check the effects of the actual environment and therefore improve overall confidence in the safety, reliability and performance of those items.

3. The purpose of ISS is to provide the information required to ensure that munitions remain safe, reliable and perform correctly throughout the period of their intended life. By complying with this AOP, nations should be able to:

a. Provide evidence that the risk from munitions in service, regardless of age, will remain tolerable and As Low as Reasonably Practicable (ALARP) for the life cycle of the munitions.

b. Provide sufficient evidence that pre-owned munitions for loan, sale (at the point of sale), or contracted disposal are currently safe and serviceable and will remain so for an agreed duration with the receiving nation/organisation.

c. Provide evidence that munitions continue to function correctly and reliably throughout their period of use.

d. Enhance predictions of a munitions end of safe life.

e. Reduce the risk of exceeding the safe life of munitions.

f. Enhance maintenance and component replacement plans.

g. Identify/Support role changes to munitions.

4. STANAG 4675, which includes this AOP, provides methods for ensuring continued safety, reliability and performance of material within the extreme conditions defined in the Life Cycle Environmental Profile (LCEP). This AOP describes the basic process and documentation required to conduct a successful munitions ISS and outlines the reasons why it is necessary.

5. Using ISS techniques to extend service life or to extend the LCEP beyond its initial boundaries should be considered in conjunction with AECTP 600.

6. There are various levels of ISS. The following lists some of the primary functions of ISS and offers estimated levels of inspection required:

a. <u>Continued safety in storage</u>
Checking on the stability and if necessary, other properties of explosive materials.
Agreed go/no go criteria – refer to System Support Engineer (SSE) (Subject Matter Expert).

b. <u>Continued safety in service</u>
Breakdown and critical analysis of “fleet leaders” (see AOP 63)
In Service Monitoring (ISM)
Safety review panel – refer to SSE

c. <u>Continued reliability or performance in service</u>
In service proof and functioning data (including electronic test sets)
Calculate statistics and quality levels
Reliability review panel – refer to the Co-ordinator

d. <u>Planning for maintenance and/or component replacement</u>
In service proof and functional data (including electronic test sets)
Checking on the stability and other properties of explosive materials
Calculate statistics and quality levels
Safety review panel – refer to SSE

e. <u>Extended safety or reliability in service</u>
S3 assessment of "fleet leaders" – including environmental stressing
Breakdown and critical analysis of environmentally stressed "fleet leaders"
Safety review panel – refer to SSE

1.4.3. System Complexity

1. The basic principle of assessing components that are degrading remains for all types of munitions. The programmes for complex munitions, having multiple energetic sub-components (i.e. complex missile systems, torpedoes, etc.), will necessarily differ from simpler munitions (i.e. gun ammunition, grenades, etc.). The complex munitions programme will likely require coordination of multiple disciplines and many more personnel in assessing the munitions as a system and in its component parts. Test sampling plans may necessitate extraction of component samples or be driven by the most critical or life-limiting subcomponent.

2. For documentation, the programme for simple munitions will likely require only simplified, short documents and plans, while the complex system will need a master programme plan with numerous annexes/sub-plans for individual components. The analysis of system reliability and performance will also require more complexity, as reliability and performance at a system level is more complex than a simple summation of the capabilities of the components. Where it is necessary to manage multiple sub-programmes for system components, in order to maintain an accurate service exposure history, it is critical for the procuring nation to have access to an accurate database recording configuration of the munitions to at least that component level.

1.4.4. Initial Service Life – National/Service Policies

It has been noted that different nations have different basic practices for initial service life. Some countries policies establish a long service life and fully expect to retire their systems at the end of that life. Others establish a shorter initial life and continue to extend service life of their systems until data, inventory depletion or operational necessity provides the impetus to remove the system from service. ISS is an essential component in both approaches. There are inconsistencies in making long term assessments that can lead to inaccurate life estimation. If the plan is comprehensive in both instances then the programme objectives can be met without the commitment of resources and time at the outset to conduct a long initial service life assessment. The nation/service preparing the System Programme Plan (SPP) should fully explain their service life policy and how ISS is to be used within it.

1.5. THE ISS FRAMEWORK

1.5.1. The ISS Framework

ISS is a modular process that combines information from a number of sources to construct the overall framework. This framework is presented pictorially in figure 1 below:

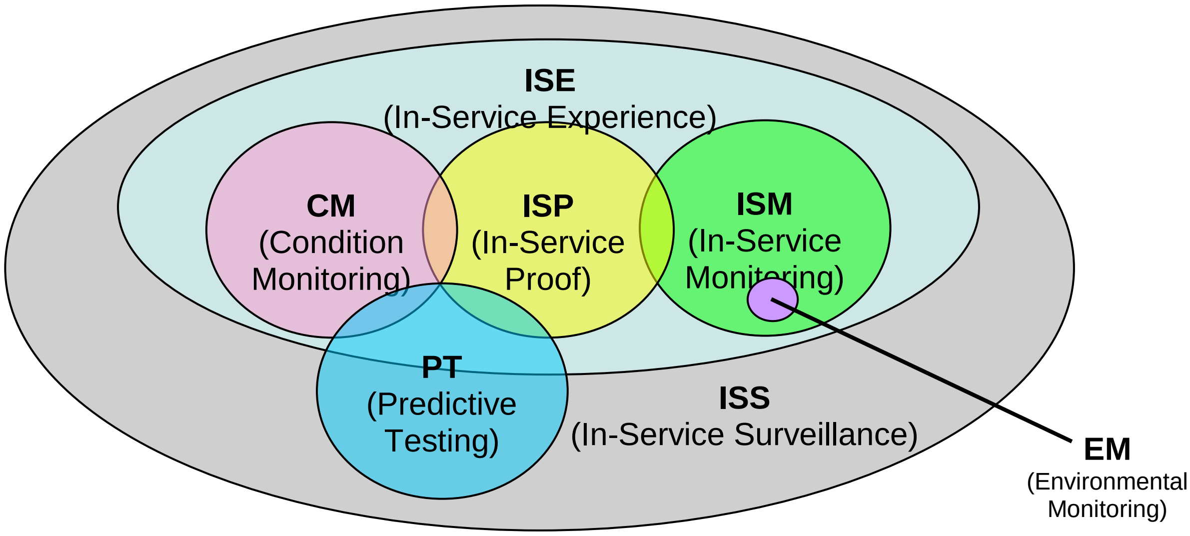

Figure 1 - ISS Framework

1.5.2. In Service Experience

In Service Experience (ISE) is the collective term used to describe a number of different methods of testing and monitoring munitions and gaining useful data regarding their condition throughout their life cycle or service life. Typical reporting methods include: Functional, Proof and Training Reports; Accident and Defect Reporting.

a. In Service Reporting

Reporting is an important source of information for reliability monitoring and logistic control, and provides a useful source of information to support removal from service decisions in the case of munitions. This reporting can provide early identification of potential life-limiting degradation/failure modes. This should not be considered a reliable source of information since not all failures are likely to be reported.

1.5.3. In Service Proof

In-Service Proof (ISP) is simply additional proof (sometimes known as batch/lot acceptance) tests that are carried out throughout the service life of munitions system. This can be conducted at system level (i.e. all-up-round), sub-system or component level. No matter which of these is used, each would include visual inspection followed by function of the item. Data gathered can vary from visual observation to detailed performance evaluation. The latter will provide safety, reliability and performance data. Typical methods include:

a. Service Firings

Service firings are carried out for operational or training purposes, but they can also be used to provide data on performance and reliability if monitored effectively. Successful service firings can give a numerical confidence in the current status of the munitions. Inconsistent reporting procedures and the lack of objective evidence means that this data should not be relied upon for predicting the future safety of munitions.

1.5.4. Condition Monitoring

Condition Monitoring (CM) is one of the most important aspects of ISS. It is usually destructive testing as typified by Breakdown Test and Critical Analysis (BTCA) where the system is dismantled into its sub-systems and/or components. Usually, this incorporates chemical analysis (e.g. composition, stability), determination of mechanical properties (e.g. tensile, hardness, modulii) and/or explosive hazard properties (e.g. response to impact, friction). Further information on CM is contained in AOP 64.

1.5.5. In Service Monitoring

In-Service Monitoring (ISM) is typically non-intrusive and non-destructive testing such as routine visual inspection and/or using test sets to interrogate the electronic hardware/software of a munitions system. Since the system is not dismantled it can be used for further testing if required or returned to the stockpile for service use.

a. <u>Environmental Monitoring</u>

(1) Environmental monitoring (EM) can be considered as a subset of ISM whereby ‘real-world’ data is gathered throughout the storage and/or deployment of a munitions system. In its simplest form this can be temperature and humidity data manually recorded in

depot, or meteorological data recorded in theatre, through to analysis of data recorded during trundling/field trials or by Environmental Data Loggers (EDL).

(2) For safety reasons the predicted environment used in basic failure/degradation models is usually (but not always) pessimistic. EM provides service data to replace the predicted service environment used in these models with an actual service environment. EM is also very closely linked to CM and is essential to making accurate predictions of the remaining life for munitions. In very basic terms, degradation models involve comparing the stresses experienced and survived by test items during predictive testing with the actual stresses experienced during service use. Provided in-service stresses remain below those experienced during testing, the in-service items can be expected to survive as comfortably as the test items. Therefore in many cases EM can lead to an increase in service life through more accurate modelling of the environment and associated degradation.

(3) It is also possible to control the environment, an example of which is to use thermally controlled ISO Containers for the transport and storage of munitions. This can slow down the degradation of munitions. The use of a controlled environment does not allow a munitions manager to ignore the effects that the surrounding environment could cause. In field conditions air-conditioning can fail quite frequently and carrying out repairs quickly is not always possible. Even in controlled environments monitoring should still be considered.

b. <u>Environmental Data Loggers</u>

(1) Environmental Data Loggers (EDL) is the title given to any device that will provide data about the environment the munitions experience. The term EDL is mostly associated with independent electronic devices that record and store temperature and humidity data. EDL is a generic term covering all devices that improve knowledge of the environments experienced by an item. This can range from simple chemical devices that change colour at certain temperatures, to health usage monitoring systems (HUMS) that can record temperature, humidity, shock, vibration, and pressure over many years.

(2) EDL can also range in position from a loose association with munitions, such as using platform based data or placing EDL outside munitions containers, to being fully embedded within the munitions. If the EDL is not fully embedded then initial assessment and analysis regarding the placement of the EDL should also include the derivation of a transfer function that can

translate the data recorded by the EDL to the position on the monitored item where degradation is most likely.

(3) As EDL technology advances, this technology should be incorporated into the ISS Plan. The more that is known about the environment actually experienced by items in service the more that testing can be focused on areas of concern. A fully monitored fleet of missiles or munitions would allow ‘fleet leaders’ to be easily identified and tested and where environments are less extreme than predicted could even allow for less frequent removal of test items for inspection.

1.5.6. Predictive Testing

1. Predictive Testing (PT) is used to investigate the degradation modes likely to be found during service use as a result of environmental stressing. This typically involves a degree of environmental stressing prior to examination and/or function of the item under investigation.

2. It must be remembered that a number of assumptions have to be made regarding the life cycle of the item, both in terms of how it will be stored/used and those failure/degradation modes likely to be encountered. A good example would be the activation energy used during thermal ageing calculations. ISS can help validate (or invalidate) those assumptions that were made during initial PT and can lead to modifications to the models, test severities and assumptions commonly used.

3. PT is likely to help determine those items that are more likely to degrade/fail early in life which can act as a focus for ISS activities. It must also be considered that other degradation/failure modes may exist that become more critical as time progresses.

4. The need for additional PT during ISS increases with age and therefore energetic materials that are intended to be kept in service well beyond their initially predicted or “guaranteed” life should undergo PT during ISS, if adequate confidence in the system safety is to be maintained. This is particularly true for munitions carried externally on fast jets where it is more difficult to model the actual stresses experienced by the energetic materials.

1.6. PLANNING FOR ISS

1. An ISS Item is that unit/section/component/sub-component or assembly whose features are susceptible to degradation over time and could affect the safety, reliability and/or performance of the system. How the system is defined and then sub-divided into items will depend on various factors including the resources available and the practicality of assessing items independently.

2. The following section on Process and Documentation describes in detail how to plan and conduct a programme for munitions of any size and complexity. Below

are some of the basic planning decisions to be made throughout this process:

a. Do I need ISS?
In principle, any system or item containing energetic materials must undergo ISS throughout its service life to ensure safety during handling, storage and operation. Only non-safety critical items that pose no risk to personnel, equipment or operational effectiveness may be considered for exemption from some or all aspects of ISS. Consideration must also be taken of National laws that detail requirements for specific testing regimes associated with energetic materials / substances.

b. What requires ISS?

(1) *Energetic materials and components containing*:
Pyrotechnics.
High explosives.
Propellants.
Thermal batteries.

(2) *Casings/pressure vessels*:
Thermal protection.
Sealing.

(3) *Electronics*:
Sealing.
Function.

(4) *Packaging*:
Sealing.
Shock attenuation.
(supporting documentation)

c. When Shall ISS Take Place?
Throughout the life cycle but should be reviewed:
(1) Periodically.
(2) After operational deployment.
(3) During training.
(4) When ISM data indicates a possible cause for concern.

d. What Testing is required?
An analysis should be done based upon expert judgement. Guidance is given in AOP 63 and AOP 64 on how to structure the programme and select appropriate tests.

All munitions should be considered for periodic testing including:
(1) Non-destructive testing – electrical test sets, inspection.

(2) Destructive testing – examine structural, chemical and physical properties.

(3) Environmental monitoring – EDL and other records of the environments experienced.

(4) Functioning – Gather reliability and performance data over time.

e. When should ISS stop?
Only on disposal. Even if munitions are no longer required, they cannot be left in store awaiting disposal for long periods without continued monitoring.

f. What Assets are required for ISS?

(1) For sample size guidance refer to AOP 63

(2) Pre-selected samples can be set aside for basic surveillance

(3) "Fleet Leaders" should be selected for any life assessment during surveillance

(4) Consider whole systems - All Up Rounds (AUR) - where environmental predictive testing is required and vibration environments are significant

1.7. ISS PROCESS AND DOCUMENTATION

1. This section provides the recommended process and required documentation for a successful In Service Surveillance programme and describes the role and responsibilities of the essential functions within an ISS programme. Ideally each function should be carried out by an independent individual or organisation. In practice, one individual or organisation may be responsible for more than one function.

a. Acquisition Programme Manager.

b. System Support Engineer.

c. Co-ordinator.

d. Programme Manager.

e. Test Engineer.

f. Field Support Engineer.

2. This section also describes the role and the format of the documentation. In this AOP the description of the documentation is comprehensive. For ISS programs for smaller or less sensitive munitions this documentation may be less substantial. However, each element of the documentation is needed.

a. System Programme Plan (SPP) – ANNEX A

b. Item Test Plan (ITP) – ANNEX B

c. Item Implementation Plan (IIP) – ANNEX C

d. Environmental Monitoring Plan. (EMP)

e. Progress Reports.

1.7.1. Process Description

1. The process of ensuring In Service Safety and Suitability for Service (S3) ideally begins during the munitions development phase, when the system developers should conduct an analysis to establish the expected/potential failure modes for the system, along with an assessment of the potential severity of the failures. This sort of analysis is often known as a Failure Mode Effects and Critical Analysis (FMECA). This tool provides the designers and in-service agents the key for selection of components and failure mechanisms to focus on when selecting parameters to study in their analyses of degradation. This information regarding failure mechanisms and components should then be used to generate a conceptual System Programme Plan. The final SPP should be completed and signed by the appropriate acquisition authority for the procuring national service as specified later in this document.

2. Prior to the procurement process the Explosive Materials must be Qualified in accordance with STANAG 4170 and AOP7 and assessed for S3 in accordance with STANAG 4315 and AOP46. During this qualification and assessment, evidence of the initial factors for stability and robustness of the munitions must be gathered and analysed to provide the baseline for future comparison. Before the munitions enter service, a Co-ordinator and primary SSE should be assigned to finalise and maintain the SPP.

3. Once the SPP has been completed the Co-ordinator will assign Programme Managers and SSE to develop Item TP for each Item identified as requiring surveillance in the SPP. The Programme Managers will also be responsible for identifying TE and Field Support Engineers (FSE) to conduct any testing and monitoring identified in Item TP. They will then prepare an IIP.

4. The Test Engineers and FSE will report progress to the Programme Managers at intervals agreed in the IIP. The Programme Managers will then discuss these results with the appropriate SSE and prepare a status report for the Co-ordinator. After each reporting period the Co-ordinator will convene a review panel to assess whether the system remains Reliable, Safe and Suitable for Service. The review panel will consist primarily of the Co-ordinator, the Programme Manager and the primary SSE. TE and other SSE may be called upon as required.

5. Once the panel has made their recommendations the Co-ordinator will decide whether the programme continues as planned or whether any of the ITP and IIP require amendment. The Test and Implementation Plans may be amended to increase/decrease periods between surveillance, change testing requirements or implement additional field monitoring. In some cases testing may be suspended if found to be inappropriate. Eventually the Co-ordinator in conjunction with the review panel will recommend that an item is withdrawn from service. The item should then enter a disposal phase. Where the item is withdrawn for safety reasons the Co-ordinator should recommend a maximum disposal period by which time all items

must be disposed of before they become unsafe. If the item is withdrawn for reasons other than safety (e.g. poor performance) then disposal may not be a priority and it may still be necessary to continue some surveillance activities until the items final disposal.

6. The SPP also needs to consider if any specific test equipment or procedure is needed for the testing of the System/Sub-components/Items/Materials. The plan should identify where this test equipment will be needed and when. Most of the test equipment should have been developed during S3 and Qualification and the SPP need only identify the continued requirement and where it is to be stored and/or installed. This may include:

a. Special handling equipment for large missile systems.

b. Inert components and Makeweights.

c. Pressurisation Equipment for airtight containers.

d. Stands and fixtures for static performance tests.

e. Jigs and fixtures for environmental tests such as vibration.

f. Tooling for disassembly/assembly of components.

g. Electronic Test sets for electrical systems such as guidance sections.

h. Environmental Data Monitoring Equipment (e.g. EDL or Instrumented Monitoring Vehicles (IMV)).

i. Any bespoke Accelerometers, Pressure transducers, Strain gauges or other recording equipment.

j. Databases and data storage requirements.

1.7.2. Roles and Responsibilities

The following is an introduction to the key functions needed for a successful programme. How each role is fulfilled may differ depending upon the nation and availability of personnel, and may change throughout the process. In some cases, where the programme is small, or resources are limited, some individuals or organisations may fill multiple roles. At each stage throughout the life of the munitions under surveillance, someone with the appropriate resources and level of responsibility must fulfil the requirements for each of the following roles, to ensure the surveillance is successful.

a. Acquisition Program Manager (APM)

The APM is responsible for integrating program assessments, recommendations, and decisions into the maintenance and quality improvement efforts of the program. The APM is responsible for funding what would typically be the pre-service In Service Surveillance program development. This includes SPP/ITP/IIP documentation, samples (spares), test equipment, Engineering and Test Engineering participation, aging, type life studies, and predictive model development. The APM is also responsible for in-service DA/PM participation as required and the planning for and acquisition of ISS samples. The roles of the APM are detailed as follows:

(1) Provides resources for the development of the initial: Program Plan, Item Test Plans, Item Implementation Plans, characterization studies, aging or predictive models, and testing procedures.

(2) Provides test Item spares including sample acquisition resources; e.g. weapon disassembly and shipment of test items to test engineers.

(3) Provides peculiar or unique test equipment, fixtures and facilities.

(4) Establish the initial Service Life criteria and safety, reliability, and performance thresholds for the inventory.

(5) Ensures participation of the relevant SSE (e.g. Munitions Safety Engineers, Environmental Engineers, Design Engineers and Materials Ageing Scientists) in the program development and in-service phases.

(6) Include the data requirement clauses in the contract for specified data and funding to acquire this data.

(7) Include an ISS support clause in the prime contract, as appropriate; to allow Design and Manufacturing attendance to meetings, to resolve action items, to review and comment on test plans and reports as requested.

(8) Provide for Government resources to collect and maintain pre-production and production; design, lot acceptance, and maintenance data.

(9) Provides resources to support the analysis of production data to determine initial inventory strata.

b. <u>APM ISS Representative</u>

Where the acquisition or product management personnel are independent of the through life management personnel, the APM may or may not wish to assign an APM Representative to work with the Coordinator. Where there is no APM Representative their roles and responsibilities should be shared between the APM and the Coordinator. The roles of the APM Representative are detailed as follows:

(1) Point of contact for integrating programme assessments with decisions on the maintenance or quality improvement of the system during the Acquisition life cycle Review of the Program Plan, approval of Item Test Plans, and Item Implementation Plans, and aging and characterization studies.

(2) Point of contact for storage and release of test item spares and direction and resource of sample acquisition requirements; e.g., disassembly and shipment of test items to test engineer.

(3) Point of contact for direction and resources for peculiar test equipment.

(4) Point of contact for System Support Engineering participation in the development and implementation phases.

(5) Co-Chair of system level Working Group meetings as appropriate.

(6) To ensure that all ISS related acquisition and maintenance data (Lot Acceptance Testing, First Article Testing, Functional Testing, production acceptance testing, etc.) are available.

(7) Notifies the PM on APM actions taken on ISS results and recommendations, including the preparation and promulgation of the revised service life expiration dates under APM signature.

c. <u>The Through Life Program Manager (TLPM)</u>

TLPM, in cooperation with APM, shall provide the required resources to execute the ISS Plan. In some cases the APM and TLPM may be the same person. Roles of the TLPM are further detailed as follows:

(1) Plans, programmes and budgets for execution of the programme after introduction to service.

(2) Reviews and endorses, as appropriate, ISS Plan test and evaluation results, assessments, and recommendations before they are forwarded to APM for information and action.

(3) Provides resources for the update or modifications of the initial: Programme Plan, ITP, IIP, characterization studies, aging or predictive models.

(4) Fosters improvement to testing and procedures.

(5) Submits periodical summary/status reports to APM and the End User as appropriate.

(6) Provides funds for the SSE participation in the programme development and in-service phases and for ISS unique tasking.

d. <u>ISS Coordinator</u>

The assigned Coordinator interfaces with the APM, or representative if nominated, as the primary point of contact for all programme level issues including overall coordination of Programme Management, work plans, and execution, programme documentation, progress reports, and reviews. Other Coordinator responsibilities include:

(1) Prepare and maintaining the Programme Plan.

(2) Ensure annual and multi-year plans are developed and submitted to TLPM for approval.

(3) Coordinate the annual ITP.

(4) Review and approve predictive model development efforts.

(5) Coordinate reviews to determine adequacy of test and analysis documentation, assessing test results, and reviewing test reports prior to forwarding reports to TLPM for review and subsequent transmittal to APM and other programme participants.

(6) Participate in the development of the ITP and IIP.

(7) Recommend working groups to the TLPM for development of documents and for resolving technical issues as required.

(8) Co-Chair ISS Working Groups.

(9) Overseeing sample acquisition process to assure timely receipt of test items.

(10) Provide yearly budget requirements to APM for sample acquisition.

(11) Include breakdown requirements, sample identification, quantity and sample acquisition manager requirements.

e. System Support Engineer (SSE)

The System Support Engineer roles and responsibilities include participation in development and maintenance of documentation, program planning and execution processes, integration of test item requirements and results and serving as a conduit for incorporating test item requirements and results into various technical groups, programs and design reviews. They could be design engineers representing the design authority/agent, technical safety specialists, reliability and performance engineers or surveillance experts. It is normal for the primary SSE to have a level of independence from the specific ISS process in order to remain more objective about the assessment of the results.

Roles are further detailed as follows:

(1) Participate in programme planning and working groups.

(2) Provide inputs and recommendations for test item candidates.

(3) Provide inputs and recommendations concerning the test item annual and multi-year plans.

(4) Collection, analysis and distribution of data from various sources including industry. Such data may include design & qualification reports, waivers, deviations, failure analysis reports, FMECA reports, etc.

(5) Provide programme initial proposed inventory stratification and rationale.

(6) Provide inputs and recommendations concerning test year specific sample requests.

(7) Provide inputs and recommendations for test methods, critical characteristics, test parameters, evaluation criteria, operational and/or specification requirements.

(8) Provide inputs and recommendations for data collection across and integral to all programme components, analysis techniques and monitoring methods.

(9) Participate in the development and review of test documentation: Test Plans, Implementation Plans, and other ISS documentation and processes.

(10) Review and comment on test item test results.

(11) Integrate test item requirements and results into assigned activity, including serving as a conduit for test item requirements in various programme and design reviews.

(12) Notify the Coordinator and Programme Managers of impending acquisition or design related test and/or exercises.

(13) Participate in development and verification of predictive models.

f. <u>Program Managers (PM)</u>

The PM is assigned for each test item (e.g., rocket motor, warhead, battery, etc.). The PM is responsible for planning, testing, evaluating and reporting test item test programs. The PM designs the execution for each test item to monitor the conditions of the inventory to establish aging trends of the critical characteristics of the test item. The PM is responsible for the planning and co-ordination of the surveillance for a particular item. They will be responsible for the ITP and ensuring the IIP and EMP are followed. For some situations it is conceivable that the Co-ordinator and PM are the same person.

Roles of the PM are further detailed as follows:

(1) Develop and maintain ITP and IIP; coordinates development and changes with Coordinator, SSE, and TE.

(2) Review and analyse data from all test sources as it becomes available, analyse it, and provide summary of impact on system safety, reliability, and performance to Coordinator.

(3) Provide design, production, lot acceptance test, etc. data requirements to Coordinator for APM inclusion in procurement contracts.

(4) Identify to the Coordinator spares requirements for APM replacement of test items to be destroyed during life of the programme.

(5) Develop and provides test item programme plans, rationale and requirements.

(6) Plan and budget for TE tasking (including any disposal costs of test residuals).

(7) Develops detailed task or Statement of Work (SOW) for TE execution.

(8) Review TE operating procedures and test equipment and approvals for execution of testing.

(9) Provide test item sample requirement profiles.

(10) Discuss ISS Test Items test results with System Support Engineers and ISS Coordinator.

(11) Submit test reports to the ISS Coordinator after review by appropriate SSE.

(12) Provide inputs to design and In-service programme reviews and working groups.

(13) Recommend the TE include alternatives and supporting analyses when capital investment is required from either PM or a redundant test capability is being considered or established.

(14) Select the TE from either the public, private, or foreign sector.

(15) Explore and document any related efforts by other services/users of the item or similar items collecting data for use in analysis as part of the report/analysis process.

(16) Select/develop and verify predictive models and analytical techniques to be used to evaluate test items.

(17) Plan and submit budgets for the development/acquisition of test and evaluation technologies, equipment, models, simulations as necessary.

(18) Report progress to Coordinator.

(19) Test reports submitted at completion of test and evaluation/analysis cycle

(20) Attend working group meetings and APM programme reviews as required.

g. <u>Test Engineers (TE)</u>

TE can be individuals or organizations from, the public, private or foreign sector. They may change over the life cycle of the program. Full documentation, verification, validation and accreditation of all test procedures and equipment will be required from all TE. The TE may conduct both destructive testing and non-destructive testing on test items and report results as specified in tasks or Statements of Work (SOW). They may participate in Test Plan development working groups at the direction of the individual engineer. TE shall provide cost estimates to execute test plans, maintain internal operating procedures, equipment calibration, and certification etc. as directed by the ISS Engineer. The TE may be from the procuring government, the vendor government, the design authority or from an independent commercial organisation.

h. Field Support Engineer (FSE)

Where the plan calls for evidence of the environment, through monitoring in the field or through field testing, it is the Field Support Engineer who will ensure the calibration and correct placement of the monitoring equipment, and manage the retrieval of the data. Their responsibilities are similar to those of the TE but they will necessarily have a closer relationship with the Items End User or Platform SSE. In some circumstances, where operational data is required, they may have to be serving military personnel.

i. Data Management

The APM should ensure that an appropriate agency is tasked and resourced for receipt and maintenance of all ISS and associated data for the life of the system. This agency is then responsible for the overall coordination and management of data.

Roles of data management agencies are further detailed as follows:

(1) Organize and coordinate all data collection, validation and analysis.

(2) Develop and maintain data information system.

(3) Perform analysis as required, including comparisons with baseline data.

(4) Develop standard ISS related data manipulation tools to provide routine ISS related data reports.

j. Sample Management

The TLPM should ensure that an appropriate agency is tasked and resourced for getting requested samples out of inventory and to the test engineer in a timely fashion.

Roles of sample management agencies are as follows:

(1) Budget for storage and maintenance of test items and/or replacement items.

(2) Record movement of test items and replacement Items.

(3) Give munitions managers sufficient warning regarding removal of test items from service.

(4) Supply test items to the TE.

(5) Integrate sample acquisition into APM maintenance workload planning process.

1.8. ISS PROCESS

The program process is comprised of two main phases:

a. Development Phase.

b. Execution Phase.

Typically the introduction to service milestone separates the two phases. Figure 2 identifies these two phases along with the primary process elements for ISS.

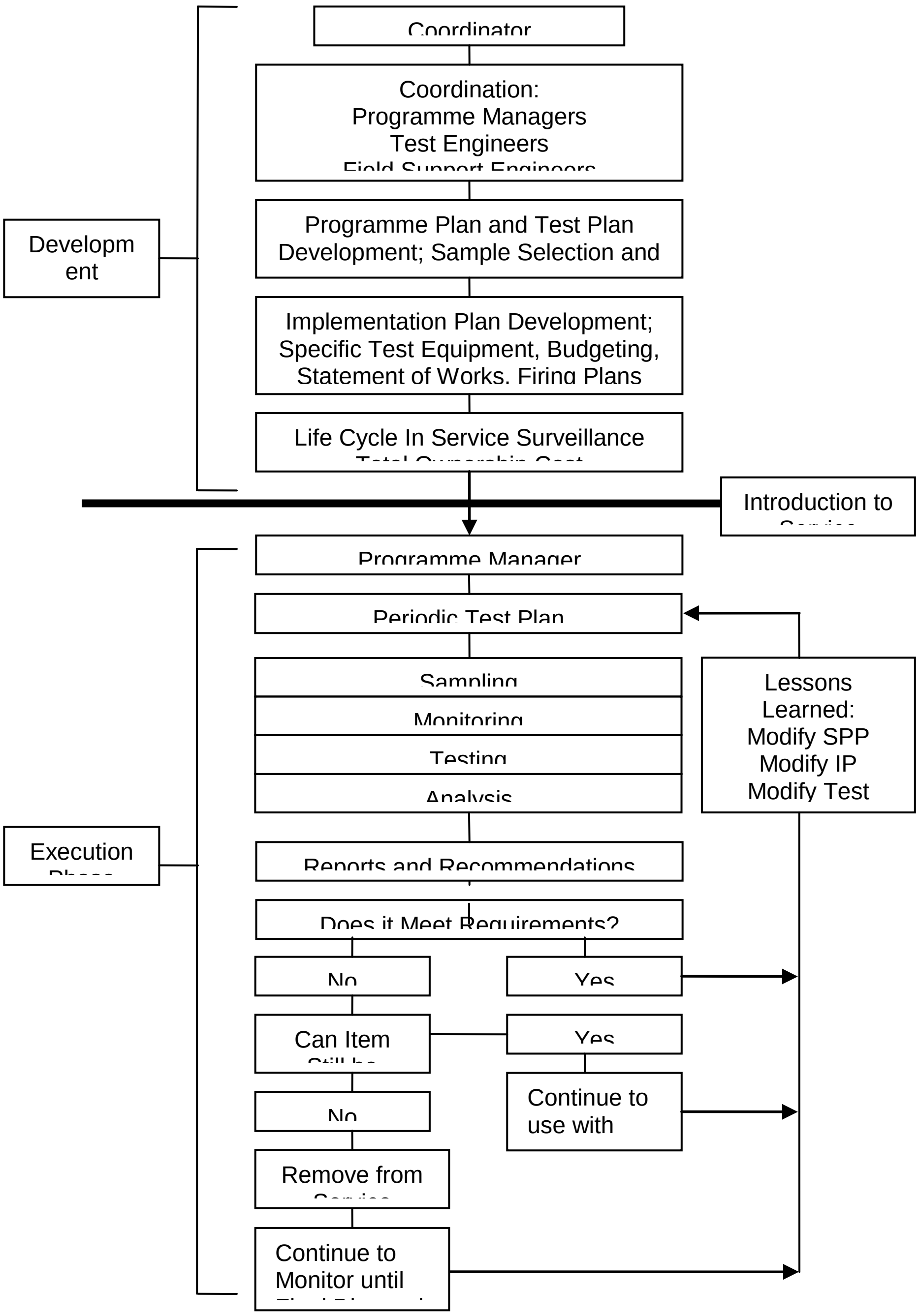

Figure 2 – ISS Program Process Flowchart

ANNEX A SYSTEM PROGRAM PLAN

A.1. FOR AN EXAMPLE SYSTEM/PROGRAM

This Program Plan and Program development guide is in the recommended Program Plan format. This document includes typical language, questions to promote thought, and/or examples of required information for most sections, for an “Example” program. As there is no such program as the "Typical Program", any and all specific Program Plans should be tailored to meet the needs and requirements of the individual programs. The goal of this document is to foster thought and facilitate documentation of ISS planning for munitions systems.

Cover Sheet:

.

This may Include Logos or other Identification of the Project and/or System. Consider Providing a Picture.

This Document should be Agreed and Signed by:

The Coordinator

The Acquisition Program Manager (or Representative)

The Through Life Program Manager

Design - System Support Engineer

Safety - System Support Engineer

Quality - System Support Engineer

A.2. CONTENTS

A SYSTEM Program Plan should include the following sections:

A.3. MANAGEMENT OVERVIEW

Good procurement managers will ensure that aging and in service surveillance programmes exist for all degradable items (especially munitions) that are being developed or acquired. The initial planning and development of the ISS System Programme Plan is an acquisition phase requirement of the (Insert appropriate organization name) in accordance with STANAG 4675

National Instructions provide further policy and guidance regarding ISS programmes to ensure that weapons and ordnance safety, reliability, and performance does not degrade in the in-service environment.

The Plan will assess the SYSTEM NAME for aging trends that influence the safety, reliability, and performance of the SYSTEM NAME system and will be documented. The Acquisition Programme Manager (APM) and the Through Life Programme

Manager (TLPM) jointly share responsibility for this programme. The APM agrees to provide resources to support the development and acquisition phase of the SYSTEM NAME as appropriate. The TLPM agrees to provide resources required to support the in-service phase of the SYSTEM NAME as appropriate. The APM, agrees to provide resources to provide engineering support, logistics support, and prepared samples for the execution phase as appropriate.

A.4. INTRODUCTION

1. System Overview

In this section is provided an overview of what mission the system was developed to perform (what platform, how, when, where, etc.). If necessary, a detailed description of the system shall be provided in Appendix A of this System Programme Plan (SPP). It may also be necessary to reference all pertinent development requirements (e.g. The System or User Requirements Documents) and relevant production documentation (e.g. Proof Schedules and Batch/Lot Acceptance Data Reports).

2. Programme Purpose

a. Munitions and their components undergo changes in safety, reliability, and performance with time and exposure to environmental stress. These changes are attributed to material properties and/or design and production processes and are affected by logistic and deployment environments and may become limiting factors that could restrict the service life of the system. It is essential that the critical characteristics and/or parameters of the system and components be identified and evaluated in relation to age and environmental stress exposure to ensure the highest state of safety, reliability and performance available. The SPP is established to evaluate this age and environmental exposure/stress related data and provide stockpile management recommendations.

b. ISS is a cooperative effort that provides practicality and cost effectiveness through minimum staffing and synergy with other test, evaluation, and analysis efforts or programmes, training exercises, school training, and maintenance and deficiency data reporting and collection programmes, as appropriate. The appropriate participants are involved in planning, testing, analysis, and reporting.

3. System Programme Plan Purpose

a. This SPP defines and describes the in service surveillance requirements for SYSTEM NAME. It identifies the objectives of the programme, roles and responsibilities of the participants, evaluation approaches at a system level and it identifies the items to be evaluated (e.g. Warhead, Rocket Motor, Batteries, etc). The details of each item such as critical characteristics/parameters, sample requirements, test requirements, costs, and procedures will be specified in the respective Item Test Plans (ITP) and Item Implementation Plans (IIP). Descriptions and requirements for each of these documents are detailed in ANNEXES B and C to this AOP.

b. System safety, reliability, and performance comprise the main ISS concerns for the SYSTEM NAME system. The SYSTEM NAME ISS programme evaluates the critical characteristics/parameters that have been identified by the Design Authorities, In-Service Support Engineers, and Safety, Reliability and Quality evaluation communities. These critical characteristics/parameters are those attributes that potentially change with age and/or environmental exposure and consequently may affect the safety, reliability, or performance of the system. Identifying the critical characteristics and/or parameters for each Test Item is not within the scope of this SPP and shall be provided in the appropriate ITP.

4. Maintenance Interval

The SYSTEM NAME recertification interval or maintenance period will be discussed in this section. The potential life limiting factors for the SYSTEM NAME as identified by the SYSTEM NAME technical community will also be discussed in this section. It should be recognized that maintenance data will affect the programme and, data will affect the maintenance programme; and as a result, this synergy may recommend End of Service Life (EOSL) and Reliability Centred Maintenance (RCM) intervals. You must address these issues here, as appropriate.

5. Configuration Control

The SYSTEM NAME SPP applies to SYSTEM NAME, variant(s) X, Y and Z in use. It includes developing a programme concept, specifying the conduct of aging and characterization studies, and providing inputs to the design process such as lessons learned, data extraction capability, documentation development and execution planning. Additionally, inputs must be made into the planning, programme and resource management process for spares procurement and logistics/maintenance funding to provide for sample removal from the inventory at the appropriate time and place. Address configuration control issues for this SPP in terms of known or anticipated configurations and variants of the items or variations in test or evaluation philosophy or processes that will be required to be covered. If necessary treat different configurations as separate Test Item populations.

6. Data Sources

The ISS baseline will be established from data derived during Engineering and Manufacturing Development (EMD), qualification tests, Lot Acceptance Tests (LAT), service firings, accelerated aging studies, predictive models, maintenance data, and engineering assessments. The SYSTEM NAME ISS will combine physical and functional data with component testing to identify changes that might affect safety, reliability, or performance.

A.5. ISS PROGRAMME OBJECTIVES

1. The objectives of the SYSTEM NAME ISS programme are to assess and evaluate (through test, evaluation, and data analysis) that the SYSTEM NAME will remain in a safe, reliable, and serviceable condition and that it will meet its operational performance requirements during its service life. This SPP implements national policy of the Nation undertaking in-service surveillance and assigns responsibility for the Programme.

Objectives include:

a. Determine the current condition, identify trends, and predict the future condition of the SYSTEM NAME inventory in terms of safety, reliability and performance.

b. Determine causes of decreased quality levels. Identify and evaluate factors affecting the current condition of the stockpile including those originating from design, production, maintenance, storage, and deployment and those resulting from combat systems interfaces.

c. Make End of Service Life recommendations to the APM/TLPM based on actual environmental conditions/stress. Provide feedback to APM/TLPM and the SYSTEM NAME Design Authority/Agent (DA) including any findings that may be design and warranty related.

d. Determine the effects of SYSTEM NAME programme stockpile improvement and/or maintenance decisions or actions on the safety, reliability and performance of the in-service stockpile.

e. Provide system and component level evaluations based on tests, modeling, simulations and other technical and statistical factors as appropriate. Identify components and/or replaceable assemblies (e.g. missile sections) requiring replacement during refurbishment maintenance periods; with sufficient advance notice to permit orderly planning and budgeting for the necessary maintenance and logistics actions.

f. Integrate findings into the acquisition process to improve design evolution and inform future product improvement processes.

g. Determine causes and effects of weapon failures, anomalies, and degradation trends.

h. Provide recommended corrective actions as appropriate.

2. STANAG 4439 tests that are performed during development assess the initial insensitive munitions hazards of the system. ISS tests, evaluation, and analyses are performed to detect changes in the properties of the energetic components. If testing (full scale or small scale) identifies changes in the mechanical, thermal, and chemical properties of the explosive from the design baseline, further tests may be proposed to investigate the explosiveness of the material. These tests should be proposed when there is reason to believe that system characteristics have changed from the original baseline.

A.6. ROLES AND RESPONSIBILITIES

Details of roles and responsibilities can be found in AOP 62 main text.

Key personnel and/or organizations should be identified in this section for each role/responsibility stated in AOP 62. In particular a responsible and empowered organization or individual must be identified for each of the following roles:

Coordinator
Acquisition Programme Manager (APM)
The Through Life Programme Manager (TLPM)
System Support Engineer (SSE)

Test Item Roles and Responsibilities

TEST ITEM	CORDINATOR	APM	TLPM	SSE e.g. Design Authority and/or Safety Authority
ITEM 1 e.g. Warhead Section				
ITEM 2 e.g. Propulsion Unit				
ITEM 3 e.g. Arming & Ignition				
ITEM 4 e.g. Guidance & Control				

Table 1 - SYSTEM NAME Item & Organization Assignments

A.7. INTERFACE WITH OTHER PROGRAMME

1. The coordinator shall coordinate joint use of test equipment from other programmes (where appropriate) and identify SYSTEM NAME test equipment requirements. These requirements shall be provided by the Coordinator annually to TLPM and the APM ISS Representative for review and consideration. APM is responsible for the initial acquisition of SYSTEM NAME unique test equipment and the TLPM is responsible for the acquisition and replacement of generic test equipment utilized by multiple test programmes.

2. Joint evaluation efforts and sharing of common data with other programmes will be pursued to the fullest extent possible. It is necessary to name and discuss the various inter-relationships with other programmes (National and International), including the sharing of funding, test equipment/facilities, comparison to data from other systems and memoranda of understanding.

A.8. DEVELOPMENT PHASE

1. This phase includes the up-front planning for the SYSTEM NAME ISS programme. It is in this phase where the programme concepts, Test Items (TI), technical approach, critical characteristics, test strategy, sampling approach/criteria, peculiar test equipment, aging & predictive models, and budget requirements need to be identified, planned and documented. The SYSTEM NAME programme must be carefully planned and budgeted as part of the Total Ownership Cost (TOC) of the SYSTEM NAME system programme. Programme development documentation includes the SPP, Item Test Plans (ITP) and Item Implementation Plans (IIP). Each is important and covers different levels of the ISS process. Detail descriptions of each of these types of documents are identified as follows:

a. System Programme Plan (SPP). This is a top-level document, which includes system level objectives, scope, description, roles and responsibilities. It explains the programme process and identifies the Test Items. The SPP is the master document, which umbrellas the ITPs and IIPs.

b. Item Test Plan (ITP). This document explains what is going to be executed during In Service Surveillance for each Test Item. An ITP is required for each TI identified in the SPP. It includes TI level objectives, scope, description, sampling concept, and critical characteristics. It is recommended that the initial ITP is prepared three years prior to the first In Service Surveillance of that particular TI.

c. ISS Item Implementation Plan (IIP). This document explains how the In Service Surveillance for a particular Test Item will be executed. It includes organizational roles, development & proofing of SOW, cost estimates for testing, milestones/timeline, storage issues, test equipment requirements, training requirements, test readiness review checklists, and budget requirements.

d. Development Phase Funding Responsibility. The SYSTEM NAME Acquisition Programme Manager (APM) will provide initial funding and ensure the resources required for ISS are included in the programme costs.

e. ISSP Development Working Groups. In the development phase, the Coordinator plays an important role in bringing the various communities together for the SYSTEM NAME programme development by use of working groups. The working groups may include Design Authorities, Engineers, Safety/Reliability/Performance Engineers, Acquisition Engineers, Test Engineers, and other members of the technical community. The issues that need to be addressed by the working group(s) during the initial planning stages include the following:

(1) Item Description. Obtain or provide a clear understanding of configuration, physical, electrical, mechanical, and explosive components, theory of operation, and application.

(2) Commonality. Investigate components and explosives common to other weapons systems. Investigate failure and aging history of those common components and explosives in order to determine what lessons learned can be applied to the SYSTEM NAME ISS Programme.

(3) Production History. Determine production profile. Determine who are the manufacturers and sub-contractors and what years of production are planned. If an item is already in production, investigate and track waivers, deviations, and Engineering Change Proposals (ECP). These may influence preliminary sample selection.

(4) Design Concerns. Determine which design elements are concerns to the Programme Manager regarding safety, reliability, and performance of the SYSTEM NAME system and TIs. Consider which design features are susceptible to malfunction or failure during extreme storage conditions and deployment environments.

(5) Critical Characteristics/Parameters. Critical characteristics are those elements that change with age and environmental stressing that may affect safety, performance, and reliability within the nominal life cycle of the SYSTEM NAME. The SPP needs to determine what the critical characteristics are not only at the TI level, but also how they interface at the sub-assembly and system level. It also, needs to determine what are the operational limits and should develop a good understanding of the aging accelerating conditions. The SPP should also investigate and recommend methods for testing and evaluating the critical characteristics and for collecting data including baseline information.

(6) Sample Strategy. The SPP shall develop a sampling strategy. This includes determining whether special samples need to be produced or if samples will be taken from the inventory, or a combination of both. The SPP should determine the initial sampling construct. This is usually based on manufacturer, year of manufacture, waivers, deviations, ECPs, and other factors which may result in production variations. Final ISS sample constructs for a particular test cycle are dynamic and can change depending on the particular test objective(s) for that test cycle. Logistics, maintenance, and in-service condition/policies shall also be considered.

A.9. EXECUTION PHASE

1. This phase includes the test and evaluation cycles of the weapon system and its components. It takes place after the system is in service and is comprised of the “traditional” ISS elements, which include sample requisitioning, testing, analysis, and reporting and recommendations.

2. Execution Phase Responsibility

a. The PM is responsible for programme execution. This includes performing test and evaluation, maintaining documents (i.e., SPP, ITP, and IIP), drafting Test Plans, and modernising, replacing, and upgrading test technologies and equipment.

b. Sampling Concept (see AOP 63 for more detail in this area). The sampling concept may vary for each TI depending on availability, design sophistication, and production quantities. Further details of sampling can be found in AOP-63. Samples are selected on the basis of manufacturer, year of manufacture (age), production lot, production variations (i.e., waivers, deviations, and ECPs) and previous experience with similar production populations and fleet exposure.

The initial goal is to collect data from a broad age group that is weighted toward older samples (See AOP 63 for a description of fleet leaders). If testing yields unusual results then additional samples are taken from the same lot or population to further investigate the proliferation or consequences of the unusual features. Any potentially unsafe conditions must be reported to the SSE and a safety assessment conducted immediately.

Samples will be selected from various groups within the inventory with the goal to develop a "focused" sample that will allow evaluation and analysis of any suspected issue/problem. Spares to replace assets pulled out from the inventory shall be planned as needed and included as part of production planning.

A.10. TESTING

1. Testing the SYSTEM NAME TIs fall under four main categories:

   a. Functional destructive testing.

   b. Non-functional destructive testing.

   c. Functional non-destructive testing.

   d. non-functional non-destructive testing.

2. Destructive tests include arena/static fire type tests, detail teardown or dissection, explosive analysis, and sub-component function test. Non-Destructive testing includes visual inspection, physical dimensions, non-destructive electrical measurements, and radiographic, ultra-sonic, or other spectral examinations and inspections. One or a combination of destructive and non-destructive type testing may be used to evaluate a particular asset. The type of evaluation depends on the type of inspections and tests required to meet the test objectives and may vary from test cycle to test cycle for a particular TI.

3. Test Readiness Review

Test Readiness Reviews (TRR) are required prior to performing testing to ensure that test objectives are clearly defined and can be met by the test methodology/equipment. The following should be checked during a TRR:

   a. Test objectives and requirements are clearly defined.

   b. Test methodology capable of supporting objectives.

   c. Test equipment can meet the requirements.

   d. Test equipment is documented, validated, verified and accredited.

   e. Supporting equipment and facility in place.

   f. All necessary documentation prepared and approved (i.e., Hazard Classification).

   g. Material movement procedures in place.

   h. Scheduling.

   i. Personnel available, authorised and suitably trained (qualified and experienced).

A.11. ANALYSIS, REPORTING & RECOMMENDATION

1. During the analysis of the data, root causes for anomalies are investigated. It is necessary to determine if anomalies are caused by production, design, handling, aging, or a combination of these factors. Other data sources such as other testing, aging studies, explosive characterization, lot acceptance testing and qualification testing are utilized to determine trends and the effect they have on the asset in terms of safety, reliability, performance, and service life.

2. Data should always be presented in a way that the characteristics of stressed and unstressed test items can be compared with any noticeable differences clearly highlighted. Where it is the intention to treat any noticeable change in test item characteristics as acceptable without further action a full explanation of the reasoning behind such a decision must be given.

APPENDIX 1 – SYSTEM DESCRIPTION

A list of applicable specifications and drawings can be found in this APPENDIX.

1. Applicable Specifications:
   Item Proof/Performance Specifications
   Explosive/Hazard Data Sheets

2. Applicable Drawings:
   System Master Record
   System Marking Drawing
   System/Item Assembly Drawing

APPENDIX 2 – REFERENCE LIST

For larger projects an additional APPENDIX may be required for additional reference documentation.

a. System requirements documents or other requirement documents
b. Cost and operational effectiveness analysis applicable to the performance of the system
c. System level FMECA
d. System/Item Test and Evaluation Plan, especially critical parameters table
e. System Safety Plan.
f. System Integrated Logistics Support (ILS) Plan.
g. Any relevant engineering reports.
h. Accelerated aging of this unit
i. Technical evaluation reports
j. Operational evaluation reports
k. Production Reports
l. Prior Failure/Engineering Investigations
m. Security Classification Guide for the System
n. Aging Studies
o. Maintenance/Recertification Plan
p. Production contract/warranty clauses

ANNEX B ITEM TEST PLAN

B.1. FOR AN EXAMPLE ITEM FROM THE EXAMPLE SYSTEM

This Item Test Plan format and development guide is prepared in the recommended format of the actual document. This includes typical language, questions to promote thought, and/or examples of the required information for most of the sections, for an “Example programme”. As there is no such programme as the "Typical Programme", any and all specific programme Item Test Plans should be tailored to meet the needs and requirements of the individual programmes. The goal of this document is to foster thought and facilitate documentation of ISS planning for munitions systems.

Cover Sheet:

May Include Logos or other Identification of the Project and System from which the Item is taken.
Consider Providing a Picture of Your ISS Item.

This Document should be Agreed and Signed by:

The Coordinator

The Acquisition Programme Manager (or Representative)

The Through Life Programme Manager

Design - System Support Engineer

B.2. CONTENTS

An ITEM Test Plan should include the following sections.

B.3. INTRODUCTION

1. The concept of the ISS programme for System Name is contained in System Programme Plan (SPP number xxx). The SPP provides the programme requirements, the roles and responsibilities of each member of the ISS team, and the planning processes required for execution of the programme. This Item Test Plan (ITP) provides the specific test and evaluation requirements for the System Name Component Name. It establishes the processes and procedures for evaluating the System Name Component Name for changes that could influence or impact system or user infrastructure safety, reliability and overall performance. The Component Name will be assessed to identify changes that may affect the mission capability of the System Name and to predict component or system level service life, maintenance intervals (i.e., reliability centre maintenance requirements), and/or storage requirements. These recommendations; i.e., service life changes or establishment, etc. will be submitted via the ISS Project Manager (PM) to the Acquisition Programme Manager (APM).

2. The introduction section will also include:

   a. An explicit statement in the ITP propagating the roles and responsibilities requirements from the applicable SPP.

   b. Mission Description. "What does the user need the thing to do and how will we know if it can do it. Example the XYZ widget must spin at 3200 RPM +/- 200 RPM for Z seconds with no more than 0.0Y seconds spool up time. This is a safety (or reliability or performance) requirement or multiple safety and reliability requirements. Is it reasonable and practical to measure this parameter? Reference the requirement documents that establish the need for the system/component and the parameters it is required to meet. Briefly summarise the mission in terms of objectives and general capabilities. Include a description of the operational and logistical environment envisioned for the system. No classified data is to be included in the ITP, but references to classified documents should be included to indicate where to find any classified information necessary.

c. Item Description. Briefly describe the item and how it fits into the overall system design. Define major subcomponents. Complete description of Item and System Design can be included in Appendices.

B.4. OBJECTIVES

Each of the items listed below should be addressed as an objective of the Component Name ISS effort. Detailed discussion of each of these is not necessary in this section; however each needs to be used in developing the specific component test, evaluation, and analysis processes.

a. Determine and evaluate changes in the Safety, Reliability and Performance (SRP) characteristics of the item and assess their impacts on in-service inventory/usage.

b. Identify changes related to age/environment/service use.

c. Determine the feasibility of establishing a predictive model that can be populated with ISS data; i.e., environmental, age, test, maintenance, usage, deficiency etc.

d. Provide end of service life or service use restriction predictions.

e. Develop contract data requirements (and justification/why) for lot acceptance data, as built configuration data, manufacturing processes data, etc. and forward to the Through Life Programme Manager (TLPM) or APM ISS representative for inclusion in acquisition contracts.

f. Provide recommendations for management of in service assets.

g. Provide feedback to engineering agencies for design related issues.

h. Determine causes and effects of weapon system failures, anomalies and degradation trends.

i. Provide recommended corrective actions for failures, anomalies, and degradation trends to APM.

B.5. ISS PROCESS FOR THE ITEM

1. To comprehend the system/component requirements that translate to the item test, evaluation and analyse requirements, the engineer must review all existing system and component documentation and data to fully understand the safety, reliability, and performance requirements the item is to meet. The SPP will include as a reference a comprehensive list of pertinent documentation and data sources that typically includes:

   a. System Development Documents – FMECA, test plans, logistics plan, system safety plans, maintenance and re-certification plans, aging studies, system security classification guide, etc.

   b. System Production Documents – Production contract and warranty clause, certificate of design, production specifications and drawings, production waivers/deviations, production failure/investigation reports, inspection and quality assurance results/data, production history homogeneity/stratification, etc.

   c. System In Service History Documents – Flight test data, environmental exposure, in service experience, depot repair data, etc.

2. From this documentation and data review the ISS team is prepared to outline the system requirements that become relevant to ISS of the Item.

3. The process the co-ordinator must follow to properly define the programme for the item, fits into three major categories; Planning, Execution, and Communication. The following process should be adapted to meet the objectives described above.

4. Item ISS parameters.

   List the critical parameters, characteristics and concerns for the ISS of this Item.

   a. List the critical parameters (including the source) – define the concern, outline its effect on safety, reliability, and performance, estimate its probability of occurrence (low, medium, high), and the technique to be used in evaluation. If an extended rationale is required include it as an appendix.

   b. Recommend frequency of testing (when will it be expected to become a problem and how will we be able to know sufficiently in advance to allow for orderly actions by the APM or users).

5. Existing Data Sources.

   List other programmes and data sources that will be used in the ISS of this Item.

   a. ISS of a similar systems or components.

   b. Programmes conducted by other services or users.

c. System maintenance or re-certification programmes.

d. Other developmental data and existing information.

6. Evaluation Test Methods.

Outline the programme required for the Item.

a. Predictive modelling and non-destructive inspections.

b. Accelerated aging programmes.

c. Destructive testing and spares or replacements.

d. Equipment from other ISS efforts that is or will be common to this effort.

e. Inventory quantities and stratification.

f. Deficiencies in data (first article testing/lot acceptance testing/qualification) that needs to be addressed.

g. Required funding profiles, milestones and schedules.

7. Evaluation Testing.

Executing the test programme:

a. Develop Item Implementation Plans (IIP).

b. Propose/receive evaluation funding.

c. Order samples, receipt inspection, distribute to test agencies.

d. Conduct test readiness reviews (document - equipment calibration, correlation of system/item operation to the test, certify operation readiness).

e. Confirm first unit results and release remaining units.

f. Dispose of residuals and waste.

g. Collect data and analyse results.

8. Reporting and Plan Revisions.

a. Progress reports (monthly, quarterly, and annual) and notification of safety failure

b. Final (completion of ISS cycle) reporting of results, comparison to criteria (e.g. pass fail criteria, previous results, etc.), impact on service life goals or predictions, other inventory recommendations, aging trends. See Appendix E for an example of the report contents

c. Review and revise the IIP, ITP and SPP as required

d. Changes to evaluation methods, sample requirements, and ISS intervals as needed

APPENDIX 1 – DETAILED DESCRIPTION OF SYSTEM & ITEM

System Description

The detailed system description should include an overview of what mission the system was developed to perform (what platform, how, when, where, etc.). A list of key components and a diagram will be included. The detailed description of the system will be provided in the SPP.

APPENDIX 2 – TEST METHODS, DESCRIPTIONS, LIMITATIONS AND APPLICATIONS OF RESULTS

For each test, fill in the information for each of the 7 elements:

1. Test 1 - Name of Test

    a. Objective: Describe the objective of the test and what critical parameter it applies to.

    b. Method: Describe the test method or refer to an established method, e.g. ASTM, appropriate STANAGs/AOPs, National procedures, etc.

    c. Instrumentation and equipment: Detail any specific equipment required for the test.

    d. Data Obtained: List the data.

    e. Test requirements/environmental conditioning and controls: For example in a rocket motor firing this section would give the time out of chambers as a function of outside temperatures and insulation requirements to protect the asset until testing.

    f. Limitation: Give the limitations of the test and the data. i.e. what does this test not do for you.

    g. Application: Give the applicability of the data. i.e. what does this test do for you.

    h. Evaluation: Parameter Limits. Do you have end of life criteria? Specification only?

APPENDIX 3 – POINTS OF CONTACT

List of everyone involved (especially at the planning stage) including; area of responsibility, name, address, phone and e-mail

APPENDIX 4 – DETAILED JUSTIFICATION SHEET

Provide a detailed cost assessment and justification for the Item Test Plan. Include objectives, likelihood of success, the number of test items required and the population of Items covered by the results (e.g. Only Version 1 is covered or only Items in deep store are covered).

APPENDIX 5 – TEST REPORT OUTLINE

1. TITLE
2. CONTENTS
3. FOREWORD

Point(s) of Contact including, Name, Activity, and telephone number

4. EXECUTIVE SUMMARY

1 to 2 Paragraphs for a small item
1 to 2 pages for a large or complex item

5. BODY OF REPORT

a. Introduction

(1) Scope: Provide a clear definition of the item, material, and processes covered by the report. Included are item/material descriptions in specific terms, the extent of the evaluation covered by the report and any limitations that have been imposed.

(2) Objectives: State specific objectives of the evaluation, relating them to the objectives of system SPP, ITP, past findings, incidents, etc.

(3) Background: This should be one or two paragraphs maximum (Reference the ITP as necessary).

(4) Item Description: This should be a general description and usage of the item including the next level and the systems(s) that contain the item. Reference the ITP as necessary.

(5) Production History: History of production of item including manufacturers of fully assembled item and major subassemblies, dates of production, and any material or process changes occurring during production of item. Provide numbers of items produced and number in current inventory.

(6) Previous Test Results: General description of previous test and evaluations of item, including report number, date of test or evaluation, performing organisation, and general evaluation results and recommendations.

(7) Service Life Parameters: Description of item characteristics, if any, that restrict usable life of item. Relate to ITP critical characteristics. Provide total and remaining service life data of item and components.

(8) Processing Restrictions: Listing and general information on instructions or messages that provide item restrictions or unusual processing requirements.

(9) Deployment History: Listing those mechanical and climatic environments that the munitions have experienced this includes durations, temperatures, packaging configuration etc. This will help in the identification of ‘fleet leaders’.

b. Sampling

(1) Criteria: State specific criteria used in selecting evaluation samples to meet objectives. Include any in service monitoring data that may have led to that particular item being selected (e.g. longest air carriage hours or extended periods in high temperature surroundings).

(2) Stratification: Identify subpopulations present in current inventory of item.

(3) Test Sample Description: Detailed description of items evaluated by manufacturer, mark/modification, manufacturers’ lot numbers, serial number ranges, vendors, and other descriptive data.

(4) Inventory Represented: Subpopulations represented by the test samples.

c. Evaluation Criteria

(1) Overview: A brief description of basis for evaluation requirements, including controlling documents (ITP, specifications, etc.), organisations determining evaluation parameters, and specific tests and inspections performed.

(2) Operating Procedures: Include any standard Operating Procedures (SOP), processing manuals, or unique processing methods or procedures that have been established for the item evaluation.

(3) Evaluation Processes: A brief description of any test equipment and facilities used during the evaluation, including calibration / certification information as required, any required preconditioning of equipment or test items, and identification of any deviations from laboratory inspection and test plans. Identify any physical inspections performed, the parameters measured during testing and retesting performed. Specify if the retest was required by test procedure or because of questionable results, and test item or equipment malfunctions.

d. Results

(1) This should give the results of the inspections and tests in both tabular and narrative form. The techniques used in test data analysis. Use of graphs, drawings and digital photographs is encouraged.

e. Data Analysis

(1) Present a narrative interpretation of the inspection and test results. Indicate any other data used in the analysis of inspection and test results; e.g., lot acceptance tests, qualification, preflight, flight, and transferable data from similar systems. Include results of previous inspections and tests as related to current results (e.g. trends to reinforce findings).

f. Conclusions

(1) The conclusions reached on the basis of inspection and test results and a discussion of evaluation results. Include comments/conclusions addressing safety, reliability and performance change indications.

6. OPERATIONAL RECOMMENDATIONS

Provide recommendations regarding the current safety, reliability and performance of the population the test items represent. If the safety or reliability is determined to be unsatisfactory, recommend actions to be undertaken such as change to training usage only, operational environment restrictions or specific maintenance operations.

7. RECOMMENDATIONS

Recommendations based on current evaluation results or evaluation programme requirements. These may include further or additional testing, modifications to the existing ITP and SOP (test frequency, sampling and test equipment) that the Coordinator needs to make, based on the change indicators or trends identified in paragraph 6.

8. OBJECTIVES STATEMENT

Statement on whether stated objectives identified in paragraph 1 were met and if not, why not. Are further tests or inspections required to meet objectives, or were objectives changed with joint community/Coordinator approval as a result of conditions found?

9. SAMPLE MANAGEMENT

Give the final disposition of evaluation samples including location and condition codes if applicable.

10. REFERENCE DOCUMENTS, DRAWINGS AND DETAILED TEST RESULTS

11. REPORT STAFFING PROCESS

a. External Review
The draft report shall be sent to the item, technical specialists and prime contractor, if applicable, for review and comments. This provides a fully staffed report to the PM and the APM instead of the PM and/or the APM having to start the review process.

b. Review Comment Incorporation
Review comments shall be incorporated into the report. A discussion on any areas of differences between engineers and reviewers together with proposed plans to resolve these differences shall be included in the report.

c. Final Review
After incorporation of community comments, report shall be submitted to the management chain for final review and sign-off:

Engineer or Report Author
System Support Engineer
Manager or APM or Designated management official for formal signature
Coordinator
Project Manager

12. REFERENCES

System ORD/MNS or other requirement documents
System Specification & Item Specification
System-level FMECA
System/Item Test and Evaluation Master Plan, especially critical parameters table
System Safety Plan
System Integrated Logistics Support (ILS) Plan
Drawings of the item
Any relevant engineering reports
Accelerated aging of this unit
Production Reports
Prior Failure/Engineering Investigations
Security Classification Guide for the System
Ageing Studies
Maintenance/Recertification Plan
Production Contract/warranty clause

ANNEX C ITEM IMPLEMENTATION PLAN

C.1. FOR SYSTEM NAME, ITEM NAME

This Item Implementation Plan format and development guide is in the recommended format. This document includes typical language, questions to promote thought, and/or examples of required information for most sections, for an “Example” programme. As there is no such programme as the "Typical Programme", any and all specific programme Implementation Plans should be tailored to meet the needs and requirements of the individual programmes. The goal of this document is to foster thought and facilitate documentation of ISS planning for munitions systems.

Cover Sheet:

May Include Logos or other Identification of the Project and System from which the Item is taken.
Consider Providing a Picture of Your ISS Item.

The IIP is a tool for communicating “How” the ISS for a test Item will be executed. It documents the process used in planning, conducting and communicating the evaluation of an Item. The IIP is the work agreement between the Acquisition Programme Manager and Test Agency (i.e. a Statement of Work)) and identifies the process for releasing to test (Test Readiness Review). The IIP can be tailored to meet the needs of a given programme; it can document either a single test, a sequence of tests, or a group of tests.

This Document is Agreed and Signed by:
The Coordinator
The Test Engineer

C.2. CONTENTS

An ITEM Implementation Plan should include the following sections.

Section	Heading
1	INTRODUCTION
2	OBJECTIVES
3	ROLES AND RESPONSIBILITIES
4	ITEM TEST READINESS AND ISS PROCESS REVIEW
5	POINTS OF CONTACT

C.3. INTRODUCTION

Item Description

Briefly describe the item and how it fits into the overall system design. Define major subcomponents or subassemblies. Provide a detailed description of how the item operates within the weapon system. Describe all features of the item that impact the safety, reliability and performance of the system.

C.4. OBJECTIVE

Determine and evaluate the response or reaction of the enter component name to enter name of test.

C.5. ROLES AND RESPONSIBILITIES

Identify all participants (organisation, name, phone number and email address) and their roles and responsibilities in the execution of work required by this Plan. Details of the roles and responsibilities can be found in AOP A.

C.6. ITEM TEST READINESS AND ISS PROCESS REVIEW

Paragraph 4 must be completed with sufficient detail to ensure thorough definition and understanding all elements of accomplishing the work. When completed, Section 4 provides a test readiness review checklist ensuring the test is ready to proceed.

1. Details of the Item and any Test History

   a. Provide historical summary of this item or similar items that have been subjected to this test. Provide relative level of concerns.
   b. Objectives and results of previous tests of this Item, ISS, evaluation trials, lot acceptance tests.
   c. Prior test results of similar items, as tested locally or by others.
   d. Identify Item failure modes.
   e. Test item configuration (S/N, lot, applicable waivers and deviations, in-service exposure). Include other developmental data and existing information.
   f. Identification of hazardous components and contents of each.

2. Data Requirements and Assessment

Provide a required Format for Data sheets, Electronic files, audio/video, or Photographs.

3. Shipping and Storage Requirements

Provide local stock numbers, interim or final Hazard Classification and identify any special handling or storage requirements.

4. Training, Test Procedures, and Equipment Requirements

   a. Define personnel training and qualifications requirements for this effort.
   b. Define methods for conducting the test (STANAG, AOP, SOP, National procedures).
   c. Specify test fixtures and unique tools required for the operation.
   d. Specify instrumentation and data acquisition systems to be used, and calibration requirements.
   e. Identify and document correlation methods. Compare proposed data and methods to previous test data and methods.

5. Test Start and Stoppage Criteria.

   a. Who must be present to start or must confirm first unit test results before proceeding.
   b. How many failures/successes before stoppage.

6. Expected Results and Pass/Fail Criteria

   a. Values (units and tolerance), mean, standard deviation.
   b. Determination and resolution of statistical outliers.

7. Supporting Analyses

Identify any other analyses required upon completion of the test. Particularly for defects or faults identified that were not expected as part of the original test regime.

8. System Safety Analysis

Provide for the Item as well as the test facility.

9. Management of Residuals and Waste

a. Define how

b. State by whom

10. Reporting

a. Milestone charts; provide progress report frequency and method, and final report requirements.

b. Document costs projected to accomplish each significant phase, such as an individual test or sequence of tests. Provide sufficient breakdown to identify ancillary costs such as packing, shipping, storage, and disposal.

11. Statement of Work/Standard Operating Procedure

A contract ready Statement of Work or a verified Standard Operating Procedure in accordance with applicable national safety requirements shall be created using the information developed in paragraph 4.

C.7. POINTS OF CONTACT

List including; area of responsibility, name, address, phone & e-mail

AOP-62 (A)(1)

NATO STANDARD

AOP-63

IN-SERVICE SURVEILLANCE OF MUNITIONS SAMPLING AND TEST PROCEDURES

Edition A Version 1

NOVEMBER 2012

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NATO LETTER OF PROMULGATION

[Date]

1. The enclosed Allied Ordnance Publication AOP-63, In-Service Surveillance of Munitions Sampling and Test Procedures has been approved by the nations in the AC/326 CNAD Ammunition Safety Group, is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 4675.

2. AOP-63 is effective upon receipt.

3.

4. This publication shall be handled in accordance with C-M(2002)60.

Cihangir Aksit, TUR Civ
Director NATO Standardization Agency

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
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RECORD OF SPECIFIC RESERVATIONS

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CHAPTER 1 IN-SERVICE SURVEILLANCE OF MUNITIONS – SAMPLING AND TEST PROCEDURES

1.1. ABBREVIATIONS AND ACRONYMS

1.1.1. List of Abbreviations and Acronyms

ALARP	As Low as Reasonably Practicable
AOP	Allied Ordnance Publication
APM	Acquisition Programme Manager
AUR	All Up Round
BTCA	Breakdown Test and Critical Analysis
CM	Condition Monitoring
ECP	Engineering Change Proposal
EDL	Environmental Data Logger
EM	Environmental Monitoring
EMD	Engineering and Manufacture Development
EMP	Environmental Monitoring Plan
EOSL	End Of Service Life
FSE	Field Support Engineer
IIP	Item Implementation Plan
FMECA	Failure Modes Effects Criticality Analysis
ISE	In Service Experience
ISM	In Service Monitoring
ISP	In Service Proof
ISS	In Service Surveillance
ITP	Item Test Plan
LAT	Lot Acceptance Tests
LCEP	Life Cycle Environmental Profile
PM	Project Manager
PT	Predictive Testing
RCM	Reliability Centred Maintenance
SOP	Standard Operating Procedures
SOW	Statement of Work
SPP	System Programme Plan
SRP	Safety, Reliability and Performance
SSE	System Support Engineer
S3	Safety and Suitability for Service
TLPM	Through Life Programme Manager
TOC	Total Ownership Cost
TP	Test Plan
WLA	Whole Life Assessment

1.2. SCOPE

1. This AOP provides guidance for selecting test items that adequately represent the whole population to be assessed. The document discusses the relative merits of probabilistic and non-probabilistic sample selection and suggests how to determine when to remove samples for testing. This part also indicates where predictive testing shall be required and how the testing requirements can be determined.

2. **Operational Imperative statement:** This document is relevant to anyone wishing to define the sampling techniques for surveillance or estimate the resources required for a surveillance program.

1.3. RELATED DOCUMENTS

AECTP-100	Environmental Guidelines for Defence Material
AECTP-200	Environmental Conditions
AECTP-300	Climatic Environmental Tests
AECTP-400	Mechanical Environmental Tests
AECTP-600	The Ten Step Method for Evaluating the Ability of Material to meet Extended Life Requirements
AOP-7	Manual of Tests for the Qualification of Explosive Materials for Military Use
AOP-15	Guidance on the Assessment of the Safety and Suitability for Service of Munitions for NATO Armed Forces
AOP-46	The Scientific Basis for the Whole Life Assessment of Munitions
AOP-48	Explosives, Nitrocellulose based Propellants, Stability Test Procedures and Requirements using Stabilizer Depletion
AOP-56	Compendium of Chemical and Physical Tests for Analysis of Energetic Materials against their applicable NATO STANAG
AOP-62	In-service Surveillance of Munitions, General Guidance
AOP-64	In-service Surveillance of Munitions, Condition Monitoring
STANAG 4110	Definition of Pressure Terms and Their Interrelationship for Use in the Design and Proof of Cannons and Ammunition
STANAG 4115	Definition and Determination of Ballistic Properties of Gun Propellants Definition of Pressure Terms and Their Interrelationship for Use in the Design and Proof of Cannons and Ammunition
STANAG 4123	Methods to Determine and Classify the Hazards of Ammunition
STANAG 4147	Explosives: Chemical Compatibility of Ammunition Components with Explosives and Propellants (Non-Nuclear Applications)

STANAG 4157	Fuzing Systems: Test Requirements for Assessment for Safety and Suitability for Service
STANAG 4170	Principles and Methodology for the Qualification of Explosive Materials for Military Use
STANAG 4178	Test procedures for assessing the quality of deliveries of nitrocellulose from one NATO Nation to another
STANAG 4324	Electromagnetic Radiation (Radio Frequency) Test Information to Determine the Safety and Suitability for Service of EEDs and Associated Electronic Systems in Munitions and Weapon Systems
STANAG 4370	Environmental Testing
STANAG 4487	Explosives, friction sensitivity tests
STANAG 4488	Explosives, shock sensitivity tests
STANAG 4489	Explosives, impact sensitivity tests
STANAG 4490	Explosives, electrostatic discharge sensitivity
STANAG 4491	Explosives, Thermal Sensitiveness and Explosiveness Tests
STANAG 4506	Explosive Materials, Physical/Mechanical Properties Uniaxial Tensile Test
STANAG 4515	Explosives, Thermal Characterization by Differential Thermal Analysis, Differential Scanning Calorimetric and Thermo Gravimetric Analysis
STANAG 4525	Explosives, Physical/Mechanical Properties, Thermo-mechanical Analysis (TMA) for Determining the Coefficient of Linear Thermal Expansion
STANAG 4540	Explosives, Procedures for Dynamic Mechanical Analysis (DMA) and Determination of Glass Transition Temperature
STANAG 4556	Explosives, Vacuum Stability Test
STANAG 4581	Explosives, Assessment of Ageing Characteristics of Composite Propellant containing an Inert Binder
STANAG 4582	Explosives, Nitrocellulose based Propellants, Stability Test Procedure and Requirements using Heat Flow Calorimetry
STANAG 4666	Explosives, Assessment of Ageing of Polymer Bonded Explosives (PBXs) Cast-Cured Compositions using Inert or Energetic Binders
STANAG 4675	In-Service Surveillance (ISS) of Non-Nuclear Munitions

1.4. GENERAL

1. Introduction

   a. In Service Surveillance (ISS) of munitions involves the selection and examination of items from the service inventory. The information gained provides evidence to support a life estimation of particular munitions. A well planned surveillance programme will also allow the early detection of degradation in energetic materials and therefore prevent accidents that might occur due to such instability. For guidance on planning ISS refer to AOP 62.

   b. The surveillance programme will identify which energetic and non-energetic components of the munitions are to be examined. This will typically involve breakdown of the munitions and destructive testing. Munitions containing nitrate esters (e.g. nitrocellulose) require particular attention because of the relatively low stability of that class of propellants. There is however a continual need for economy and operational efficiency which leads to a pressure to minimize the amount of testing, amount of inspections (periodicity) and the number of assets inspected. The use of data obtained from training and non-destructive testing can help in building confidence in the condition of the munitions but such data is rarely complete.

2. Purpose

   a. This AOP provides guidance on how to maximise the value of a surveillance programme through choice of inspection items, size of inspection sample and the timing of inspections and tests. By complying with this AOP nations should be able to:

      (1) Identify what level of surveillance is required for their munitions. (Surveillance Type)

      (2) Quantify the amount of surveillance required for their munitions. (Sample Size)

      (3) Estimate when surveillance should take place. (Periodicity)

   b. STANAG 4675, which includes this AOP, provides methods for ensuring continued safety, reliability and performance of material within the extreme conditions defined in the Life Cycle Environmental Profile (LCEP). This AOP assists in the planning of munitions surveillance by providing guidance on the selection of surveillance assets.

   c. Using ISS techniques to extend service life or to extend the LCEP beyond its initial boundaries should be considered in conjunction with AECTP 600.

1.5. PLANNING FOR ISS

1. AOP 62 describes the process, documentation and roles/responsibilities essential for an effective ISS programme. It outlines the formulation of a System Program Plan, Item Test Plans and Item Implementation Plans. This AOP assumes that this process is being followed and offers guidance on how to reach some of the decisions required during that process.

2. Before munitions can enter service the Coordinator (as defined in AOP 62) should have developed a System Program Plan (SPP). In order to do this they will need to clarify the scope of the system they are responsible for and which components and sub-components are considered as critical items for the surveillance. Munitions can be matched with ordnance or launch systems which in turn can be integrated into platforms. In these cases there may be key interface parameters or materials which need to be considered during the surveillance (e.g. performance of propulsion systems may be linked to targeting systems).

3. In defining the relevant items for test, the SPP must also consider the nature of the test for each item. If structural testing such as modal analysis or vibration are necessary (e.g. in an attempt to look at air carriage hours for an air launched missile) it is neither practical nor accurate to test each sub-component in isolation. Items that require a structural assessment should be kept as All-Up-Rounds, if practical, in order to ensure that the correct structural profile can be replicated in the tests.

4. In general where some form of field simulation or accelerated physical stress is required in the testing then the SPP should identify an Item Test Plan (ITP) that covers the complete munition or even the complete launch system. Where chemical and physical properties, particularly of energetic materials are to be analysed then the ITP would only need to cover the section that includes the material for analysis.

5. Where the SPP identifies the need for functional testing the configuration of the test item may again be different. For performance testing or some reliability assessments it would be necessary to ensure that the system and launcher are included in the ITP. Where critical parameters such as rocket motor pressure or warhead fragmentation are to be measured only that component and its particular ignition system need to be included in the ITP.

6. The SPP must also consider the objectives of the ISS. These objectives can be broken up into two distinct types, basic and extended.

   a. **Basic Objectives.** Basic Objectives cover the mandatory requirement of ISS to check that the system remains safe and suitable throughout its service life and that the system remains safe to handle and store until disposed of.

   b. **Extended Objectives.** Extended objectives are those objectives where it is expected that the ISS provides information regarding the future of the system such as extending the end-of-service date or increasing captive carriage duration.

7. The basic objectives of an SPP would deal only with the current status of the system. They only consider providing confidence that the system is, or is not, meeting service requirements and do not consider life estimation directly. The extended objectives cover the intention to use the data to determine and adjust the life of the system. When attempting to meet extended objectives, the Coordinator and Engineers must be careful not to place more confidence in the data and its associated models than is reasonable. Many degradation processes are non-linear, accelerating over time therefore single point measurements taken periodically may not accurately predict the end of life.

8. In order to have accurate predictions of munitions life using data, three things must happen:

a. The sample (size and condition) must be sufficient to give an accurate estimate of the population condition.

b. The periods between data collection points need to decrease as life increases.

c. The data must include both point measurements and rate measurements.

Guidance on requirements at (a) and (b) is given in more detail in future sections of this AOP.

9. Some of the methods which are outlined in AOP 64 and the stabiliser depletion methods in AOP 48 cover the requirement at 8c for some chemical degradation processes. Combined effects, and most physical effects caused by vibration and shock, cannot be covered by small scale laboratory tests. Consideration should be given to including an amount of accelerated ageing (Predictive Testing) for some or all of the surveillance assets, in order to estimate the future rate of degradation. This can effectively turn an ISS trial into a Life Extension Trial (See AECTP 600) but should not prevent it from being included in the ISS process.

10. Although not recommended for those with little ISS experience, it is occasionally possible to cover the extended objectives without including accelerated environmental tests. However, any failure mode which occurs over a relatively short period of time that cannot be identified through regression analysis may allow an extremely short lead time for corrective action or new purchases of that item. Where it is the intention to predict system life, without using additional Life Extension techniques, even greater care is required when addressing the requirements of 8a and 8b. Effective In Service Monitoring (ISM) and selection of “fleet leaders” also becomes more important.

11. Where there is low confidence in the system under surveillance; where initial life predictions were excluded; or where the extended objectives of the surveillance programme include significant changes to the usage profile or munitions life, then the Coordinator should refer to AECTP 600 for guidance on Life Extension and consider the inclusion of predictive testing (See Section 1.7) within the SPP and subsequent

ITP. In particular, Life Extension test techniques should be included within the programme where long term external carriage on fast jets, or munitions lives in excess of 10 years are being considered.

12. In certain cases it may be considered reasonable to use items/components/materials procured and stored specifically for surveillance purposes. This would typically be where:

a. The munitions are generally stored under defined conditions with a limited operational life that is only expected for national defence.

b. The extraction of embedded components that require surveillance could lead to the undesirable destruction of a considerably more expensive system.

c. The difference between the stored component life and the operational system life is negligible.

d. The stockpile is too small to destructively test operational systems.

e. The surveillance program does not specifically cover safety.

13. The storage of items procured specifically for surveillance has to be controlled and monitored if the surveillance is to be effective. These items can still be subject to predictive testing prior to analysis where necessary.

14. Further guidance on how to populate the sampling and testing sections of System/Item Test Plans for different classes of munitions is given in Annex A to C. The completed documentation should be in accordance with the formats given in AOP 62 to help understanding when transferring data between nations.

1.6. SAMPLE SELECTION AND GROUPING OF AMMUNITION FOR ISS PURPOSES

1.6.1. General

1. In most situations, due to the number of munitions held in the inventory it would be uneconomic to carry out ISS on each batch or lot procured. To reduce the outlay in resources munitions can be "grouped" to form a specific population from which a statistical sample can be examined in detail.

2. Where a number of batches/lots **within a single nature** of conventional munitions meet certain criteria, it is assumed, unless evidence is forthcoming to the contrary, that such batches will function and age uniformly. They can be said to belong to the same surveillance group and to be homogeneous. The essential criteria for forming such a group are as follows:

a. **Manufacturer.** All munitions within a group are to have the same filler, assembler and manufacturer.

b. **Model Number.** The munitions are to be of the same design and model number and are therefore to have the same item modification/mark, Asset Code and Catalogue Number (Cat No.).

c. **Age.** The munitions within a group are to be of a similar age and are to have been produced within the same manufacturing period (usually manufacture should be no more than 12 months apart).

d. **Environmental History.** The munitions are to have experienced a similar environmental history.

1.6.2. Results of Surveillance Testing

This assumption of homogeneity within a group means that the group can be sampled as one population and the results of surveillance carried out on such samples can be held to apply to the group as a whole. Should a sample from a grouping be assessed as a failure, then remaining lots within that group may be submitted for further testing. Note that the previous results cannot be rejected without additional evidence and are retained for further analysis.

1.6.3. Selecting Samples

It is assumed during most ISS that the population being surveyed is homogeneous. Therefore a Probabilistic Sampling Strategy (PSS) can be applied. Homogeneity should be demonstrated during batch/lot acceptance and designed into the system. If the overall population is not homogeneous, but individual parts of it can be considered to be, then sampling will need to consider the stratification of the population. Whether they be divided by batch/lot or usage profile, inhomogeneous or heterogeneous populations can be considered for ISS with samples selected using a Non-probabilistic Sampling Strategy. Reliability cannot be estimated in this way and confidence in results cannot be estimated numerically. The non-probabilistic approach should only be considered if the primary System Support Engineer and the Coordinator agree that no other approach is practical.

1.6.4. Probabilistic (Random) Sampling

1. **Simple random sampling**: This is where the sampling is conducted by drawing a predetermined number of items from the population on a purely random basis. Numerically this provides the easiest sample type for estimating probability of occurrence and confidence levels and is ideal for reliability. Few munitions populations are entirely homogeneous and therefore it is rarely possibly to employ this sampling technique across an entire munitions population. Even where the population is homogeneous often location and availability reduce the ability to have a sample that is purely random.

2. **Systematic random sampling**: With this method the selection of the sample has a numerical pattern rather than being truly random. This is effectively the same as random sampling and more likely to occur as making selections on a purely random basis is very difficult.

3. **Stratified random sampling**: With this method there is known stratification or sub-division to the population. Simple or Systematic methods are then used to select samples from each strata or sub-group. This is the method used for the reliability of items such as gun ammunition that is manufactured in distinct lots. Each lot may vary slightly from each other but homogeneity within lots can be assumed. This method can be proportionate or disproportionate. With proportionate selection, the number of sample items is randomly drawn from each stratum relative to the discrete population size for that stratum. With disproportionate selection, the sample size for a stratum can be varied such that it contributes more or less to the overall assessment. For instance when selecting gun ammunition by lot for firing, the lot with the greatest pressure variability could have an increased sample size if safety on firing was of paramount concern.

4. **Cluster random sampling**: This is a sampling method where the items within the population are considered to be separated into clusters. For example, for a population that is scattered around the world, the items within each location can be considered to be in one cluster. A cluster would be selected at random and all items in that cluster sampled. This could be appropriate for mobile electronic test set measurements, physical inspections or other non-destructive tests.

5. **Multi-Stage random sampling**: This is an acknowledgement that in many cases it might be appropriate to combine one or more of the above sampling methods. Most munitions sampling techniques for reliability are effectively multi-stage random. Items are often stratified into lots and clustered by age or environment. It is not practical to sample an entire cluster therefore it is usual to take a systematic random sample from each cluster (e.g. the top box from every pallet in magazine X).

6. Although it is desirable to be able to put a numerical confidence into ISS assessments the probabilistic approach is not always possible for munitions which have left their primary storehouse. Often it can be impracticable to actually recover a random sample for these munitions. If the population is truly homogeneous then this may not be that important. Many populations are both stratified and clustered with only those clusters held in store available for sampling. The variability of sample age, build standard and the variability of environmental conditions they have experienced can lead to an immeasurable bias error associated with test results. This can render meaningless any confidence and probability levels calculated for those populations. In these cases it is still possible to achieve meaningful ISS results by careful selection of the samples using a non-probabilistic approach and expert judgement of the primary failure modes to be examined.

1.6.5. Non-Probabilistic Sampling

1. **Convenience/Accidental sampling**: This is where the sample is selected because it is the only one that is available or some accident or event has determined that this item is most likely to display the characteristic under investigation. (e.g. we are looking for physical damage internally or externally after the item had been dropped).

2. **Judgement sampling**: This is where the sample is a deliberate choice. Judgement is often used to select ISS samples although the actual method employed bears most resemblance to Quota sampling below. This does have the disadvantage of relying heavily upon expert judgement regarding how well the selected items represent the main population. Even experts can get this wrong.

3. **Quota sampling**: This is similar to stratified sampling where key variables are identified that distinguish sections of the population such as lot, age or environmental exposure. Then a fixed quantity (or quota) is selected from the population using judgement. This is the recognised methodology that best describes the “fleet leader” sampling process often used for ISS and explained below. As with stratified random sampling the influence of each stratum upon results can be adjusted by increasing or decreasing the sample size for that stratum.

4. **“Fleet Leader” sampling**: This is a complex combination of the above non-probabilistic methods. Due to the expense involved in testing and analysing munitions it is often the case that only a small sample can be selected for inspection at each stage. Probabilistic sampling in this situation is unlikely to be practical and therefore the programme must rely upon the expert judgement of the Engineers for selecting the sample. They will try to select a sample that has experienced more and worse conditions than any other item in the population (or fleet). Hence the sample items are known as “Fleet Leaders”. Using Figure 1, an example of a fleet leader selection process is detailed below.

   a. **Deciding key assessment criteria:** Select the key assessment criteria based upon past and future user requirements. This may be chemical degradation with time and temperature or mechanical aging through fatigue or fretting caused by vibration, temperature cycling or shock. It is most likely to be a combination of chemical and physical deterioration and could include age, time at temperature, movement or time on platform, potential stabiliser level, case thickness tolerances and firing pressures.

   b. **Quota Sampling**: Select samples by gathering the relevant information from usage data, environmental data, S3 and lot acceptance records for the entire fleet and ordering them by the key assessment criteria.

   c. **Inspection:** Physically inspect the items identified by quota sampling and conduct any appropriate non-destructive testing. Select those items that looked to be in the worst condition during physical inspection or gave poor results in the non-destructive tests. Do not remove damaged/failed items from the test population unless it is possible to identify and segregate all similarly damaged/failed items from the overall population.

d. **Judgement Sampling**: Using expert judgement, choose a number of samples (more than you intend to use) from the inspected quota samples. The samples should best represent the balance between the most significant parameters as identified by the System Support Engineer. From this group, reject items from lots or production runs that are known to be at the top end of the tolerance band for acceptance (i.e. reject items from lots known to behave well in test).

e. **Convenience Sampling**: Ensure that the selected samples are available for surveillance and can be returned, within timescales to the Test Engineers. If not, it may be necessary to promote others from the selected population. It is good practice to have identified twice as many samples as needed for testing at this point.

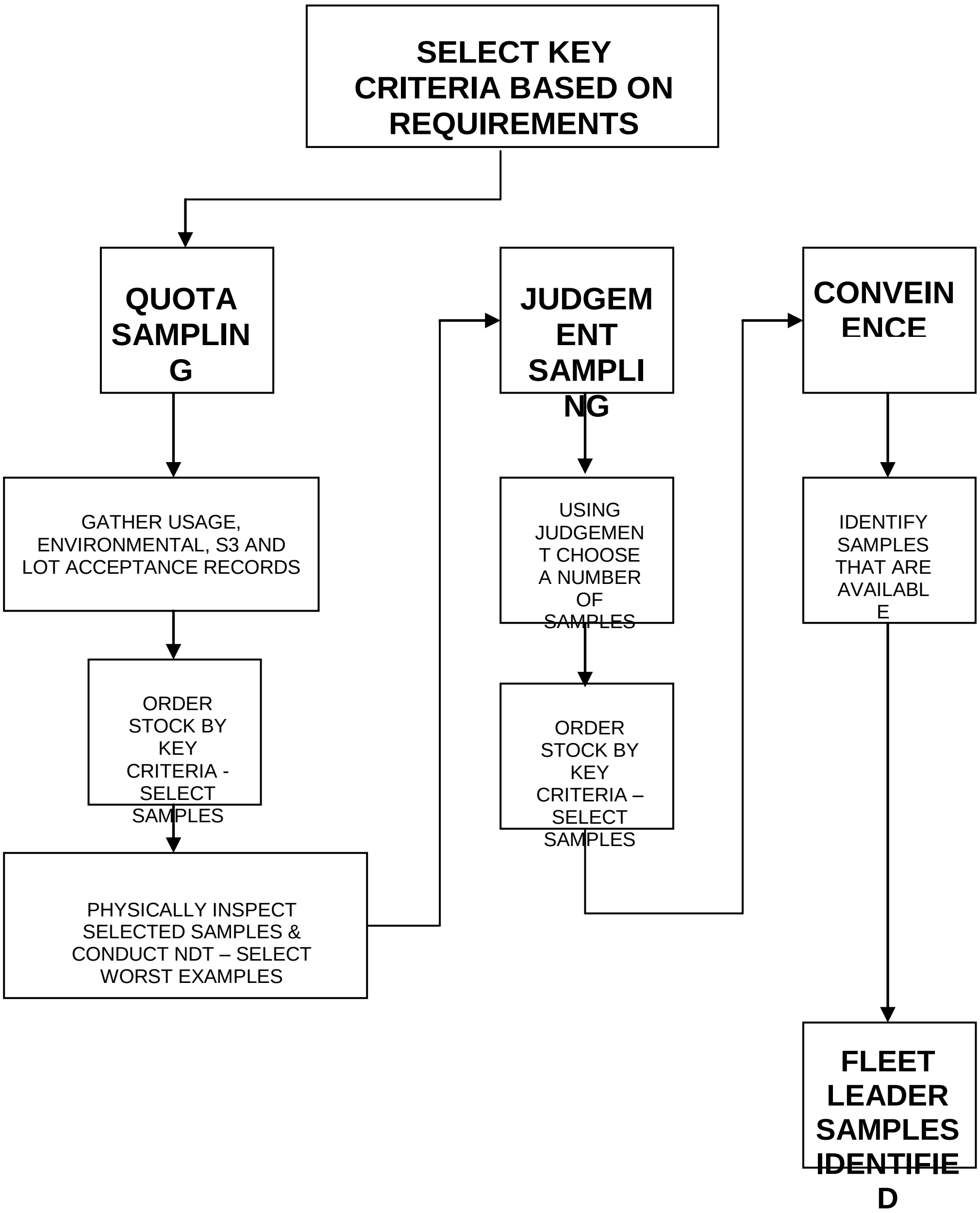

Figure 1 – Fleet Leader Identification

"Fleet Leaders" should be used primarily for safety and life assessments as they are specifically chosen to bias the data towards the worst case. Reliability and performance assessments would be better conducted with probabilistic samples. Statistical probabilities and confidences are unlikely to be meaningful when calculated using "Fleet Leader" samples. Analysis of the results and reporting of the continued confidence in the population must be carried out by experienced subject matter experts and approved by the primary System Support Engineer.

1.6.6. Sample Size

1. For Probabilistic Sampling where the results will be analysed statistically the following factors will influence sample size:

   a. Margin of Error – This is a measure of the difference between the estimated value taken from the sample and the actual value expected for the whole population.
   b. Confidence Level – This is a measure of the likelihood that the data obtained from the sample lies within the margin of error. In very simple terms the larger the sample, the higher the confidence level.
   c. Variability – This is the range of difference across the entire population, often represented by the standard deviation. This affects the accuracy and therefore the sample size required to accurately describe the population.
   d. Population Size – This is simply the number of items the sample is intended to represent. If the sample size is likely to be greater than 5% of the overall population then consideration should be given to population size. If the sample is less than 5% of the population then it is unlikely, that population size has any effect upon the result from that sample.
   e. Population Proportion – This is the proportion of items in a population that display certain attributes that are to be measured on the sample. The sample must therefore be large enough to include enough items with these attributes.

2. For selecting a probabilistic sample, reference should be made to statistical texts and national or international sampling plans (e.g. ISO 2859). The basic goal is to minimise sample size while maximising confidence level.

3. For Non-probabilistic sampling there is no reliable numerical method for determining sample size (other than the bigger the better). Sample size is determined only by the amount of items/material the testing requires and the judgement of the subject matter experts who will analyse the results of the tests. Where increased confidence is required, such as in a safety assessment, this is achieved for non-probabilistic samples by ensuring that the sample condition envelopes, rather than just represents, the population. "Fleet Leader" selection

and/or additional environmental stressing, representing the LCEP, are the accepted methods for ensuring an envelope of the population.

4. The System Support Engineer should be responsible for ensuring the sample size is considered large enough by the subject matter experts to give an accurate enough snapshot of the overall population and cover the safety, reliability and performance characteristics required. The Coordinator should be responsible for balancing the cost of sampling and testing against the estimated risk of the sample being too small. The final sample size should be agreed between the System Support Engineer and the Coordinator. Where the safety of energetic materials is concerned the System Support Engineer should only compromise on sample size when it is balanced against additional testing or design data to increase the confidence in the materials. Figure 1 below shows pictorially the typical balance between design knowledge, sampling, item population, individual item cost and individual item size.

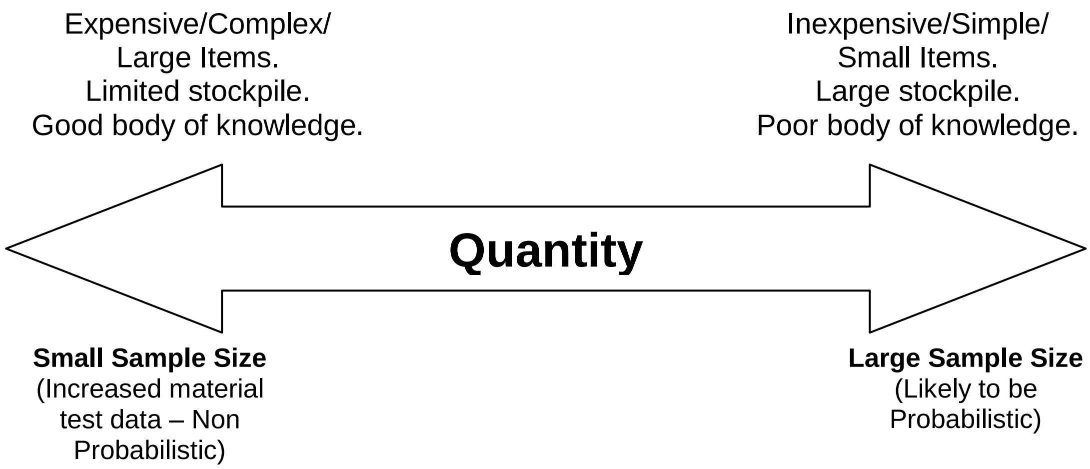

Figure 2 – Choosing a sample size

5. The minimum sample size the System Support Engineer should consider is four, particularly where mechanical stressing is an issue. This allows for two items stressed under mostly hot conditions and two items stressed under mostly cold conditions. Within each pair one item can be functioned and one item can be broken down and analysed. Only when thermal stressing is the primary concern and the items under test are extremely large or expensive, and therefore well cared for, should a number smaller than this be considered for assessing munitions safety.

1.6.7. Timeline and Periodicity

1. For ISS to be effective it must give sufficient data to accurately plot the degradation of an item (particularly the energetic materials) and it must identify critical failures before they spread through the bulk of the population. If used to predict life, the process must report life extension information before the existing life predictions are exceeded.

2. A system may consist of a number of items which are all degrading. The following diagram details the timeline for an item. For the system timeline a number of these processes could be occurring in parallel. The item that will degrade to an unsafe or unreliable state first will determine the periodicity of the system programme.

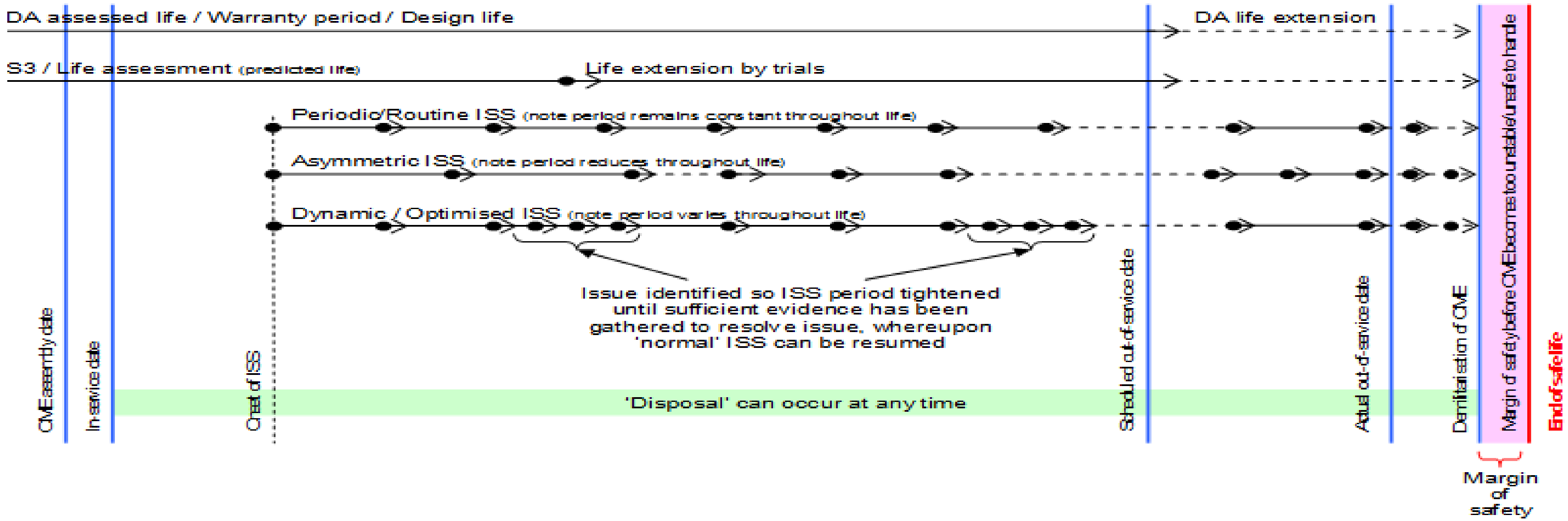

Figure 3 – A Typical Item Timeline

3. Figure 3 illustrates the relationship in terms of time between ISS and the safety and suitability cycle of munitions. There are six key dates in this cycle:

a. **Date of Manufacture** – This is the date when the rate determining material in the item was manufactured.

b. **Munitions Assembly Date** – This is the date that materials, components and sub-assemblies are brought together into the system that is the ammunition or weapon (This is usually the date associated with a single batch or lot). It should be noted that the munitions assembly date may also fall after the In Service Date (ISD) for subsequent procurements such is the case for re-procurement of general munitions.

c. **In Service Date** – This is the date that the system enters service. This date is significant only in that the owning government becomes responsible for the safety and suitability of the system from that date. It can be the start date for ISS planning purposes but should not be confused with the date of manufacture when calculating munitions age.

d. **Out of Service Date (OSD)** – This is the date that the system is removed from service. Although the system is no longer in use after this date, ISS should still continue until the entire inventory has been disposed of. Note that the actual OSD may be some period after the scheduled OSD if the system has had its life extended.

e. **Disposal** – This is the date that the owning government have, used, sold or disposed of (demilitarised) all of the relevant munitions in their inventory.

f. **End of Safe Life** – This is the date at which a significant number of the inventory would be considered to be unsafe. The desire is that this date will always be after the inventory has been disposed of either through demilitarisation or use. It is this date that life assessment and ISS programmes must predict before it is reached. The longer the period predicted the less accurate it is likely to be. Predictions that this date is more than 10 years into the future should be treated with caution.

4. There is another significant date that may be relevant to the item. This is the **refurbishment and maintenance date**. If the item which is ageing can be replaced or maintained in such a way that the ageing process is arrested then the timeline for that item can be reset, effectively moving the date of manufacture forward to the refurbishment date. When considering the whole system, it should be remembered that there may be several items ageing at different rates. Replacing one item may reduce concern regarding that item, but may mean that the item which was ageing at the next fastest rate is now of more concern. When replacing deteriorated components it may not be possible to reset the effective start date all the way to the refurbishment date.

1.6.8. The Three Types of ISS (Periodicity)

1. Figure 2 differentiates between three types of ISS as follows;

   a. **Periodic/Routine** – In this approach, the period between discrete ISS points remains constant throughout the life of the system. This type of ISS is better suited to simple items with relatively small quantities of energetic materials. It is easy to plan and conduct, but is not adaptable to the complex ageing processes of items such as large rocket motors. This approach will usually start sometime after ISD and should end at OSD for reliability and performance and at Disposal for safety in storage. The period length can vary from every year for simple function and stability tests to every 5 years for complex performance tests such as Warhead Arena assessments.

   b. **Asymmetric** – In this approach the period between the discrete ISS points reduces through the life of the system, to reflect the exponential nature of most degenerative processes in energetic materials, where the rate of degeneration increases with time. The intervals between samples will be relatively long at the outset but will decrease as the system gets older. Sampling will start sometime after ISD but before the end of the initial service life prediction. Sampling can end up to two years before OSD. If there is no Periodic ISS then sampling for safe storage must continue until Disposal. The maximum period between testing should be 3-5 years. For systems over 12 years this should be reduced to 2-4 years and for systems over 20 years this should be reduced to 1-2 years. The Item Test Plan should ensure that each test period is reported before the life estimated by the previous test period runs out. The initial period should report no later than 9 years after date of manufacture.

   c. **Dynamic/Optimised** – In this approach the period between discrete ISS points varies throughout the life of the system. This method is usually reactive. Typically either a periodic or asymmetric approach would be adopted initially but an issue may arise which requires more in-depth study. This would necessitate shorter ISS periods to gain sufficient data with which to make an informed decision on the situation. Once the issue has been resolved, or a decision made, the period between ISS points may resume in accordance with the original approach, or at the increased rate. If another issue arises which requires more in-depth study, the process may be repeated. Another situation where this approach may be appropriate is when maintenance or replacement of components occurs. Improved characteristics may cause the time periods to be increased following replacement of components. A more likely scenario is that new components will not be to exactly the same build standard as the original components and the periods are shortened until confidence is gained in the newer materials.

2. System timelines can be much more complicated than the examples given above. The exact nature of the tests and the length of time between tests will be detailed in the individual Item Test Plans, which can vary greatly and will depend upon test selection, item complexity and life required. It may be that, for complex munitions, different approaches are adopted for different components. On a guided weapon, the seeker may be subject to routine ISS using an electronic test set but the rocket motor may require an Asymmetric approach to the measurement of stabiliser content.

1.7. TEST SELECTION

1.7.1. Basic vs Predictive Testing

1. A basic test is one which measures a parameter or set of parameters at a given point in time. This type of test provides information on the current state of the item but does not provide any estimate of the rate at which that parameter may be changing. Over time, regression analysis can be performed on a number of these measurements in order to predict future results. For safety assessments during ISS, it may be too late by the time sufficient data has been gathered. The non-linear, exponential nature of degradation, is such that individual parameters will change very little early on, but may change significantly in very short periods of time towards the end of the surveillance period. Added to this is the inherent variability of munitions populations, particularly of those which are deployed frequently, which may mask early trends in the sample data. Basic testing is most suited to meeting the basic objectives of ISS.

2. A predictive test will not only measure a parameter but it will also attempt to analyse the rate of change of that parameter with other variables such as time or temperature. Using predictive testing, ensures that at each ISS point, both the individual parameter and the rate at which it is predicted to change are known. This rate data can often be crucial for early detection of safety related deterioration of munitions. An example of predictive testing can be seen in AOP 48, the recommended method for assessing the stability of nitrate ester propellants. Predictive testing often includes an element of artificial stressing to measure the rate of degradation, therefore samples that are subject to predictive testing are more likely to encompass the current population and represent the future.

3. Life assessment using accelerated environmental testing to simulate cumulative stress is a system level form of predictive testing. Where life assessment data during safety and suitability for service is poor, it is recommended that a reduced life assessment programme is considered for items prior to basic testing (or even small scale predictive tests). This is particularly recommended for air carried systems which are life limited by the amount of air carriage vibration they can withstand. Testing at accelerated rates for the full air carriage life at the outset can be too demanding. Pre-stressing of assets is also recommended where initial life assessment is too reliant upon DA life estimations as the DA long term assessments

are often limited in the environments they cover.

1.7.2. Categories of Testing

Table 1 shows the various categories of testing that should be considered for ISS. It is understood that systems tests and life modelling do not distinguish between Life Extension and ISS. More information on specific destructive testing is contained in AOP 64.

Category of Testing	Testing Technology/Methods	Remarks
Non Destructive Examination (Probabilistic, Basic Testing)	a. Physical Examination	Used to determine a snapshot of the in-service condition of munitions and select "fleet leader" samples.
	b. Radiography- X-ray, gamma and neutron particles	
	c. Imaging – Computerised axial tomography	
	d. Ultrasonics – Laser and piezoelectric	
	e. Interferometry – Holograph	
	f. Boroscope	
	g. Electronic test sets performance of the electronics	
Non-Destructive Examination (Monitoring)	a. Environmental Data Logger (EDL) Temperature, humidity, vibration, pressure and shock	Used for through life monitoring to help populate life estimation models and select "fleet leader" samples.
	b. Health Monitoring Systems platform data for temperature, vibration and shock	
	c. Embedded sensors	
	d. Weapon Record Books Time on platform, launcher etc…	
Destructive Testing (Basic and Predictive Testing)	a. Hazard safety testing (charge scale & small (powder) scale)	Used to meet basic objectives of ISS to help make basic judgements regarding the condition of the Item.
	b. Mechanical Testing - (eg Dynamic mechanical analysis)	
	c. Thermal testing - Microcalorimetry	
	d. Chemical composition - (Chromatography etc…)	
	e. Performance testing - burning rate, closed vessel, static motor firings.	
	f. Energetic material characterisation - prediction of degradation processes and vulnerability.	
	g. Proof and Service firings, arena trials	
Systems Tests & Life Modelling (Predictive Testing)	a. System/item level accelerated aging – diurnal cycling	Used to meet extended objectives of ISS to help populate ageing models for Item and System. Note that a., b. and c. can be sequential.
	b. System/item level accelerated aging - transport and tactical vibration and shocks	
	c. System/item level accelerated aging – destructive testing at extremes of temperature	
	d. Monitored/controlled natural ageing of material samples (storage life modelling)	
	e. Monitored/controlled accelerated aging of material samples (material life monitoring)	

Note: The table above is only intended to offer examples and is not exhaustive.

Table 1 – Test Categories

ANNEX A EXAMPLE SAMPLING AND TESTING BREAKDOWN FOR A GUIDED WEAPON SYSTEM

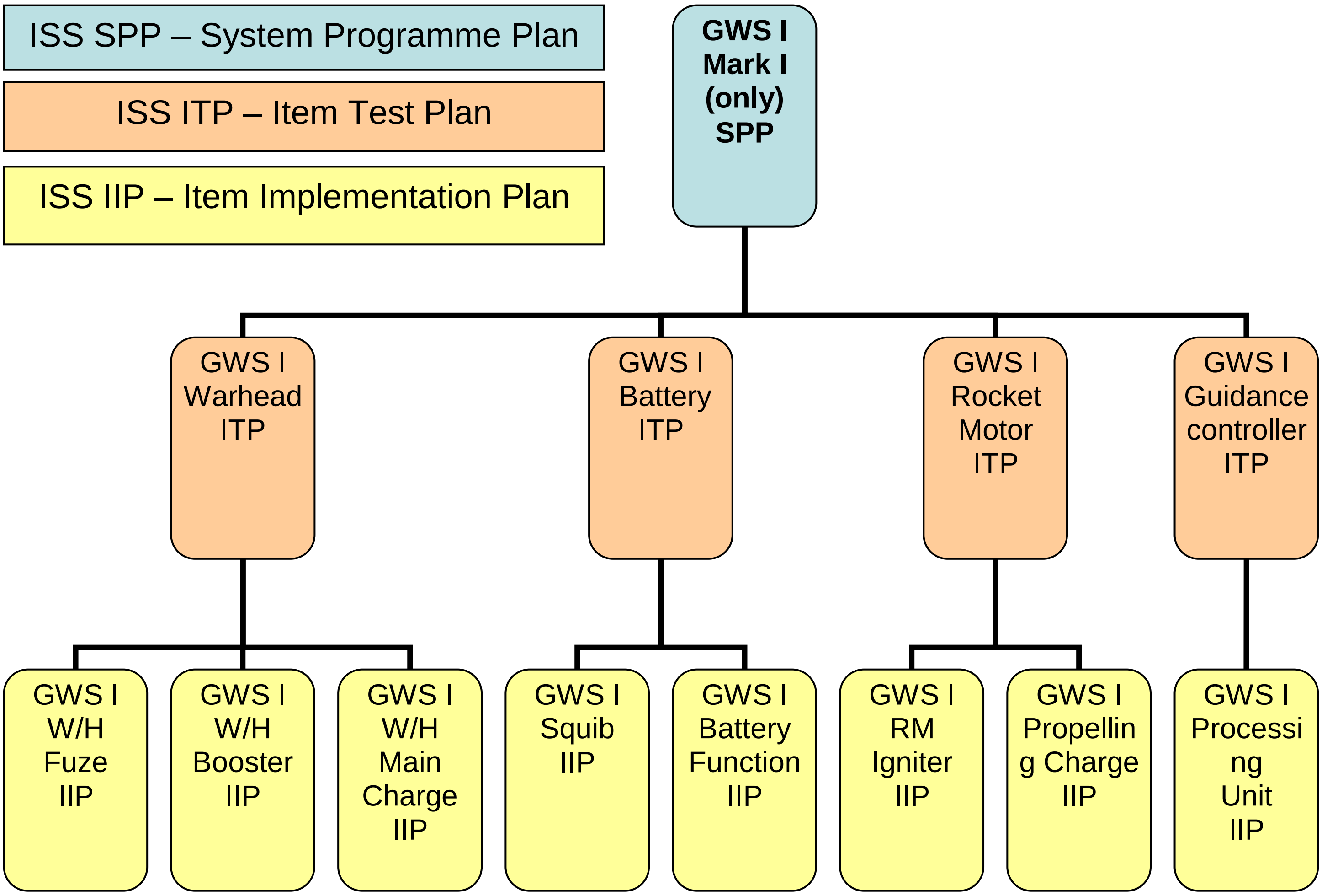

Figure A1 – Example Documentation Structure for a Complex Guided Weapon System ISS Programme

1. The Guided Weapon System structure covers most complex systems and in particular guided missiles. For these systems an In Service Surveillance System Programme Plan is probably required at the Ammunition (Missile) Level for each variant. An Item Test Plan will be required for each of the major components and there may be several Item Implementation Plans associated with each of these specifying the testing for sub-components and materials.

2. The number of surveillance assets would depend on size and cost of the weapon but would generally be small. Probably only between 1 and 4 units would be available for destructive assessment at any given surveillance point. There would be a greater reliance on non-destructive testing, electrical testing and visual inspection alongside tighter control of the environmental exposure, wherever possible, to offset the small number of destructive tests.

ANNEX B EXAMPLE SAMPLING AND TESTING BREAKDOWN FOR A MEDIUM WEAPON SYSTEM

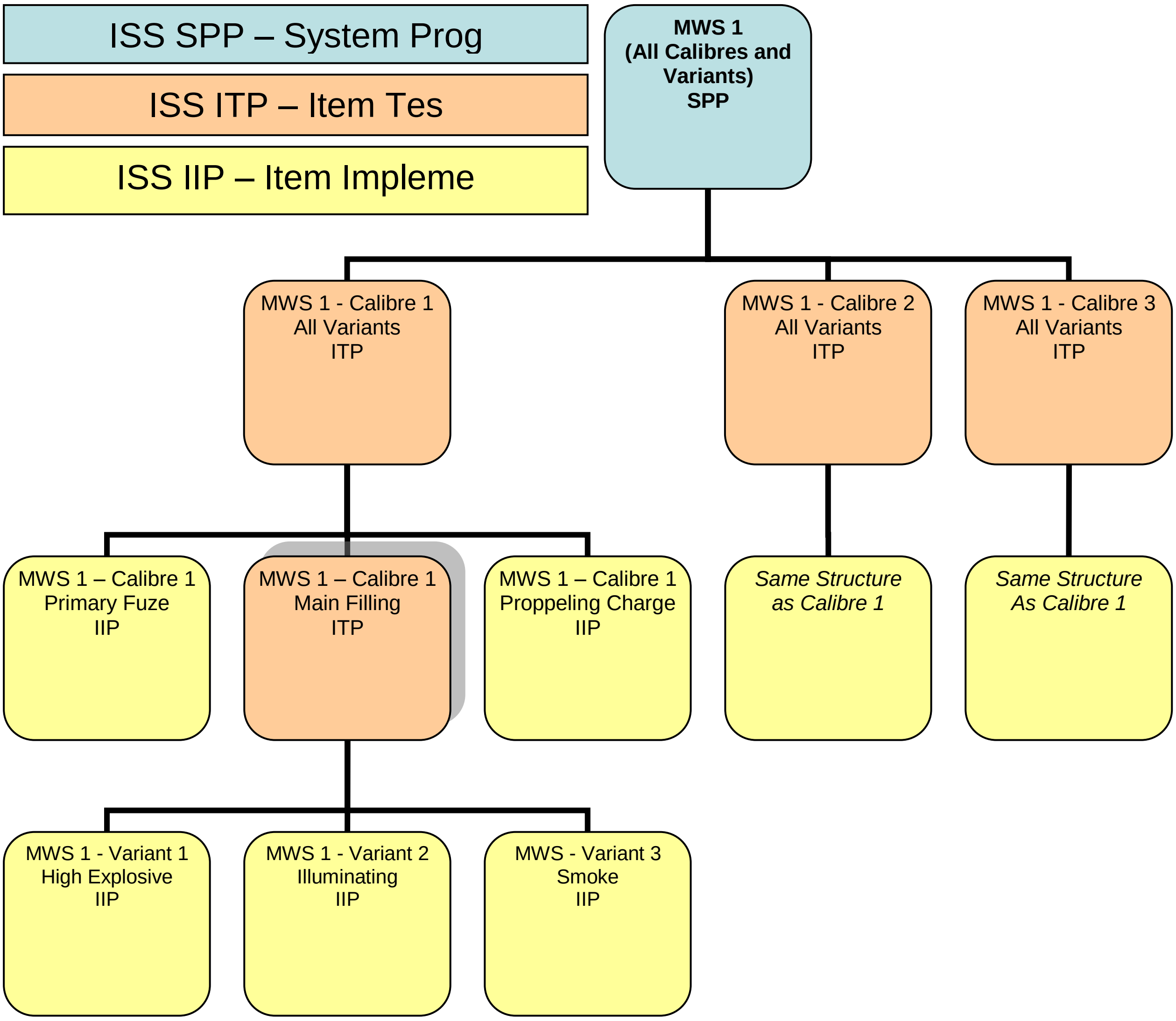

Figure B1 – Example Documentation Structure for a Medium Weapon System ISS Programme

1. A Medium Weapon System, such as large calibre guns, is likely to be a system where the In Service Surveillance System Programme Plan is established at the Weapon level covering all natures of Ammunition fired through the designated weapon. Item Test Plans may be required for each calibre of the weapon or for each nature of ammunition used within the weapon. Item Implementation Plans will be needed to identify the testing associated with each component.

2. There would be a reasonable number of assets available for destructive testing (12+) with a medium weapon system but this may still fall short of the numbers needed for a full statistical analysis. Usually a balance between detailed inspection and firings is needed to give a good qualitative assessment.

ANNEX C EXAMPLE SAMPLING AND TESTING BREAKDOWN FOR A SIMPLE WEAPON SYSTEM

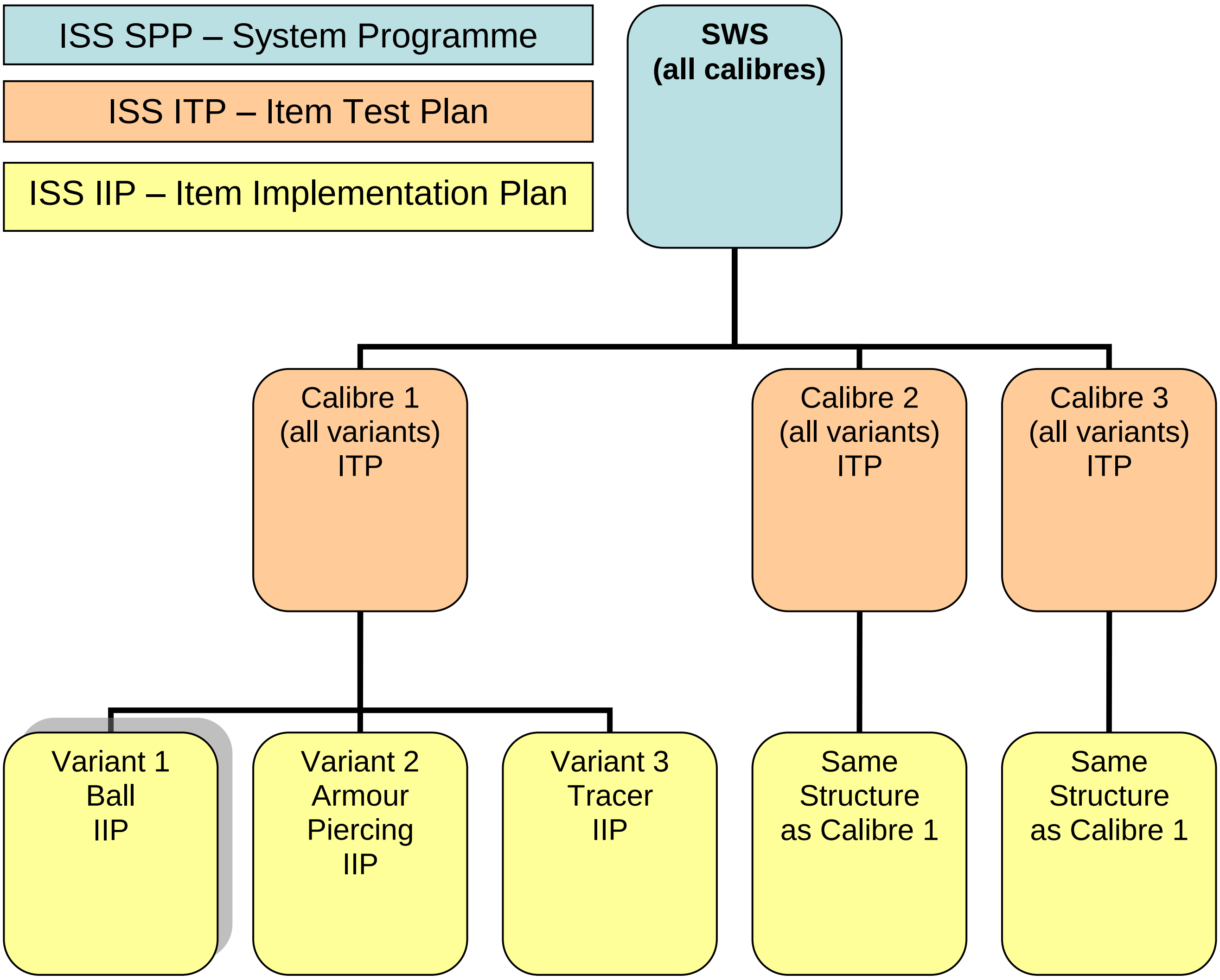

Figure C1 – Example Documentation Structure for a Simple Weapons System ISS Programme

1. A Simple Weapon System, such as small arms, is similar to a Medium Weapon System where the In Service Surveillance System Programme Plan is established at the Weapon level and covers all natures of Ammunition fired through the designated weapon. Where it differs is that the ammunition is so simple that it is not broken down into sub components. There is only likely to be one Item Test Plan for each calibre of the weapon and one Item Implementation Plan for each ammunition nature for each calibre. In many cases the Item Test Plan and Item Implementation Plan may be the same.

2. Usually with simple systems there are sufficient numbers available to conduct significant probabilistic testing during surveillance, mostly functional tests. Stability testing may be necessary on some energetic materials to support this assessment but chemical and physical analysis is usually limited. Grouping and data read across is also more common on simple systems.

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AOP-63 (A)(1)

NATO STANDARD

AOP-64

IN-SERVICE SURVELLIANCE OF MUNITIONS CONDITION MONITORING OF ENERGETIC MATERIALS

Edition A Version 1

NOVEMBER 2012

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[Date]

1. The enclosed Allied xxx Publication AxP-yy, [TITLE], which has been approved by the nations in the [TA], is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG xxxx.

OR

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CHAPTER 1 IN-SERVICE SURVEILLANCE OF MUNITIONS – CONDITION MONITORING

1.1. ABBREVIATIONS AND ACRONYMS

1.1.1. List of Abbreviation and Acronyms

AAT	Accelerated ageing test
AP	Ammonium perchlorate
ASTM	American Society for Testing and Materials
CTPB	Carboxy-terminated polybutadiene
DMA	Dynamic mechanical analysis
DPA	Diphenylamine
DSC	Differential Scanning Calorimetry
ESD	Electrostatic discharge
GAP	Glycidyl azido polymer
GC	Gas chromatography
GC/MS	Gas chromatography/Mass spectrometry
GPC	Gel permeation chromatography
HFC	Heat-flow calorimetry
HMX	Octogen
HPLC	High performance liquid chromatography
HTPB	Hydroxyl-terminated polybutadiene
ISS	In-service surveillance
NC	Nitrocellulose
NDT	Non-destructive test
PBX	Polymer-bonded explosives
QSPT	Quasi-static pressure test
RDX	Hexogen
RES	Remaining efficient stabilizer
SEC	Size exclusion chromatography
SEM	Scanning electronic microscopy
SIP	Safe interval prediction test
TGA	Thermo-gravimetric analysis
TLC	Thin layer chromatography
TMA	Thermo-mechanical analysis
TNT	Trinitrotoluene
UV	Ultraviolet

1.2. SCOPE

In-service Surveillance (ISS) becomes increasingly important with the relatively fast changes in storage conditions that may occur when the ammunition is used in world-wide operations. The need for monitoring is heightened because of stress from elevated ambient temperatures, high temperature stress field storage conditions, more transport shocks, more vibration, changing air pressure, and changes in humidity conditions.

It is preferred that the minimum amount of ammunition is destroyed in order to assess its usability in field operations. This focuses the demand on non-destructive methods and predictive methods. The decisive question is at what ageing state of the energetic material is the fulfillment of the military mission no longer possible?

This AOP provides standards for the procedures required to assess continued or extended service use of an item. This includes the essential chemical and mechanical degradation modes of energetic materials that should be measured, and it provides examples of ISS programs performed by different nations. This document is relevant to scientists or engineers looking for guidance on test procedures and for program managers seeking guidance on defining minimum inspection standards for service munitions.

Each nation should tailor its program to specific requirements and environments that apply to its inventory. It is not possible to prescribe a single protocol for each energetic material that will suit all nations.

1.3. RELATED DOCUMENTS

AECTP-100	Environmental Guidelines for Defence Material
AECTP-200	Environmental Conditions
AECTP-300	Climatic Environmental Tests
AECTP-400	Mechanical Environmental Tests
AECTP-600	The Ten Step Method for Evaluating the Ability of Material to meet Extended Life Requirements
AOP-7	Manual of Tests for the Qualification of Explosive Materials for Military Use
AOP-15	Guidance on the Assessment of the Safety and Suitability for Service of Munitions for NATO Armed Forces
AOP-46	The Scientific Basis for the Whole Life Assessment of Munitions
AOP-48	Explosives, Nitrocellulose based Propellants, Stability Test Procedures and Requirements using Stabilizer Depletion
AOP-56	Compendium of Chemical and Physical Tests for Analysis of Energetic Materials against their applicable NATO STANAG

AOP 62	In-Service Surveillance of Munitions General Guidance
AOP-63	In-service Surveillance of Munitions, Sampling and Test Procedures
STANAG 4115	Definition and Determination of Ballistic Properties of Gun Propellants Definition of Pressure Terms and Their Interrelationship for Use in the Design and Proof of Cannons and Ammunition
STANAG 4123	Methods to Determine and Classify the Hazards of Ammunition
STANAG 4147	Explosives: Chemical Compatibility of Ammunition Components with Explosives and Propellants (Non-Nuclear Applications)
STANAG 4157	Fuzing Systems: Test Requirements for Assessment for Safety and Suitability for Service
STANAG 4170	Principles and Methodology for the Qualification of Explosive Materials for Military Use
STANAG 4178	Test procedures for assessing the quality of deliveries of nitrocellulose from one NATO Nation to another.
STANAG 4324	Electromagnetic Radiation (Radio Frequency) Test Information to Determine the Safety and Suitability for Service of EEDs and Associated Electronic Systems in Munitions and Weapon Systems
STANAG 4370	Environmental Testing
STANAG 4487	Explosives, friction sensitivity tests
STANAG 4488	Explosives, shock sensitivity tests
STANAG 4489	Explosives, impact sensitivity tests
STANAG 4490	Explosives, electrostatic discharge sensitivity
STANAG 4491	Explosives, Thermal Sensitiveness and Explosiveness Tests
STANAG 4506	Explosive Materials, Physical/Mechanical Properties Uniaxial Tensile Test
STANAG 4515	Explosives, Thermal Characterization by Differential Thermal Analysis, Differential Scanning Calorimetric and Thermo Gravimetric Analysis
STANAG 4525	Explosives, Physical/Mechanical Properties, Thermomechanical Analysis (TMA) for Determining the Coefficient of Linear Thermal Expansion
STANAG 4540	Explosives, Procedures for Dynamic Mechanical Analysis (DMA) and Determination of Glass Transition Temperature
STANAG 4556	Explosives, Vacuum Stability Test
STANAG 4581	Explosives, Assessment of Ageing Characteristics of Composite Propellant containing an Inert Binder
STANAG 4582	Explosives, Nitrocellulose based Propellants, Stability Test Procedure and Requirements using Heat Flow Calorimetry

STANAG 4666 Explosives, Assessment of Ageing of Polymer Bonded Explosives (PBXs) Cast-Cured Compositions using Inert or Energetic Binders

1.4. GENERAL

1.4.1. Introduction

1. The essential part of any ISS programme is the assessment of the condition of the materials involved, particularly the energetic materials. The primary mode of degradation must be known and a measurable parameter that indicates that degradation must be identified if real confidence in the ISS program is to be established. For guidance on planning ISS refer to AOP-62 and for guidance on sampling and test procedures refer to AOP-63.

2. The primary purpose of ISS is to monitor the condition of in-service munitions and to demonstrate that the munitions will still function safely and reliably after exposure to the service environment. The ISS programme should allow validation and confirmation of the natural ageing effects predicted from the environmental trials programme. ISS provides real time results, so that if unacceptable degradation is identified in test samples, then such deterioration may be widespread amongst the population. In order to minimise the impact of this, the munitions selected for surveillance testing will normally be those from very early production that have experienced worst case service conditions ("Fleet Leaders" – See AOP-63). ISS programmes may also be used for extending the life of munitions for which no unexpected safety failure is likely.

3. The ISS programme should include critical examination involving non-destructive testing techniques, chemical/physical analysis and testing of materials and functional testing. Firings should be carried out at extreme service temperatures. For complex munitions such as missiles or torpedoes, the number that can be selected for an ISS programme is very limited. It is therefore essential that the maximum information is extracted from the investigation. When the store is simple, cheap and abundant then relatively large sample sizes can be taken allowing a high degree of confidence in the results.

1.4.2. Purpose

1. This AOP explains the physical and chemical mechanisms involved in the ageing of munitions and leading to their degradation. In particular the AOP describes the primary causes of instability in energetic materials (during ageing) with increasing in-service time. This AOP may repeat the principles of AOP-46 because the life assessment of munitions includes In-service Surveillance.

NOTE: AOP-46, The Scientific Basis for Whole Life Assessment, already refers to life assessment, life modelling and in-service surveillance. This series of documents (AOP-62, AOP-63 and AOP-64) reinforces these aspects to provide a methodology for In-Service Surveillance that supports the principles of AOP-46.

1.4.3. ISS objectives

1. Explosive materials such as high explosives, propellants and pyrotechnics are used in weapon systems to perform a variety of functions. They provide the energy required to deliver the payload and produce the terminal effect. Because of their high energy content, these materials are sensitized and they can be initiated by stimuli such as heat, shock, friction, impact. Those stimuli can be encountered in service and their effects are assessed in ISS programs.

2. The objectives of an ISS program are:

   a. To ascertain the reliability, performance & safety of the munitions in the inventory.

   b. To provide reasonable assurance that only serviceable munitions are issued for use.

   c. To provide a comprehensive overview of the state of health of the inventory, thus allowing for necessary management decisions to be made and actions to be taken in a timely manner.

   d. To provide reasonable assurance those unserviceable munitions will still continue to be safe for storage, handling and transport only.

1.4.4. Degradation mechanisms (macroscopic effect of ageing)

The materials used in munitions can deteriorate in different ways. We can classify the different modes of degradation as follows:

a. <u>Thermochemical</u>

These failure modes may be defined as changes occurring in the chemical composition of materials resulting in unacceptable degradation of safety or functioning characteristics. Certain explosive compositions are inherently unstable and are continually undergoing slow decomposition even at ambient temperature. The decomposition reaction rate is altered by temperature and sometimes by other factors such as humidity. Examples of chemical failure modes include decomposition reactions of nitric ester propellants, (even when slowed down by the presence of stabilisers), corrosion of metals, incompatibility between materials and also the degrading effect of solar radiation on natural and synthetic organic materials such as rubbers and plastics.

b. Mechanical

Two principal mechanical failure modes can be identified. The first of these is fatigue, where under the action of cyclical loading, a crack is initiated and propagates leading to failure of the component. The second principal failure mode is due to the applied stress exceeding a threshold and breaking the component.

Loss of material may cause structural weakness or looseness between mating surfaces. The occurrence of fretting under these conditions between exposed explosive surfaces can lead to the possible formation of “hot spots” with subsequent ignition and/or explosive events. Explosive material in the form of dust may also occur under these conditions and can have a much higher sensitiveness than the parent bulk composition and lead to a hazardous condition.

c. Thermomechanical

This term applies to mechanical stresses in materials that are induced by thermal effects resulting in mechanical failure. A change of temperature in systems containing materials with different thermal properties, thermal diffusivity and coefficients of thermal expansion produces stresses within the materials and particularly at bonded surfaces. Coefficients of expansion of metals are much smaller than those of plastics and rubbers. Such problems are often encountered in case bonded rocket motors between propelling charge, liner and case or, in motors with loose charges, between charge and inhibitor. The results of differential thermal expansion and contraction of materials in munitions leading to dimensional changes can cause problems such as cracked explosive fillings or seal failures, the latter permitting ingress of moisture or exudation of explosive material. Cracking of TNT (trinitrotoluene) based compositions in the main fillings of munitions occurs due to thermomechanical stressing and is more severe when such fillings are bonded to the case material thus restricting volume contraction of the explosive on cooling.

In NATO nations, the bulk of surveillance activity on energetic materials is applied to nitrocellulose based propellants. The safe storage life of these propellants is directly related to the level of stabilizer present. If the stabilizer is depleted below a minimum acceptable level then the rate of decomposition of the propellant will accelerate rapidly with self-heating and, in extreme circumstances, spontaneous ignition may occur. This critical safety aspect explains the concentration of surveillance effort on this class of explosives. In practice, with a properly qualified propellant composition, the safe storage life can be significantly greater than the ballistic performance life for both gun and rocket applications.

1.5. APPLICATION

1.5.1. Chemical and physical ageing phenomena (microscopic effect of ageing)

1. The mechanical properties of the energetic materials may be degraded by different ageing phenomena. Those phenomena are linked to the mechanisms of degradation already cited. The principal ageing phenomena are:

   a. Oxidation of binder or charges (due to oxygen, possibly facilitated by moisture)
   b. Degradation of binder or Nitrocellulose (NC). With NC the reduction of chain length (decrease of molecular weight) results in decrease of mechanical strength
   c. Diffusion of mobile ingredients and contact components
   d. Action of chemical species produced by chemical decomposition
   e. Agglomeration or separation of particulate fillers in charges

2. The factors (impacting quantities) determining the extent of ageing includes:

   a. Time
   b. Temperature
   c. Moisture
   d. Oxygen
   e. Electromagnetic radiation (mainly UV)
   f. Air pressure
   g. Shocks

3. One of the most common failure modes resulting in the munitions becoming unsafe or unsuitable for service is the contamination of the internal environment of the weapon system by moisture, i.e. interactions/reactions of water with energetic materials.

4. The different chemical tests are listed by class of energetic materials in the appendix.

1.5.2. Failure modes and ageing phenomena of energetic materials

1. Single base gun propellant

Nitrate esters in propellants decompose very slowly at normal ambient temperatures, but more rapidly as the temperature and the relative humidity increases. However, the reaction is autocatalytic and therefore a stabiliser is required to react with the accelerating decomposition products to prevent autocatalysis. Measurement of the stabilizer depletion and Heat Flow Calorimetry (HFC) are the test methods most often employed to estimate ageing of NC based propellants.

Propellant decomposition produces gases inside the propellant grain which will diffuse to the atmosphere at exposed surfaces.

2. Double base, triple base gun propellants and rocket propellants

As for single base propellant, stabilizer depletion and released gases (NOx) concentration can cause serious problems, as can migration of ingredients in the nitrocellulose matrix. This is particularly relevant to the migration of nitroglycerine or other plasticisers into inhibitors of rocket propellants; the flame resistance of the inhibitor is reduced with contact to nitroglycerine. Swelling of the inhibitor originating from this migration can occur and cause high stress concentrations with subsequent bond failures. The inhibitor may also become mechanically weak and softened due to plasticiser absorption. A build-up of internal gas pressure greater than the tensile strength of the grain will lead to cracking with serious consequences particularly for double base rocket propellant.

3. Composite propellant

a. The qualities of composite propellants are directly related to the rubbery properties of the binder which is often hydroxyl-terminated polybutadiene (HTPB) or carboxyl-terminated polybutadiene (CTPB).

b. Cross-link density seems to be an important indicator of the ageing states of the binder polymer and also the propellant. Polymers used in composite propellants, such as the commonly used HTPB are susceptible to oxidative cross-linking. This can lead to hardening and embrittlement of the propellant with associated loss of extensibility (strain capacity) and an increased propensity for cracking. The presence of moisture modifies the properties and ageing of HTBP/Ammonium Perchlorate (AP) composite propellants in practically all situations. In addition to influencing binder oxidation, moisture may affect the binder-filler interface.

4. Composite modified double base type

The general term composite modified double base propellant is used to describe hybrid propellants that contain nitrate esters with, in addition, inorganic oxidants such as ammonium perchlorate to increase the energy. Test methods applied to double base propellants are also routinely applied to composite modified double base because the nitrate ester component is thought to be the least stable. Experience has shown however that the addition of oxidant may also introduce undesired extra reactions that reduce reliability or safety and which may not be identified by the usual test procedures. Rapid decomposition reactions have been observed in certain propellants after prolonged storage at high temperatures, 90°C and above. While above normal storage or operational temperatures, this situation could be seen in a rocket motor in close proximity to a fire, for example. It is recommended that a degree of caution is adopted in the ISS of propellants of this type.

5. Booster explosive

Booster explosives are used to transmit and augment the reaction initiated by the primary explosive. For Trinitrotoluene (TNT) based secondary explosive compositions, a potential failure mode is exudation. The exudate may be incompatible with contact materials and sensitive to external stimuli (e.g. impact and friction).

a. Melt cast explosive, high explosive

For melt cast explosive, TNT exudation is a failure mode which should be monitored. The exudate may be incompatible with contact materials. The commonly used ingredients hexogen (RDX), octogen (HMX) and TNT all possess excellent long term chemical stability and are not expected to change to any measurable extent with properly formulated explosive compositions.

b. PBX cast cured or pressed explosives

Polymer bonded explosives (PBX), in which the energetic material commonly is bound in a rubbery binder, are being used increasingly in warheads. Polybutadiene binders (such as HTPB) are often used and these can degrade in the same way as composite propellants, resulting in embrittlement and cracking of the composition. There may also be an energetic binder such as Glycidyl-azide-polymer (GAP). The presence of moisture is again of significance although the typical fillers (RDX or HMX) are much less water-sensitive than AP.

The primary method of degradation of PBX is oxidation. Oxidation releases free radical species from the binder. Those species are able to subsequently react in the condensed phase of the heterogeneous polymer. These polymeric free radicals may cause cross-linking and molecular weight increase or decrease.

The migration of plasticizer may lead to heterogeneous mechanical properties.

c. Primary explosives

Primary explosives are mostly ionic compounds having high melting points so exudation is not a problem. The main potential failure modes are due to material incompatibilities and moisture ingress. The former should be eliminated by standard screening tests and choice of materials. The reaction of moisture with initiatory substances such as lead azide can lead to non-functioning failure.

d. Pyrotechnics compositions

Traditional pyrotechnic compositions, in comparison to the organic nature of the other types of energetic material, are physical mixtures of inorganic ingredients, occasionally with polymeric binder. However several oxidisers (e.g. sodium nitrate) used in-service compositions (e.g. illuminating flare) are hygroscopic and some fuels (e.g.

magnesium) are readily hydrolysed by moist air. This may result in the development of internal gas pressure in stores, which in the case of hydrogen leads to a flammability hazard. The adsorption of moisture can also lead to physical and chemical changes due to the partial solution of ingredients of the compositions, changes in the density or shape of the consolidated product, cracking and crystallisation of salts on the surfaces of the composition. The performance of pyrotechnic devices is often adversely affected by moisture ingress.

e. Liquid propellant (nitrate ester type)

Decomposition of the nitrate ester is the main effect on ageing with subsequent depletion of stabilizer. The presence of metallic impurities may catalyse this reaction.

f. Combustible items

Combustible items include celluloid and nitrofilms, cartridge and combustible cases. Combustible cartridge munitions, which contain nitrocellulose, were developed to protect the propellant charge, to reduce the weight of ammunition and to improve the ballistics efficiency of the gun (increased firing rate).

Although nitrate esters and stabilizer migrate from the propellant into the combustible cartridge or combustible case, a small concentration of the same stabilizer is present also in the combustible item to protect the nitrocellulose from oxides of nitrogen in a similar manner to the stabilization of propellant.

An issue however is the degradation of the mechanical properties of the combustible cases with plasticizer migration, which can affect the functionality of the system. In addition, the plasticizer migration into the combustible case means that the propellant formulation is no longer as manufactured, and therefore performance can be affected.

g. Polymers

Natural and synthetic materials such as rubbers, adhesives and polymers deteriorate in a variety of ways in different environments. Small changes in composition can lead to considerable changes in the ageing behaviour of the materials. In general, they are more or less sensitive to temperature, moisture, oxygen and solar radiation, particularly the ultra-violet part. However they can be quite sensitive to the order of exposure to different environments. The deterioration of rubbers in natural exposure can vary depending on whether they are exposed early to strong solar radiation which forms a protective skin or whether there is regular rainfall which may wash away autocatalytic products of decomposition.

Absorbed moisture will tend to plasticise an adhesive or polymeric structure, thus changing the glass transition temperature. The stress and the failure strain may either increase or decrease. Moisture can also displace the adhesive from the interface with the adherent. In particular, it affects joints involving metals which may react to form hydroxides or oxides, reducing joint strength.

ANNEX A CLASSIFICATION OF FAILURE MODES AND AGEING PHENOMENA BY TYPE OF ENERGETIC MATERIAL

A.1. SOLID GUN PROPELLANT

A.1.1. Single base gun propellant

Ageing phenomena	Possible effects	Tests	Reference	Notes
Breakdown of the CO-NO_2 bond in nitrate ester	• Heat generated	• Heat Flow Calorimetry (HFC)	STANAG 4582	[I] (a)
	• Gas (NOx) evolved	• Visual • Fume test • Abel heat test • Mass loss at 90°C	 AOP 7 (US, GE) AOP 7 (UK) AOP 7 (GE)	 [N] (c) [N] (c) [N] (d)
	• Stabilizer depleted	• High Performance Liquid Chromatography (HPLC) • Gas Chromatography (GC), Thin Layer Chromatography (TLC)	AOP-48, AOP-7	[I] (b) [N]
NC Chain scission	• Decrease of mechanical strength	Gel permeation chromatography (GPC)	STANAG 4178 test 13	[I] (g)
	• Change in ballistic properties	Ballistic Closed vessel test	STANAG 4115	[I] (f)
Uptake of moisture		Water content (Karl-Fischer titration)		[N]
Uptake of nitroglycerine (where contact with double base type is possible)	• Stabilizer depleted faster than expected	HPLC	AOP-48	[I]

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations

- (a) HFC measures total heat produced by all reactions. Assumptions are necessary to allow 10 years sentencing. Applicable to all NC-based propellant types and stabilizers used for them
- (b) Stabilizer analysis by HPLC is historically the most commonly applied test. Assumptions are required about stabilizer daughter products (consecutive reaction products of the added stabilizer) to allow 10 years sentencing.

  According to AOP 48, HPLC is the preferred method, with other methods (e.g. GC, TLC) being allowed if they show equivalent precision and are able to differentiate between different stabilizers, their daughter products and other propellant ingredients.

  TLC is used additionally by Germany.

  GC is used by France only for single base gun propellant stabilized by Diphenylamine (DPA). The goal is to give a first result of the stabilizer consumption with a low-cost method. If the result isn’t relevant HPLC is required.
- (c) and (d) long standing national test methods.
- (e) The terms Gel Permeation Chromatography (GPC) and Size Exclusion Chromatography (SEC) are used equivalently and mean the same polymer analytical technique.
- (f) Closed vessel test used for testing gun propellants (infrequent use in surveillance)
- (g) Suitable sample preparation (usually extraction of other components following national procedures) may be required prior to performing GPC Analysis of Nitrocellulose according to STANAG 4178.

A.1.2. Double base, triple base gun propellant

Ageing phenomena	Possible effects	Tests	Reference	Notes
Breakdown of the CO-NO_2 bond in nitrate ester	• Heat generated	• HFC	STANAG 4582	[I]
	• Gas (NOx) evolved	• Abel Heat Test	AOP-7	[N]
		• 80° Self-heating Test	AOP-7	[N]
		• Methyl Violet Test (120°C)	AOP-7	[N]
		• 65.5° Red Fume Test	AOP-7	[N]
		• B&J test (115°C)	AOP-7	[N]
	• Stabilizer depletion	• HPLC or GC	AOP-48	[I]
NC Chain scission	Embrittlement and reduction in mechanical strength	GPC (SEC),	STANAG 4178 test 13	[I]
		Quasi-Static Pressure Test (QSPT) for embrittlement of AP grains		[N] [a]
		Tensile test	STANAG 4507	[I]
	Change in ballistic properties	Ballistic Closed Vessel Test	AOP-7 STANAG 4115	[I]
Uptake of moisture	Slow hydrolysis of some additives	GC determination of Water (and residual solvent)		[N]
		Karl-Fischer titration		[N]
Others	Changes in colour,	Visual examination		
	Grains become brittle or powdery			
	Exudation of nitroglycerine			

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations
- [a] QSPT is a test performed by Germany

A.2. SOLID ROCKET PROPELLANT

A.2.1. Double base, triple base gun propellant

Ageing phenomena	Possible effects	Tests	Reference	Notes
Breakdown of the $CO\text{-}NO_2$ bond in nitrate ester	• Heat generated	• HFC	STANAG 4582	[I]
	•Gas (NOx) evolved	• Abel Test	AOP-7 (UK)	[N]
		• 80° Self-heating Test	AOP-7 (UK)	[N]
		Methyl Violet Test (120°C)	AOP-7 (US)	[N]
		• 65.5° Fume Test	AOP-7 (US)	[N]
		• B&J test (115°C)		[N]
	• Stabilizer depletion	•HPLC	AOP-48	[I]
NC Chain scission	Decrease of molecular weight	GPC	Under development	[a]
	Embrittlement and reduction in mechanical strength	Tensile test	STANAG 4507	[I]
	Change in ballistic properties	Strand Rate Burning Test	AOP-7	[I]
		Ballistic Closed Vessel Test	STANAG 4115	[I]
Diffusion of plasticizer, and other mobile additives	Change in mechanical and visco-elastic (glass transition temperature) properties	Tensile test, Dynamical Mechanical Analysis	STANAG 4507	[I]
	Change in ballistic properties	Strand rate burning	AOP-7	[I]
	Incompatibility issues with contact materials	HFC, Stabilizer loss, ThermoGravimetric Analysis (TGA), Differential Scanning Calorimery (DSC)	STANAG 4147	[I]
	Nitroglycerine migration into charge inhibitor coating	HPLC		[I]
Uptake of moisture	Slow hydrolysis of some additives	GC determination of Water (and residual solvent)	National (US)	[N]
		Karl-Fischer titration		[N]

Others	Changes in colour, grains become brittle or powdery	Visual examination		[N]
	Exudation of nitroglycerine			

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations
- [a] Nations can orient their GPC method with STANAG 4178 as a guidance

A.2.2. Composite propellant

Ageing phenomena	Possible effects	Tests	Reference	Notes
Oxidation of binder	Depletion of anti-oxidant	HPLC analysis	STANAG 4581	[I]
Increase in cross link density (HTPB)	Hardening occurs	Sol-gel determination Shore A Hardness	STANAG 4581	[I]
Decrease in cross link density (polyether)	Softening occurs	Sol-gel determination	STANAG 4581	[I]
		Shore A Hardness	STANAG 4581	[I]
Uptake of moisture	Agglomeration of AP	Karl Fischer titration		[N]
	Degradation of Aluminium			
	Gas evolution leading to crack	Non-Destructive Test (NDT)		[N]
Change to polymorphism of oxidant	Dewetting with binder, dimensional change			[N]
Diffusion of plasticizer, surface agent or other mobile additive	Change in mechanical and visco-elastic (glass transition temperature) properties	Tensile test, DMA	STANAG 4506 STANAG 4540	[I]
	Change in ballistic properties	Strand Rate Burning Test	AOP-7	[I]
		DMA	STANAG 4540	[I]
	Incompatibility issues with contact materials	HFC, Stabilizer loss, TGA, DSC	STANAG 4147	[I]
Mechanical damage due to shock, vibration or thermal cycling	Void formation	NDT	According to National procedures	[N]
	De-wetting of filler	NDT		
	Loss of bond line integrity	Dimensional measurement Peel test		

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations

A.2.3. Composite modified double base type

Ageing phenomena	Possible effects	Tests	Reference	Notes
Breakdown of the $CO\text{-}NO_2$ bond in nitrate ester	Heat generated Gas (NOx) evolved	HFC	STANAG 4582	[I]
	Stabilizer depleted	HPLC analysis	AOP-48	
NC Chain scission	decrease of mechanical strength	GPC (SEC)	under development	
	Changes in mechanical properties	Tensile test, DMA	STANAG 4506, STANAG 4540	[I]
	Change in ballistic properties			
Diffusion of plasticizer, surface agent or other mobile additive	Change in mechanical and visco-elastic (glass transition temperature) properties	Tensile test, DMA	STANAG 4506, STANAG 4540	[I]
	Change in ballistic properties	Small-scale burning test		
	Incompatibility issues with contact materials	HFC, Stabilizer loss, TGA, DSC	STANAG 4147	[I]

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations

A.3. EXPLOSIVES

A.3.1. Booster explosive

Ageing phenomena	Possible effects	Tests	Reference	Notes
Decomposition of nitro-compounds	Build-up of impurities, which can cause instability	Vacuum stability	STANAG 4556	[I]
		Melting point (setting point)	AOP-56	[I]
Incompatibility with contact materials over long time period	Sensitive metal salts and other sensitive compounds may be produced	Visual examination		[N]
	Stability may be degraded	Impact and friction testing	STANAG 4489, 4487	[I]
		Vacuum stability at 100°C	STANAG 4147	[I]
Exudation of mobile species	May deposit energetic compounds on surface or into threads	Visual examination		[N]
Water uptake	Salt formation, agglomeration, degradation	Water content by Karl Fischer titration		[N]
		Weight loss on drying		[N]

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations

A.3.2. Melt Cast explosive, high explosive

Ageing phenomena	Possible effects	Tests	Reference	Notes
Decomposition of nitro-compounds	Build-up of impurities, which can cause instability	Vacuum stability	STANAG 4556	[I]
Incompatibility with contact materials over long time period	Sensitive metal salts may and other sensitive compounds be produced (TNT with lead compounds; Ammonium nitrate with metals)	Impact and friction testing	STANAG 4489, 4487	[I]
	Stability may be degraded	Vacuum stability at 100°C	STANAG 4147	[I]
Exudation of mobile species (e.g. wax)	May deposit energetic compounds on surface or into threads	Visual examination		[N]
Gassing from aluminised filling	Hydrogen gas build-up in severe cases			
Water uptake	Salt formation, agglomeration, degradation	Water content by Karl Fischer titration		[N]
		Weight loss on drying		[N]
Polymer chain scissioning in melt-cast PBX	Loss in mechanical strength	GPC (SEC)		[N] [a]
Polymer chain scissioning in melt-cast PBX	Loss in mechanical strength	GPC (SEC)		[N] [a]

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nation
- [a] STANAG 4178 may be applicable or provide a basis for developing a procedure

A.3.3. PBX Cast cured

Ageing phenomena	Possible effects	Tests	Reference	Notes
Oxidation of binder	Hardening occurs	Shore A Hardness	STANAG 4666	[I]
Uptake of moisture	Agglomeration of explosive filler causes hardening	Karl Fischer test and Visual inspection		[N]
Increase in cross link density	Hardening occurs	Sol-Gel determination	STANAG 4666	[I]
Decrease in cross link density	Softening occurs	Sol-Gel determination	STANAG 4666	[I]
	Change in mechanical and visco-elastic (glass transition temperature) properties	TMA, DMA, DSC for glass transition temperature	STANAG 4515 STANAG 4540 STANAG 4525	[I]
Change to polymorphism of explosive filler	De-wetting with binder, dimensional changes	Scanning Electronic Microscopy (SEM)	STANAG 4666	[I]
Diffusion of plasticizer, surface moderant or other mobile additive	Change in mechanical properties	HPLC or GC analysis	STANAG 4666	[I]
	Incompatibility issues with contact materials	Vacuum stability test	STANAG 4147	[I]
Mechanical damage due to shock, vibration or thermal cycling	Void formation	NDT		[N]
		Tensile strength	STANAG 4506	[I]
	De-wetting of filler	Dimensional measurement tests, NDT		[N]
	Increase in sensitivity to shock, impact, friction, or ESD	Impact and friction test, ESD test, Shock test	STANAG 4487, 4488, 4489, 4490	[I]

A.3.4. Pressed explosives

Ageing phenomena	Possible effects	Tests	Reference	Notes
Uptake of moisture	Loss of cohesiveness	Karl-Fischer test and visual inspection		[N]
Change to polymorphism of filler	Dimensional changes	Scanning Electronic Microscopy	STANAG 4666	[I], [a]
Mechanical damage due to shock, vibration or thermal cycling	Void formation	NDT		[N]
		Tensile strength	STANAG 4506	[I]
	De-wetting of filler	Dimensional measurement tests, NDT		[N]
	Increase in sensitivity to shock, impact, friction, or ESD	Impact and friction test, ESD test, Shock test	STANAG 4487, 4488, 4489, 4490	[I]

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations
- [a] Nations can orient the Scanning Electronic Microscopy method with STANAG 4666 as a guidance

A.3.5. Primary explosives

Type	Ageing phenomena	Possible effects	Tests	Reference	Notes
Primary Lead or Silver Azides Lead styphnate Tetrazene Blackpowder Percussion cap composition Conducting cap composition	Uptake of moisture	Slow chemical decomposition of principal ingredient leading to reduced efficiency or even failure	Chemical analysis, Karl-Fischer titration, weight loss on drying		[N]
Azides (especially)	Long term incompatibility with contact materials	Formation of highly sensitive salts with metals (e.g. Copper azide)	Visual examination for corrosion of contact components		[N]

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations

A 4. PYROTECHNIC COMPOSITIONS

Ageing phenomena	Possible effects	Tests	Reference	Notes
Uptake of moisture	Caking or dissolution of metallic salts	Oven drying at 103°C	National methods depending on exact pyro composition	[N]
	Build-up of acidity (blackpowder)	Titration		[N]
	Corrosion of metallic contact materials	Visual examination		[N]
	Build up of hydrogen gas (Al, Mg compositions, forming Al and Mg oxides and hydroxides)	Visual (distortion of packaging) Free Mg Test Gas analysis		[N]
	Build up of phosphine gas (Red phosphorus containing compositions)	Gas analysis, GC/MS, Trace analysis by e.g. Draeger tube	STANAG 4679 (closed vessel test)	[N]
	General impairment of performance	Functioning test (e.g. burning rate in a tube)		[N]
Oxidation	Reduction in free metal content (Al, Mg) or reduction in fuel element (B, P) leading to impaired performance	Chemical analysis Atomic absorption spectroscopy	National methods depending on exact pyro composition	[N]
	Change in temperature of ignition	Burning Rate Test,	STANAG 4491	[I]
		Proof firing		[N]
		DSC	STANAG 4515	[I]
others	Unreliability caused by any of the above factors	Functioning test,	This is most often used in ISS	[N]
		Proof firing		

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations

A 5. LIQUID PROPELLANT (nitrate ester type)

Ageing phenomena	Possible effects	Tests	Reference	Notes
Breakdown of the $CO-NO_2$ bond in nitrate ester	Heat generated	HFC	STANAG 4582	[I]
	Stabilizer depleted	HPLC, GC	AOP 48	[I]
Uptake of moisture		Karl-Fischer titration		[N]
Presence of metallic impurities from contact materials	May degrade stability	Chemical analysis, Atomic absorption or emission spectroscopy		[N]

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations

A 6. COMBUSTIBLE CARTRIDGE AND CASES

Ageing phenomena	Possible effects	Tests	Reference	Notes
Breakdown of the $CO\text{-}NO_2$ bond in nitrate ester	Heat generated	HFC	STANAG 4582	[I]
	Stabilizer depleted	HPLC, GC	AOP 48	[I]
NC Chain scission	Embrittlement and reduction in mechanical strength	Tensile test, DMA	STANAG 4507 STANAG 4540	[I]
Uptake of moisture		Karl-Fischer titration		[N]
Diffusion of plasticizer, and other mobile additives	Change in mechanical and visco-elastic (glass transition temperature) properties	Tensile test, DMA	STANAG 4507 STANAG 4540	[I]
	Change in ballistic properties	Burning rate (strand burning, closed vessel)	AOP-7	[I]
	Nitrate ester migration	HPLC, GC	AOP 48	[I]

- [I] denotes an internationally recognised test which has been documented in published standards (e.g. STANAG, ISO, ASTM)
- [N] denotes a national test, often with long experience in use but not necessarily approved by other nations

A 7. NON-ENERGETIC USE OF POLYMERS

Such polymers can have special functioning in munition systems as sealing or spring functioning. These functions determine strongly the type of inspections and surveillance. The list below gives only a few examples with typical ageing phenomena and subsequent effects.

Type	Ageing phenomena	Possible effects	Tests	Reference	Notes
Polyurethane	Oxidation	Hardening, dimensional changes as swelling or permanent setting	Visual inspection		
Foams, O-rings, and others		Consumption of anti-oxidants and other stabilizers (UV)		ASTM D6042 as a guidance	
Phenolic mouldings	Oxidation	Hardening, dimensional changes	Visual inspection		
		Acidic vapour in enclosed spaces			
Polyolefins (polyethylene foam and mouldings)	Loss of plasticizer	Hardening , cracking	Visual inspection		
Vinyl polymer (Polyvinyl chloride)	Loss of plasticizer	Hardening , cracking	Visual inspection		
Acrylic Polymer (Polymethyl methacrylate)		Cracking	Visual inspection		
Silicone polymer		Hardening, dimensional changes, powdering	Visual inspection		
Rubber	Oxidation, loss of plasticizer and anti-oxidant	Hardening, dimensional changes		ASTM D4676, ASTM D1992	
Paint and varnish	Oxidation (embrittlement of oil type)	Low molecular mass species evolved in enclosed spaces		ASTM D2832	

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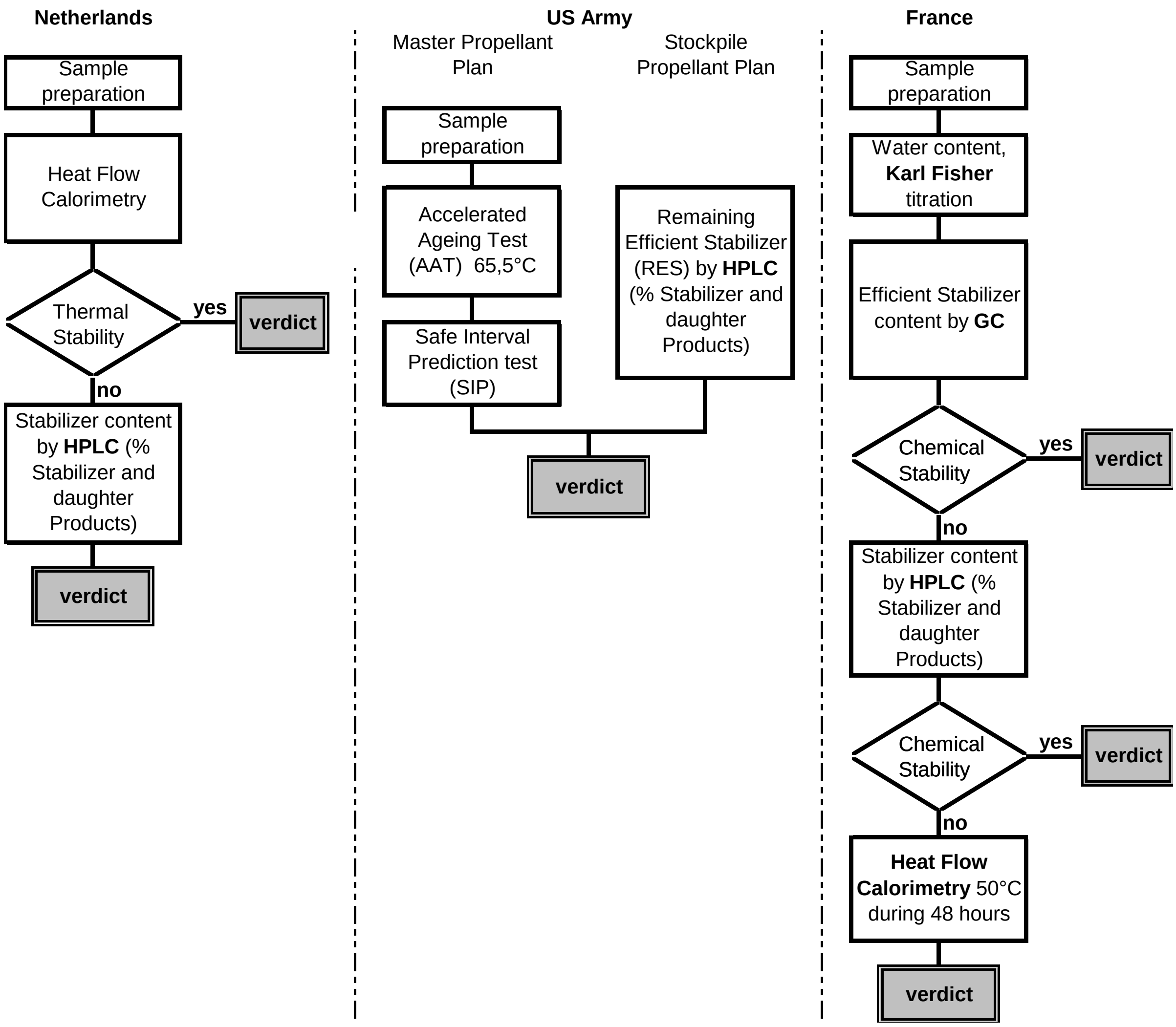
ANNEX B FLOW CHART – EXAMPLE OF ISS PROGRAM

This diagram provides examples of ISS Condition Monitoring programs and is intended to be illustrative of how test methods may be applied for certain energetic material types. The nation's ISS program presented here may be modified. Each nation should tailor its program to specific requirements and environments that apply to its inventory. It is not possible to prescribe a specific protocol that will suit all nationsText.

Example : Single base gun propellant stabilized by Diphenylamine (DPA).



Notes:

1. Heat Flow Calorimetry at 80°C during 10.6 days is an internationally accepted method described in STANAG 4582 Heat Flow Calorimetry at 50°C during 48 hours is a national procedure described in the French instruction MAT 2423 about ISS of ammunitions.
2. France: the Karl Fischer titration is only performed for 120 to 155 mm calibre ammunitions.
3. US Army: Information from U.S. Army Propellant Management Guide, prepared by US Army Defence Ammunition Centre
4. SIP: The test measures the decrease of initial stabilizer using High Performance Liquid Chromatography (HPLC) at regular intervals. The test is run at 65.5°C, like the AAT. Each sample also is tested prior to aging and the level of remaining effective stabilizer (RES) is determined.
5. US Army: The remaining effective stabilizer (RES) level is determined in duplicate for both the Stockpile Propellant sample and for the Master Propellant sample. A comparison for the propellant lot identifies errant behaviour between the fielded propellant and stored propellant, and provides the basis along with SIP testing of the Master Propellant sample.

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