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A New Tool for Understanding Ground Vehicle Reliability, Availability and Maintenance

Presentation at 79th MORS Symposium, Monterey, CA
June 20-23, 2011

S. R. Renn, Project Leader
J. S. Hong

September 2011

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Ground Combat Vehicle (GCV) Analysis Tools Study

- **Sponsor: DOT&E (Office of Director, Operational Test and Evaluation)**
- **Objective**
  - **Develop analytical tools to assist DOT&E in assessing the operational significance of GCV performance parameters**
  - **Tools will assist DOT&E in designing test strategies, planning tests, and anticipating and assessing significance of GCV test results**
    - » **Determine which performance characteristics are important in advance of tests**
    - » **Determine if a change in a specific performance characteristic makes a difference**
    - » **Allow rapid assessment of operational consequence of such a change of performance characteristic**
- **Tools were developed for three areas: *Mobility, Survivability, and Reliability***

Big Four KPPs

Capacity: 3 crew + 9 passengers
Force Protection: Occupant Protection
Full Spectrum: Modular Amor, Open Architecture, Growth
Timing: 7 yr to IOC

Final Design from GCV AoA TIA

Sensors: 2nd gen FLIR CIV w upgrade,Satblized CROW 2 with out Hunter-Killer Capability
Survivability C-Kit Engine Protection Reduction, Reduced Turret Armor-Level 0 B Armor
Force Protection: Full Arc Coverage, Base Protection - Titanium for B0 & B1, RPG protection-Raytheon Vert w Full MFRF Radar
Lethality: CIWS-Stabilized RWS w M2 0.50 cal MG, M242-25mm, CCMS –TOW missile removed

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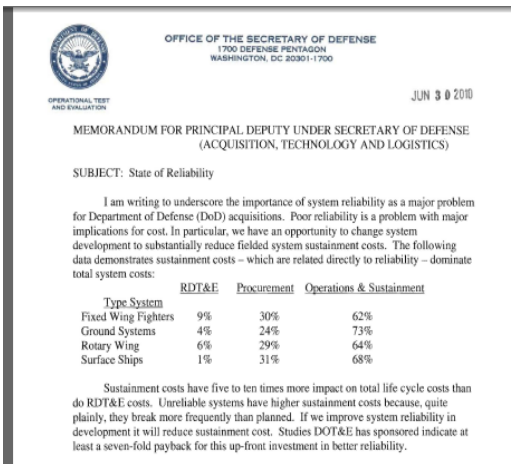
DoD's Concern with Reliability

- **Reliability dominates total systems costs including RDT&E and procurement**
  - **Reliability issues often caught in post design testing which causes schedule delays and budget over-runs**
  - **$700M to bring F-22 reliability up to acceptable levels**
- **Reliability issues can delay system deployment and impact system effectiveness**
- **OT&E beyond LRIP program reports finding systems unsuitable because of reliability issues.**
  - **In 2008, 2 of 6 systems were unsuitable**
  - **In 2007, 4 of 8**
- **May 2008, DSB report states**
  - **"High suitability (reliability) failure rates were caused by the lack of a disciplined systems engineering process…"**



OFFICE OF THE SECRETARY OF DEFENSE
1700 DEFENSE PENTAGON
WASHINGTON, DC 20301-1700

OPERATIONAL TEST AND EVALUATION

JUN 30 2010

MEMORANDUM FOR PRINCIPAL DEPUTY UNDER SECRETARY OF DEFENSE (ACQUISITION, TECHNOLOGY AND LOGISTICS)

SUBJECT: State of Reliability

I am writing to underscore the importance of system reliability as a major problem for Department of Defense (DoD) acquisitions. Poor reliability is a problem with major implications for cost. In particular, we have an opportunity to change system development to substantially reduce fielded system sustainment costs. The following data demonstrates sustainment costs – which are related directly to reliability – dominate total system costs:

Type System	RDT&E	Procurement	Operations & Sustainment
Fixed Wing Fighters	9%	30%	62%
Ground Systems	4%	24%	73%
Rotary Wing	6%	29%	64%
Surface Ships	1%	31%	68%

Sustainment costs have five to ten times more impact on total life cycle costs than do RDT&E costs. Unreliable systems have higher sustainment costs because, quite plainly, they break more frequently than planned. If we improve system reliability in development it will reduce sustainment cost. Studies DOT&E has sponsored indicate at least a seven-fold payback for this up-front investment in better reliability.

J. Michael Gilmore
Director

- **Dec 2008, memo by Ashton Carter**
  - **Announced policy for reliability analysis, planning, tracking, and reporting**

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A. Maintenance Operations in the HBCT

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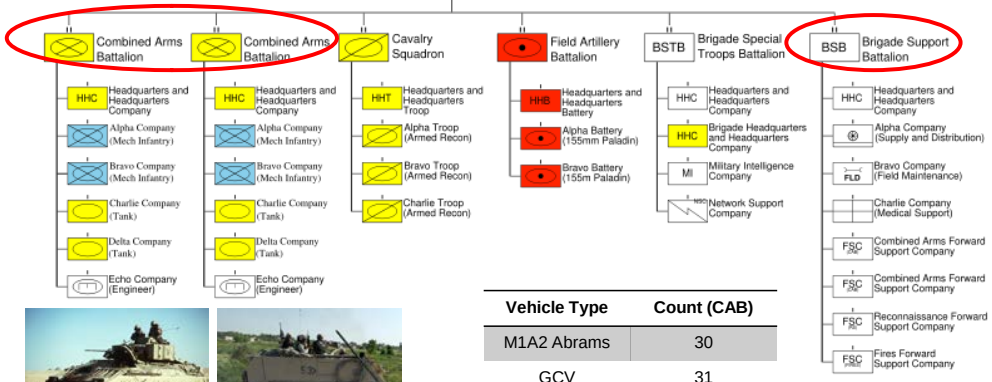
HBCT


M1A2 Abrams


M109 Paladin


M88 Hercules




M2/M3 Bradley


M113 APC

Vehicle Type	Count (CAB)
M1A2 Abrams	30
GCV	31
M2 Bradley	15
M113	30

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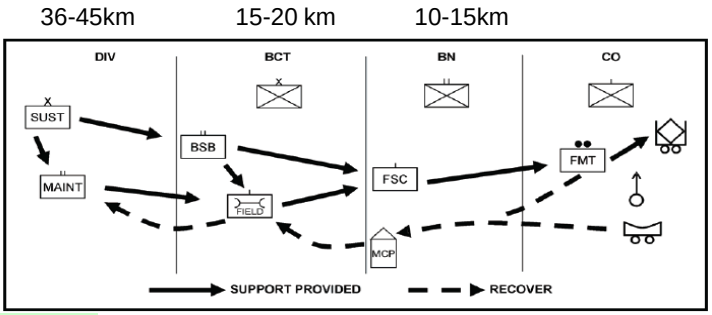
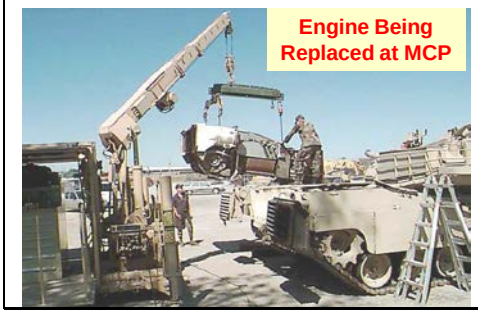
HCBT Maintenance Operations

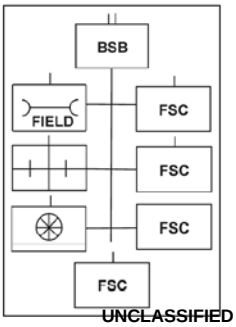
- FMT- field maintenance team (aka MAINT SPT Team)
- FSC – forward supply company
- MCP or UMCP – maintenance collection point



Repairs done by MAINT Spt TMs are very limited


Engine Being Replaced at MCP

- BSB Contains 4 forward Support Companies (FSC)
  - One for each of 2 CABs and one each for ARTY & Cav Bn
- Each FSC contains
  - Srv Recovery (M88s)
  - 2 MAINT Support Teams
  - MAINT SEC



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B. The Reliability Model

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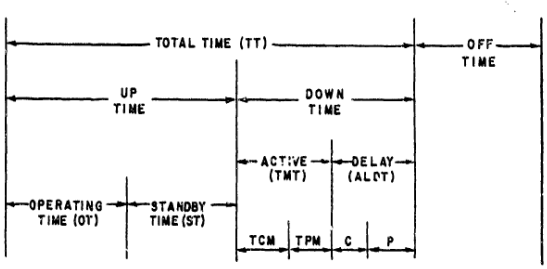
Availability & Reliability Lexicon

- **Operational Availability (A0)** - Percent time that a system is tasked or available to be tasked
- **ALDT - Administrative and Logistics Down Time**. All time waiting for parts, administrative processing, maintenance personnel, or transportation.
- **TDT –Total Down Time**
- **MDT– Mean Down Time**
- **TMT-Total Maintenance Time**
- **TCM-Total Corrective Maintenance (unscheduled)**
- **TPM-Total Preventative Maintenance (scheduled)**
- **Standby Time -vehicle is not executing a mission, but functioning properly and is available for tasking**
- **$N_{Standby}(t)$, $N_{Operating}(t)$ - Number of vehicles which are on standby or are operating at time t**
- **System Abort –** A system failure which causes mission termination
- **Essential Function Failure** – Failures which seriously degrade systems without aborting missions
- **MTTR – Mean time to repair**



$$A_0 = \frac{OT + ST}{OT + ST + TMT + ALDT}$$

$$TDT = TMT + ALDT$$

$$A_0(t) = \frac{1}{N_{Total}} E[N_{Standby}(t) + N_{Operating}(t)] \qquad A_0 = \frac{1}{TT}\int_0^{TT} dt\{A_0(t)\}$$

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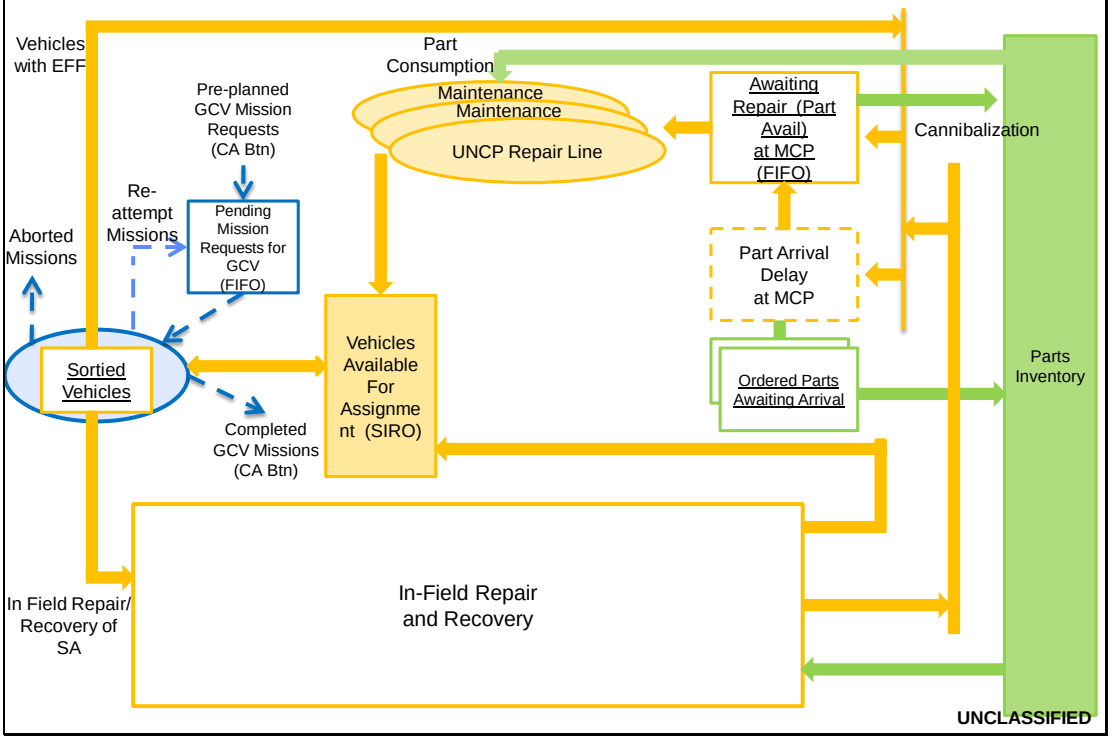
GCV Repair and Availability Simulation Model



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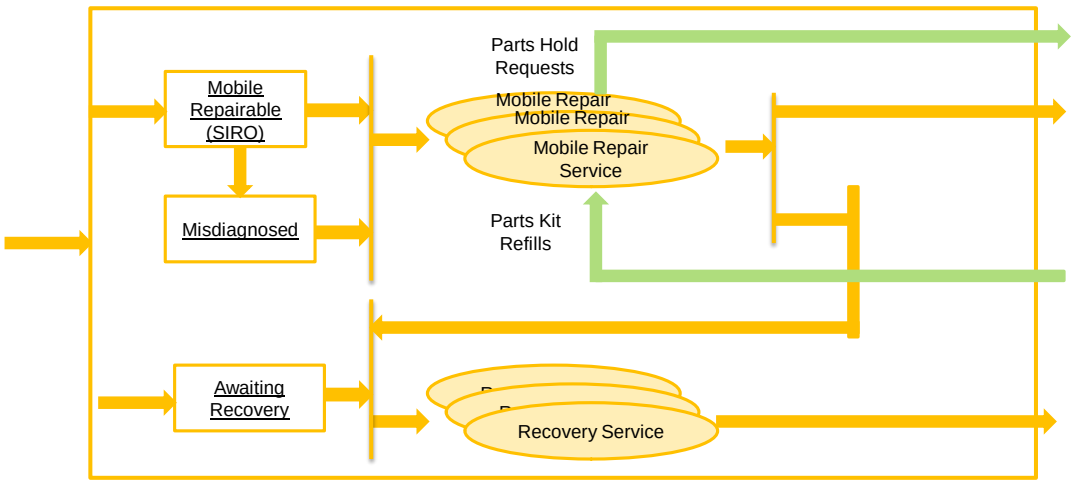
In Field Repair and Recovery



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Outline of GCV Repair and Availability Simulation Model

Input

- **Scenario and Basing Data**
  - Vehicle inventory and number of maintenance lines at maintenance collection point
  - Mission request rate
  - Avg. mission time (assuming no SA)
  - Probability the aborted sortie is re-assigned
  - Mean time to recover SA vehicle to maintenance collection point
- **GCV Reliability**
  - MTBEFF and MTBSA
- **Repair and Logistics Capability**
  - Number of mobile repair teams
  - Probability of parts available to mobile team
  - Probability a part type is consumed by mobile team
  - MTTR by mobile repair team and repair line at maintenance collection point
  - Probability that a part type is consumed by a repair at the maintenance collection point
  - Mean time to deliver a part of type to maintenance collection point
  - Initial parts inventory

GCV Repair and Availability Simulation Model

Output

- Operational Availability
- Breakdown of ALDT into wait-times, part-delivery times, recovery times
- Various categories of service and wait time distributions
- Parts Consumption Profile

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Assumptions of the Reliability Model

- Missions, repairs, and logistics modeled at the CAB/FSC level
- Mission continues for EFF only (not SA)
- Repairs by crew and repairs due to combat damage not considered
- Mobile repair team and UMCP share parts
  - Disabled vehicles not cannibalized for parts
  - UMCP never runs out of part type used by mobile repair team

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C. Illustrative Results from the Reliability Model

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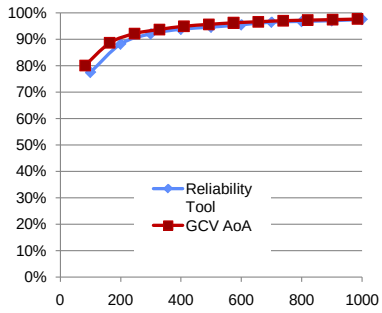
Reliability Tool Input Data

- 3 day MCO operation based on GCV OMS-MP
- Vehicles considered
  - 31 GCV, 30 M1A2, 15 M3, and 30 M113 (CAB level)
  - All deployed at h-hour
- 30% in field repairs
  - 2 mobile service teams for in-field repair
  - 1 for M1A2, 1 shared by GCV & M3
- 70% recoveries to UMCP
  - 8 hour recovery time for all vehicles
  - 8 M88 recovery vehicles

Operational Availability of GCV



Reliability tool closely match GCV AoA estimates

MTBSA & MTTR (hrs)

	MTBSA	MTTR
GCV	Varies: (Base 310)	5
M1A2	100	5
M3	150	5
M113	500	5

Source: FCS System Engineering Review, GCV CDD Appendix H

- Exponential Time Distributions chosen for
  - Mobil repair team arrival/repair , vehicle recovery , and UMCP repair
- Part delivery Time =F(supplier echelon)
- Vehicle Repair Priority M1A2>GCV>M3>M113

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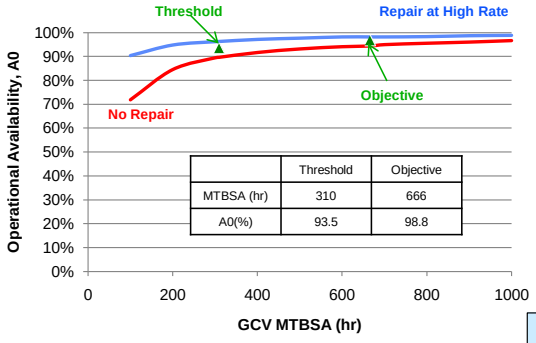
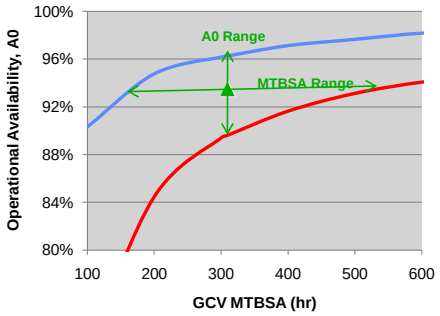
GCV Reliability Shortfall Implications

Operational Availability of GCV



	Threshold	Objective
MTBSA (hr)	310	666
A0(%)	93.5	98.8



Case	Mobile Service Teams	UMCP Repair Lines	Part Delays
No Repairs	0	0	N/A
Repair at High Rates	2	10	N

- **To satisfy GCV CDD requirements, some repairs must be done on battlefield**
  - **If no repairs are to be done on battlefield, MTBSA must be raised to 540**
  - **If repairs are done at high rate, MTBSA can be as low as 170**
- **If GCV MTBSA requirements are met, depending on battlefield repair resources, operational availability can range from 90 to 96%**

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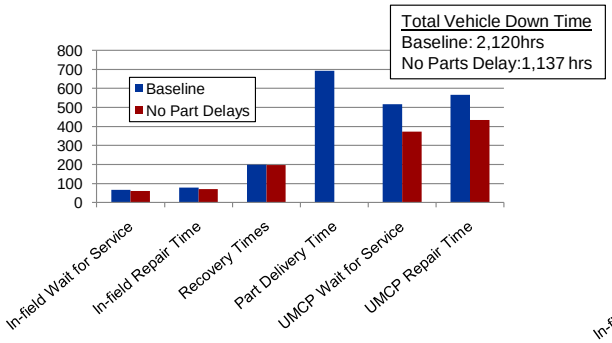
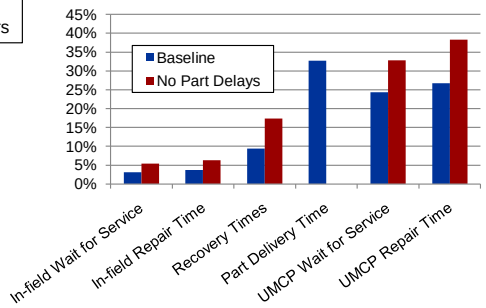
What Are the Major Causes of Vehicle Down Time?

Vehicle Down Time (hrs)



Vehicle Down Time (%)



Part Delay Parameters

Category	Occurrence (%)	Avg. Delay Time (hrs)
Re-order from BSB	29	8
Special Order BSB	24	8
Special Order EAB1	29	16
Special Order EAB2	18	89
Special Order EAB3	0	298

- **Vehicle down time depends strongly on availability of parts**
- **If parts are readily available, down time can be lowered by reducing time spent at UMCP**
  - **Reduce UMCP repair time and/or increase number of repair lines**

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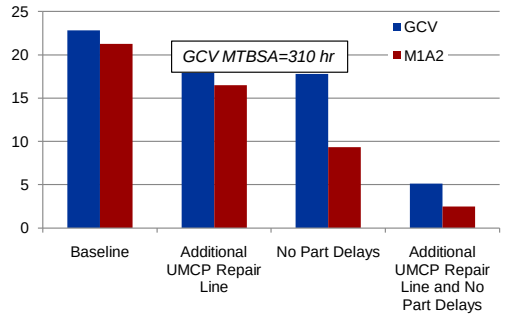
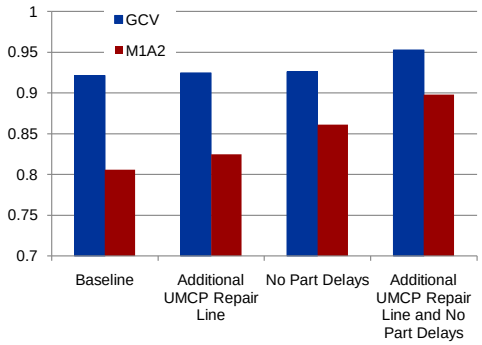
Sensitivity of GCV A0 on UMCP Repair Capacity and Part Delivery Efficiency

UMCP Service Wait Time



Operational Availability



- **Adding an additional UMCP repair line and eliminating part delay significantly reduces UMCP wait time (eliminating part delay has a larger effect)**
- **Increase in Operational availability of GCV is modest when compared to M1A2**
  - **M1A2 has higher repair priority than GCV**

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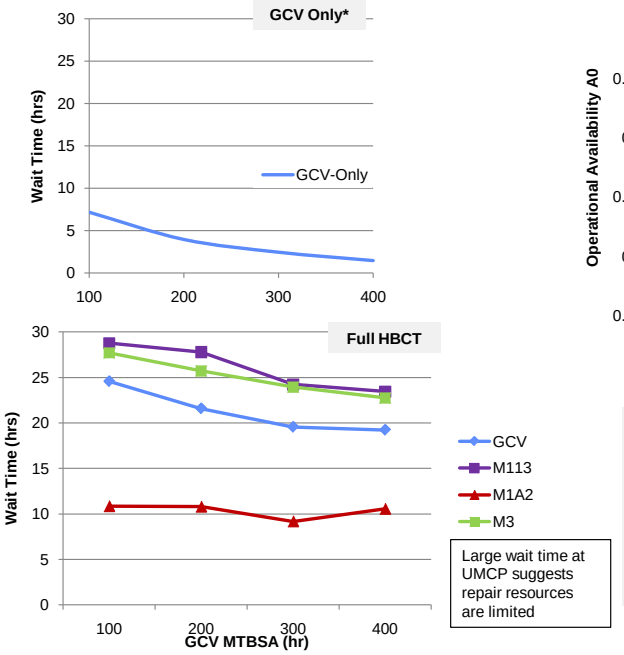
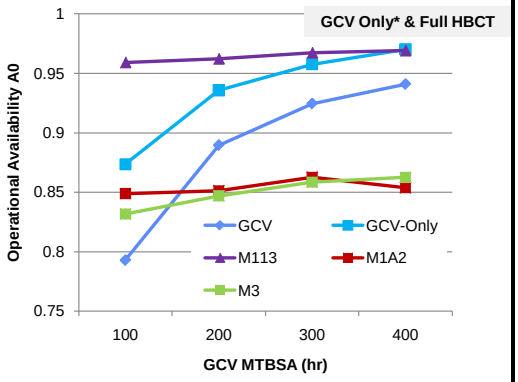
Implications of a GCV Reliability Shortfall in a Repair Capability Limited Environment

UMCP Service Wait Time



Large wait time at UMCP suggests repair resources are limited

Operational Availability



- **Operational availability of GCV is reduced and more sensitive to MTBSA when repair resources are limited**
  - **GCV reliability should be assessed in a HCBT context and not in isolation**
- **Other vehicles (e.g., M3) can be negatively affected by a GCV reliability shortfall**

* Only the reliability of GCV is taken into consideration (i.e. other vehicle do not suffer breakdown)

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D. Summary

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Summary

- **Created a model of field level maintenance and logistics for tactical vehicles in BCTs (e.g. HBCT, IBCT, and SBCT)**
  - **Vehicle SA and EFFs occurring during scripted mission feeds the network of recovery and repair queues**
  - **Simulates parts demand, consumption, and back-order generation at the bottom two levels of a multi-echelon supply chain**
- **Model used to predict the operational availability in terms of**
  - **Vehicle reliability**
  - **Scenario and Basing Data**
  - **Maintenance Capability**
  - **Parts delivery Times**
- **Model can explore how availability issues can be mitigated by additional repair resources and improved logistics**

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13. SUPPLEMENTARY NOTES

Scot R. Renn, Project Leader

14. ABSTRACT

High operational availability that allows tactical ground vehicles to execute operational tasks to satisfy mission capability requirements is crucial to combat brigade effectiveness. Hence, we have developed a simulation model to understand the impact of mission demands and tactical ground vehicle reliability on operational availability. This model was built for the DOT&E sponsored Ground Combat Vehicle Analysis Tools Study conducted at the Institute for Defense Analyses during summer of 2011. The model to be presented assesses the operational availability of a HBCT fleet of ground vehicles by representing (1) Mobil repair teams, (2) Recovery vehicles, (3) Collection point repair services, and (4) Parts deliveries as a queuing network simulation. The inputs for this model may include vehicle reliability data, repair times, failure modes, part availability, vehicle recovery times, and maintenance staffing. However many of the inputs are optional, so the model can flexibly accommodate incomplete data sets. During this talk, the audience will gain insight on how mission demands and vehicle reliability affect operational availability. In addition, we will also explore to what extent can any availability issues be mitigated by additional repair resources and improved part delivery logistics.

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