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IN-SERVICE SURVEILLANCE OF MUNITIONS SAMPLING AND TEST PROCEDURES

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NATO LETTER OF PROMULGATION

27 February 2017

1. The enclosed Allied Ordnance Publication AOP-63, Edition A, Version 1, IN-SERVICE SURVEILLANCE OF MUNITIONS SAMPLING AND TEST PROCEDURES, which 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, Edition A, Version 1, is effective upon receipt.

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

Edvardas MAŽEIKIS
Major General, LTUAF
Director, NATO Standardization Office

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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-4682	ENERGETIC MATERIALS, TEST METHODS FOR INGREDIENTS
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 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.

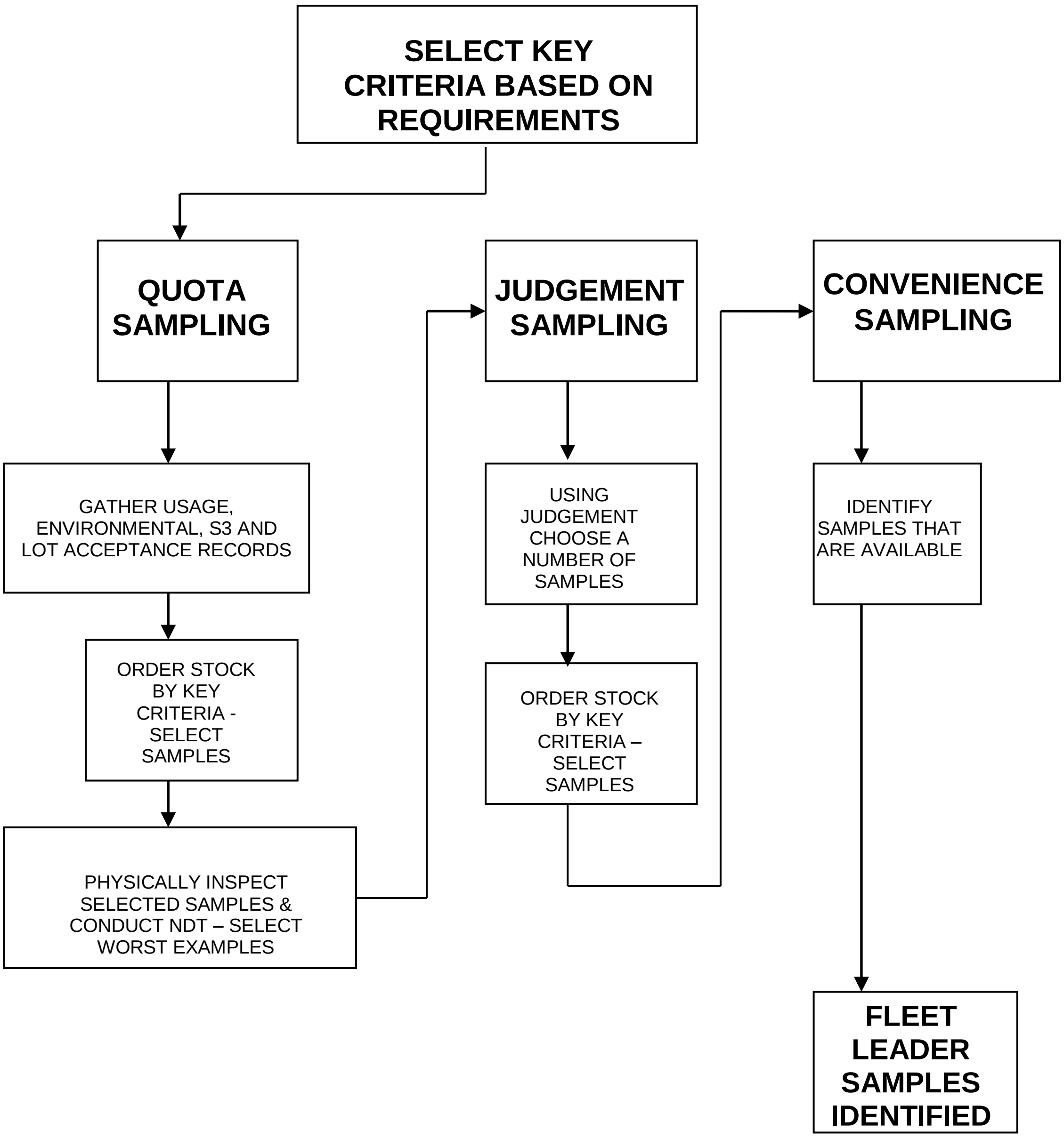

Figure 1 – Fleet Leader Identification

"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 2 below shows pictorially the typical balance between design knowledge, sampling, item population, individual item cost and individual item size.

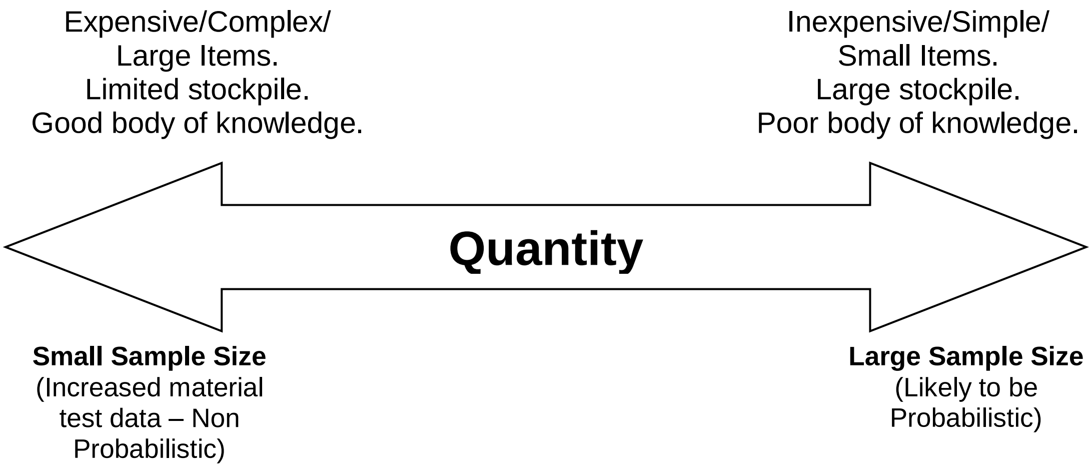

Figure 2 – Choosing a sample size

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.

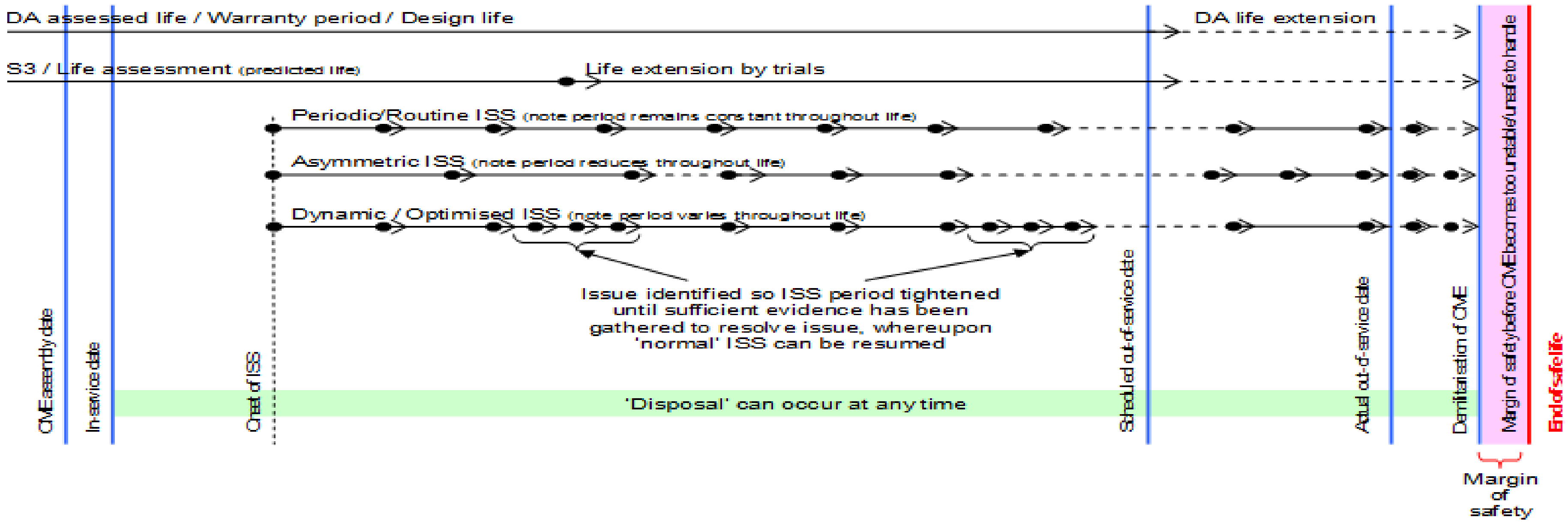

Figure 3 – A Typical Item Timeline

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 3 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

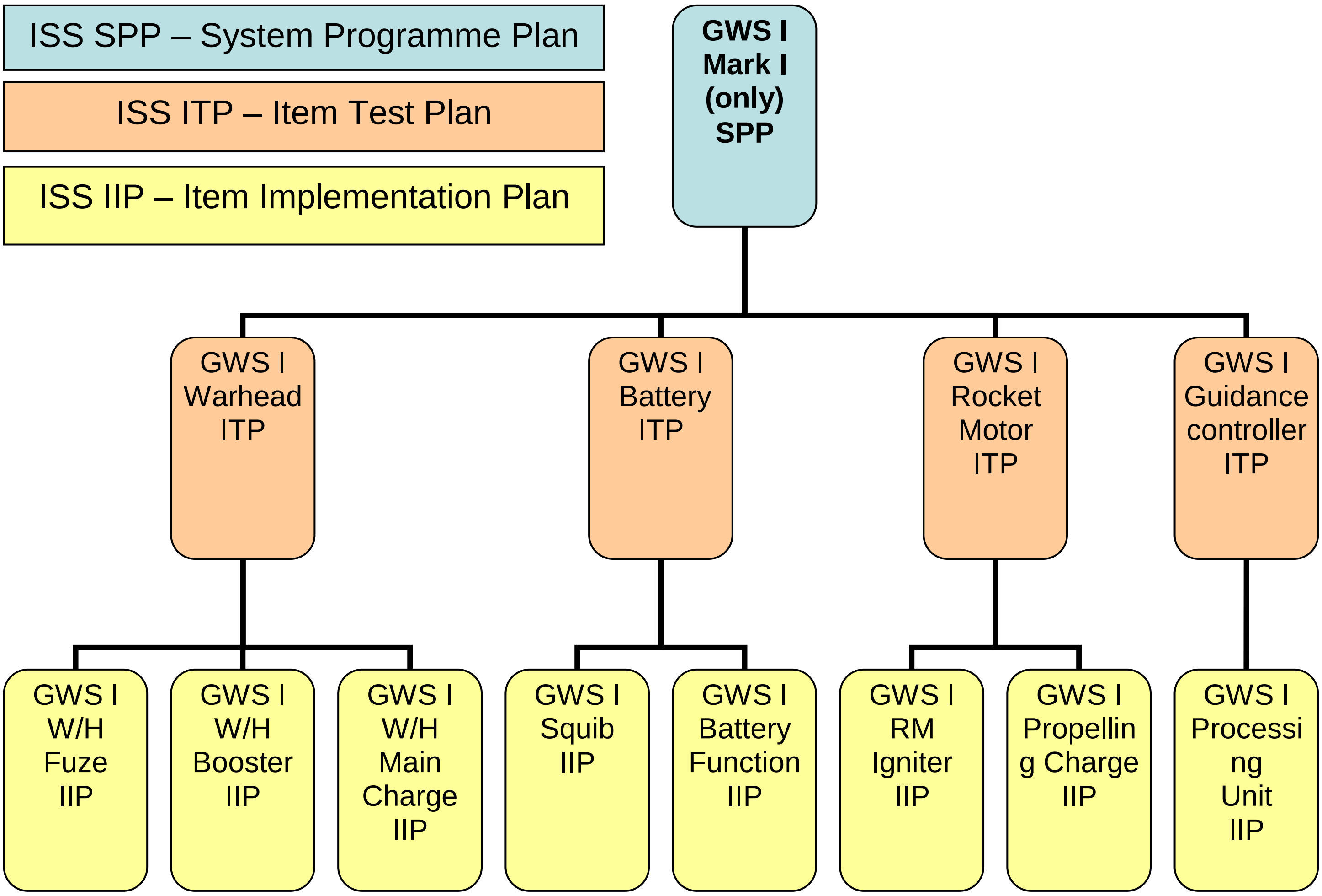

Figure A1 – Example Documentation Structure for a Complex Guided Weapon System ISS Programme

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

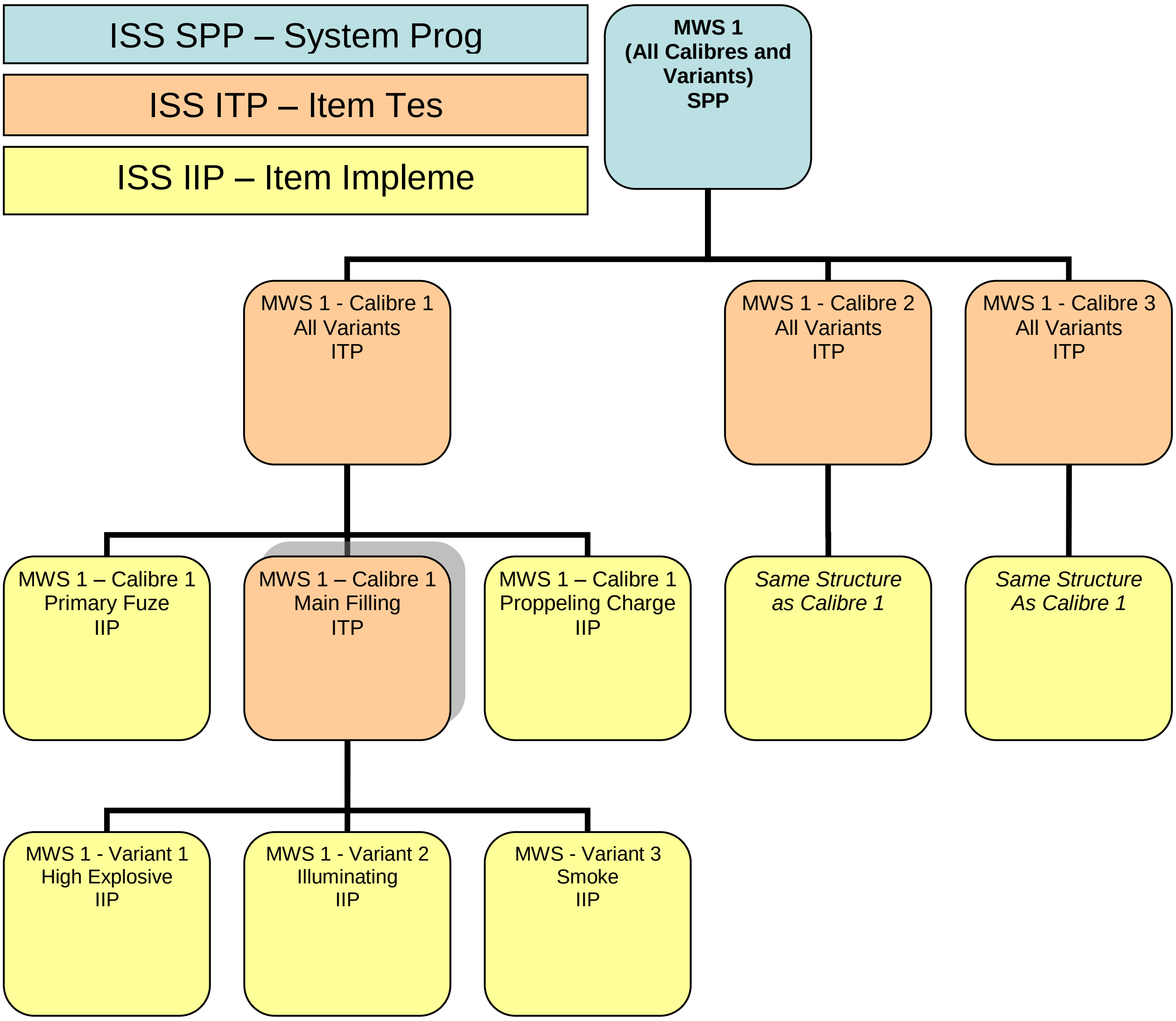

Figure B1 – Example Documentation Structure for a Medium Weapon System ISS Programme

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

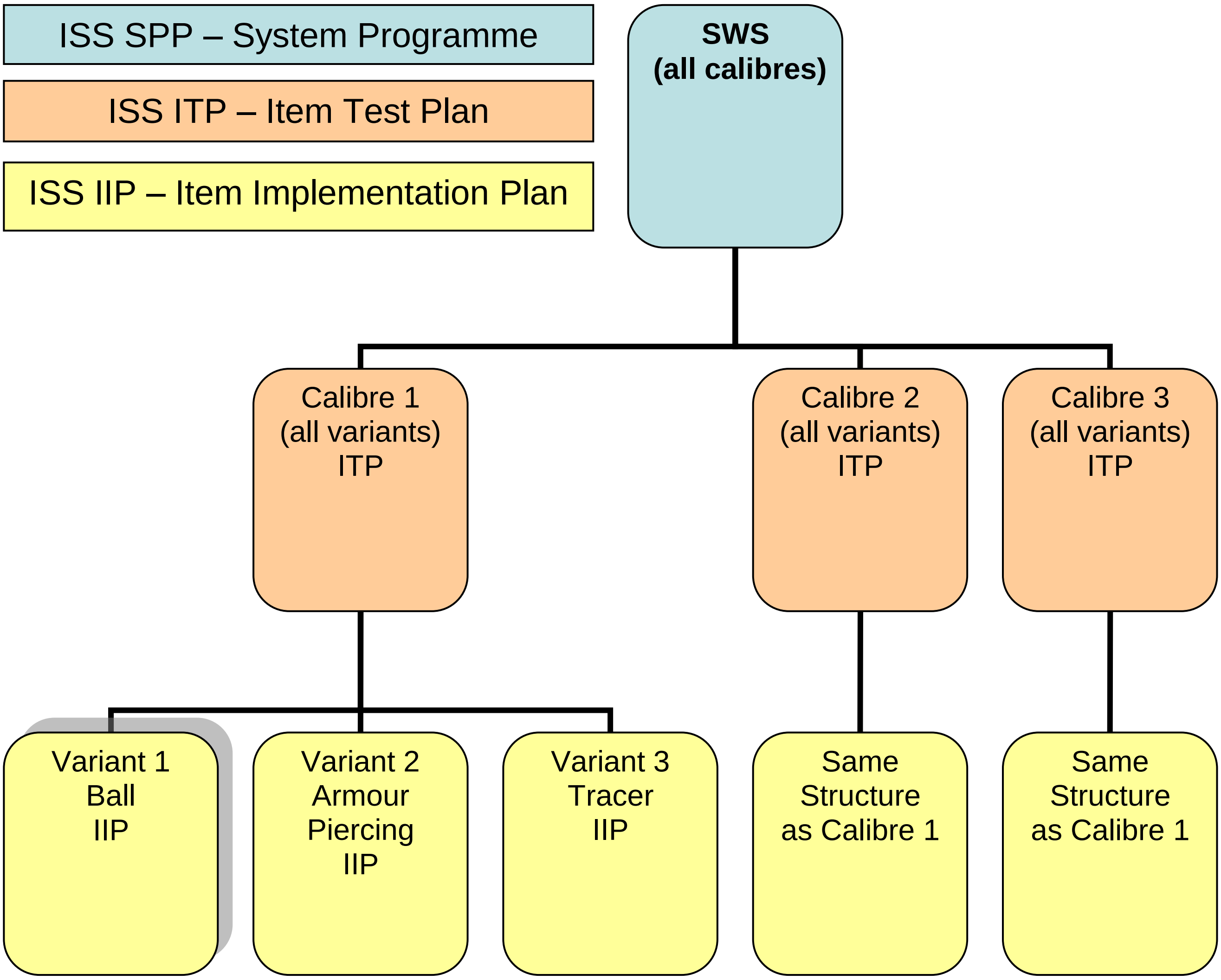

Figure C1 – Example Documentation Structure for a Simple Weapons System ISS Programme

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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