14183

Improving Ground Vehicle Reliability

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Report Documentation Page

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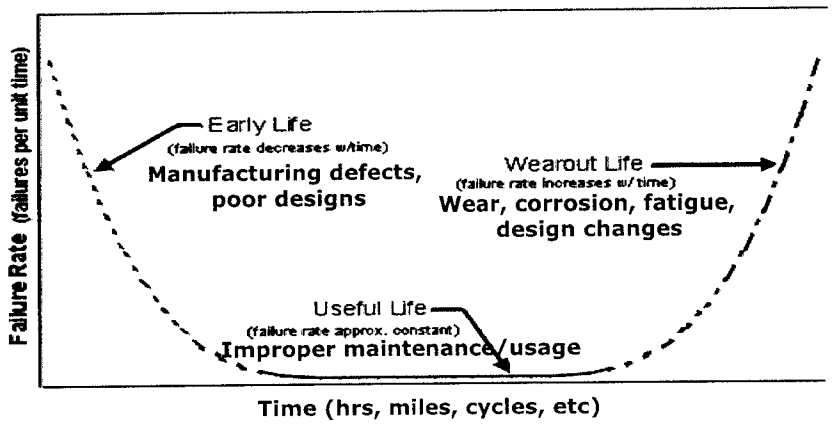
Reliability Introduction

Quality – conformance to specifications

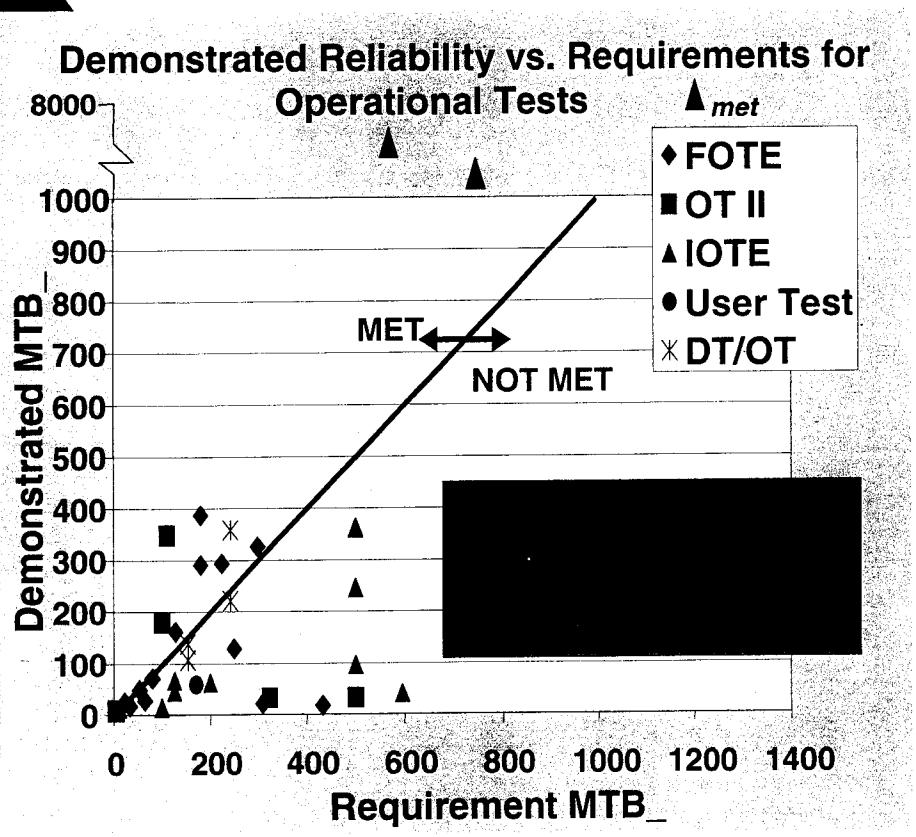
Reliability – conformance to specifications *over time*
or continuation of quality over time



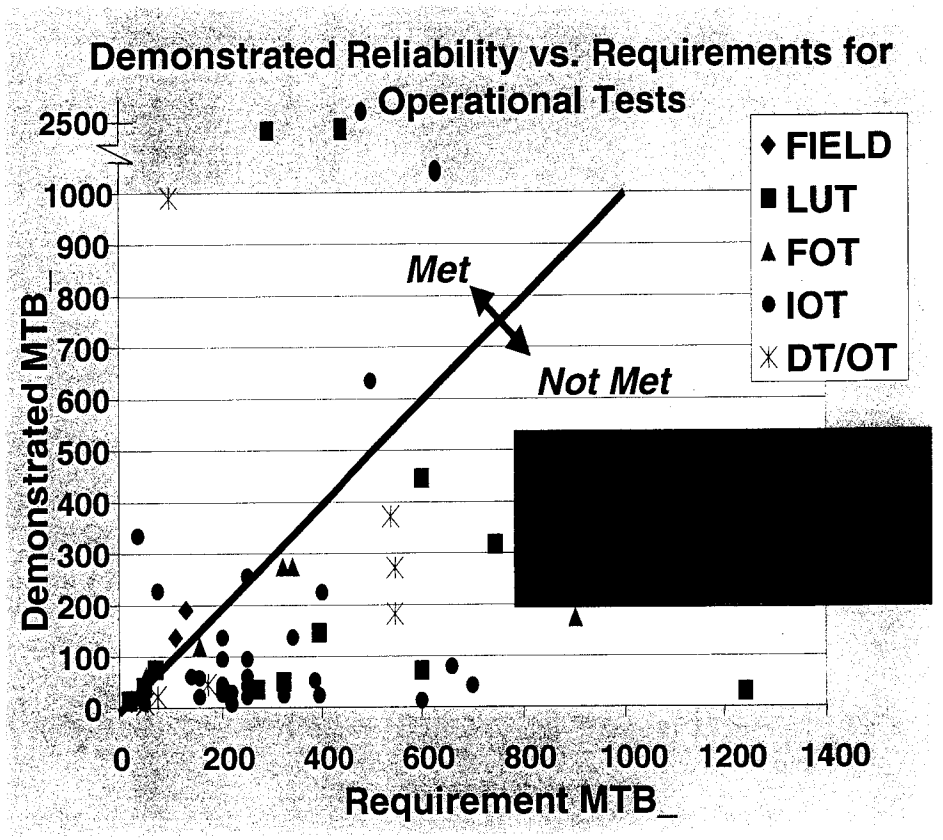
"Bathtub curve"

Reliability Track Record

1985-1995



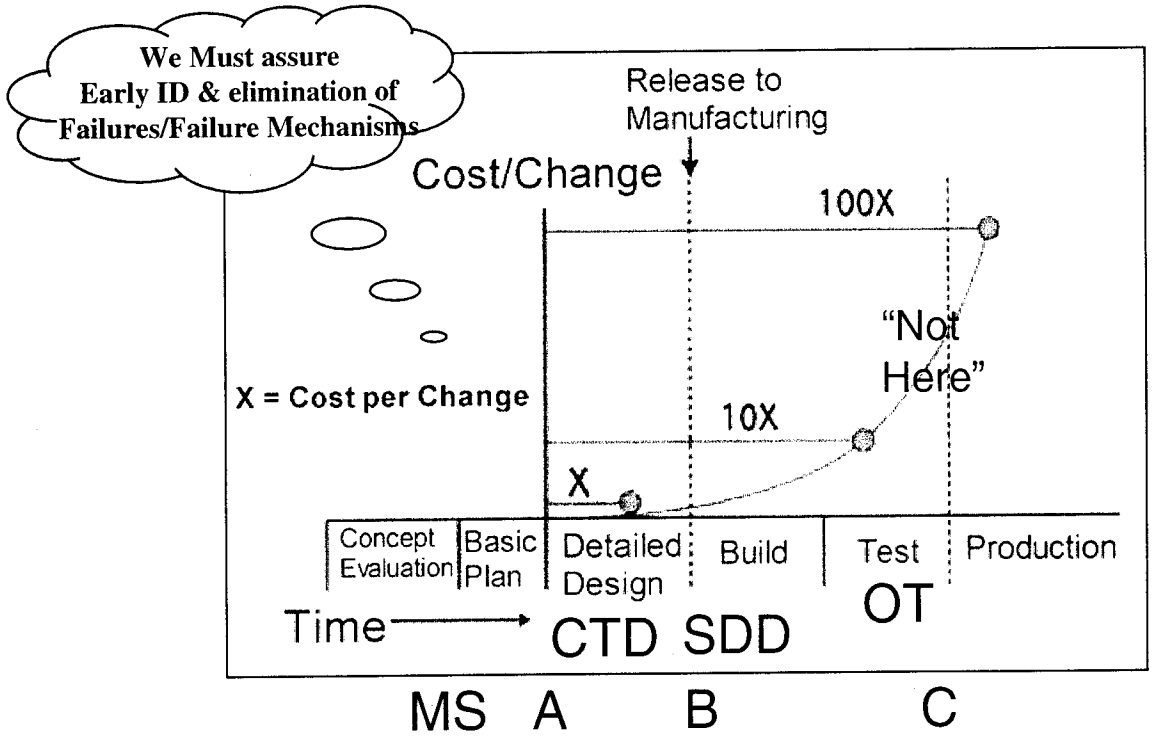
1996-2000



Most Of Our Systems Fail To Achieve Reliability Requirements In OT

And The Trend Appears To Be Downwards

Implications of Design Changes on Cost throughout the Life Cycle



Historical Reasons Systems Fail

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

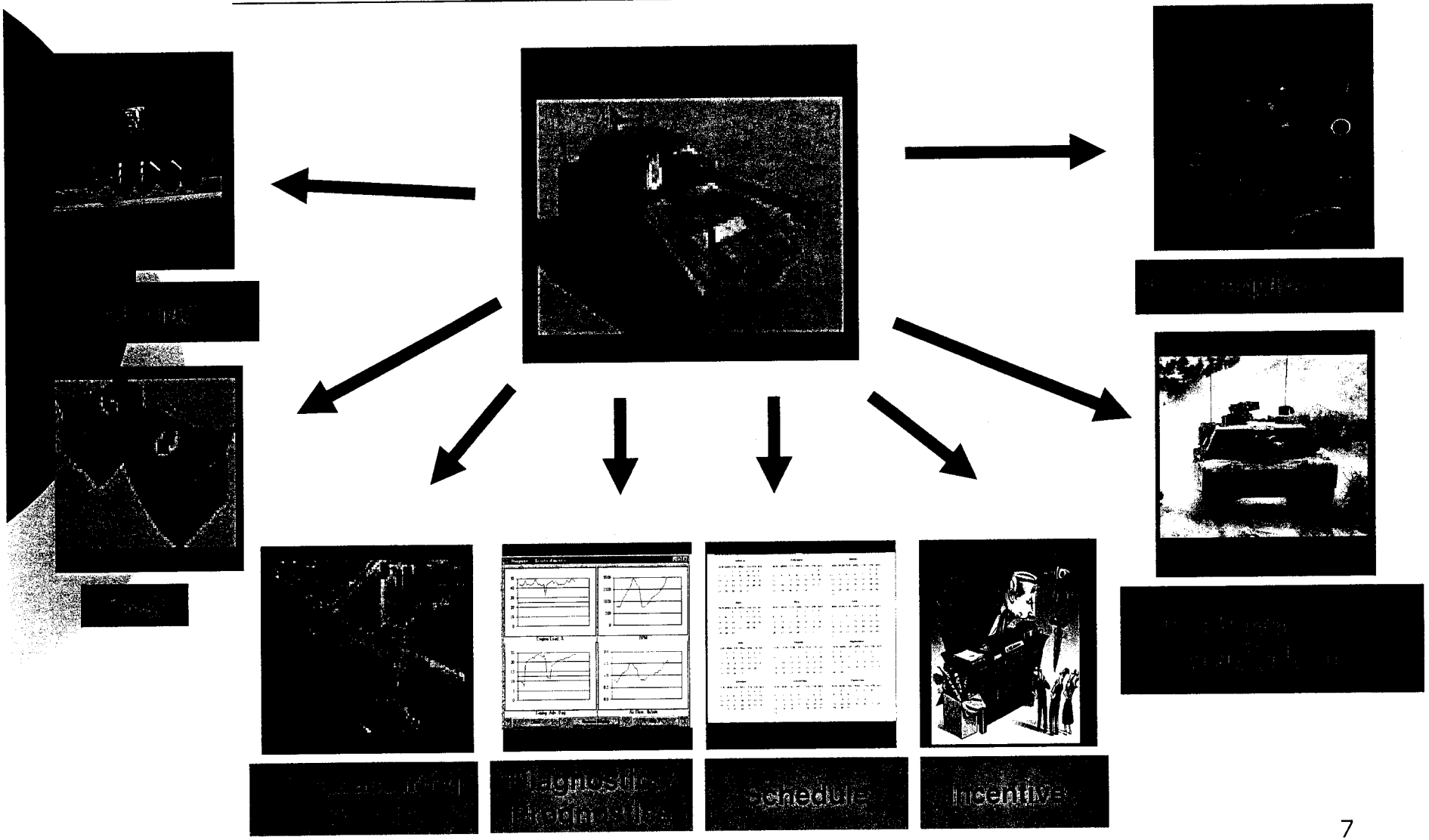
Importance / Ranking Varies by System

Management of Reliability

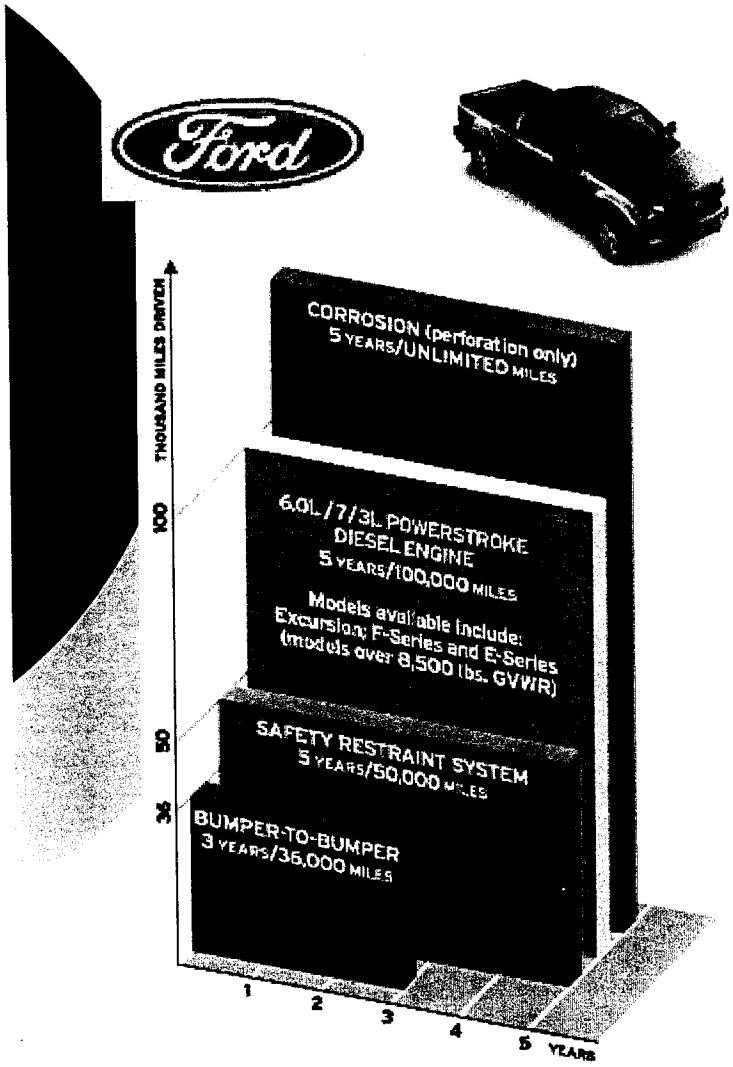
- Incentives
- Physics of Failure / RBDO
- Training
- Accelerated Tests
- Diagnostics/Prognostics
- Smart Data Collection & Data Analysis
- Pit-stop Engineering
- Technology Maturity
- Warranties
- Supplier Management
- Maintenance
- User Requirements
- Fault Trees to include SOS
- Manufacturing Quality/Variability
- Fielded Performance
- Systems Engineering Process
- Vehicle Aging
- Recapitalization
- Contractual Rqmts
- Etc

Reliability is Complex and Multi-faceted

Balancing Reliability Requirements



Automotive Reliability Leveraging



The 2004 E500 Sedan
MSRP $56,270.00*

Mercedes-Benz

The MBUSA New Vehicle Limited Warranty includes the Mercedes-Benz Commitment This warranty covers any defects in material or workmanship and all routine maintenance services, as called for by the Flexible Service System and specified in the Mercedes-Benz Service Booklet, for 48 months or 50,000 miles, whichever comes first.[1,2]

Mercedes Care Optional Extended Limited Warranty Within one year from the start date of the New Vehicle Limited Warranty the original owner can purchase extended Basic or Premium Warranty Coverage for an additional 12, 24, or 36 months - up to 100,000 total accrued miles.[3]

HYUNDAI

Hyundai Advantage™

AMERICA'S BEST WARRANTY™*

10 YEAR 100,000 MILES POWERTRAIN PROTECTION Covers most engine & transaxle components.	**5** YEAR 60,000 MILES BUMPER-TO-BUMPER Covers nearly every new vehicle components
5 YEAR UNLIMITED MILES 24 HOUR ROADSIDE ASSISTANCE Covers towing (including accident-related) look-out, flat tire and jump starting.	**5** YEAR 100,000 MILES ANTI-PERFORATION WARRANTY Covers corrosion-related rust-through of body sheet metal from inside to out.
8 YEAR 80,000 MILES FEDERAL EMISSION AND PERFORMANCE WARRANTY	**7** YEAR 70,000 MILES CALIFORNIA EMISSION CONTROL SYSTEM WARRANTY
12 MONTH 12,000 MILES REPLACEMENT PARTS AND ACCESSORY LIMITED WARRANTY	HYUNDAI PROTECTION PLAN America's Best Service Contract

Automotive Reliability Historical Perspective

1981 Auto Industry	Averages ~ 500 defects per 100 vehicles
1997 Auto Industry	Averages ~ 100 defects per 100 vehicles

- 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

Further Automotive Insight

- To maximize reliability, as a rule of thumb new automobile models change $\leq$ 30% of their component technologies from existing models
  - ~70% reuse
  - Warranties, experience
  - Very little geometric change within subsystems
- Auto Suppliers today are required to carry more of the reliability "load"
  - Smarter Testing
  - Stick-reward approach
  - More Supplier Involvement Earlier

Automotive Company SOW's

Ford Motor Company

QUALITY / RELIABILITY 10 Year / 150,000 Mile STATEMENT OF WORK

Supplier Name: _____

Component/Subsystem/System Name: _____
(The above to be filled in by PMT Leader and given to supplier at start of TA Process)

Objective of this Quality / Reliability Statement of Work (QRSOW):

Reliability Data

- Automotive & Aerospace Companies generally treat their Reliability Data as close-hold / competition sensitive
- Automotive Industry
  - "Smart data collection"
  - Gathers LOTS of reliability data on their worldwide fielded systems usage (monitor dozens of systems on instrumented fielded vehicles)
- Field vs. Lab Data
- This reliability data can improve our M&S capabilities among other things

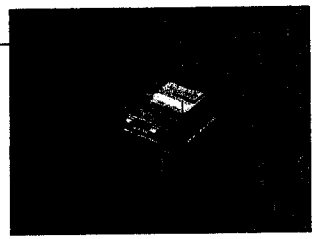
Good field reliability data is crucial!!

Simulation-Based Automotive Design

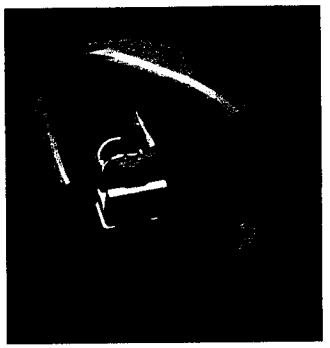
TARDEC

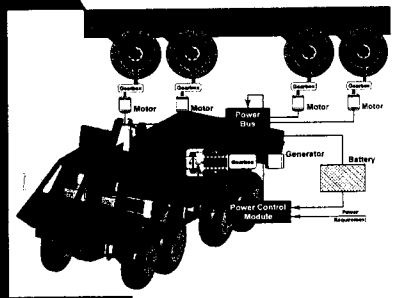
NAC

Dynamics and Control of Vehicles and Mobile Robots

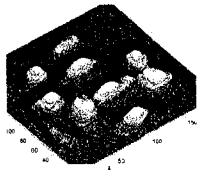


Human Centered Design Simulation





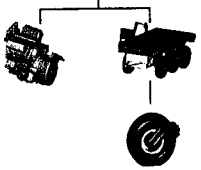
System Mobility Evaluation



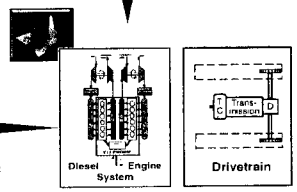
System Complexity Reduction

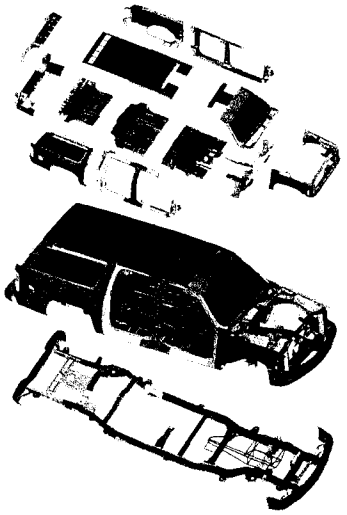
Robust "Systems of Systems" modeling

Control & Design Integration

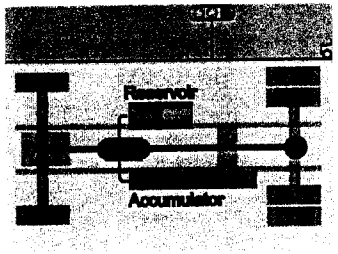


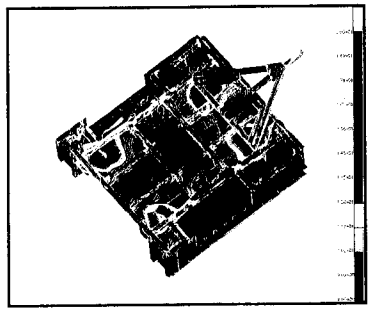
Optimal System Design & RBDO





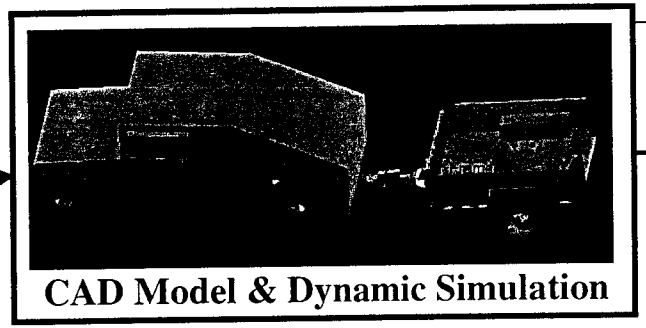
Advanced Diesels and Hybrid Propulsion Systems



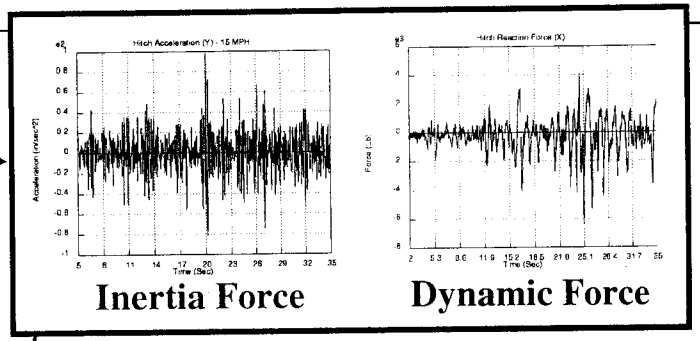


High Performance Structures And Materials

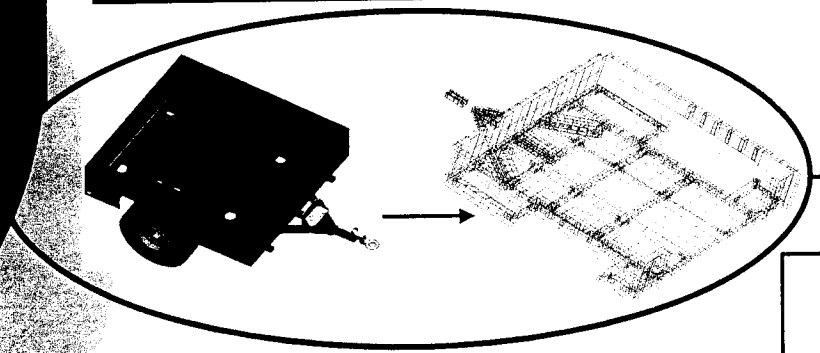
Development of M&S Processes for Durability & Design Optimization

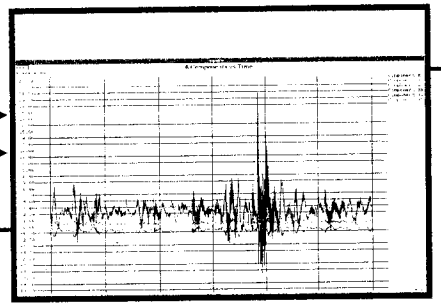


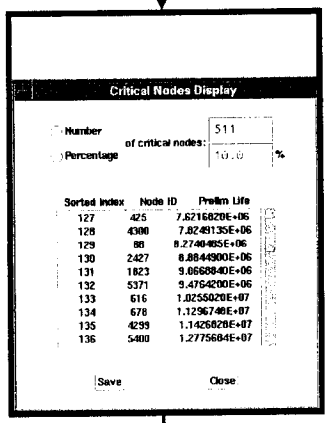
CAD Model & Dynamic Simulation

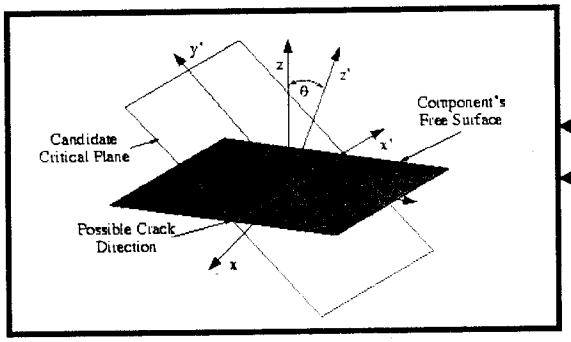


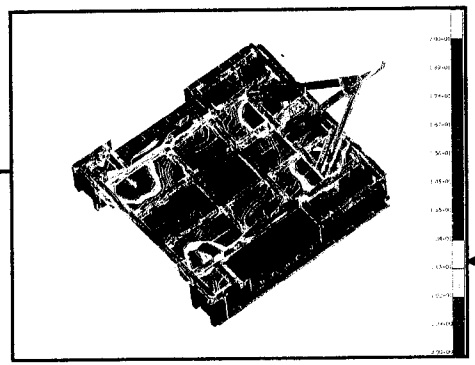
Inertia Force Dynamic Force







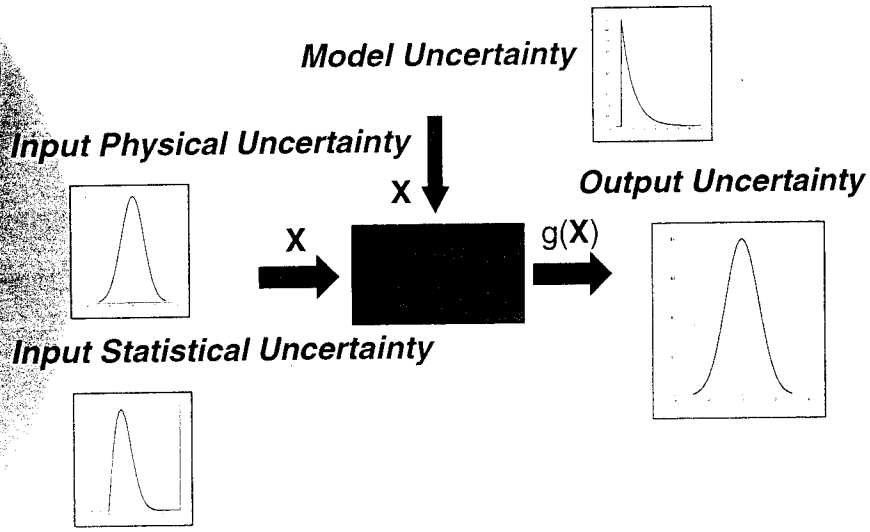


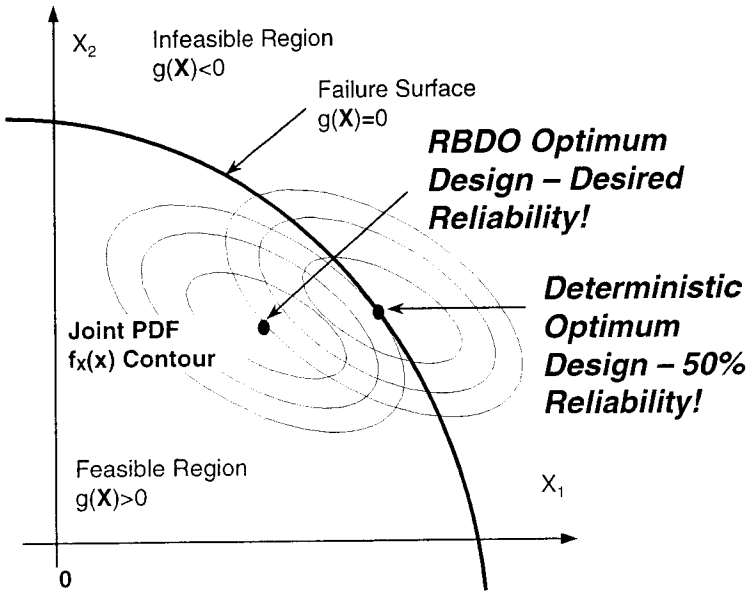


University of Iowa

Uncertainty and RBDO

- 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 ⇒ Leads to higher manufacturing costs, which hinders product marketability.



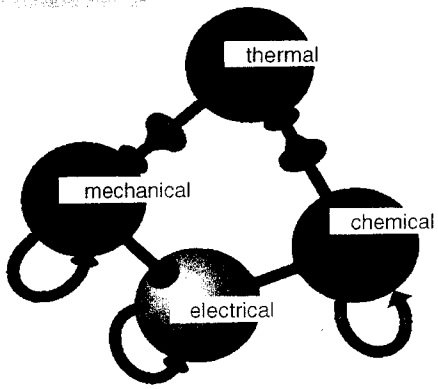


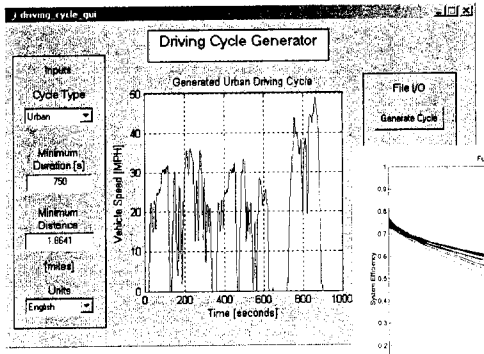
- RBDO methodology provides not only optimum design, but also a confidence range ⇒ 6-Sigma Design for Manufacturing.

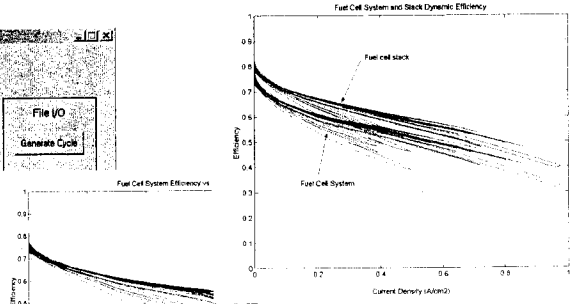
University of Iowa

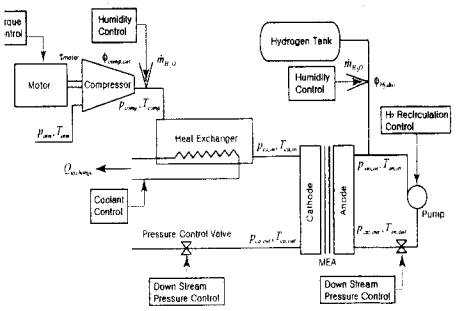
Ohio State University Hybrid-Electric Modeling, Simulation, Experimental Validation & Concept Design

- Effective HEV design must be all-inclusive and comprehensive
  - Retrofitting a "conventional" with some electronic systems is insufficient
  - Fails to capture all benefits of hybridization and results in operation in bad regimes
- Many considerations
  - System requirements (i.e. driving cycles, off-road requirements),
  - Traction system, power generation system, suspension systems
  - New level of "supervisory" control to co-ordinate power flows in two different systems
- Strong inter-relations between the various systems, requirements and controllers- each cannot be separately optimized, all must be collectively researched
- **PM UA reliability**

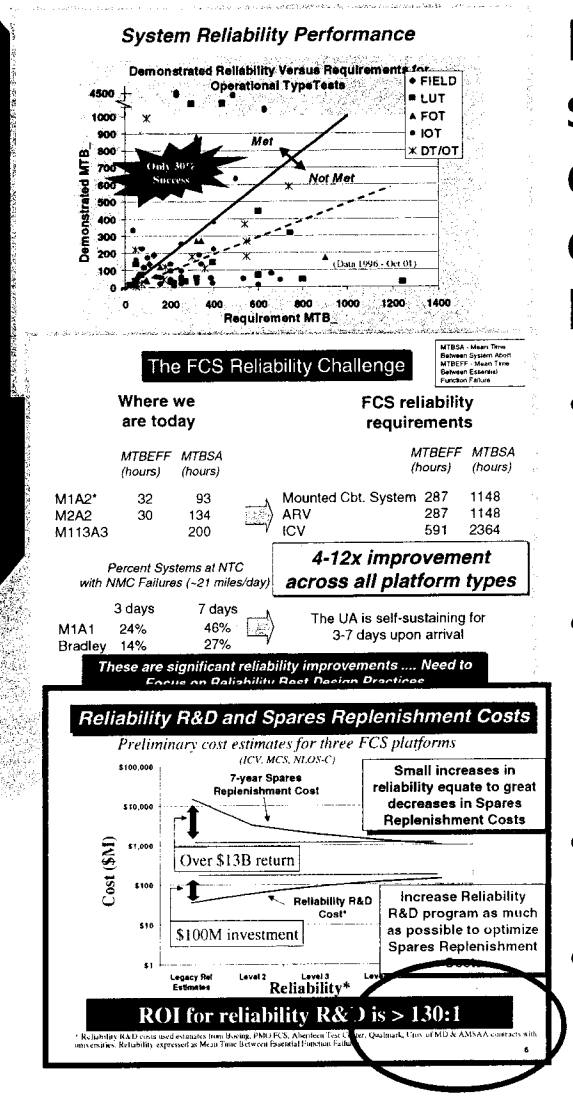








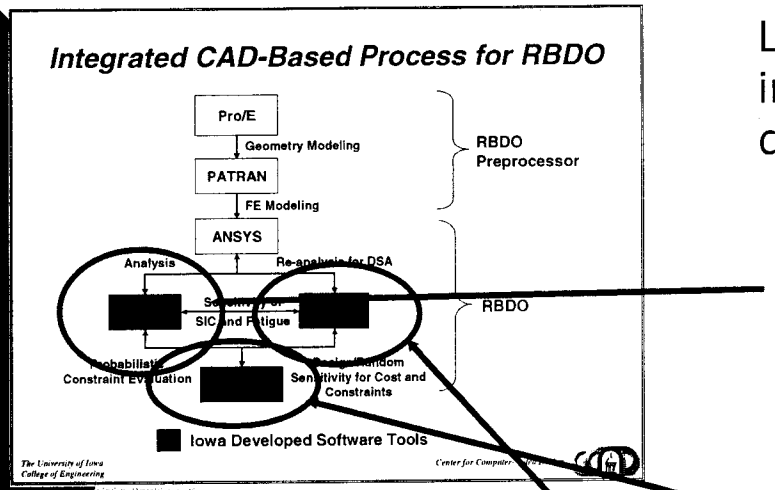
TARDEC-Funded RBDO Commercialization Success!



LMS and the University of Iowa have signed a letter of intent to build and commercialize a breakthrough COTS engineering tool for Reliability Based Design Optimization (RBDO) …

- ***Leverage the TARDEC / ARC- funded RBDO technology and methods of U of Iowa, current commercial LMS products and contractor install base***
- ***Defined by the needs of the Army and the FCS program with active involvement by the Army in requirements definition and validation testing, executed on current combat vehicle problems***
- ***Coordinated with the efforts of SAE G-11 sub-committee***
- ***Open to market-leading third party, commercial solutions for structural analysis (MSC NASTRAN, ANSYS, ABAQUS,…)***

Commercialized RBDO Tool



LMS and the University of Iowa are proceeding in steps, with useful tools for FCS reliability delivered at each step...

- Migrate contractors from LMS DADS to LMS Virtual.Lab (50% complete)
- Replace Iowa DRAW durability code with LMS Virtual.Lab Durability (loads data analysis and fatigue life prediction) product (underway)
- Incorporate Iowa Reliability code into LMS Optimization Products (in planning; allow 4 months)
- Provide for mesh-based optimization with Iowa Design Sensitivity Analysis (DSA) incorporated into LMS Virtual.Lab (in discussion)

LMS Will Incorporate TARDEC – Funded RBDO into the CAE products they supply UA OEM's & Other Army OEM's

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, NASA, TACOM, Sandia National Lab,
  - Industry-Ford, GM, General Dynamics, UDLP, Delphi, Rolls Royce, LMS, MSC, nCode, Honeywell, Lockheed Martin, GE, Boeing, Prediction Probe
  - Academia-U. of Iowa, Oakland U., U. of Tennessee, UofM
  - International-U.K., Canada, Spain

SAE G-11 RMSL

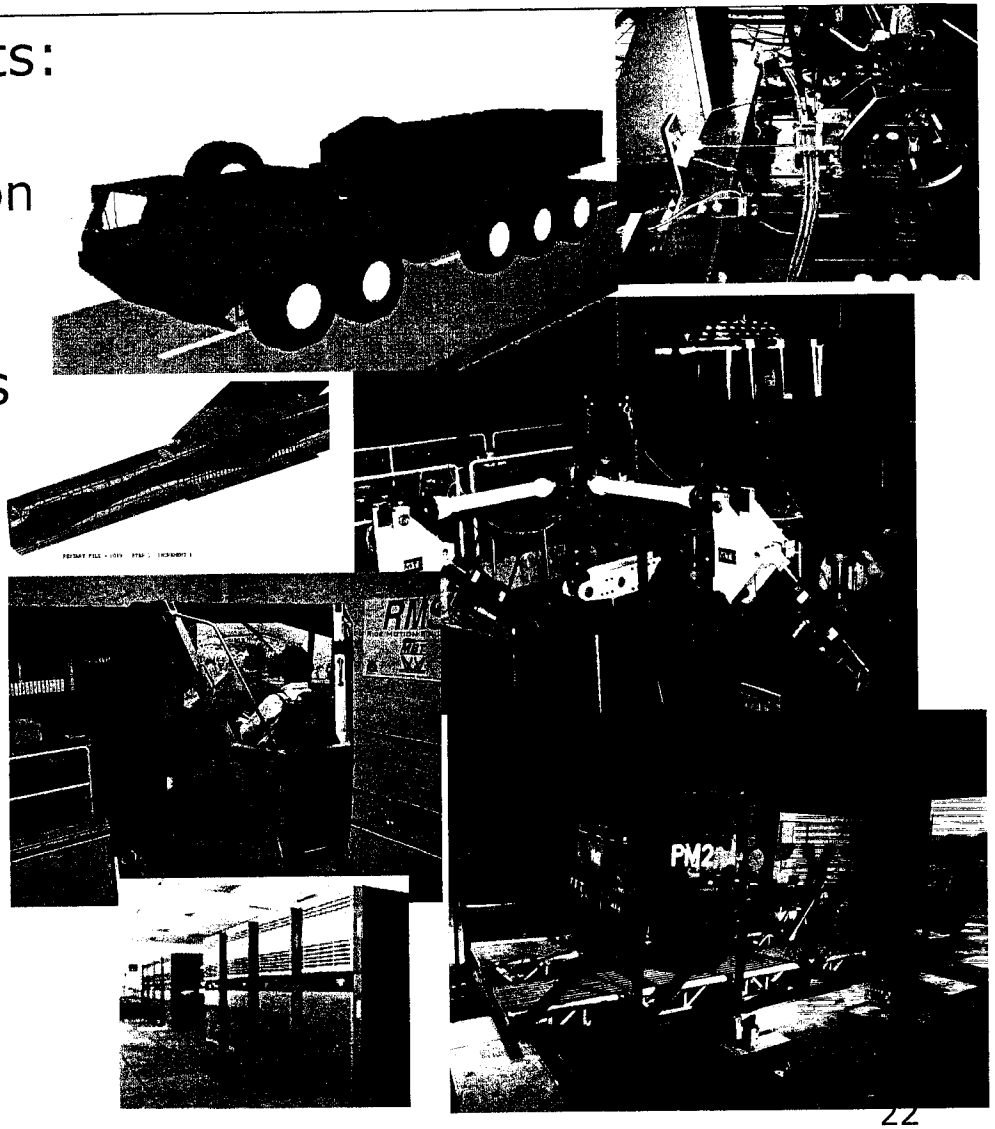
- **Accomplishments**-reliability standards and guidelines being used in developing RFPs
  - JA1003, Software Reliability Program Implementation Guide, January 2004
  - JA 1002, Software Reliability Program Standard, January 2004
  - Draft AIR(in balloting) Reliability Terms Definition and Clarification
- **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
  - Use case studies

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 AIR Oct 04
  - System Reliability and Integration-Draft AIR Oct 05
  - Case Studies and Application-Draft AIR Mar 05
  - Method Evaluation-Draft AIR Oct 05
  - Physics of Failure Guidelines-Draft AIR Oct 04

What is the Ground Vehicle Simulation Laboratory ?

- Army's primary experts:
  - Vehicle Dynamics
  - Full Vehicle Simulation
  - Man-in-the-loop simulation
- Leveraged Capabilities
  - FEA analysis
  - High Performance Computing
  - Vehicle Characterization
- Services
  - SSEB support
  - Durability Testing
  - Vehicle Analysis
  - Human Performance Eval.



Advantages of Laboratory Simulation

- Controlled environment
- Accelerated testing
- Location (co-location with PM)
- Focused emphasis if needed
- Component-only evaluation if needed.
- Effective for testing vibration-related issues

Principal of Equivalence

- All vehicle testing has one aim
  - Gain confidence that vehicle will endure its service environment.
- Principal of equivalence
  - Proving ground test = service life (X^{th} percentile)
- Laboratory principal of equivalence
  - Laboratory test = vibration part of proving ground test

Accreditation

Up-Armored HMMWV Test

Objective

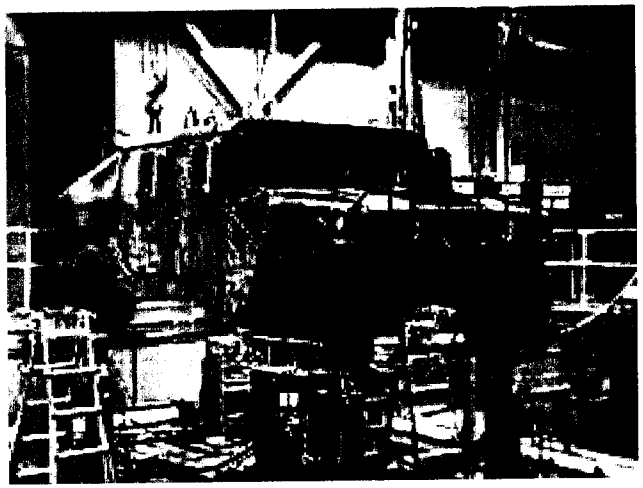
- Test endurance of steel up-armor kit

Experiment Details

- Standard M1026A2 fitted with armor kit
- Placed on and secured to the Re-configurable Four-Post Simulator (RFPS)
- Accumulated 1650 miles over a continuous 61-hour period

Results

- Armor successfully remained secure in its proper location throughout the duration of the test
- Minor wear in shocks and door latches



RFPS provides vertical motion and force inputs into the HMMWV to reproduce dynamic conditions experienced in the real world

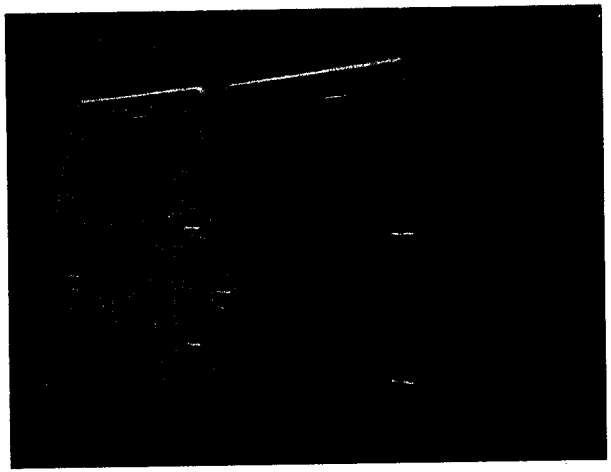
Reliability Simulation for a Composite HMMWV Door

Physical Simulation Testing

- The Physical Simulation Team performed a 6000 mile cross-country durability/reliability simulation experiment.
- March 2004

Manufacturing Facts

- Readily Producible
- In-Process Production Flexibility
- Current Production Capacity: 1800 doors/month



These lightweight composite doors are easy to install and offer superior protection without a significant increase to the weight of the HMMWV.

Some of the Customers & Systems TARDEC/NAC Has Supported

Customers:

EO GCS
O CS & CSS
UA
DEC
Stryker
BL
C
SCEN
OM
COM – PM TRADE
ICOM – PM CATT
MC – TEA
M Survivability
Pm Construction Equipment
PM LOSAT
PM CMS/Grizzly
PM Bradley
PM CMS/Hercules
PM Abrams
PM MTVR
PM Force Projection
USMC
Benet Labs
Ft Belvoir
TECOM – ATC
Source Selection Boards

Vehicles Affected:

Combat Vehicles:

M9ACE - Tracked Engineering Vehicle
M88 - Tracked Recovery Vehicle
IRV/M1 - Improved Tracked Recovery Veh
M1A2 - Heavy Tank
M1A2-SEP - Heavy Tank
M113A3/BMP
Interim Armored Vehicle
M2A2 - Medium Tracked Fighting Vehicle
Crusader - Tracked Howitzer
M109A6, Paladin - Tracked Howitzer
AGS - Armored Gun System, Medium Track
CAV ATD - Composite Armored Vehicle, Tracked Fighting Vehicle
M113
AFAS/FARV Concept Vehicle
Future Combat Systems

Tactical Vehicles:

PLS - Palletized Loading System - Medium Truck
LVS - Medium Truck w/ Articulated Joint
M939A2 - Wheeled Heavy Tactical Truck
M931 - Wheeled Heavy Tactical Truck/Tractor
FMTV - Wheeled Medium Tactical Truck, M1088
HIMARS - Medium Truck with Missile
HMMWV, M1097A2, XM1113, XM1114
MTVR - Marine Corp Medium Truck Remanufacture
Narrow Track HMMWV Concept Vehicle
Up-armored HEMTT, PLS, and 5-Ton Truck
HTTMP - Helo-Transportable Multi Mission Platform
Combatt
M923A2 5 Ton Truck
FTTS

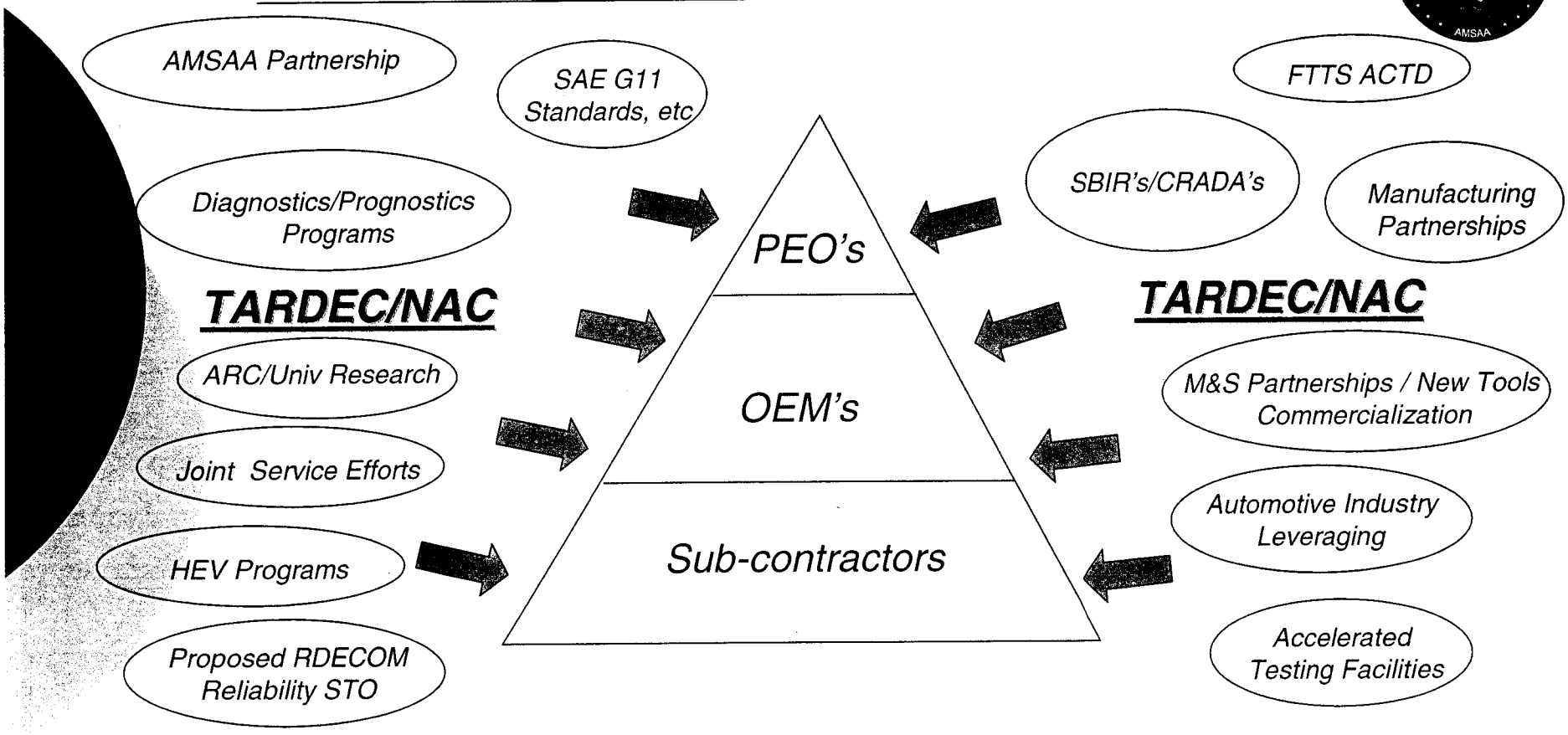
Trailers:

M149A2, M101A3, M832, M840, M853, M390, M129A2
M871A1 Flatbed
M747 Trailer
M1073 Trailer
M105A2 Trailer
M1098 Tanker
ATAAT - Adverse Terrain Ammunition Assembly Trailer
M871A2/JSIPS - Joint Services Imagery Processing System (Trailer)
M1048 6-Ton Flat-bed Trailer
M373 Trailer
M969 Semi-Trailer Tanker
XM1098 - Water Tanker Trailer
HETS - Heavy Equipment Transporter System
Improved Common Bridge Transporter (ICBT)/ Palletized Load Handling System Trailer
Articulated Electric Drive Trailer (AEDT)
NAC's Quick Disconnect Fuel Delivery System
Self Loading Off-Loading Trailer

Other:

CCTT - Closed Combat Tactical Trainer
AVLB - Armored Vehicle Launch Bridge
M198 Howitzer
Rough Terrain Fork Lift
Grizzly
GSTAMIDS

Strategy to Achieve World Class Systems Reliability



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

Conclusions

- Achieving high reliability is critical but difficult
- TARDEC/NAC is well positioned to leverage auto industry reliability efforts
- TARDEC involvement in SAE G-11 is important in developing industry/military reliability standards
- Development / commercialization of TARDEC funded reliability and M&S tools will positively impact new vehicle designs