High Mobility Trailer

Diverse Team Surmounts Design Problems to Produce a Trailer Capable of Living Up to Its Name

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Surmounting a wave of unfavorable publicity and serious design flaws in the Army's High Mobility Trailer (HMT), an Integrated Product Team (IPT) at the U.S. Army Tank-automotive and Armaments Command (TACOM) successfully solved design problems in the HMT that were deadlining the fleet of trailers and delaying full delivery and fielding. The HMT, which will be fielded in three versions, is a new family of trailers designed to be towed by the Army's inimitable "Humvee" – officially known as the HMMWV, or High Mobility Multipurpose Wheeled Vehicle.

Led by the Project Manager for Light Tactical Vehicles (PM-LTV), the IPT, which included acquisition managers, engineers, logisticians, and testers, developed a materiel solution through extensive use of modeling and simulation, tested the redesign and approved its application, and are currently fielding the HMT. In so doing, they are providing soldiers in the field with an outstanding trailer capable of living up to its name.

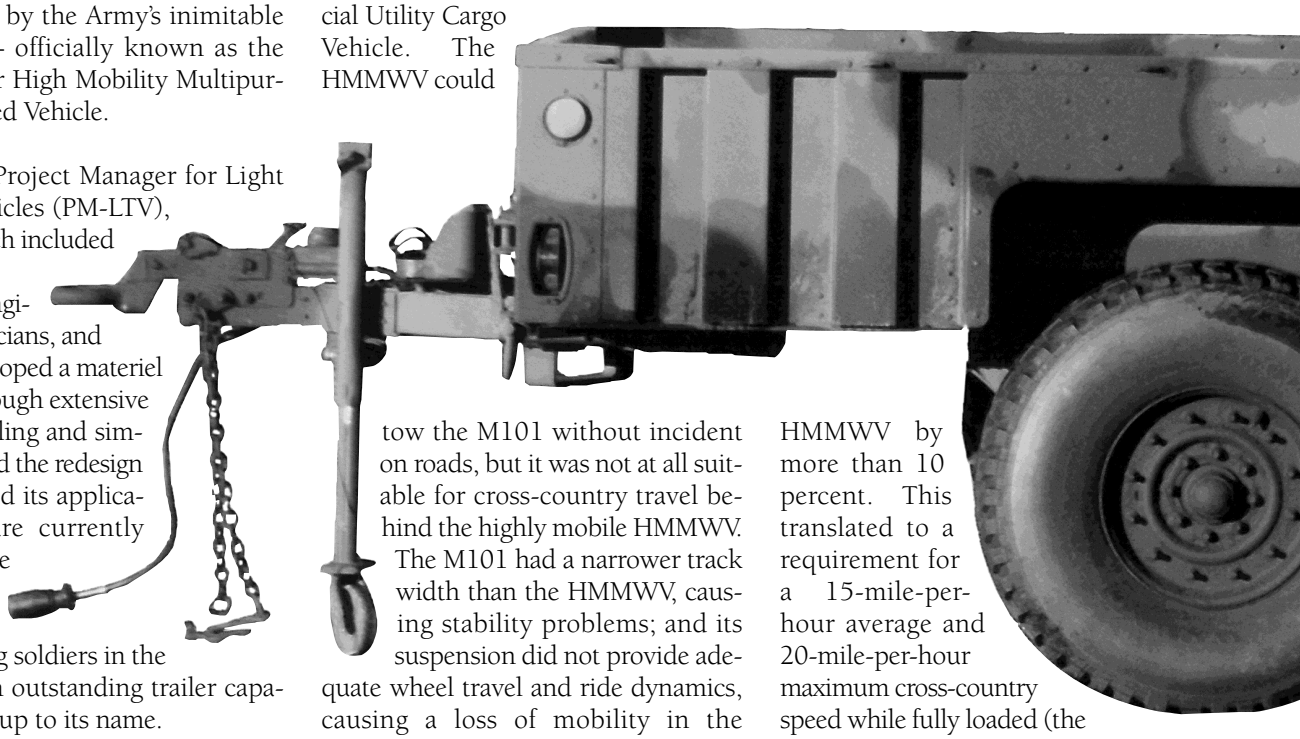
Process Improvement

In 1984, the Army began producing a 1¼-ton HMMWV to replace the venerable M151 series ¼-ton Jeep and companion M416 ¼-ton trailer as the Army's primary light tactical vehicle. Each of the lightest HMMWVs would replace a set of two Jeeps and three trailers. As the HMMWV proliferated in the Army, units began using it to tow the M101 ¾-ton utility trailer.

The M101 was designed in 1952 to be towed by the M37 ¾-ton truck and has been paired with a variety of prime movers since then, such as the M880 series pickup truck and the Commercial Utility Cargo Vehicle. The HMMWV could tow the M101 without incident on roads, but it was not at all suitable for cross-country travel behind the highly mobile HMMWV. The M101 had a narrower track width than the HMMWV, causing stability problems; and its suspension did not provide adequate wheel travel and ride dynamics, causing a loss of mobility in the truck/trailer system.

When towing the M101 trailer cross-country, the HMMWV was forced to slow down to minimize trailer wear and tear and preclude the propensity for trailer rollovers. The Army needed a family of HMTs to match the HMMWV's mobility and to reduce the number of trucks and trailers needed to perform unit missions.

Army leadership directed that TACOM develop the HMT to meet this need. Two key requirements were that the HMT have the same tracking or tire spacing as its prime mover – the HMMWV; and that it not degrade the mobility of the HMMWV by more than 10 percent. This translated to a requirement for a 15-mile-per-hour average and 20-mile-per-hour maximum cross-country speed while fully loaded (the most demanding portion of the mission profile). To reduce acquisition time and development costs, PM-LTV procured the HMT as a commercial-off-the-shelf, nondevelopmental item. Following full and open competition, they subse-



Moulton *was the Project Manager, Light Tactical Vehicles, U.S. Army Tank-automotive and Armaments Command, Warren, Mich., from June 1998 until June 2001.* ***Noyes*** *is a Senior Analyst with Science Applications International Corporation (SAIC), Sterling Heights, Mich. The PM-LTV team is dedicated to providing safe, reliable products that meet mission needs. Members of the IPT wish to express thanks to all those involved in, and supportive of, the effort to get these critically needed trailers in the hands of the nation's soldiers.*

U.S. Army photos and images

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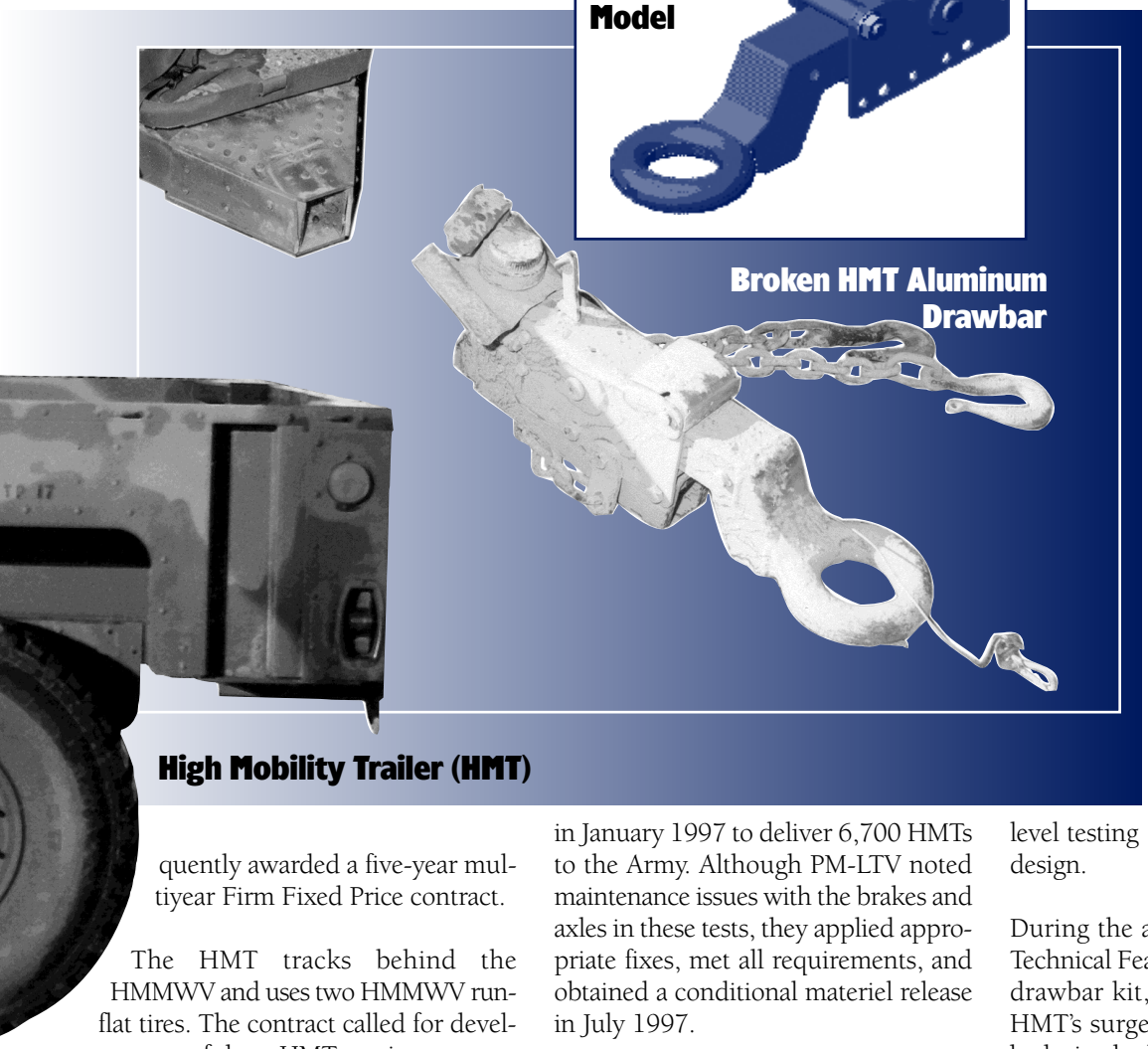

quently awarded a five-year multiyear Firm Fixed Price contract.

The HMT tracks behind the HMMWV and uses two HMMWV run-flat tires. The contract called for development of three HMT versions:

- A light cargo trailer with a 1,500-lb. payload
- A heavy cargo trailer with a 2,500-lb. payload
- A trailer chassis with a 2,700-lb. payload.

Following Production Qualification and First Article testing, production began in January 1997 to deliver 6,700 HMTs to the Army. Although PM-LTV noted maintenance issues with the brakes and axles in these tests, they applied appropriate fixes, met all requirements, and obtained a conditional materiel release in July 1997.

Safety Problem

During initial performance testing, some HMMWV rear bumpers and cross-members were cracked by the forces exerted while being towed over rough terrain with full loads. In November 1997, during follow-on HMMWV bumper testing, an HMT drawbar completely failed when the aluminum drawbar broke apart, separating the HMT from the HMMWV. TACOM engineers analyzed the failures and determined that the aluminum drawbar design did not have an adequate safety margin.

In March 1998, TACOM issued a Safety of Use Message, deadlining the HMT fleet until a fix could be developed and tested. By this point, PM-LTV had already fielded over 1,700 HMTs to Army units. Leveraging the expertise of all key players, PM-LTV forged a full partnership between the TACOM Deputy for Systems Acquisition; the TACOM Research, Development and Engineering Center (TARDEC); and the Army Test and Evaluation Command. PM-LTV also fully involved all IPT members, including the U.S. Forces Command. Together, engineers from PM-LTV and TARDEC designed and developed a solution – a steel drawbar kit that would replace the previous aluminum drawbar design.

Using data collected from test courses at Aberdeen Proving Ground (APG), Md., engineers tested the solution on the TARDEC Pintle Motion Based Simulator. They also successfully conducted system-level testing at APG to validate the kit design.

During the accelerated cross-country Technical Feasibility Testing of the steel drawbar kit, damage occurred in the HMT's surge brake assembly. A surge brake is a hydraulic brake activation system that uses the trailer's forward inertia to apply the trailer brakes. As the towing vehicle slows down, the trailer pushes forward against the vehicle. This compresses a hydraulic cylinder in the surge brake, which applies the trailer's brakes until the forward speed of the trailer matches that of the towing vehicle. When the towing vehicle and trailer speeds are equal, the pressure is re-

moved from the surge brake and the trailer's brakes are released. This is a common braking system on trailers in the 6,000- to 8,000-lb. weight range that are towed by private vehicles and operated almost exclusively on improved roads, but it is not common on trailers used primarily for cross-country travel.

During testing, cracks and deformities in the surge brake's inner slide, outer housing, and lunette assemblies appeared. The IPT believed that the damage was caused by powerful up-and-down acceleration forces between the HMT and the HMMWV pintle as the truck and trailer negotiated the cross-country test courses at APG. Surge brakes on commercial trailers typically undergo very little vertical stress because they operate almost exclusively on paved or improved roads with little or no cross-country operation at all.

The performance of the HMT on primary and secondary roads was never an issue. Testing over cross-country terrain showed that the HMT could be safely towed at up to 12 miles per hour, with a full payload, without evidence of brake actuator wear or fatigue; however, this was still well below the HMT's required speed. An evaluation of the reliability, availability, maintainability, and maintenance ratio requirements – taking into consideration the fact that the brake actuator is a maintenance item – showed that in spite of the projected brake actuator replacement rate, the design would still meet all Required Operational Capability (ROC) requirements.

However, a careful safety assessment by the IPT determined that the location of the cracks could cause separation of the trailer from the HMMWV if not detected during Preventive Maintenance Checks and Services. Therefore, TACOM classified location of the cracks as a high-risk safety issue. In August 1999, PM-LTV asked the user community to waive the cross-country speed requirement in the ROC and accept a 10-mile-per-hour cross-country speed restriction, which was significantly better than the previous 6-mile-per-hour restriction for the M101. The user community refused to do so, and TACOM then charged PM-LTV with reducing the risk to "low" while achieving the 15-mile-per-hour average cross-country speed through a design change.

To better understand the nature of the problem, PM-LTV's IPT turned to computer modeling and simulation. IPT engineers from PM-LTV and Science Applications International Corporation (SAIC) created a three-dimensional computer model of the surge brake assembly using Computer Aided Design software. AM General Corporation, manufacturer of the HMMWV, also created computer models of the HMMWV's rear crossmember to study its stresses while towing the HMT.

Computer Solid Modeling

A computer "solid" model represents the actual item with features and properties that can be altered during the course of design and development. Modelers identify the solid model's characteristics – such as dimensions, volume, surface area, weight/density (based on the material selected), center of gravity, material properties, and natural frequency for vibration – as precisely as possible to accurately represent the physical item in the computer. This model then supports the process of Finite Element Analysis (FEA) in which the computer model is subjected to simulated physical forces to determine the location of stress points and the ability of the item or assembly to withstand the applied forces.

As the model identifies unacceptable stresses, it can be altered in terms of design or material specifications to measure whether the changes improve the item's performance. Once the FEA predicts an acceptable design, the Computer Aided Design software produces the engineering specifications needed to translate the model into the physical item for manufacturing. SAIC's engineers followed such a process to analyze the surge brake.

Concurrent with development of the surge brake computer model, PM-LTV organized a test at APG to precisely measure the forces exerted on an HMT surge brake and drawbar during fully loaded cross-country travel at required speeds. An HMT surge brake and drawbar were instrumented with strain gages and accelerometers; a towing HMMWV was equipped with data recorders to record 48 channels of data simultaneously, 400 times per second for up to 15 minutes; and a video camera provided a visual record of the surge brake throughout the tests. The instrumented HMT was towed several times on the Perryman No. 3 cross-country test course at APG in the fall of 1999.

Once the IPT analyzed the test data from APG to learn the maximum forces being applied to the surge brake, they learned that the heavy HMT surge brake was subjected to peak loads of over 32,000 lbs. along the longitudinal axis of the drawbar, and upward loads of over 8,000 lbs. during the fully loaded cross-country tests. These were loads the surge brake was not designed to withstand.

PM-LTV also analyzed the measured loads for frequency of occurrence and duration, and developed nominal analysis loads to be inputs to the FEA. The HMT Surge Brake Finite Element Analysis is a graphical prediction of the amount of strain each portion of the surge brake might experience in the real world. Different colors highlight the areas where strain occurs at or above levels that are of interest to the designers.

Growing Outside Pressure

While the IPT worked to develop a solution to the HMT's design deficiencies, outside pressure grew to find a solution. In October 1999, the U.S. General Accounting Office issued a report to the U.S. Senate (GAO/NSAID-00-15), titled "Defense Acquisitions – Army Purchased Truck Trailers That Cannot Be Used as Planned." Prepared at the request of Iowa Senator Tom Harkin, the report detailed the programmatic and technical problems in the program's history and recommended that the Army, before procuring additional trailers, demonstrate that the HMT design will

perform, as required, without causing damage to the HMMWV.

Release of the report and Senator Harkin's subsequent press conference on the results focused national news media attention on the HMT. On Oct. 27, 1999, *ABC World News Tonight* broadcast a report on the HMT in its regular news segment, "It's Your Money." This is a recurring report in which ABC News highlights ways the Federal Government spends or does not spend the taxpayer's money. The HMT broadcast was quite critical of the HMT program.

Determining a Course of Action

As a graduate of the School For Innovators, the PM-LTV led the IPT, along with members of the Army Research Lab Physics of Failure team, in a "Thinking Adventure" at APG for three days in December 1999, to identify all innovative alternatives for resolving the HMT issues. The meetings heavily emphasized creative problem-solving methods and ended with a convergence on realistic alternatives. Following a series of intensive meetings and another two weeks of remote collaboration, the IPT arrived at the following major alternatives:

- Leave the design unchanged and emphasize regular maintenance inspections.
- Field the HMT with a 10-mile-per-hour cross-country speed restriction.
- Field the trailer as a redesignated M101A4.
- Convert all heavy HMTs to light HMTs. Users requiring the heavy version would have to accept a permanent 10-mile-per-hour speed restriction.
- Develop a dampening device to absorb the unacceptable forces occurring during fully loaded cross-country movement at required speeds.
- Adopt an alternative surge brake design.

To evaluate the feasibility of the alternative surge brake designs, the IPT again turned to modeling for assistance. They considered four alternatives; conducted a market survey; and SAIC modeled one design in three variations, only one of which showed evidence, through the FEA model, that it would work with reliability and with an adequate safety margin. Using the modeling and simulation information and assessing other factors such as operational and technical supportability, cost, and risk, PM-LTV put together a decision matrix to assist in the decision-making process. Considering all factors, the PM-LTV decided to modify the existing surge brake to increase its strength rather than adopt a new brake design. They also approved the configuration changes, developed a cost estimate to complete the reconfiguration, and prepared program strategy alternatives for senior Army leadership.

The HMT program has logged over 550 modeling and simulation hours and over 200,000 miles of testing during the course of the program, which has resulted in a superior trailer design.

On Feb. 25, 2000, and again on March 27, 2000, the Army convened HMT General Officer Summits at the U.S. Army Materiel Command headquarters in Alexandria, Va. The leadership considered three options for a strategy to resolve the HMT issues:

- Store all the trailers until all modifications were applied.
- Replace the aluminum drawbar with the steel replacement drawbar and field the HMT with an interim cross-country speed limit until all other modifications were applied.
- Withdraw all HMTs from the field, terminate the program, and develop a new trailer sometime around 2009.

The Army leadership determined that the best solution for the Army was to keep all HMTs in storage until all modifications could be applied.

Following approval of the Army's "path forward," PM-LTV and Rock Island Arsenal (RIA) engineers collaborated to design improved brake actuator housing components. The original surge brake inner and outer housings had been fabricated with an alloy steel that was not strong enough to withstand its operating environment. IPT engineers recommended that the housings be cast using a harder alloy steel. RIA, with its extensive foundry operation, undertook the manufacture of prototype improved surge brakes, installing six prototype surge brakes on both light and heavy HMTs. PM-LTV used several test courses at APG to replicate the HMT's cross-country mission profile – over 4,000 miles for each trailer – followed by a system test to verify that all safety concerns were resolved.

PM-LTV completed testing on Oct. 31, 2000, without any safety incidents, and identified corrective actions to address the minor test incidents that did occur. Both the light and heavy HMTs achieved average cross-country speeds of over 18 miles per hour, exceeding the requirement; both also exceeded the 1,500- and 2,500-lb. payload requirements. The IPT determined that the surge brake assembly was a safe and durable product and did not cause damage to the HMMWV/HMT interface. To reflect the production configuration, modelers updated the computer solid models. RIA has begun producing production surge brakes to replace all current HMT surge brakes.

Final Thoughts

The HMT program has logged over 550 modeling and simulation hours and over 200,000 miles of testing during the course of the program, which has resulted in a superior trailer design. Modifications to the entire HMT fleet are nearing completion to replace the aluminum drawbar with one made of steel; and the modified brake being produced by RIA will replace the surge brake. The

TACOM Commanding General approved Full Materiel Release on March 16, 2001, and materiel fielding is ongoing.

Headquarters, Department of the Army, has provided funding to PM-LTV to implement modifications to two HMMWVs for every HMT assigned to each unit – referred to as the 2:1 approach. PM-LTV has requested an increase in funding to modify all HMMWVs in units assigned HMTs – called the UIC [Unit Identification Code] approach. All HMTs are scheduled to be modified and fielded no later than September 2002.

Throughout its history, and especially during the rigorous technical testing, the HMT has proved that it provides greater capabilities to our soldiers than any trailer in its class. The HMT will not have a cross-country speed limit. Safe cross-country speed will be adjusted and determined by driving conditions according to operator judgment.

The HMT provides the Army with a greatly needed capability to move cargo over all types of surface conditions at all required speeds, and will reduce the Army's logistics burden as it takes on payloads now carried by other HMMWVs. It also stands as an outstanding example of a diverse team, with competing objectives, coming together to solve difficult problems.

Editor's Note: The authors welcome questions or comments on this article. Contact Noyes at *NoyesE@tacom.army.mil.*

Report of the Military Research Fellows DAU 2000-2001

From Chaos to Clarity: How Current Cost-Based Strategies are Undermining the Department of Defense

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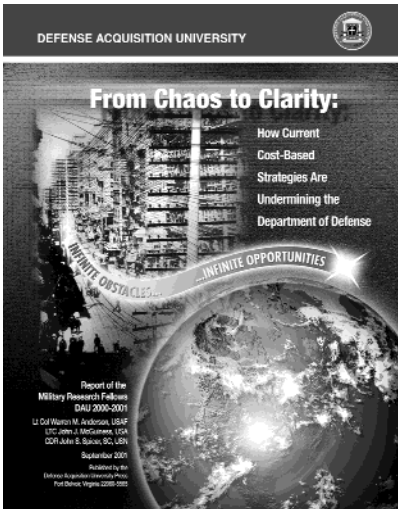
The latest Defense Acquisition University Military Research Fellows Report, *From Chaos to Clarity: How Current Cost-Based Strategies are Undermining the Department of Defense,* is now available in hard copy as well as online. Dated September 2001, the report details how DoD's cost-based initiatives fail to align with the Department's business strategy.

Historically, DoD has followed a generic strategy of differentiation, not cost leadership. The Department's beliefs, values, and mission are aligned to support this generic strategy. Office of Management and Budget (OMB) Circular A-76 and related initiatives, with their focus on cost, are not well suited for an organization such as DoD, which competes on quality, not cost. This misalignment of strategy and outsourcing policy has generated a great deal of concern within DoD, especially among base and installation commanders who must implement A-76 and related measures.

The authors make the case that A-76 results, as measured by savings goals, have not generated anywhere near the results expected. Indeed, cost-driven outsourcing strategies,



according to their report, are undermining DoD. The effort put into OMB Circular A-76 and related initiatives is great, yet the savings are at best marginal. Evidence is now emerging that these initiatives are degrading mission performance.

The intended audience is the DoD acquisition, technology and logistics workforce as well as policy makers.

The report may be downloaded from the DAU Web site at *http://www.dau.mil/pubs/misc/clarity.htm*. Non-government personnel may purchase hard copies of DAU publications for a nominal charge by calling the Government Printing Office at (202) 512-1800; to fax a request, call (202) 512-2250. Government personnel may obtain single copies of DAU publications at no cost by writing or faxing a request, on official stationery, to the address shown below:

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