Managing Ground Vehicle Reliability

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Reliability Introduction

Quality – conformance to specifications
Reliability – conformance to specifications over time or continuation of quality over time

Most Army systems fail to achieve reliability requirements in operational testing and the trend is downwards

- 2002 Army Test and Evaluation Command/Army Evaluation Center (ATEC/AEC) report

Achieving High Reliability is Not Easy
Historical Reasons Systems Fail

Inadequate Design
Unanticipated/Improper Use
Mechanical, Electrical, Software, Communications/Network Failures
Manufacturing Problems
Poor Maintenance
Inadequate Testing
Wear/Fatigue/Corrosion
Improper Storage
Inadequate Protection During Shipping
Etc

Importance / Ranking Varies by System
## Management of Reliability

<table>
<thead>
<tr>
<th>Incentives</th>
<th>Supplier Management</th>
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<td>M&amp;S, Physics of Failure</td>
<td>Cost Trade-off’s</td>
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<td>Data (Usage, Failure, etc)</td>
<td>Fault Trees to include SOS</td>
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<td>User Requirements</td>
<td>Manufacturing Quality/Variability</td>
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<td>Training</td>
<td>COTS, non-COTS</td>
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<td>Maintenance</td>
<td>Systems Engineering Process</td>
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<td>Accelerated Tests</td>
<td>Vehicle Aging</td>
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<td>Diagnostics/Prognostics</td>
<td>Recapitalization</td>
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<td>Pit-stop Engineering</td>
<td>Etc</td>
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<tr>
<td>Research vs. Near Term Solutions</td>
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<tr>
<td>Future vs. Fielded Equipment</td>
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Reliability is Complex and Multi-faceted
Data, Data, Data

Usage Data
Field Failure Data
Data Scarcity
  - Diagnostics/Prognostics efforts to address
  - Proving Grounds data only part of equation
Can improve our models

Good field reliability data is crucial
Automotive Reliability
Historical Perspective

<table>
<thead>
<tr>
<th>Year</th>
<th>Auto Industry</th>
<th>Defects Average</th>
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<tr>
<td>1981</td>
<td></td>
<td>~ 500 defects per 100 vehicles</td>
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<tr>
<td>1997</td>
<td></td>
<td>~ 100 defects per 100 vehicles</td>
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</tbody>
</table>

- Competition has helped drive defect reduction, quality & reliability improvements
- Automotive warranties today have gotten longer too – some are now up to 10 yrs & 100K miles

The competitive marketplace has resulted in automobiles being increasingly reliable
Implications of Design Changes on Cost throughout the Life Cycle

We Must assure Early ID & elimination of Failures/Failure Mechanisms

Early Use of M&S Tools Can Reduce Life Cycle Costs
Simulation-Based Automotive Design

Dynamics and Control of Vehicles and Mobile Robots

Human Centered Design Simulation

System Complexity Reduction

Robust "Systems of Systems" modeling

Optimal System Design & RBDO

Control & Design Integration

Advanced Diesels and Hybrid Propulsion Systems

High Performance Structures and Materials

System Mobility Evaluation

Mobility Evaluation

System Analysis and Design
Development of M&S Processes for Durability & Design Optimization

- CAD Model & Dynamic Simulation
- Inertia Force
- Dynamic Force
- Critical Region
- Fatigue Life Contour
- Dynamic Stress & Strain
- Dynamic Force

University of Iowa
Simulation Support to the High Mobility Trailer

Crack from Physical Testing

- Engineering Simulations to Determine Cause of Cracking
- Computer Simulation of alternative “fixes”
- Repeatable, Accelerated Physical Testing of current and “fixed” designs

Finite Element Structural Analysis

Utilizing TACOM-TARDEC’s HPC Facility

Physical Testing on TACOM-TARDEC’s Pintle Motion Base Simulator

Vehicle Dynamic Simulation

MSC.Software® 2004 v[pd] • Huntington Beach, California
Due to competitive market, designs are pushed to the limit of the design constraints using deterministic optimization, leaving little or no room in manufacturing variability \Rightarrow\text{Leads to higher manufacturing costs, which hinders product marketability.}

RBDO methodology provides not only optimum design, but also a confidence range \Rightarrow 6-Sigma Design for Manufacturing.
SAE G-11 Reliability, Maintainability, Supportability, and Logistics (RMSL) Division

Goal: Coordinated effort of military, academia and industry to create standards and guidelines for probabilistic and reliability methods to quantify uncertainties associated with military vehicles

Membership

- Army-RDECOM/TARDEC, AMSAA, ARDEC, AMRDEC, NASA, TACOM, Sandia National Lab, others
- Industry-Ford, GM, GD, UDLP, Delphi, Rolls Royce, LMS, MSC, nCode, Honeywell, Lockheed Martin, GE, Boeing, Prediction Probe, others
- Academia- Univ of Iowa, Oakland Univ, Univ of Tennessee, Univ of Michigan, others
- International-U.K., Canada, Spain
SAE G-11 RMSL

**Accomplishments** - reliability standards and guidelines being used in developing RFPs

- JA 1002, Software Reliability Program Standard, January 2004
- Reliability Terms Definition and Clarification

**Ongoing Efforts**

- Establish NATO acceptance of software supportability and reliability publications
- Partner with US/European/Canadian and ISO/ISEE/ANSI standards organizations to adopt software and reliability publications
- Create ground vehicle reliability standards
SAE G-11 RMSL

Reliability Applications Subcommittee
- Chair-Dr. David Gorsich, RDECOM/TARDEC
- Co-Chair-Dr. K.K. Choi, U. of Iowa

Current Projects:
- Verification and Validation-Draft Nov 04
- Physics of Failure Guidelines-Draft Nov 04
- Case Studies and Application-Draft Mar 05
- Method Evaluation-Draft Oct 05
- System Reliability and Integration-Draft Oct 05
In-house Accelerated Testing

Durability Experiments for M939 5-Ton Truck and Light Tactical Trailer

- TARDEC’s Physical Simulation Team is currently conducting physical simulation durability experiments on the M939 truck and Light Tactical Trailer (LTT)
- Both vehicle will be simulated over various terrains and the M939 will also be tested with extra armor and machine gun turret on the cab

Physical Simulation Team
Committed to Excellence

Ground Vehicle Simulation Lab
PRODUCT DEVELOPMENT CONFERENCE
In-house HMMWV Endurance Test

Vertical motion and force inputs are provided into the HMMWV to reproduce dynamic conditions experienced in the real world

Tested endurance of steel up-armor kit
Accumulated 1650 miles over 3 days
Used a paved, secondary, and cross-country operational mode summary/mission profile

Physical Simulation Team
Committed to Excellence

Ground Vehicle Simulation Lab
Joint Service Reliability Efforts Involvement

We are following / involved with:

DARPA Prognosis program
- Determination of remaining usable life and the quantitative prediction (Prognosis) of future operating capability

AFRL/AFOSR MEANS project
- Micro-Meso-Macro integration of RBDO for durability
- Optimized materials for durability and reliability
Strategy to Achieve World Class Systems Reliability

Leverage NAC Efforts from all Sides to Help Army Achieve High System Reliability

- TARDEC/NAC
- M&S Partnerships / New Tools Commercialization
- ARC/Univ Research
- Automotive Industry Leveraging
- TARDEC/NAC
- New Technology & Product Identification
- SBIR’s/CRADA’s
- Manufacturing Partnerships
- TARDEC/NAC
- DoD Partnerships
- HEV Programs
- Diagnostics/Prognostics Programs
- FTTS ACTD
- Potential RDECOM Reliability STO
- Accelerated Testing Facilities
- OEM’s
- PEO’s
- Sub-contractors
Conclusions

Achieving high reliability is critical but difficult
Development / commercialization of TARDEC funded reliability and M&S tools will positively impact new vehicle designs
U.S. Army TARDEC/NAC is committed to ensuring Army systems have high reliability!