U.S. Army Research, Development and Engineering Command
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Gun Assembly Safety Certification – US Approach

Briefing for the NDIA
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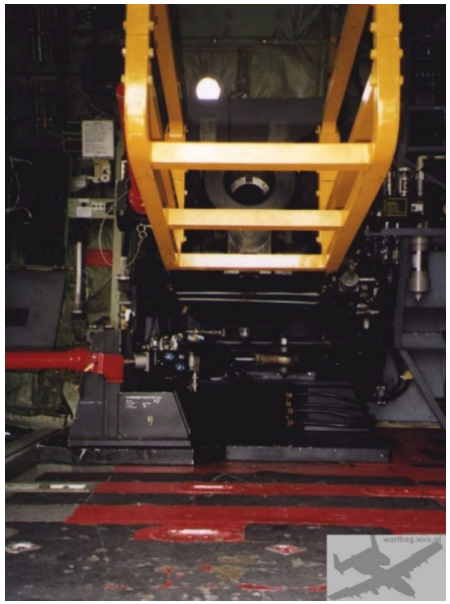
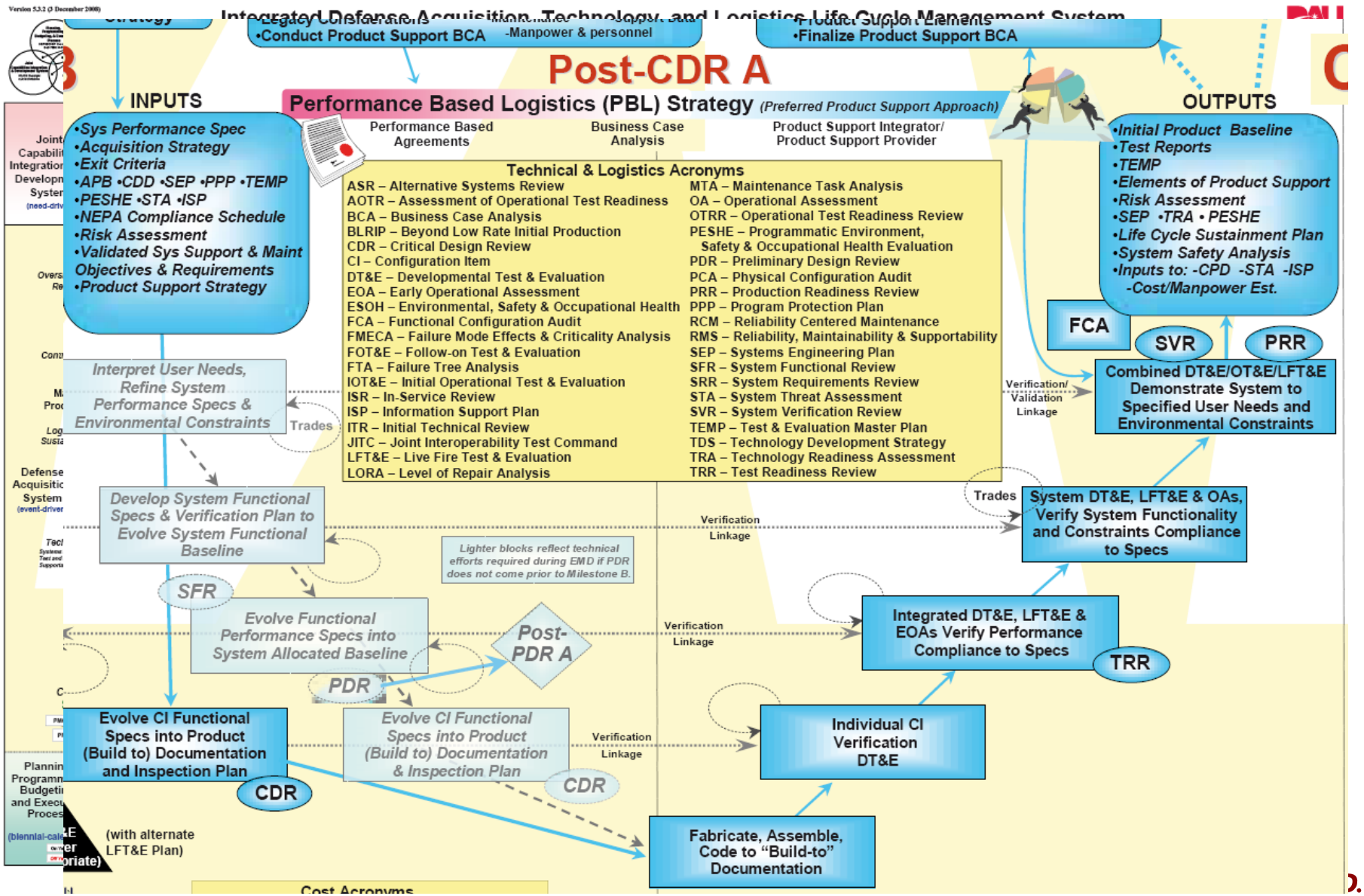
Gun Assembly Safety Certification Agenda

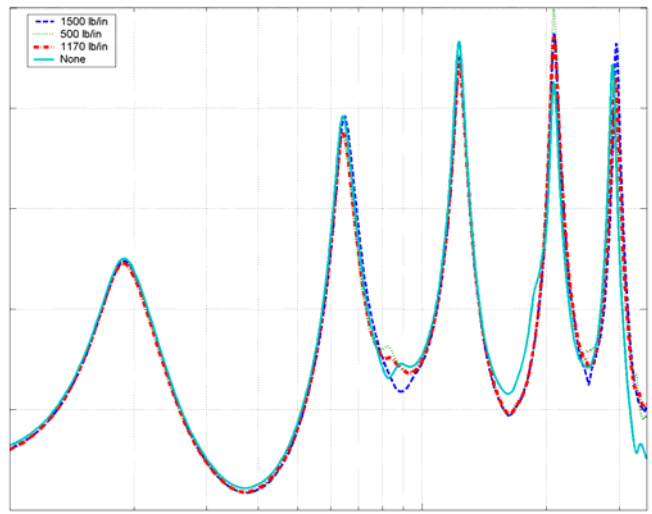
- Acquisition Process
- Weapon Safety Certification
- Gun Qualification Tests
- Typical Gun Test Program
- Test Supporting Elements
- Certification

105 MM M137A1 Cannon mounted in AC-130 Gunship (Photos: Janes Weekly)




Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System
•Conduct Product Support BCA
-Manpower & personnel
•Finalize Product Support BCA
Post-CDR A
INPUTS
Performance Based Logistics (PBL) Strategy (Preferred Product Support Approach)
Performance Based Agreements
Business Case Analysis
Product Support Integrator/ Product Support Provider
OUTPUTS
•Sys Performance Spec
•Acquisition Strategy
•Exit Criteria
•APB •CDD •SEP •PPP •TEMP
•PESHE •STA •ISP
•NEPA Compliance Schedule
•Risk Assessment
•Validated Sys Support & Maint Objectives & Requirements
•Product Support Strategy
•Initial Product Baseline
•Test Reports
•TEMP
•Elements of Product Support
•Risk Assessment
•SEP •TRA • PESHE
•Life Cycle Sustainment Plan
•System Safety Analysis
•Inputs to: -CPD -STA -ISP -Cost/Manpower Est.
Technical & Logistics Acronyms
ASR – Alternative Systems Review
AOTR – Assessment of Operational Test Readiness
BCA – Business Case Analysis
BLRIP – Beyond Low Rate Initial Production
CDR – Critical Design Review
CI – Configuration Item
DT&E – Developmental Test & Evaluation
EOA – Early Operational Assessment
ESOH – Environmental, Safety & Occupational Health
FCA – Functional Configuration Audit
FMECA – Failure Mode Effects & Criticality Analysis
FOT&E – Follow-on Test & Evaluation
FTA – Failure Tree Analysis
IOT&E – Initial Operational Test & Evaluation
ISR – In-Service Review
ISP – Information Support Plan
ITR – Initial Technical Review
JITC – Joint Interoperability Test Command
LFT&E – Live Fire Test & Evaluation
LORA – Level of Repair Analysis
MTA – Maintenance Task Analysis
OA – Operational Assessment
OTRR – Operational Test Readiness Review
PESHE – Programmatic Environment, Safety & Occupational Health Evaluation
PDR – Preliminary Design Review
PCA – Physical Configuration Audit
PRR – Production Readiness Review
PPP – Program Protection Plan
RCM – Reliability Centered Maintenance
RMS – Reliability, Maintainability & Supportability
SEP – Systems Engineering Plan
SFR – System Functional Review
SRR – System Requirements Review
STA – System Threat Assessment
SVR – System Verification Review
TEMP – Test & Evaluation Master Plan
TDS – Technology Development Strategy
TRA – Technology Readiness Assessment
TRR – Test Readiness Review
Interpret User Needs, Refine System Performance Specs & Environmental Constraints
Trades
Develop System Functional Specs & Verification Plan to Evolve System Functional Baseline
Verification Linkage
Verification/ Validation Linkage
Combined DT&E/OT&E/LFT&E Demonstrate System to Specified User Needs and Environmental Constraints
FCA
SVR
PRR
Trades
System DT&E, LFT&E & OAs, Verify System Functionality and Constraints Compliance to Specs
Lighter blocks reflect technical efforts required during EMD if PDR does not come prior to Milestone B.
SFR
Evolve Functional Performance Specs into System Allocated Baseline
Post-PDR A
PDR
Verification Linkage
Integrated DT&E, LFT&E & EOAs Verify Performance Compliance to Specs
TRR
Evolve CI Functional Specs into Product (Build to) Documentation and Inspection Plan
CDR
Evolve CI Functional Specs into Product (Build to) Documentation & Inspection Plan
CDR
Verification Linkage
Individual CI Verification DT&E
(with alternate LFT&E Plan)
Fabricate, Assemble, Code to "Build-to" Documentation
Cost Acronyms

- Most testing and safety evaluations done during System Design & Development Phase (now called Engineering & Manufacturing Development)
- Every type of product will have differing tests, standards & requirements
- Weapons Systems have a reasonably well defined set of safety standards and tests, oriented around NATO Standardization Agreements (STANAGs) and International Test Operational Procedures (ITOPs)
- Performance and Operational Tests are individually designed and executed for each System.



Natural Frequency Response Testing of 120 MM Tube

- Given the nature and expense of testing it is usually quite impossible to completely isolate safety testing from other required development testing for issues such as reliability, maintainability, performance evaluation. As a result:
  - Conflicts often arise when failures occur in test hardware – do we continue testing and risk further failures or do we stop tests to correct the problems
- A properly laid out development program has a Test & Evaluation Master Plan (TEMP) developed and coordinated at the very beginning of the program (as early as the concept phase) that addresses which requirements – safety and performance – will be assessed addressed at what phase of testing.
- Failure Mode Effects Criticality Analysis (FMECA) – While this is primarily a reliability tool, it can also serve as a test & safety assessment tool. Example shown later
- Large caliber guns require expensive, long lead processes to obtain forgings, parts, etc, and as such, their development will precede most of the other vehicle developments, to allow the safety cert activities to occur in timely fashion to allow other vehicle developments and tests to proceed.
- Gun Assemblies are typically not safety certified by themselves. They are normally tested and certified as part of a vehicle system. As such they typically are integrated with vehicle test & development activities. Conversely, use of the same gun in a different vehicle will require some level of re-certification (testing or evaluation)

- What is a Gun Safety Certification?
  - Certification by an independent (from the developer) evaluator that no significant hazards exist.
  - Certification is supported by analysis, testing, validations submitted by the developer.
  - Certification is required before military personnel are allowed to be in the Vehicle when the weapon is fired. (live fire)
  - Certification is required to pass Milestone (C)
- Testing is required to obtain a Safety Certification on a Gun.
  - Governed by ITOPs, STANAGs, MIL STDs (see next page)
  - Tailored for each weapon and each program

155 MM M284 (left) on US M109A6 (Iraq 2007) – 155 MM M185A2 (below) on Israeli M109 (Gaza 2003)

Weapon Safety Certification References

- STANAGs:
  - 4110; Definition Of Pressure Terms And Their Interrelationship For Use In The Design And Proof Of Cannons Or Mortars And Ammunition
  - 4385; 120 MM Tank Ammunition
  - 4493; Tank Ammunition Safety & Suitability for Service
  - 4650; International Test Operation Procedures (ITOP) On Testing Of Large Caliber Weapons And Ammunition
- ITOPs
  - 3-2-829 Cannon Safety Test
  - 3-2-050 Testing Of Mortar Systems
  - 3-2-500 Weapon Characteristics
  - 3-2-506(1) Artillery Self-propelled And Towed
  - 3-2-506(2) Tank Cannon & Recoil Mechanism
  - 3-2-605 Tank System Accuracy Reference Firing
  - 4-2-504(1) Safety Testing Of Artillery Ammunition
  - 4-2-504(2) Safety Testing Of Tank Ammunition
- MIL STDs
  - MIL STD 882; System Safety Program Management
  - MIL-STD-1474D, Noise Limits

- Roles:
  - Development Agency – Gun Assembly (Benet) & Vehicle Developer
  - US Army Test Center(s) – Testers (Developmental and Operational)
  - US Army Training & Doctrine Command (TRADOC) – Requirements Developer
  - Project Manager – Customer (for the US Soldier)
  - US Army Developmental Test Command (DTC) – Independent Evaluation and Certification
- Prior to test, Developer completes"
    - Failure Mode Effects Criticality Analysis (FMECA): Provides clues to what highest safety and reliablity isses will be
    - Safety Assessment Report: Provides an assessment of the gun to the tester and certification agencies, matures with increasing testing.
    - Health Hazard Assessment Report (HHAR): Draft prior to testing, increasing maturity during testing, finalized at end of testing. Provides certification that all hazards mitigated and product is safe for use.
    - Test & Evaluation Master Plan: Provides a roadmap of all tests, when requirements will be assessed, what methodology used, what standards to be used.

- Summary:
  - Proof & Baseline Tests
  - Fatigue Test
  - Mount Safety Test
  - Wear Test
  - Strength of Design
  - Toxic Fumes
  - Noise and Blast Overpressure
  - Safe Maximum Pressure *

120 MM M256 Gun Firing off M1A1 Tank in Iraq.

* not yet a required test

- Proof & Baseline:
  - Cannons:
    - All prototype cannons are proofed with 5 to 7 rounds*
    - Proof rounds typically utilize adjustments to ensure proof pressure achieved
    - Cannon must be inspected before and after proofing
    - Direct Fire cannons are also baselined for precision - 10 rounds per cannon per round type to be tested.
    - Reference:
      - International Test Operations Procedure (ITOP) 3-2-829, “Cannon Safety Test,” 23 Oct 92
      - International Test Operations Procedure (ITOP) 3-2-605, “Tank System Accuracy/Reference Firing”

* Production Gun Assemblies are also proofed

- Proof & Baseline (cont'd):
  - Mounts:
    - All prototype gun mounts are proofed with 3-5 rounds*
    - Maximum impulse conditions (round and elevation) must be met
    - Mount is inspected before and after proofing
    - Reference:
      - International Test Operations Procedure ITOP 3-2-506(2) "Tank Cannon & Recoil Mechanisms"
      - International Test Operations Procedure ITOP 3-2-506(1) "Artillery (Self-Propelled and Towed)"

* Production Gun Assemblies are also proofed

- Fatigue Test
  - Required for all new gun systems
  - Required if significant modifications have been made in fatigue-sensitive areas of the tube and/or breech as a basic design change, provided:
    - Sufficient experience with service use indicates change is in a non-critical area
    - And, Modeling and Analysis shows change won't affect performance
  - New Gun - Interim Fatigue Life Test
    - Two tubes and breeches are fired ~500 rounds and are cycled to failure in fatigue simulators. (Rounds are not dedicated to this test, but should provide maximum fatigue impact (pressure))
  - New Gun - Final Fatigue Life Test
    - Four additional tubes are fired ~500 rounds. Tubes and four additional breeches are cycled to failure in fatigue simulators. (Rounds are not dedicated to this test.)
  - Existing Gun - Two tubes and breeches are fired ~500 rounds and are cycled to failure in fatigue simulators. (Rounds are not dedicated to this test.)
  - ITOP 3-2-829
  - (Test phases are typically referred to as 'Pre-Fatigue Testing', and 'Laboratory Fatigue Testing')

Gun Qualification Tests

- Mount Safety Test
  - Weapon Firing Phase
    - Test the overall performance of the mount at various elevations – 50 rounds
  - Recoil Firing Phase
    - Test the performance of the recoil system at various elevations and with ammunition conditioned to temperature extremes – 50 rounds
  - Extreme Temperature Phase
    - The mount is conditioned to temperature extremes and fired. – 22 rounds
  - ITOP 3-2-506(2), Tank Cannon and Recoil Mechanism

Gun Qualification Tests

- Wear Test
  - Two tubes are fired until range or accuracy criteria are not met. (Rounds are not dedicated to this test, but a mix of rounds is typically used to assess total life)
  - Testing is usually conducted in groups of 'expenditure' rounds and groups of 'accuracy' rounds.
  - Reference: ITOP 3-2-829
- Strength of Design
  - Verify that ammunition can successfully withstand the maximum launch forces – 30 rounds for each type of ammunition to be tested.
  - ITOP 4-2-504(2) Safety Testing of Tank Ammunition)
- Toxic Fumes
  - Vehicle is instrumented and the concentration of gases produced as a result of firing is measured at various locations - 20 to 30 rounds.
  - ITOP 2-2-614, Toxic Hazards Tests for Vehicles and Other Equipment
- Noise and Blast Overpressure
  - Noise and blast overpressure are measured at various locations around the vehicle – 20 to 30 rounds.
  - ITOP 4-2-822, Electronic Measurement of Airblast Overpressure and Impulse Noise, and MIL-STD-1474D, Noise Limits

Gun Qualification Tests

- Ammunition Requalification/Autoloader Qualification
  - Autoloader Vibration - Ammunition is placed in the autoloader, vibrated on a vibration table and cycled through the autoloader – 20 rounds for each type of ammunition to be tested. (ITOP 3-2-051, “Automatic Loaders for Tank Systems)
  - Sequential Rough Handling - The following tests are conducted in succession, one iteration with rounds conditioned to high temperature, another with rounds conditioned to low temperature:
    - 2.1 Meter Drop
    - Logistic Vibration
    - 1.5 Meter Drop
    - Autoloader Cycling
  - Firing - Number or rounds depends on packaging configuration – 90 to 100 rounds for each type of ammunition tested. (ITOP 4-2-504(2) and ITOP 4-2-602, “Rough Handling Tests)

- Ammunition Requalification/Autoloader Qualification (cont'd)
  - Sequential Life Cycle - Following tests are conducted in succession, one iteration with rounds conditioned to high temperature, another with rounds conditioned to low temperature:
    - Tactical Vibration
    - Hot/Dry Storage Cycle (half of the rounds conditioned to high temperature)
    - High Humidity Cycle (the other half of the rounds conditioned to high temperature
    - Cold Storage Cycle (rounds conditioned to low temperature only)
    - Hull Vibration
    - Autoloader Vibration
    - Chamber/Extract Cycles
  - Firing - Number of rounds depends on whether the projectiles contain explosive elements – between 100 and 140 rounds for each type of ammunition to be tested. (ITOP 4-2-504(2) and ITOP 3-2-051)

- Worn Tube
  - Fire rounds in a worn tube to verify that ammunition can function safely in a worn tube. For rounds with explosive elements in the projectiles – 70 rounds for each type of ammunition to be tested. Other rounds – 20 rounds for each type of ammunition to be tested.
  - ITOP 4-2-504(2)

- Safe Maximum Pressure:
  - not governed by an ITOP
  - Rounds are fired at increasing pressure levels until SMP is observed by plastically deforming cannon
  - Hazards and gun performance is assessed and used to define hazard levels and resultant operational procedures.

Example Test Overview

- Cannon Safety:
  - Firing Tests
    - Cannon Safety Test #1 - Pre Fatigue
    - Cannon Safety Test #2 - Pre Fatigue
    - Cannon Safety Test #3 - Pre Fatigue
    - Cannon Safety Test #4 - Pre Fatigue
    - Cannon Safety Test #5 / Tube Wear Test#1
    - Cannon Safety Test #6 / Tube Wear Test#2
    - Laboratory Fatigue Tests
      - 6 Breech Assemblies –
      - 6 Gun Tubes –

ITOP 3-2-829

- Gun Mount & Recoil System Tests
  - Firing Tests
    - Basic Firing Program – zero QE
    - Basic Firing Program – Max/Min QE
    - Extreme Temperature Test
  - Laboratory Tests
    - Two Recoil Durability Tests @ RIA

ITOP 3-2-506(2)

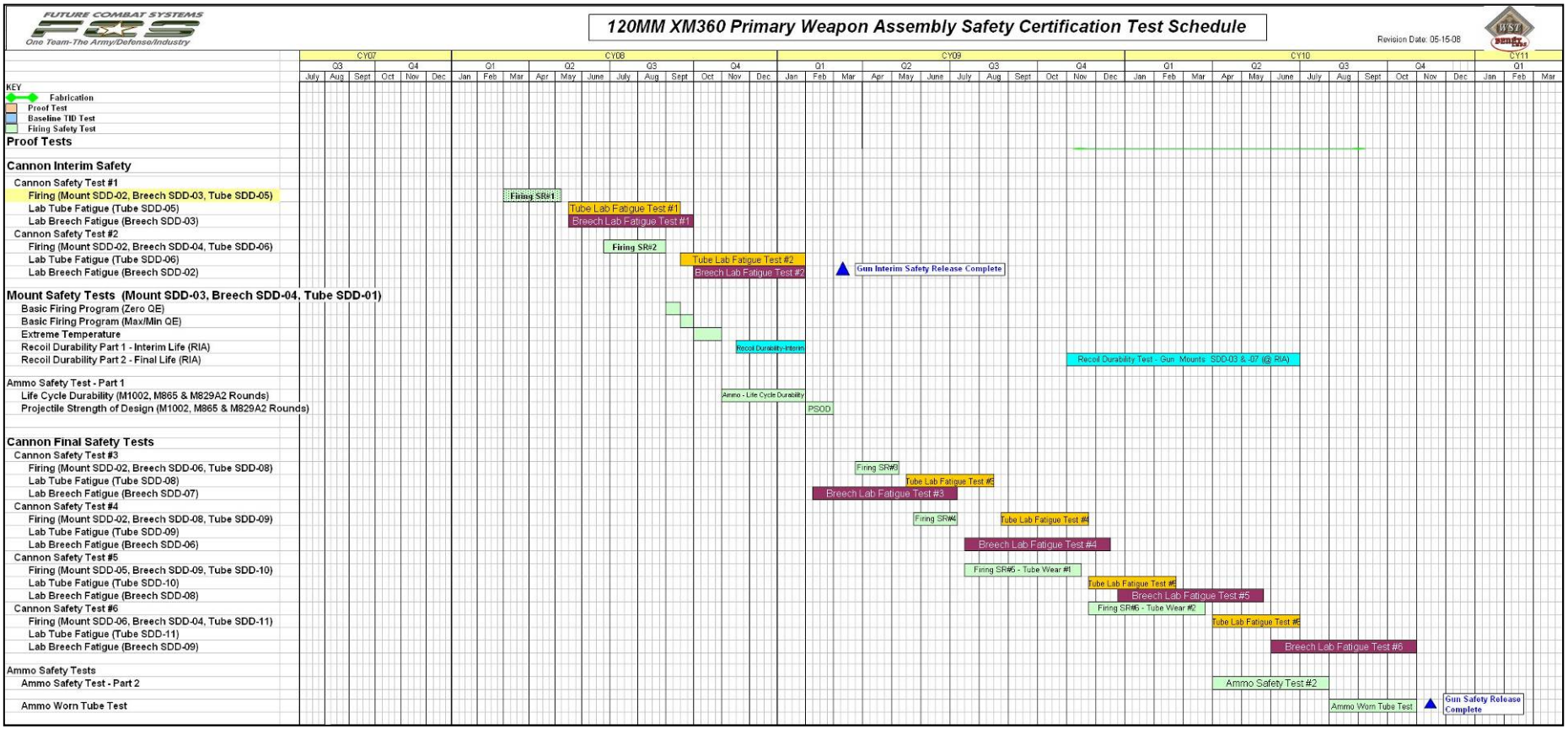
Example Test Overview

- Ammunition Safety:
  - Ammo Safety Test #1
    - Projectile Strength of Design Test
    - Cannon Strength of Design Test
    - Abbreviated Life Cycle Durability Test
    - Testing to be conducted on M1002, M865 & M829A2 Rounds
  - Ammo Safety Test #2
    - Same Tests as Test #1, but with remaining Rounds
  - Ammunition Worn Tube Test (July – Oct 2010)
    - 30 (Non-HE) to 70 (HE) rounds fired from a 4th quarter Tube.
    - Test determines if rounds functioned properly.
    - To be conducted on all Rounds

- Ammo Handling, BOP, and Toxic Fumes Tests will be conducted during vehicle tests

ITOP 4-2-504(2)

Example Test Overview

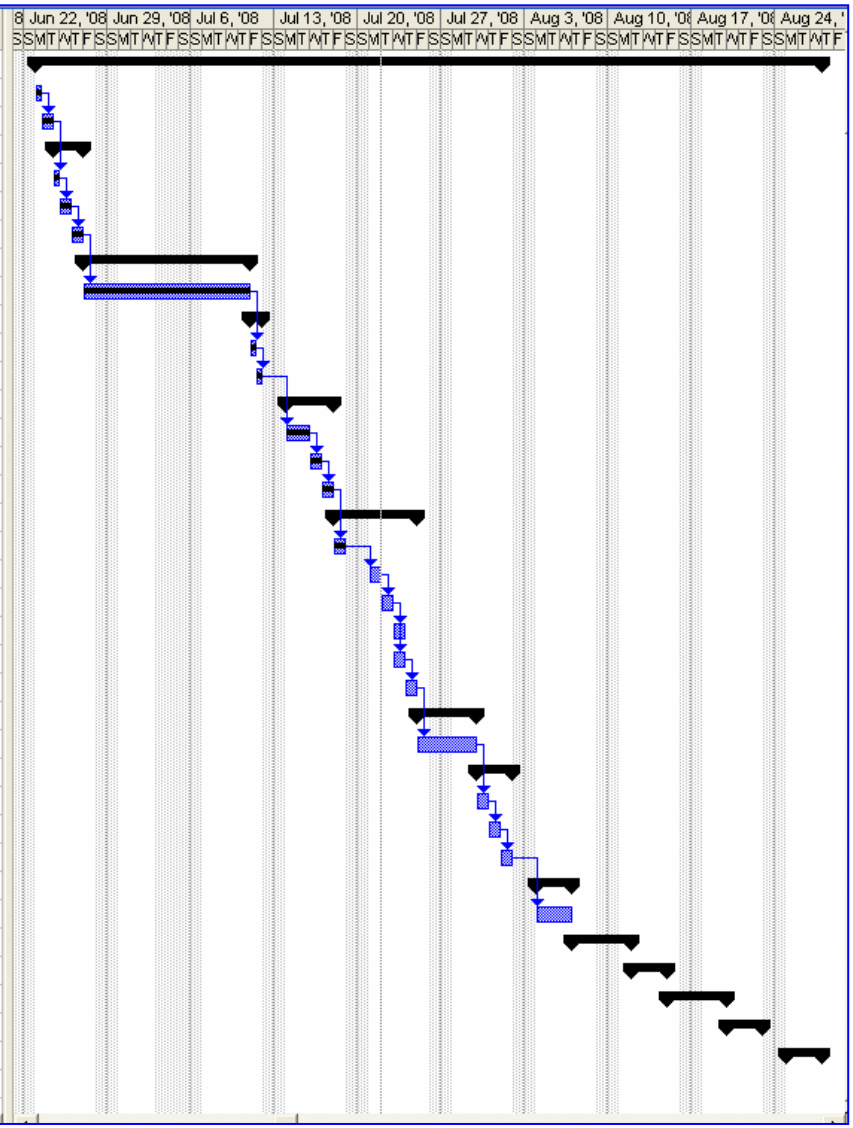


TEMP - Firing Test Plans 05-16-08.pdf

- Specific Test Layout – Safety Test 2
  - Objective: To provide the 2nd of two Gun Tube Fatigue Test Samples for use in the Establishment of an Interim Fatigue Life per ITOP 3-2-829 for the Weapon Assembly . This test will consist of firing 500 rounds of ammunition capable of producing pressures in accordance with STANAG 4385. 500 rounds will be fired per a request for an interim safe life of 500 rounds. This is the 2nd of six Safety Tests which will be used to request a Final Safety Release on the XM360 Gun Assembly. This will be accomplished by performing the following series of tests:
    - Conduct Target Impact Dispersion (TID) Testing
    - Conduct Field Blast Over Pressure (BOP) Testing.
    - Conduct Expenditure Testing.
    - Conduct Post Test Inspections.
    - Evaluate gun performance differences when the gun is fired with and without the Breech Counterweights.
    - Monitor the overall performance of the Gun System.
    - Conduct Dynamic Muzzle Reference System and Gyro Testing per customer test plans noted in Appendix E.

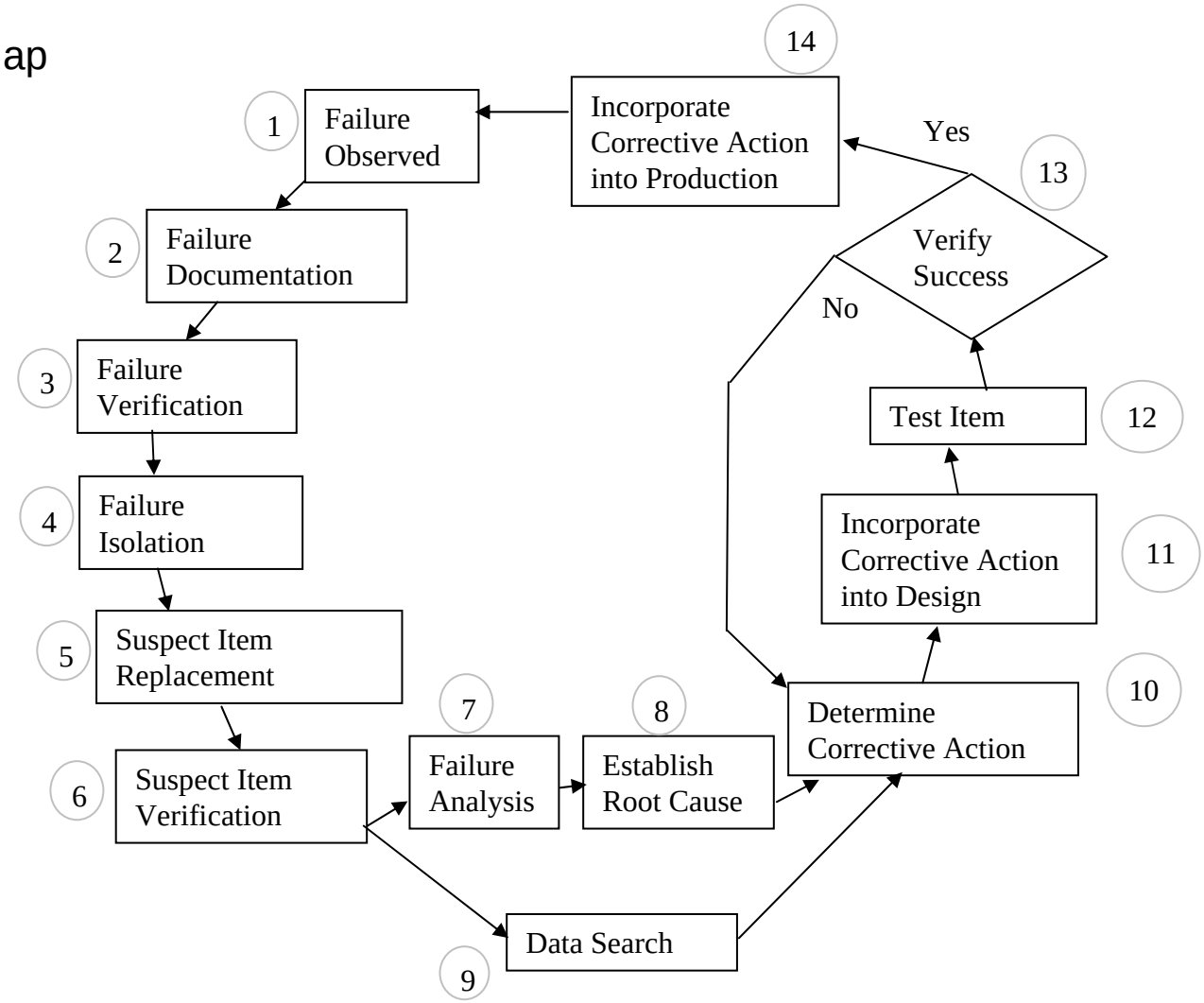
Example Test Overview

	Task Name	Duration	Start	Finish	% Complete
21	**Conduct Cannon Safety Test #2**	**46 days**	**Mon 6/23/08**	**Wed 8/27/08**	**38%**
22	Move Gun to Barricade B1	0.5 days	Mon 6/23/08	Mon 6/23/08	100%
23	Set Up for Cannon Safety Test	1 day	Mon 6/23/08	Tue 6/24/08	100%
24	**Fire Baseline TID Group #1 (Rounds 1-30)**	2.5 days	Tue 6/24/08	Thu 6/26/08	100%
25	Fire M1002 Baseline TID (Rounds 1-10)	0.5 days	Tue 6/24/08	Tue 6/24/08	100%
26	Fire M829A3 Baseline TID (Rounds 11-20)	1 day	Wed 6/25/08	Wed 6/25/08	100%
27	Fire M829A3 Baseline TID woithout Counterweights (Rour	1 day	Thu 6/26/08	Thu 6/26/08	100%
28	**Expenditure Group #1 (Rounds 31-80)**	**8 days**	**Fri 6/27/08**	**Thu 7/10/08**	**100%**
29	Fire 50 M829A2 @ 70F (Rounds 31-80)	8 days	Fri 6/27/08	Thu 7/10/08	100%
30	**Fire Baseline TID Group #2 (Rounds 81-110)**	**1 day**	**Fri 7/11/08**	**Fri 7/11/08**	**100%**
31	Fire M829A3 Baseline TID (Rounds 81-90)	0.5 days	Fri 7/11/08	Fri 7/11/08	100%
32	Fire M829A3 Baseline TID without Counterweights (Rounc	0.5 days	Fri 7/11/08	Fri 7/11/08	100%
33	**Prepare for BOP Testing**	**4 days**	**Mon 7/14/08**	**Thu 7/17/08**	**100%**
34	Implace Stands	2 days	Mon 7/14/08	Tue 7/15/08	100%
35	Install BOP Pressure Gages	1 day	Wed 7/16/08	Wed 7/16/08	100%
36	Measure BOP Locations	1 day	Thu 7/17/08	Thu 7/17/08	100%
37	**Conduct BOP Testing (Rounds 111-140)**	**5 days**	**Fri 7/18/08**	**Thu 7/24/08**	**17%**
38	Fire 5 M829A3 @ 70F (Rounds 101-105)	1 day	Fri 7/18/08	Fri 7/18/08	100%
39	Fire 5 M829A2 @ 70F (Rounds 106-110)	1 day	Mon 7/21/08	Mon 7/21/08	0%
40	Fire 5 M829A3 @ 120F Hot (Rounds 111-115)	1 day	Tue 7/22/08	Tue 7/22/08	0%
41	Fire 5 M829A2 @ 120F Hot (Rounds 116-120)	1 day	Wed 7/23/08	Wed 7/23/08	0%
42	Fire 5 M829A3 @ -25F Cold (Rounds 121-125)	1 day	Wed 7/23/08	Wed 7/23/08	0%
43	Fire 5 M829A2 @ -25F Cold (Rounds 126-130)	1 day	Thu 7/24/08	Thu 7/24/08	0%
44	**Expenditure Group #2 (Rounds 131-190)**	**3 days**	**Fri 7/25/08**	**Tue 7/29/08**	**0%**
45	Fire 50 M829A2 @ 70F (Rounds 131-190)	3 days	Fri 7/25/08	Tue 7/29/08	0%
46	**Fire Baseline TID Group #3 (Rounds 191-220)**	**3 days**	**Wed 7/30/08**	**Fri 8/1/08**	**0%**
47	Fire M1002 Baseline TID (Rounds 191-200)	1 day	Wed 7/30/08	Wed 7/30/08	0%
48	Fire M829A3 Baseline TID (Rounds 201-210)	1 day	Thu 7/31/08	Thu 7/31/08	0%
49	Fire M829A3 Baseline TID woithout Counterweights (Rour	1 day	Fri 8/1/08	Fri 8/1/08	0%
50	**Expenditure Group #3 (Rounds 221-270)**	**3 days**	**Mon 8/4/08**	**Wed 8/6/08**	**0%**
51	Fire 50 M829A2 @ 70F (Rounds 221-270)	3 days	Mon 8/4/08	Wed 8/6/08	0%
52	**Fire Baseline TID Group #4 (Rounds 271-300)**	**3 days**	**Thu 8/7/08**	**Mon 8/11/08**	**0%**
56	**Expenditure Group #4 (Rounds 301-370)**	**3 days**	**Tue 8/12/08**	**Thu 8/14/08**	**0%**
59	**Fire Baseline TID Group #5 (Rounds 371-400)**	**3 days**	**Fri 8/15/08**	**Tue 8/19/08**	**0%**
63	**Expenditure Group #5 (Rounds 401-470)**	**3 days**	**Wed 8/20/08**	**Fri 8/22/08**	**0%**
66	**Fire Baseline TID Group #6 (Rounds 471-500)**	**3 days**	**Mon 8/25/08**	**Wed 8/27/08**	**0%**
70					
71					



- Failure Reporting, Analysis, and Corrective Action System (FRACAS).
  - Provides a closed loop process to assess, review, correct problems
  - Failures are broken down to:
    - **Critical** – Involves a catastrophic or critical hazard related to health or safety of personnel; Categories I and II per MIL STD 882D/
    - **Major** – Involves a marginal hazard to safety of personnel (Category III per MIL STD 882D). Involves a critical safety hazard to the item/system under test (unplanned major system damage; Category II per MIL STD 882D), two or more repetitive minor incidents can also indicate a major failure.
    - **Minor** – Reflects an actual or incipient malfunction, defect, hazard, or negative finding that does not qualify as critical or major. Reports subtest results that reflect marginal performance.
    - **Informational** – Reports modification to the tested item, current condition of the tested item, test findings, subtest results, safety release information, or other types of information.
- Test Incident Report (TIR) generated during test events, a Corrective Action Report (CAR) is generated to document the failure, cause, and corrective action.
  - When the corrective action has been verified, the TIR can be closed

- Process Map


1
Failure Observed
2
Failure Documentation
3
Failure Verification
4
Failure Isolation
5
Suspect Item Replacement
6
Suspect Item Verification
7
Failure Analysis
8
Establish Root Cause
9
Data Search
10
Determine Corrective Action
11
Incorporate Corrective Action into Design
12
Test Item
13
Verify Success
Yes
No
14
Incorporate Corrective Action into Production

FMECA

Item/Functional Nomenclature	Function	Failure Mode	Failure Mode Cause	Local Effect	Next Higher Effect	System Effect	Design Mitigation	Failure Detection Mode	SEV	OCC	DET
Housing	Platform for mechanisms which enable breech block to be driven open and closed via actuation of the breech housing assembly.	Fractures	Vibration, fatigue, shock load; bumper stop failure; galvanic corrosion	Loss of breech housing function	Breech will not close/open	Unable to fire; debris in the turret	FEA; ATD live fire testing; based on previous (LW120) systems	Visual inspection; detection via diagnostic sensor(s)	5	2	3
		Distortion	Firing loads, breech block impact, thermal expansion	Component misalignment	Breech may not open/close	May not be able to fire/load/unload		Visual inspection; detection via diagnostic sensor(s)	4	2	3
		Fastener(s) fail	High shear loads; loosening	Component misalignment	Breech may not open/close	May not be able to fire/load/unload; debris in the turret		Visual inspection; detection via diagnostic sensor(s)	4	3	4
		Bearing failure	Fatigue, misalignment	Bearings wear unevenly	Increased breech cycle times and motor torque	Reduced system functionality; electric actuation in jeopardy		Visual inspection; detection via diagnostic sensor(s); resolver cycle times	4	2	3

- Item/Functional Nomenclature
- Function – short description of item function
- Failure Mode – primary item failure means
- Failure Mode Causes – underlying causes for the primary failure modes
- Local Effect – failure effects on the item level
- Next Higher Effect – failure effects on the next level up assembly/subassembly
- System Effect – failure effects on the system level
- Design Mitigation – means to minimize the failure mode and causes
- SEV – hazard severity level
  - 5 Catastrophic
  - 4 Critical
  - 3 Marginal
  - 2 Negligible
  - 1 Minor
- OCC – hazard probability of occurrence
  - 5 Frequent
  - 4 Probable
  - 3 Occasional
  - 2 Remote
  - 1 Improbable
- DET – probability of detection during design
  - 1 Very High (> 99%)
  - 2 High (90-99%)
  - 3 Moderate (75-89%)
  - 4 Low (60-74%)
  - 5 Very Low (< 60%)
- RPN – risk priority number; “The higher the resulting index the more urgent the need to find a solution”

$$RPN = SEV \times OCC \times DET$$

- FMECA provides (from a test standpoint):
  - Guideline on instrumentation and test focus areas
  - Clues on failure modes and approaches

- Upon completion of testing:
  - All test reports reviewed for safety related incidents & concerns
  - HHAR is completed (All safety related issues must be mitigated)
  - Request is sent to DTC to independantly assess and verify all test reports
  - DTC issues Safety Certification Finding
  - Review Board (Defense Acquisition Board) accepts or rejects findings and “Type Classifies” the product (no longer ‘experimental’)
  - Product is now considered ‘fielded’ and can be used by soldiers

120 MM XM360 Firing off XM1202 Mounted Combat System Turret – Aberdeen Test Center – January 2009.