Artillery Application Requires Thorough Testing

Planning for Failure Analysis

• Constrained Budgets & Schedules in Current Weapons Development Environment

• Test Failures Will Still Happen and Will Have to Be Analyzed & Fixed Quickly

• Still Need to Follow a Very Disciplined Failure Analysis & Corrective Action Approach

• Expect & Plan for Failure Analysis
  • Develop a solid knowledge base on the product design and build processes
  • Conduct early Failure Modes Effects Analysis to characterize potential failures
  • Plan early tests that stress the system
  • Use design-of-experiment techniques
  • Collect as much data as possible during tests
  • Have a well defined failure analysis process
  • Document & share lessons learned

Expect & Plan for Failures During Development & Production
PGK Example - Many Test Scenarios

- Two projectile types (M795, M549A1)
- Two gun types (M109A6, M777A2) – new to end-of-life tube
- Five zone charges (MACS1- MACS5)
- Wide range of gun elevation angles (200-1300mils)
- Wide temp range (-25 F to +145 F)
- Harsh environmental conditioning sequence for fuze safety certification
Primary Sources of Data for Gun-Launched Weapons

• High Speed Telemetry (TM) System
• On-Board Recorder (OBR) System
• High Speed Muzzle-Exit Cameras (Video and Still)
• Muzzle-Exit Velocity Radar System
• In-Flight Radar Tracking System
• In-Flight Optical Tracking System
• High Speed Target Video Cameras
High-G Test Setup at Yuma Proving Ground

- Projectile Tracking Radar
- Mobile Vertical Gun & Ramp
- High Speed Camera Tower
- Muzzle Velocity Radars
High-G Facilities for Launch & Impact Testing

Unique facilities provide capability for early structural integrity testing and data gathering to support failure investigations.

**Vertical Gun Test Facility at YPG**

**Ballistic Rail Gun Test Facility at ATK**

**SCat (Soft Catch) Gun Test Facility at ARDEC**

**Air Gun Test Facility at ATK**
Disciplined Process is Key to Rapid Failure Resolution

8-D Problem Solving Process
(8 disciplines needed for effective problem solving)

1) Form the Right Team to Investigate the Problem .... more later


3) Implement Containment Actions – Temporary Corrective Actions

4) Identify & Verify Root Causes & Escape Points.... more later

5) Choose & Verify Permanent Corrective Actions....more later
   (and Possibly Preventive Actions for Potential Problems)

6) Implement Corrective Actions & Evaluate Results

7) Prevent Recurrence – Document & Share Lessons Learned

8) Celebrate Success – Formally recognize the collective efforts of the team.
Form the Right Team

• Select an experienced problem-solving facilitator
• Select a cross-functional team with relevant subject matter expertise – systems, design, production, process, quality, test, materials, purchasing
• Include independent team members with “fresh sets of eyes”
• Establish a clear set of ground rules and schedule objectives
• Provide adequate resources
Clearly Define the Problem

Einstein is quoted as having said that if he had one hour to save the world he would spend *fifty-five minutes defining the problem* and only *five minutes finding the solution.*

*Need to make sure we’re solving the right problem*
Apply Disciplined Process to Identify & Verify Root Causes

- Fault Tree Analysis
- 5 Whys
- Fishbone
- FMEA
- Difference or Change Analysis
- Pedigree Analysis

Allows initial focus on most likely root causes

Usually an iterative process of data gathering & analysis to support or refute root cause hypotheses

Use Design-of-Experiments techniques to effectively & quickly gather & analyze data
Choose, Implement, & Verify Corrective Actions

Use the same discipline to define & verify Corrective Actions

- Design
- Assembly Processes
- Test Procedures
- Tests
- Inspections
- Materials
- Specifications
- Training
- Tooling

Use Design-of-Experiments techniques to effectively & quickly gather & analyze data
Conclusion

• Failures will occur during development & production testing

• Must have a systematic failure investigation & resolution process to find & fix problems quickly and effectively

• The 8-D process at ATK attacks problems to identify the true root causes, implement long-term solutions, and drive continuous improvement
Contact Information

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