Reliability Growth of Mobile Gun System during PVT

Dmitry E. Tananko, Ph.D., Reliability and Robust Engineering, GDLS
Sharad Kumar, Senior Director, System Engineering, GDLS
John Paulson, Director, Stryker Program, GDLS
Jenny Chang, PM SBCT, TACOM
LTC David J. Rohall, PM SBCT, TACOM
James Ruma, VP, Engineering Programs, GDLS
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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Stryker Family of Vehicles

- Infantry Carrier Vehicle (ICV) 130
- Reconnaissance Vehicle (RV) 52
- Medical Evacuation Vehicle (MEV) 16
- Engineer Squad Vehicle (ESV) 13
- Commander’s Vehicle (CV) 28
- Fire Support Vehicle (FSV) 14
- Mobile Gun System (MGS) 27
- NBC Reconnaissance Vehicle (NBCRV) 3
- 120mm Mounted Mortar Carrier (MC-B) 37
- Anti Tank Guided Missile (ATGM) 10

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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
  - Failure Categories
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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

PreART & ART
RGT
PVT

Rounds Fired

Rebaselined Idealized Growth Curve

20% RGT Threshold

Input Parameters

MTBF_i = 47
\( t_i = 909 \)
\( T = 6757 \)
\( \alpha = 0.22 \)
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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

Design Phase

Manage Growth Potential

- Higher Initial MTBF At Start Of Test
- Failure Prevention
- Failure Categorization
- Timely Corrective Actions

Increase Initial MTBF

RG/DT
Design for Reliability Management
Focuses on Failure Prevention

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

- **Analyses**
  - FMEA and Fault Tree
  - Reliability Design Tradeoff
  - Design – Stress Reliability
  - Safety
  - Maintainability Analysis
  - Parts Selection
  - Manufacturing for Reliability

- **Testing**
  - Verification
  - Validation
  - Reliability Growth
  - IRGT, FRACAS

- **Design for Reliability**
  - Failure Mode Mitigation Risk Modes
  - Expanded FMEA Worksheet

- **Reliability Growth In Design**

- **Failure Prevention and Review Board**
  - DART Process
  - FPRB

- **Management Systems**
  - Interactive Reliability and Design Activity And Reviews

- **Outputs, Results, Issues**
  - Critical Issues

- **Update Status**
  - Issues Resolved / Closed

- **Requirements Review Board**
  - Identify Risk Modes

**General Dynamics Land Systems**

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Stryker – Mobile Gun System
Failure Prevention and Resolution Implementation

EXTERNAL EXPERTS

FPRB STEERING COMMITTEE
Weekly

FPRB
Daily

QUALITY COMMITTEE
2X per Week

PREVENTION & SYSTEMIC ISSUE COMMITTEE
Weekly

HYDRAULIC LEAK FOCUS TEAM

HARNESS & ELECTRICAL FOCUS TEAM

LRU & SIGHTS FOCUS TEAM

INDEPENDENT (MUNRO) FOCUS TEAM

ADDITIONAL TEAMS AS REQ’D

PVT RETROFIT REVIEW
2X per Week

CA DESIGN OVERSIGHT

FAILURES ANALYSIS
2X per Week

CORRECTIVE ACTION
2X per Week

RELIABILITY ASSESSMENTS AND PRED ICTIONS

DECISIONS / APPROVAL

STATUS

ISSUES

DECISIONS

ISSUES

DECISIONS

APPROVAL

APPROVAL

APPROVAL

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
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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
Categorize Failures and take Relevant Management Actions

- Root Cause Analysis
- Design Corrections
- Selective Redesigns
- Supplier Quality Management
- Performance 43%
- Human 26%
- Quality 7%
- Reliability 24%
- Robust Design
- Adequate Design Margin
- DFMEA
- Step-wise Verification

- Training and Manuals
- Design Simplifications
- Management of Maintenance Actions
- Failure Chargeability
- Supplier Quality Management
- Design Corrections
- Selective Redesigns
- Human 26%
Data Grouping

Known Equivalent Time

Unknown Equivalent Time

Instantaneous MRBSA vs Rounds

Instantaneous Failure Intensity vs. Rounds

Beta = 0.5945

Beta = 0.5827
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

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

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

\[ MTBF_i = (r_i)^{-1} = \left( \lambda \cdot \beta \cdot T^{\beta - 1} \right)^{-1} \]
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

KJ

QFD

D

C

FMEA

DFMEA

Function Modeling Boundary Diagram

P-Diagram

Concept Generation & Selection

Concepts

V

O

DoE

Reliability & Robustness Metrics

Reliability/Robustness Demonstration

DoE

Reliability & Robustness Metrics

Reliability Demonstration

GENERAL DYNAMICS
Land Systems

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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
Dmitry Tananko, Ph.D.

- General Dynamics Land Systems
- Tel.: (586) 634-5071
- E-mail: tanankod@gdls.com