

## The Role of R&D in an Acquisition Program

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### Abstract

The U.S. Army has a poor reputation for bringing new ground vehicles from the Science and Technology (S&T) phase to deployment. However, a counterexample is the Joint Light Tactical Vehicle (JLTV), which successfully passed through the acquisition gauntlet. The Research and Development (R&D) forerunner to the JLTV was the Future Tactical Truck System (FTTS) Advanced Concept Technology Demonstration (ACTD) that was initiated with TARDEC serving in the role of Technology Developer. Two utility variant prototypes were built as part of that program and were evaluated in a Military User Assessment in 2007. PM JLTV was stood up in 2006 and adopted technologies and personnel from the FTTS program. Both the organizational construct and the use of prototypes early on in the vehicle development cycle are considered key successes of the JLTV program, particularly the close collaboration of the PM with other groups including the OSD, TRADOC, and ASA(ALT) as well as their counterparts in the USMC. This paper documents the important role of R&D in the acquisition process.

**Keywords:** Prototype; Acquisition; US Army; R&D; JLTV; FTTS

### Introduction

We began to see clear indicators of the value of early prototyping many years ago. The Future Tactical Truck System (FTTS) is a good example of how Army S&T seed corn enabled the Joint Lightweight Tactical Vehicle (JLTV) acquisition program. The FTTS effort started over fifteen years ago at the Tank Automotive Research Development and Engineering Center (TARDEC). TARDEC led the S&T technology development effort that demonstrated mature technologies which ultimately led to realistic and achievable requirements. The FTTS prototyping model stressed close coordination between the technology, requirements, and acquisition communities.

Statement by Ms. Mary J. Miller, Dep. Asst. Sec. Army for R&T to the House Armed Services Committee, Feb. 24, 2016

The U.S. Army has a poor reputation for bringing new ground vehicles from the Science & Technology (S&T) phase to deployment; by one account, over \$38 billion of R&D resources was spent on cancelled programs between 1985 and 2014 [1]. Twenty major acquisition programs were cancelled in the past 30 years [1]. However, a bright spot in this grim picture is the Joint Light Tactical Vehicle (JLTV), which successfully passed through the acquisition gauntlet.

The Army's current light tactical vehicle is the High Mobility Multipurpose Wheeled Vehicle (HMMWV) that first appeared in 1984 and is still in wide use today, 30 years later. In 2015, Oshkosh was selected as the manufacturer of the JLTV, the partial replacement for the HMMWV, following 10 years of development. The precursor Science and Technology project that helped to jump-start the JLTV program was the Future Tactical Truck System (FTTS) at the Tank Automotive Research, Development and Engineering Center (TARDEC). As the Honorable Mary Miller states in the above reference, the S&T program known as FTTS, including early prototypes, was the foundation for the JLTV acquisition program. The story of this transition from S&T to a successful acquisition program is described below<sup>1</sup>.

### Literature Review

#### History overview and timeline

Over the past 20 years the role of the tactical vehicle has changed from an unprotected vehicle working in a logistics capacity to one

in which trucks could routinely fall into harm's way. The HMMWV is a highly mobile vehicle, but thin-skinned and lacking in any real protection. Many armor upgrades have been added to make it a more protective vehicle, particularly as the use of Improvised Explosive Devices (IEDs) ramped up from 22 strikes a month in 2003 to 2000 per month in 2006 [2]. As the HMMWV was made more protective, the vehicle weight more than doubled. Much of the payload capacity and mobility disappeared along the way. To cope with the rapidly increasing IED threat, the Army rushed commercial-off-the-shelf Mine-Resistant Ambush Protected (MRAP) vehicles into service under a Joint Urgent Operational Needs (JUON) statement as a short-term solution to an immediate problem.

Meanwhile, GEN Dail, Chief of the US Army Transportation Corps was in discussion with Paul Skalny, Director of TARDEC's National Automotive Center [3]. They wanted to replace the entire Army tactical fleet and reduce four classes of tactical trucks (light, light-medium, medium, and heavy) to only two classes with common components. They also wanted the tactical trucks to be able to keep up with and support combat vehicles as part of Future Combat Systems and to drastically increase fuel economy. To make this happen, tactical trucks would need better protection, be more mobile and have a longer driving range. This brainstorming between the US Army Transportation Corps and TARDEC eventually led in 2003 to the establishment of a Future Tactical Truck System (FTTS) Advanced Concept Technology Demonstration (ACTD) with TARDEC serving in the role of Technology Developer.

There were two phases to the FTTS ACTD: Phase I consisted of a Modeling and Simulation (M&S) phase where multiple vendors presented concept technologies to be incorporated into integrated vehicle designs for two vehicle types: a smaller Utility Variant (UV) and a larger Maneuver Sustainment Vehicle (MSV). The M&S awards

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went to Oshkosh and Stewart & Stevenson (S&S) for the MSV and to AM General, International Military Group (IMG, military branch of Navistar), Lockheed Martin and S&S for the UV. Phase II was the down select and demonstrator build phase; in Feb. 2006 awards were made to S&S to build the MSV and IMG and Lockheed Martin to each build their version of the UV. After the builds in 2007, the prototypes went through a safety assessment at the Aberdeen Proving Ground followed by a Soldier evaluation in a Military User Assessment at Fort Lewis, WA.

Although the original intent of the FTTS was to replace all tactical vehicles, it later was downscaled to define requirements for a UV-type tactical vehicle. To carry that forward, a program was approved in November 2006 for the Army and U.S. Marine Corps (USMC) to jointly develop a lightweight tactical vehicle and the Project Management Office for the Joint Light Tactical Vehicle (PM JLTV) was formed. JLTV entered a 13-month concept refinement phase and in December 2007, they received approval for Milestone A to move into a Technology Development (TD) phase.

Three awards were issued for the 27-month TD phase on Oct. 2008: BAE Systems Land and Armaments and Navistar Defense; General Tactical Vehicles (GDLS and AM General); and Lockheed Martin. Due to increasing costs concerns and the possibility of the entire program being terminated, a one-year period of requirements stabilization took place. JLTV achieved status as a Program of Record in Jan. 2012. A Request for Proposals was issued for the Engineering and Manufacturing Development (EMD) phase and three groups were selected: Lockheed Martin, Oshkosh Defense, and AM General, each to build 22 prototypes in 27 months. The average unit production cost was set at \$250K. Finally, in August 2015, Oshkosh was awarded the contract to build the JLTV for the Army and USMC.

The timeline described above is shown pictorially from the start of FTTS to the JLTV Technology Development Phase in Figure 1. The next two sections describe the FTTS ACTD and the JLTV in far more detail.

**FTTS ACTD:** Prior to the FTTS ACTD, nearly all of the S&T work at TARDEC involved combat vehicles. FTTS was one of the first S&T efforts involving tactical trucks, which suddenly needed to be mobile, fuel efficient, and protective. For the first time, tactical trucks were being considered in terms of sophisticated survivability options and advanced communications.

By definition, an ACTD involves prototypes and ends with a

Military User Assessment and is considered “the most effective way to leverage research and development ... and a continuous assessment of new component technologies” [4]. Some of the attributes of an ACTD are the following [5]:

- A joint effort by the acquisition and operational communities
- Identifies a significant need and then matches with a technology program
- Objective is met by developing fieldable prototypes for evaluation
- Combat developer evolves the operational requirements to support a follow-on acquisition

An FTTS Mission Needs Statement was written by the user community as follows [6]

*Provide a multifunctional, multi proponent tactical vehicle system for transport of cargo, equipment, and personnel in support of maneuver, maneuver sustainment and maneuver support units in the battle space. The FTTS will support Army forces capable of rapid deployments, forced and early entry operations, and follow-on missions. The FTTS must deploy with full capabilities anywhere on the globe without pause or preparation, regardless of the nonpermissive, semi-permissive, or permissive access conditions.*

TARDEC’s National Automotive Center hosted an FTTS Industry Day in December 2002 to bring together government and industry to collaborate on viable solutions for FTTS. GEN Dail, Chief of Transportation, started the day citing statistics for the current tactical wheeled vehicles: less than 10% had communications capability and the average range was 300 miles [7]. He explained that range is a huge factor because 70% of the logistics burden was for fuel transport. He was hoping for a range of 600 to 900 miles although the technology analysis indicated only a 30 to 50% increase was possible. GEN Dail also called for a 50% improvement in speed, and an 18-36% increase in survivability as well as other ambitious goals. Fifty industries attended Industry Day and were given one month to relay their comments [8].

One of the drivers for pursuing a tactical truck redesign was to meet the sustainment operations and provide required support to the Future Combat Systems (FCS) platforms. The vision was that the vehicles would possess significantly increased capabilities in survivability, deployability, tactical mobility/agility, network connectivity, commonality and cargo capacity. The operational range necessary to support the FCS was estimated to be 450 to 900 miles [9]. TARDEC’s Advanced Concepts Team developed many concepts with goals of speed and range comparable to the combat vehicles they were supporting: integral armor; C4ISR systems to provide continuous levels of awareness and communication in complex terrain; a minimum payload of 4500 lbs; and the transportability requirement of two at a time on a C-130 with roll-on, roll-off capability.

The FTTS was all about requirements, which were assembled by a team including TARDEC, PM Tactical Vehicles, Transportation School, and PEO Combat Support and Combat Service Support (CS&CSS). Hundreds of requirements were given to industry with the goal of meeting as many as possible. One supplier noted that these included “an aggressive and comprehensive specifications document covering fuel economy, ride and handling, the ability to climb steps and cross ditches, the number of occupants, the payload, survivability requirements, and transportability requirements” [10]. TARDEC wanted to explore technologies, including leveraging automotive technologies, and systems for future tactical vehicles to enhance

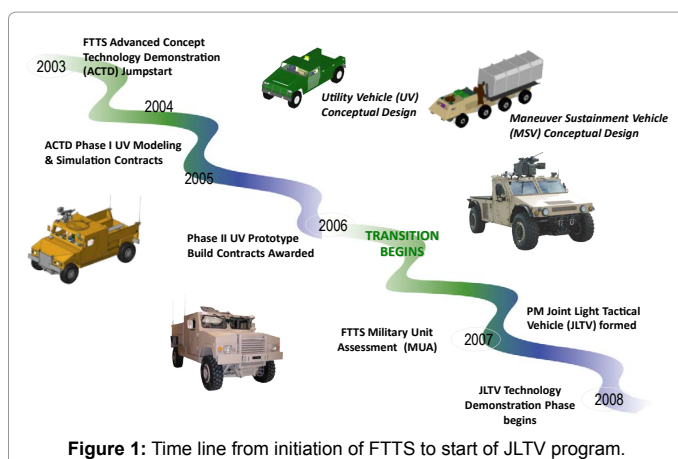


Figure 1: Time line from initiation of FTTS to start of JLTV program.

fleet capabilities. Through this process, TARDEC learned what was achievable and what was not.

To meet the aggressive specifications for fuel economy and range, the bidders selected hybrid-electric (HE) propulsion systems. Both IMG and Lockheed Martin went with a parallel hybrid resulting in a range of over 500 miles [11]. Determining fuel economy can be challenging for any vehicle, as it depends on the driver, the terrain, the driving speed, and road conditions. However, it's even more difficult to determine for a hybrid electric vehicle, where fuel usage is also impacted by the vehicle control systems that manage engine operation, power assist, regeneration and traction battery state of charge.

TARDEC carried out a large-scale program known as the Hybrid Electric Vehicle Experimentation and Assessment Program (HEVEA) to establish a Test Operating Procedure for determining fuel economy for HE vehicles [12,13]. Traditionally, the Army measured fuel economy on the Munson Standard Fuel Course, a mostly flat course that did not provide varied-enough driving to evaluate hybrids. Under HEVEA, the FTTS prototypes were tested on a number of different courses for the first time to measure fuel economy under different conditions. They learned that hybrids were better than conventional powertrains on flat paved terrain but worse on hilly terrains.

Another key requirement was survivability. As early as 2002, TARDEC had written detailed descriptions of survivability options, including signature management, integral and applique armor, mine protection, and Nuclear, Biological, and Chemical (NBC) detection systems [6]. Eventually, integrated armor with built in crew protection was designed into the cab structure to provide a new level of protection that didn't require personnel/equipment and time to gain this protection. Tactical vehicles had never been designed to have integrated armor before, so this was a major development. It was unclear if you could both design a tactical truck that leveraged commercial truck designs but also included integrated armor. The challenge was to add integral armor, but design a platform robust enough to also carry additional payload. Armored tactical vehicles started with FTTS and eventually went forward to every tactical vehicle in the fleet.

The development process was supported by TARDEC's introduction of an Advanced Collaborative Environment (ACE) [14,15]. ACE consisted of a secure, web-based information management system and an immersive virtual environment. A Windchill-ProjectLink solution was chosen as the web-based system, which allowed stakeholders, both government and contractor, to effectively collaborate even when separated functionally or geographically. For instance, an engineer could push 3D FTTS concepts onto the web environment and other distributed users could view and provide feedback within minutes.

Immersive environments went another step toward allowing participants to visualize and improve a design without a physical prototype. Two environments were used, a single wall system displaying a stereo image on a flat screen and a CAVE (Cave Automatic Virtual Environment) that surrounded the user with the 3D virtual scene, such as inside the crew cab of an FTTS design. ACE also helped connect the end-user, the Soldier, with the product early in the process. By bringing Soldiers into the design environment, their feedback could result in rapid and inexpensive tradeoffs.

The M&S efforts of Phase I was used to downselect the choices to the eventual IMG and Lockheed Martin demonstrators. Some of the technologies that were applied, in addition to HE drive, included integral armor, network centric systems and onboard diagnostics. The IMG vehicle weighed 18,500 lb with the hybrid engine in the rear to



**Figure 2:** Trio of FTTS demonstrators. International's utility variant in front, Lockheed Martin's utility variant in the center and Stewart and Stevenson's maneuver sustainment vehicle bringing up the rear.

allow for more room in the cab and four-wheel steer such that it could drive sideways. The LM vehicle was larger at 25,000 lb and a top speed of 75 mph. It had adjustable ride height, a tilt system for rough terrain and a V-hull to deflect underbody blasts [16]. The performance testing later verified the values derived from M&S. By knowing that the hardware performance could be accurately predicted through M&S lessened the risk in the future JLTV efforts [17]. The final two utility variants and one Maneuver Sustainment Vehicle built are shown in Figure 2.

The Military User Assessment (MUA) was held at Ft. Lewis in 2007 and represented the final step of the ACTD. This was the opportunity to place the prototypes in the hands of Soldiers and get their feedback based on various operational scenarios. The vehicles were "loaded with such bells and whistles as diesel-electric hybrid engines, companion trailers, cranes to load cargo and pull their own engines, FLIR and video cameras, improved ergonomics, fire suppression systems and exportable power" [16]. The MUA helped determine which of the exotic technologies, such as crab steer, adjustable height suspension and hybrid technology [18], would move forward to the JLTV.

**JLTV:** During this time period, the Marine Corps Combat Development Command (MCCDC) was also pursuing a replacement for their light tactical vehicle. The Office of the Secretary of Defense (OSD) decided that the commands should work together to produce a Joint Light Tactical Vehicle. In early 2006 the FTTS ACTD was transitioned from TARDEC to the PM Joint Combat Support Systems (JCSS).

The work to develop requirements and specifications for the FTTS UV became the starting point for the JLTV with a primary goal of transitioning the knowledge gained through the FTTS ACTD to the JLTV. To ensure a successful transition, many of the TARDEC associates involved with FTTS transitioned to the newly formed PM JLTV including the Chief Engineer for PM JLTV and several other key engineering and leadership positions.

It had become customary in the Army to skip the Technology Development phase for new programs based on the assumption that the required technology was mature enough to move forward. This was expected for the JLTV since the FTTS program had successfully produced prototypes [19]. However, The Honorable John Young, the Under Secretary of Defense for Acquisition, Technology and Logistics, felt that there had been too many Nunn-McCurdy Breaches where programs were halted due to cost overruns. He directed the Army and Marines to go back to the drawing board to develop a robust Technology Development phase [20]. This decision was based on his analysis of requirements stability, technology maturity and funding adequacy.



From 2006 to 2007 the Combat Developers (MCCDC and CASCOM) collaborated in a Joint IPT to develop the Capability Development Document (CDD). TARDEC's Advanced Concept Team conducted a Whole System Trade Study (WSTS) at the request of the JLTV Combat Developers that focused on three objectives:

- **Transportability and Force Protection:** Can the Force Protection requirements be met while maintaining transportability in a CH-47 helicopter?
- **Payload and Mobility:** What is the maximum payload that can be carried and still meet the mobility and protection requirements.
- **Sustainability:** Can reliability and maintenance ratio requirements be met and what is the fuel efficiency for each payload category.

New JLTV vehicle designs were developed and space, weight, survivability, helo-lift, and reliability analyses were conducted. The study's recommendations were evaluated by the JLTV Combat developers and were incorporated into CDD version 2.6. The analysis significantly reduced the JLTV requirements risk as the program proceeded into the Technology Demonstration phase. The vehicle changed considerably during this period [19]. The six-passenger version and the trailer were dropped. The force protection level was increased, whereas the communications and reliability requirements were lessened. Vehicle weight was significantly decreased.

In July 2006, TARDEC's Advanced Concepts Team was tasked with developing a Technology Maturity Assessment (TMA) as needed for Milestone B. When the JLTV program was pushed back to Milestone A, this information was used for the Technology Development Strategy (TDS) [21,22]. The system requirements in CDD v.2.6 were decomposed into a Work Breakdown Structure. These were distributed to Army and USMC Subject Matter Experts (SMEs) in 13 technical areas, such as mobility or survivability. The SMEs identified all applicable technologies that met the criteria. When a mature technology was not available, it was labeled as a Critical Technology Element (CTE), which was evaluated for its Technology Readiness Level (TRL). TRL 6 was required for Milestone B and TRL 7 was required for Milestone C. The results of this laborious process were captured in the TMA document [23].

The TD phase was all about requirements and the PM was faced with over 1600 requirements at the start, including items as minor as the placement of drainage holes. The OSD was intent that there should be no unachievable requirements [24]. Before and during the TD phase, the JLTV Requirements Management and Analysis Plan (RMAP) described the requirement development process that would be used to create updated CDDs and Purchase Descriptions (PDs). To ensure that the process was progressing properly, seven Knowledge Points (KPs) were scheduled during the TD phase to review the progress in a given area and allow for an update of the CDD and PD [25]. The RMAP was so successful that the Honorable Heidi Shyu, U.S. Asst. Sec of Army for Acquisition, Logistics and Technology, had the process adopted for all new programs.

Since there were so many requirements, one of the successes of the RMAP was to have a tiered system of requirements, which helped drive down the authority level. The highest level, the Key Performance Parameters (KPPs), were nonnegotiable but lower tier items could be removed or traded at correspondingly lower authority levels [24]. This also helped the commercial vendors prioritize the principal requirements from those less essential.

A Memorandum of Agreement (MOA) was established between TARDEC and the Office of Naval Research (ONR) in August 2009 to

define the scope of each group in providing Science and Technology support to JLTV. Included from TARDEC was the work by the FTTS ACTD, the fuel economy analysis, mine blast modeling, reliability centered initiatives and concept designs including M&S efforts.

At the conclusion of the TD phase in early 2011, the JLTV Program Office announced that the EMD phase would be delayed for a year until early 2012. Requirements had still not stabilized as changes in protection level, weight and cost remained in flux. In September 2011, the entire program was in jeopardy as the Senate Defense Subcommittee recommended that the JLTV program be entirely terminated due to cost growth and unstable requirements. However, the program was reinstated shortly after in October.

TARDEC took the lead in a 9-month long Cost-Informed Trades Assessment. Many technologies were evaluated in an effort to reduce costs, but with a minimum loss in capabilities. As Schultz and Johnson [26] described, in some cases such as power generation, a lower cost trade was reasonable, but in other situations such as suspension, a trade was not reasonable.

Many of the advances used and demonstrated with the FTTS were successfully transitioned to the JLTV. Integrated armor on tactical vehicles that was demonstrated on the FTTS was transitioned. The protection level kept increasing over time as threats continually increased. When the Explosively Formed Penetrator (EFP) threat arose, additional force protection was needed. The Advanced Collaborative Environment, particularly Windchill, was used for the first time by a PM and was crucial to keeping all the players in alignment. It served as a dedicated resource managing tool, but also included firewalls to prevent the three prototype developers from learning the plans of their competitor [24].

Many of the technologies developed for FTTS ACTD did not transition to the JLTV either due to cost issues or "not-ready-for-prime-time" issues. The use of lightweight materials, such as for titanium mufflers, matured a great deal but was ruled out due to cost considerations; powertrain components, such as Integrated Starter Generators (ISG) and 6T Li ion batteries similarly did not transition [27]. But all of this work helped move the technologies forward for future use; for instance, the ISG is slated for use on future vehicles.

But possibly the largest difference between the FTTS and JLTV vehicles was the propulsion system. During the FTTS era, fuel prices were rapidly rising, and fuel economy was a major concern. This led to the choice of the hybrid-electric system for the FTTS utility variants. However, HEVEA and actual testing during the MUA suggested that fuel economy was not always better with the HE powertrain [24]. During this time period, TARDEC also developed a virtual method for measuring fuel economy [12]. A driving simulator was developed that could simulate the ride on different programmed courses while power consumption and fuel economy were measured [13]. Virtual JLTVs were "driven" by Soldiers using duty cycles that represented urban, convoy, and mountain patrol driving (Figure 3). Vehicle parameters such as suspension or payload could be varied to test the effect on fuel economy, even prior to prototypes being built [28]. TARDEC's simulator studies and HEVEA indicated that the duty cycle for military vehicles, often including long idling periods, did not offer sufficient improvements in fuel economy to justify their use. Based on virtual and real-life driving, the decision was made to use a conventional powertrain for the JLTV rather than the hybrid of the FTTS. In general, one of the successes of the FTTS was in demonstrating that M&S was predictive of actual testing results, which gave the JLTV team confidence in M&S going forward [17].

As requirements changed, TARDEC’s Advanced Concepts Team developed a series of evolving concepts to identify space and weight impacts of integrating technologies. As underbody protection was increased based on the IED threat, the vehicle became too heavy for CH-47 transport so the size had to be reduced. Trades had to be made between technologies and protection vs. weight and size resulting in a series of concepts based on shifting requirements as shown in Figure 4.

Three contracts were awarded in June 2012 for the EMD phase. Each vendor was to produce 22 prototypes in a 12-month period. This was followed by an aggressive 14-month test schedule that addressed program requirements in seven areas: Performance testing; transportability; command, control, communications, computers, intelligence and interoperability; reliability, availability and maintainability; ballistic coupon testing; system-level live fire; and limited user tests. Several sub-areas of testing were involved in each of the main areas; for instance performance testing included soft-soil mobility, side-slope traversing, braking, steering and handling, ride quality, fording, fuel consumption, top speed, acceleration, grades and slopes and more. The Product Manager for Test had to be diligent to reduce test creep to meet timing and cost objectives [29].

**Successes**

**Organization.** AN ACTD is defined succinctly on the Defense Acquisition University Website [30]:

*The advanced concept technology demonstration process was initiated to permit the early and inexpensive evaluation of mature advanced technology to meet the needs of the warfighter. The evaluation is accomplished by the warfighter to determine military utility before a commitment is made to proceed with formal acquisition. ACTDs also allow the warfighter to develop and refine operational concepts to take full advantage of the new capability.*

*An ACTD is sponsored and executed jointly by a team comprised of an operational user and a technology developer, with approval and oversight from the Deputy Under Secretary of Defense for Advanced Systems and Concepts (DUSD(AS&C)). The ACTDs are normally conducted under an Integrated Product Team approach that considers the operational needs, training, supportability, and other related issues, as well as concerns of the acquisition community.*

The collaborative approach between agencies is a hallmark of an ACTD and was instrumental to the success of the FTTS program. FTTS was jointly envisioned between CASCOM and TARDEC and provided the perfect example of the user community working together with the acquisition, logistics and technical communities to make a difference. An Integrated Concept Team (ICT) was formed as early as 2001 between TARDEC and the PM offices and the User community to define issues [31]. TARDEC translated the Combat Developer requirements into performance specifications, which were given to the M&S contractors for Phase I of the FTTS.

An ICT was also formed for the JLTV that included the Combat Developers (CASCOM and MCCDC), the Material Developer (JLTV JPO), S&T Developers (TARDEC and ONR) and a Testing authority (ATEC and MCOTEA) [32,33]. Requirements management took center stage pre Milestone B and was managed by the ICT. Questions would be raised by the ICT on the impact of various requirement trades and the S&T community would evaluate the effect of the trades on vehicle specification. Meetings were held with the Army Vice Chief of Staff and the Marines Assistant Commandant on a regular basis to make final decisions on requirements. Strategy for these meetings was developed with the Office of the Secretary of Defense.

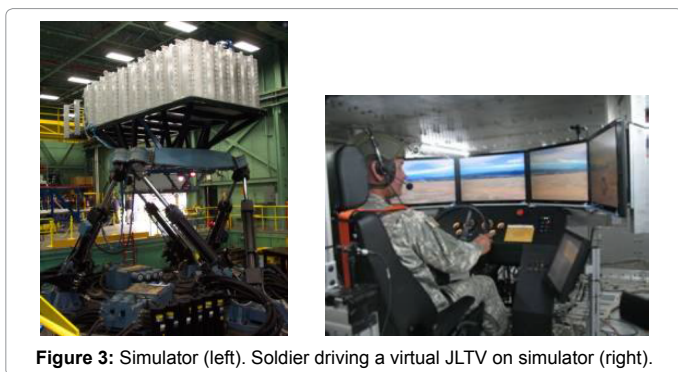
TARDEC worked closely with PM JLTV to provide R&D assistance wherever needed, both as employees embedded with the PM office or assisting through TARDEC. This support continued throughout the JLTV program. As an example, in FY14 TARDEC’s Chief Integration Engineer for the JLTV coordinated over 50 person-years and over \$9.7M of TARDEC engineering services and support to JPO JLTV [27].

**Funding and prototypes**

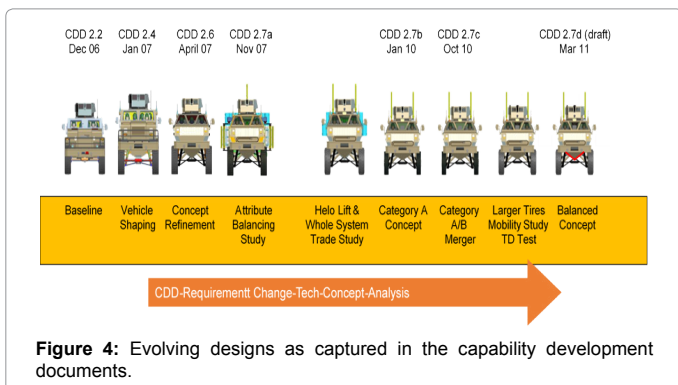
At the point when the FTTS ACTD was approved, it was left up to TARDEC to find funding for the project, including developing fieldable prototypes for evaluation. Initial FTTS funding came from TARDEC’s D440 program element line for pre-Milestone A system concepts, development and integration. In 2005, the D440 line was terminated when the funding was shifted over to FCS, a situation that remains today. Eventually necessary FTTS funds were assembled from OSD, ASA(ALT), and Congressional Adds. Total funding was about \$62M, which financed Phase I M&S awards to five vendors and the Phase II Demonstrator Build Phase with awards to 3 vendors.

Two FTTS ACTD Utility Variants and one Maneuver Sustainment Vehicle were built and successfully met the objectives of the Safety certification and subsequent Military Use Assessments at Ft. Lewis, WA. TARDEC found that it was indeed beneficial to build system level demonstrators in that lessons were learned that could prove out technology and compress the traditional vehicle development schedule [32]. Overall, the benefits from the relatively small \$62M FTTS ACTD investment were critical in demonstrating significant tactical vehicle performance increases and technology maturation/risk reduction for a major Joint Acquisition program.

As the JLTV program got underway, the Honorable John Young felt that many major programs were initiated without adequate



**Figure 3:** Simulator (left). Soldier driving a virtual JLTV on simulator (right).



**Figure 4:** Evolving designs as captured in the capability development documents.

understanding of the technical risk involved. Therefore, a competitive prototype directive was issued indicating that all new programs needed prototypes from at least two defense contractors to reduce risk, maximize performance, decrease costs and synchronize requirements [29]. The JLTV was the first program to be required to comply with this directive [2]. During the TD phase, contracts were issued to three vendors to build seven prototype vehicles each. During the EMD phase, contracts were awarded to three suppliers to produce 22 test vehicles each.

Copeland et al. [34] examined the effect of prototyping demonstration on weapon system developments to reduce technology risk and improve technology maturity. After analyzing 139 major defense acquisition programs, they concluded that prototype demonstrations have a profound positive outcome on weapon systems development performance.

Further, the following statements were made in support of the President's Budget [35]:

*Building prototypes early in the lifecycle of proposed systems gives the Army (and Soldiers) a better idea of what the system looks, feels, and performs like; affords an opportunity to try out innovative approaches prior to committing to a major PoR for a technology; and helps to drive down considerable program risk as we work through those unanticipated integration issues... The benefit of using prototypes can be illustrated by the Future Tactical Truck System (FTTS) S&T program which designed and developed three drivable prototype systems that emphasized the use of innovative technology and afforded Soldiers and the Army the ability to try out these technologies / capabilities before they finalized the requirements for the Joint Light Tactical Vehicle.*

### Change in industry

There is no doubt that the FTTS program changed the entire tactical truck supply chain [32]. Starting with Industry Day in 2002, both traditional and non-traditional bidders were brought into the discussion. Throughout the process, industry was provided data and information to update specifications or to look at requirements in a different way. Prior to FTTS, TARDEC tended to work with smaller firms, but FTTS gave TARDEC associates experience working with more traditional commercial automotive vendors with manufacturing capabilities.

In 2003, Navistar set up a Defense Division known as International Military and Government (IMG) and they were selected as a Phase I FTTS vendor in 2004. IMG got their start with FTTS and then went on to be a supplier for the MRAP program [32]. Lockheed Martin also felt that their capabilities had been greatly expanded through their experience with the FTTS ACTD program [3].

## Discussion

### Summary

In 2003 the Future Tactical Truck System (FTTS) Advanced Concept Technology Demonstration (ACTD) was initiated with TARDEC serving in the role of Technology Developer. Two utility variant prototypes were built as part of that program and were evaluated in a Military User Assessment in 2007. PM JLTV was stood up in 2006 and adopted technologies and personnel from the FTTS program. Many successful new processes were put in place for the JLTV to manage the extensive requirements, which carried over to other programs. Both the organizational construct and the use of

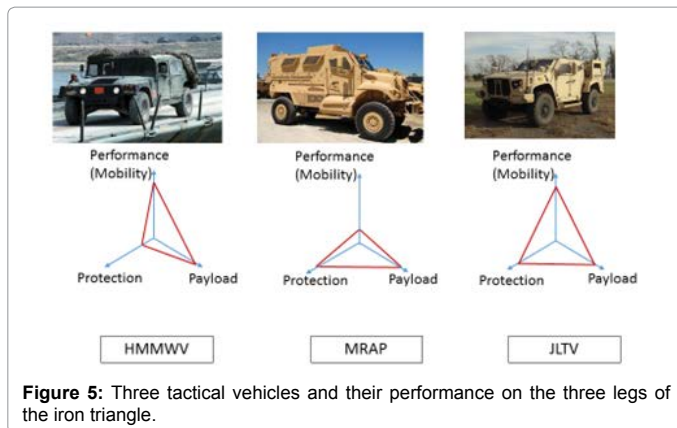
prototypes early on in the vehicle development cycle are considered key successes of the JLTV program.

The success of the JLTV program was due, in part, to the close collaboration of the PM with other groups including the OSD, TRADOC, and ASA(ALT) as well as their counterparts in the USMC. This paper documents the important role of R&D, in this case TARDEC, in the acquisition process. TARDEC's contributions included:

- Served as program and technical lead on the development of the FTTS
- Developed fieldable FTTS prototypes with new technologies such as integral armor and v-hulls that were tested by Soldiers during the MUA
- Demonstrated integrated technologies that informed requirements and reduced overall risk leading to JLTV [32]
- Helped mature technologies such as lightweight materials, hybrid electric powertrains, and batteries for later use
- Expanded and enhanced the tactical truck supply chain with non-traditional OEMs
- Transferred personnel and knowledge from TARDEC FTTS directly to PM JLTV
- Conducted Technology Maturity Assessment (TMA) and assigned TRLs
- Provided SMEs in areas of TMA, Technology Development Strategy, Data Management, Environment, Safety & Occupational Health, Intelligent systems, Modeling and Simulation, Materials, Mobility, CBRNE, Software, Survivability, Testing and Evaluation [21]
- Created HEVEA and virtual simulations to determine and standardize tactical vehicle fuel economy testing
- Provided an Advanced Collaborative Environment with Windchill and the CAVE
- Conducted several Whole System Trade Studies to provide answers to Combat Developers integrated requirements questions
- Developed an MOA with ONR to define scope of work to leverage each other's R&D investments
- Led a Cost-Informed Trades Assessment (CITA) to balance cost and performance
- Developed a series of concept vehicles balancing protection, weight, size and cost to provide JLTV Combat Developers independent assessments of their proposed requirements changes
- Demonstrated that M&S was predictive of actual testing results

During the FTTS and JLTV phases, the term "Iron Triangle" came into wide usage. The Iron Triangle represents the three desirable attributes of a military tactical vehicle: payload, protection, and performance (or mobility). The three tactical vehicles shown in Figure 5 perform differently on the three legs of the Iron Triangle. The basic HMMWV had good payload and mobility, but poor protection. The up-armored HMMWV had improved protection, but mobility and payload suffered, which led to the MRAP. The MRAP had excellent protection and payload, but poor mobility characteristics. Finally, the JLTV has the desired balance of protection, payload and mobility that the Army and Marine Corps wanted.





## Conclusion

This paper documents the benefits of having a significant R&D effort as the foundation for a successful acquisition program. In this case, prototypes were built in the R&D phase, which allowed high-risk items to be tested and technology readiness levels evaluated. This eventually led to realistic requirements for the JLTV and ultimately a successful acquisition program. In addition, the collaborative relationship between the technology, requirements and acquisition community allowed the differing objectives of each group to be navigated along the way.

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