Application of MIL-HDBK-189 Reliability Growth Analysis (RGA) on Mobile Gun System (MGS) Product Verification Test (PVT)

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Agenda

- What is MGS
- Success Factors of MGS PVT
  - Program Management – Integrated Team
  - System Engineering and Reliability Attainment
  - Reliability Data Analysis – RGA
    - FDSC – Failure Definition Scoring Criteria
    - Failure Categories
    - Inherent vs. Induced Reliability
    - Mission Profile and Life Variable
    - Data Grouping and Modeling
    - Instantaneous vs. Cumulative Reliability
- MGS Lesson Learned - DFR
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● MGS Lesson Learned - DFR
Stryker Family of Vehicles

- Infantry Carrier Vehicle (ICV) 130
- Commander's Vehicle (CV) 28
- Fire Support Vehicle (FSV) 14
- Mobile Gun System (MGS) 27
- Reconnaissance Vehicle (RV) 52
- Medical Evacuation Vehicle (MEV) 16
- Engineer Squad Vehicle (ESV) 13
- Anti Tank Guided Missile (ATGM) 10
- NBC Reconnaissance Vehicle (NBCRV) 3
- 120mm Mounted Mortar Carrier (MC-B) 37
- Medical Evacuation Vehicle (MEV) 16
Mobile Gun System – The Bunker Buster
BLUF – Key Factors for Successful Reliability Growth Program

- Program Management – Integrated Team
  - The systems, tools, and practices now in place between the US Government and General Dynamics Land Systems allowed the system’s reliability to grow (repeatable process)
  - Reliability growth requires commitments from Material Developer Team, Combat Developer, and Independent Test and Evaluation Communities (requirements, test, data, methodology, tools)

- System Engineering – Reliability Backbone
  - Integrates All Reliability Tasks
  - Redirects Tasks Toward a Single Objective
  - Crosses Boundaries Affecting Operational Reliability
  - Provides Program Manager Authority, Funding, and Focus on Engineering, Processes, Documentation, Training, Manufacturing, and Testing for Reliability

- Reliability Data Analysis – Reliability Assessment
  - FDSC – Failure Definition Scoring Criteria
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# MGS Program Management

## Plan
- **Phase I - Conduct an Additional Reliability Test (ART)**
  - Validate effectiveness of 216 PQT and Post-PQT corrective actions
- **Phase II - Implement changes to Government and GDLS Systems Engineering Processes**
  - Management and process changes
- **Phase III - Redesign of Sub-System components and integration**

## Tests
  - 2 vehicles
  - Pre-ART – XXX rounds & X00 miles
  - ART – XXX rounds & X,000 miles
  - Reliability Point Estimate XX MRBSA
- **Reliability Growth Test (JUL-AUG 2005)**
  - 2 Vehicles
  - XXX rounds
  - X,000 miles
  - Reliability Point Estimate XX MRBSA
- **Production Verification Testing (APR 2006 - DEC 2007)**
  - 3 Vehicles
  - XXXX rounds
  - XX,000 miles
  - On-going – Current estimate XXX MRBSA
MGS Idealized Growth Curve

MGS Rebaselined MEP Idealized Growth Curve
RGT Demonstrated Reliability

Input Parameters

MTBFi = 47

20% RGT Threshold

Rounds Fired
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MGS - Systems Engineering Approach

- Integrates All Reliability Tasks
- Redirects Tasks Toward a Single Objective
- Crosses Boundaries Affecting Operational Reliability
- Provides Program Manager Authority, Funding, and Focus on Engineering, Processes, Documentation, Training, Manufacturing, and Testing for Reliability
- Approach Provides Metrics that can be Measured
SE Approach to Reliability

Increase Design Effectiveness Using Robust Design Methodology

- Modeling
- Allocation
- Prediction
- FMEA
- Parts Program
- FRACAS
- Failure Prevention & Review Board Verification

Potential MTBF

Increase Initial MTBF

Design Phase

Manage Growth Potential

Higher Initial MTBF At Start Of Test

Failure Prevention
Failure Categorization
Timely Corrective Actions

RG/DT
Design for Reliability Management
Focuses on Failure Prevention

- **Outputs, Results, Issues**
  - Critical Issues
  - DART Process
  - Outputs, Results, Issues

- **Failure Prevention and Review Board**
  - Management Systems
  - Interactive Reliability and Design Activity And Reviews
  - Issues Resolved / Closed

- **Analyses**
  - Failure Mode Mitigation Risk Modes
  - Expanded FMEA Worksheet
  - Reliability Growth In Design
  - Reliability Growth
  - IRGT, FRACAS

- **Requirements Review**
  - Performance Requirements
  - Environmental Requirements
  - Reliability Requirements Definitions
  - Safety Requirements
  - Maintainability Requirements
  - Support Requirements

- **Testing**
  - Verification
  - Validation
  - Reliability Growth

- **Design for Reliability**
  - Identify Risk Modes

- **Environmental Requirements**
  - Safety Requirements
  - Maintainability Requirements
  - Support Requirements

- **Reliability**
  - Reliability Requirements
  - Safety Requirements
  - Maintainability Requirements
  - Environmental Requirements
  - Manufacturing for Reliability

- **Manufacturing for Reliability**
  - Parts Selection
  - Manufacturing for Reliability

- **Maintainability Requirements**
  - Maintainability Analysis
  - Parts Selection
  - Manufacturing for Reliability

- **Safety Requirements**
  - Safety
  - Maintainability Analysis
  - Parts Selection

- **Reliability Requirements Definitions**
  - Reliability Design Tradeoff
  - Design – Stress Reliability
  - Safety

- **Reliability Requirements**
  - FMEA and Fault Tree
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- **Safety**
  - FMEA and Fault Tree
  - Reliability Design Tradeoff
  - Design – Stress Reliability

- **Environmental Requirements**
  - Reliability Requirements Definitions
  - Safety
  - Maintainability Analysis

- **Maintenance Requirements**
  - Reliability Requirements
  - Safety Requirements
  - Maintainability Requirements

- **Support Requirements**
  - Reliability Requirements Definitions
  - Safety
  - Maintainability Analysis

- **General Dynamics Land Systems**

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Stryker – Mobile Gun System
Failure Prevention and Resolution Implementation

External Experts

STATUS

FPRB Steering Committee
Weekly

Reliability Assessments and Predictions

STATUS

ISSUES

FPRB Daily

ISSUES

Decisions / Approval

ISSUES

FPRB

Decisions / Approval

PVT Retrofit Review
2X per Week

CA Design Oversight

Corrective Action
2X per Week

Failure Analysis
2X per Week

Hydraulic Leak Focus Team

Harness & Electrical Focus Team

LRU & Sights Focus Team

INDEPENDENT (MUNRO) Focus Team

ADDITIONAL TEAMS AS REQ’D

Quality Committee
2X per Week

Prevention & Systemic Issue Committee
Weekly

STATUS

DECISIONS

APPROVAL

STATUS

DECISIONS

APPROVAL

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● **MGS Lesson Learned - DFR**
Reliability Data Analysis

● Proper Reliability Assessment is a key for the program success at PVT

● Reliability Assessment must be discussed up front and consensus should be reached on:
  ➤ FDSC – Failure Definition Scoring Criteria
  ➤ Failure Categories
    ■ Inherent vs. Induced Reliability
  ➤ Mission Profile and Life Variable
  ➤ Data Grouping and Modeling
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FDSC – Failure Definition Scoring Criteria

- FDSC is Contractual Document that defines
  - Failure/non-Failure Event
  - Test related Event
  - Severity of Failure as it relates to the Mission
  - Cause of the Failure

- FDSC is prepared as required by Army Regulation 70-1, Army Acquisition Policy.

- FDSC is being used through out the test for Scoring purposes, hence it is a major document for Reliability Assessment
Failure Categories

- Performance FM – FM is repeatable with 100% probability of failure for the given procedure/conditions. (Example: TDS overheating)

- Software FM – same as above, but software related.

- Quality FM – happens when vehicle is not built/maintained/operated as designed and is not repeatable after fixing (probability of failure =0%). Can be broken down into Initial Quality, Maintenance, Operator error, etc. (Example: Improperly installed harness, turret lock bended, etc.)

- Potential Reliability FM – happens when vehicle was built/maintained/operated as designed/intended; probability of failure is greater than 0% and less than 100%; usually happens due to wear out, environment, insufficient design, manufacturing variability, etc.
Failure Mode Categorization Process
Inherent vs. Induced Failure

[Diagram of flowchart showing the categorization process]

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Categorize Failures and take Relevant Management Actions

- Root Cause Analysis
- Design Corrections
- Selective Redesigns

- Training and Manuals
- Design Simplifications
- Management of Maintenance Actions

- Supplier Quality Management

- Failure Chargeability
- Human 26%
- Performance 43%
- Quality 7%
- Reliability 24%

- Robust Design
- Adequate Design Margin
- DFMEA
- Step-wise Verification

- Supplier Quality Management

- DFMEA
- Step-wise Verification
Data Grouping

Known Equivalent Time

Unknown Equivalent Time

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Rounds and Miles Accumulation per Vehicle vs. Calendar Time

UET model takes into account any discrepancies between different vehicles following through the test in calendar time.

KET Model can be useful in the beginning of the test when vehicles have not accumulated enough mileage and rounds.
Crow/AMSAA Model

Cum Number of Failures
\[ E(N) = \lambda \cdot T^\beta \]

Cum Failure Rate
\[ r_c = \frac{E(N)}{T} = \lambda \cdot T^{\beta-1} \]

Cum MTBF
\[ MTBF_c = (r_c)^{-1} = (\lambda \cdot T^{\beta-1})^{-1} \]

Inst Failure Rate
\[ r_i = \frac{d(E(N))}{dt} = \frac{d(\lambda \cdot t^\beta)}{dt} = \lambda \cdot \beta \cdot t^{\beta-1} \]

Inst MTBF
\[ MTBF_i = (r_i)^{-1} = (\lambda \cdot \beta \cdot T^{\beta-1})^{-1} \]
Cumulative vs. Instantaneous Reliability

- Reliability growth on the Development test is the result of Corrective Actions.
- Estimating Reliability of the product by taking the Cumulative reliability (total number of failures / total time on the test) does not take into account the growth on the test.
Idealized Growth Curve and Observed Parametric Curve for Demonstrated Instantaneous MRBSA
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DFR Process Elements

- **Boundary Diagram / System Block Diagram**
- Interface matrix
- **P-Diagram**
- **DFMEA**
- Reliability & Robustness Metrics
- **DVP&R**
- Reliability Demonstration Metrics
DFSS (DCOV) Flow of Analysis & Tools

- **VOC**
  - Customer Needs/Statements

- **KJ**
  - Customer Requirements

- **QFD**
  - Technical Requirements

- **FMEA**
  - Functions

- **Boundary Diagram**
  - Concepts

- **P-Diagram**
  - Reliability & Robustness Design & Tolerance Design

- **DFMEA**
  - Reliability & Robustness Metrics

- **Function Modeling**
  - Reliability/Roobustness Demonstration

- **Concept Generation & Selection**

- **DoE**

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Design For Reliability Map
MIL-HDBK-189 RGA Method

MGS MEP PVT Instantaneous MRBSA

- Demonstrated Instantaneous MRBSA for decision-makers
- Growth Rate is 0.4
- RGA Methodology was developed and agreed by RAM-T Community

- Failure Rate continues to decrease, thus demonstrating substantial reliability growth in PVT
- Sustained decrease of MGS Failure Rate suggests infant mortality region is passed and design is maturing

- Continuing the effort to ensure MGS reliability growth
  - Systems Engineering Process continues to be worked “24/7”
  - GDLS Senior Leadership briefed on a daily basis
  - Focus on implementation of Corrective actions on both the Test Vehicles and the Fielded vehicles
  - GDLS teams at our vendors to work failure analysis and ensure MGS gets their top priority
  - Outside experts on reliability and quality regularly review our processes in engineering and Manufacturing so we keep getting better
Keys to Success

- Program Management forms Integrated Team (Material Developers, Tester/Evaluators, User) that has clear priority and focus on Reliability with clear understanding of Evaluation Criteria and Test Methods up front.

- System Engineering assembles Reliability tools into Disciplined processes and Working Organizations

- Reliability Assessment is reached through in-depth analysis and consensus between all involved parties

Program Management + System Engineering + Reliability = Success
Questions and Discussion
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