

## Development of a Survivable Tire

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### Abstract

The U.S. Army is making a major effort to lighten the weight of equipment to improve strategic and tactical mobility. This effort has rejuvenated interest in the combat survivability of wheeled vehicles which normally are lighter than tracked vehicles. The tire, as one of the most vulnerable components, has drawn a lot of interest. A key issue in comparison of wheeled and tracked vehicles is mobility in off-road operations. The Army is also very concerned about operating and support (O&S) costs to equip, train and employ combat forces. These concerns led the U.S. Army Tank-Automotive Command (TACOM) to initiate a tire R&D program in 1986. A primary goal of the program is the development of a survivable tire system capable of continued operation after sustaining battle damage.

### Introduction

The U.S. Army has relied for some time on industry to provide expertise in the area of tire development and design for military vehicles. Over the past few years, interest in this subject has been renewed within the Army for two reasons: technical specifications have not been updated to accommodate the inclusion of improved technology in tires purchased for military vehicles since there was no in-house technical/engineering effort and the increased emphasis on light forces has led to greater emphasis on wheeled vehicles. The renewed interest resulted in the formation of a Task Force at TACOM in September 1985 to coordinate the Survivable Tire Symposium held in November 1985 and to develop a Tire R&D Program.

The symposium generated a great deal of interest among both government and industry personnel. The findings of the symposium were that:

- a. Many military tire requirements are unique.
- b. Army knowledge in tire design and development is limited.
- c. Current technology offers improvements to the tires purchased by the Army.
- d. The Army needs to better define requirements.
- e. TACOM should take the lead in development/implementation of improvements to tires used by the military.

### Military Requirements

Military tire requirements are unique in that off-road usage is greater and involves more severe terrain conditions than most off-road enthusiasts experience. Users who operate in terrain similar to Army operations and to the extent we do, select tires designed specifically for that type of terrain. For reasons of deployability, operations, cost and logistics, the Army must use a tire that compromises for off-road as well as on-road use.

Units stationed around the world must be prepared to deploy to new areas of trouble on short notice. The new location could be drastically different terrain than that at the unit's home station. The tasks to be accomplished upon notification to deploy range from administering medical inoculations to loading equipment, from personal concerns to issuing of ammunition. The need to change tires on all unit vehicles would be a significant additional job to perform.

In an area of operations, units may be required to disengage from limited contact in deep sand to move long distances on paved roads, quickly, to engage a main attack of enemy forces in yet another type of surface condition or terrain. In this case, the time required to change tires could be the difference in accomplishment or failure of the combat mission. The cost of maintaining a set of tires for each vehicle for specific contingency missions would greatly increase O&S costs. Logistically, the handling requirements and storage space required to maintain and issue a variety of tires for different terrains would be an added burden. The same holds true for environmental considerations, since the Army must be prepared to operate anywhere in the world with only minimal time for preparation and deployment.

Another element unique to military vehicle requirements is combat/battlefield survivability. The private or commercial vehicle operator's ability to stop and replace a punctured tire on the interstate is not available to the tactical vehicle driver whose tire has just been punctured by small arms fire or shrapnel from bursting artillery projectiles. A VIP sedan may be able to move 2-3 miles to escape an area of danger and replace a tire after sustaining tire damage in an ambush attack but the disengagement of a High Mobility Multi-purpose Wheeled Vehicle (HMMWV) mounting a TOW antitank missile could greatly decrease the combat effectiveness of a small unit.

### The Program - Goals

The Tire Task Force published the "Tire R&D Program" in February 1986. Three major goals were established in the following priority:

- a. Improve survivability to allow the vehicle to continue performance of the assigned mission over all terrain after sustaining combat damage to the tire(s);
- b. Improve life-cycle cost by improving the durability of tires purchased for military vehicles;
- c. Improve mobility by allowing for quicker, easier adaptation to varying terrain/surface conditions and maintain or improve current levels of mobility while improving survivability.

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The goals of improved survivability and improved life-cycle cost (durability) are both directly related to the areas of reliability and maintainability. Survivability is a measure of reliability and maintainability in combat, while durability is the major factor in peacetime, day-to-day reliability and maintainability.

In the Letter Report, Phase I Testing of the Survivable Tire Systems (T140) (reference 1), Survivability has been defined as follows:

A Survivable Tire System (STS) is a tire and wheel which can sustain reasonable combat damage from small arms, battlefield debris, and shrapnel; operate in a degraded (deflated) condition, and provide a "get home" capability (minimum of 30 miles, allowing for tire destruction); or be capable of continued use in mission operation (150 miles minimum) dependent upon the type of damage sustained. The tire should have the ability to interface with central tire inflation devices to allow enhanced mobility through footprint adjustment. In peacetime operation, the tire, depending on the severity of the damage, should be repairable and reusable with minimal impact to its rated tire life and give tread life comparable to its commercially used counterparts. Its storage "shelf life" should meet the special needs of the military user.

In terms of this program, durability is considered to be the major factor in life cycle cost. Durability will be measured in the amount of mileage that a tire is able to operate in the normal (inflated) condition before the tire must be replaced. The tire may be repaired as often as necessary during its life. Recapping/rethreading of the tire is a life cycle cost consideration.

Survivable Tire System concepts have been divided into four categories: run flat inserts, sealants/liners, filled and self-supporting. The run-flat insert provides a device inside the tire that will support the weight of the vehicle. When air is lost, this prevents the wheel rim flanges and sidewall friction from quickly destroying the tire and uses tractive effort of the tire to maintain mobility. Sealants and liners are liquid or semi-solid and are intended to close punctures and prevent the loss of air. Filled tires replace the air in the tire with a solid material. Self-supporting tires provide the characteristics of survivability through the design and construction of the tire and wheel without requiring inserts, sealants/liners or a solid filling.

#### Accomplishments

The first effort by the Task Force was to provide central coordination of the ongoing activities related to tire development and improvement in various Army agencies. One example is the Survivable Tire Test planned by the Army Development and Employment Agency (ADEA). This test was included as a project in the R&D program. The test was conducted for ADEA by the Combat Developments Experimentation Center (CDEC) Board at Ft. Lewis, Wash. in April and May 1986.

The Army Transportation School participated as the Training and Doctrine Command (TRADOC) proponent and published the Evaluation Report. Waterways Experiment Station provided instrumentation and expertise to measure vehicle ride as indicated by absorbed power. This test assembled the team to conduct the Army program, provided a learning experience for all involved and provided an initial evaluation of existing survivable tire system concepts in a user test. The Letter Report ref. 1 was published in Feb 1987.

Prototypes of each category (run-flat insert, sealant/liner, filled and self-supporting) were tested in the ADEA test. The HMMWV and the surrogate fast attack vehicle (SFAV - a "dune buggy") were used as the test vehicles. The test was conducted as a user test with drivers provided by the 9th Infantry Division, Ft. Lewis, WA. A ten mile test course was established based on the Mission profile of the HMMWV: 30% hard surface road, 30% secondary (improved) road and 40% cross-country. Each candidate prototype was driven in the normal, undamaged mode by different drivers over the test course to evaluate performance, i.e. ride, handling, etc. Tires of each candidate prototype were taken to a firing range and damaged in accordance with reference 2 to evaluate survivability. An M14 rifle was used to fire 7.62 mm rounds into the tires: 5 into the sidewall and 2 into the tread, at a distance of 50 meters. The tires were then placed on the right front of the vehicle and the vehicle was driven up to 100 miles over the test course until the concept prototype failed. A data recorder rode in each vehicle and collected information on time to run the course, speed, damage accrued, control of the vehicle, etc. The vehicle was stopped at each circuit of the course (10 miles) for a visual inspection. Accelerometers were placed on the right front A-frame of the vehicles and below the driver's seat. These instruments collected data on energy absorbed through the vehicle.

The results of this test enabled us to better define requirements for future testing.

Other survivable tire projects were defined in the R&D program and were submitted for possible funding in the Mission Area Material Plan (MAMP) process. General discussions led to the conclusion that a survivable tire system would preclude the necessity of Battlefield Damage Repair (BDR) procedures for the tire/wheel. A project was proposed to develop BDR procedures/kits for vehicles which would not be outfitted with survivable tire systems. Efforts to obtain funding are continuing.

A Request for Proposal for the procurement of prototype survivable tire systems for test and evaluation was issued in April 1987. Prototype tire/wheel systems will be tested for survivability, durability and mobility beginning in Fourth Quarter FY88.

The U.S. Army has joined the Federal Republic of Germany in conducting live fire testing to study Battle Damage Assessment and Repair (BDAR) techniques and abilities. Tests were conducted in 1986 and 1987 at Meppen, Germany (reference 3). The tests inflicted shrapnel damage on vehicles from exploding projectiles and allowed BDAR teams to attempt to repair damage and get vehicles back into operation.

A test procedure to subject tires to damage by small arms fire has been in use for some time. This is the NATO Finabel Standard (reference 2). An effort was initiated by the TACOM Tire Task Force in August 1986 to develop a test procedure to subject tires to possible damage by shrapnel and battlefield debris. The procedure is expected to be finalized in early FY88. Ballistics Research Laboratory, the Transportation School and ADEA are assisting in this effort. Right circular cylinders will be used to simulate shrapnel in order to allow for controlled repetition in testing. Testing and statistical analysis are being conducted to determine the size and speed of fragment that could be expected to impact the tire at a distance from an artillery burst at which the vehicle and crew would not be destroyed or totally immobilized. Initial testing indicates that reducing

tire pressure has a large impact on reducing the probability of sustaining damage to the tire. All subsequent testing of survivable tire systems will include the use of both procedures.

The Army is utilizing industry-developed improvements in tire technology to improve tire durability. New fielded vehicles use state-of-the-art tires. The effort required through the R&D program will be to develop improved methods of specifying tire requirements for military vehicles to ensure that replacement tires are comparable to tires purchased for vehicles to ensure that replacement tires are comparable to tires purchased for the vehicle as original equipment, and incorporate improvements in technology as they become available.

One of the first efforts in the area of durability is a comparison of radial and bias ply tires on older model 2-1/2 ton and 5 ton cargo trucks. The test portion of this evaluation was conducted at Aberdeen Proving Ground, MD in FY86 and 87. Data accumulated is being reviewed to determine the cost effectiveness of converting to radial tires on these vehicles.

A working group with industry has been established to call on their expertise in addressing these problems. It has been determined that it would not be cost effective or necessary for the military to develop the ability to design its own tires. Such an effort would be a wasted duplication of commercial capability. The Army must have the technical ability to translate its operational and performance requirements into terms understandable by the tire industry. This is the main goal of the continuing Tire R&D Program.

The successful continuation of this effort will lead to improved reliability and maintainability of tires, a very vulnerable component of the Army's workhorse tactical truck fleet.

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#### Biographies

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MAJ Ullrich graduated from Texas A&M University in 1972 with a degree in Aerospace Engineering. He was commissioned a Second Lieutenant in the U.S. Army Field Artillery on 9 Dec 1972. He has served in a variety of Field Artillery assignments including Battery Command in the Federal Republic of Germany and the Republic of Korea.

Since 1983, MAJ Ullrich has been assigned to the U.S. Army Tank-Automotive Command, Warren, MI as an R&D coordinator in the Research, Development and Engineering Center. He was named as Chief of the Tire Task Force in Sep 85.

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Mr. Pacis graduated from FEATI University, Manila, Philippines in 1963 with a B.S. degree in Mechanical Engineering. After working briefly in the Philippines, Mr. Pacis went overseas and was employed by Northern Electric Co. of Canada from 1966 to 1968 as a Manufacturing Engineer; Boeing Aircraft Co., Auburn, WA from 1968 to 1969, as a Tool & Manufacturing Engineer; and at Chrysler Corporation, Detroit, MI from 1969 to 1981, as a Product Engineer in the steering and suspension engineering. In 1981, Mr. Pacis joined the US Army Tank-Automotive Command, Warren, MI, as a Project Engineer in the Track & Suspension Division, Research, Development and Engineering Center. Mr. Pacis is a naturalized American citizen.