Technology Transition — Lessons Learned From Fido®/PackBot®

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Albert Einstein once said that we can't solve problems by using the same kind of thinking that was used to create them. This article relates how new thinking was used to successfully address an urgent critical need to counter a major threat to our ground forces overseas.

Recently, the Defense Advanced Research Projects Agency (DARPA) awarded a 15-month, $10 million completion-type, cost-plus-fixed-fee contract to small business qualifier Boston Dynamics Inc. The company is building a dog-like robot with the capability to run fast, traverse rough terrain, jump over obstacles 40" tall or 2 meters wide, and operate for 2 hours without refueling. The priority application is a robot that could eventually accompany Soldiers in the field as a load-carrier across nearly any terrain. The prototype pictured here is dubbed BigDog and measures 40" long, 28" tall and weighs 165 pounds. The robot is powered by a gasoline engine driving a hydraulic actuation system. An on-board computer controls locomotion and handles a wide variety of sensors including joint position, joint force, ground contact, ground load, a laser gyroscope, a stereo vision system, as well as monitors for hydraulic pressure, oil temperature, engine temperature and battery charge. Once perfected, other sensors and capabilities like those discussed in this article could be programmed into the robot. (Photo courtesy of *Defense Industry Daily*.)

Yuma Proving Ground (YPG), AZ, was still hot and dusty the last week of October and first week of November 2005 — hovering around 100 degrees during the day. The Fido/PackBot team of Active Army Soldiers and Marines, government contractor scientists and engineers (S&Es), and a group of Reservists called in from the Arizona National Guard put a robotic dog through its paces during a rigorous test to see if it could find explosives in and under vehicles hidden there by YPG explosives experts. With its wide-view camera and unique explosives sensor located on its highly maneuverable and extendable arm, the robotic dog looked and sniffed under truck carriages, in car trunks and inside vehicles. When the faint whiff of an explosive was sensed, an unmistakable signal was sent to Soldiers in a van at a safe distance away who were operating Fido/PackBot through its Operator Control Unit, making note of detections and keeping score. After 2 long weeks of testing, the tired and dusty team and their robotic dog declared victory and concluded their experimentation and tests.

It was less than a year earlier that the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASAALT) Research and Laboratory Management Directorate conceived the idea of integrating Fido on a robotic platform. Fido's sniffer is based on an amplifying fluorescent polymer (AFP) whose high sensitivity to explosives was created by eminent scientist Dr. Tim Swager, affiliated with the Army's Institute for Soldier Nanotechnology (ISN) at the Massachusetts Institute of Technology (MIT). The detection technology associated with AFP was developed over several years at the ISN and by a small startup company, Nomadics Inc., through a congressional add-in collaboration with the Night Vision Laboratory (NVL) and commercialized as a hand-held explosives detector.

The U.S. Marine Corps (USMC) and NVL had also experimented earlier with putting Fido on a robotic system. So putting the detector on a robotic platform that could also see for remote detection of improvised explosive devices (IEDs) for operational use in theater looked like a no-brainer for the staffers who approached the Military Police (MP) at Fort Leonard Wood (FLW), MO, with the concept. As it turned out, this new capability was responsive (it actually provided much more capability) to an Operational Needs Statement (ONS) promulgated by the Maneuver Support Center at FLW for vehicle inspection at checkpoints. The MP user representative at FLW became an integral Fido/PackBot team member.

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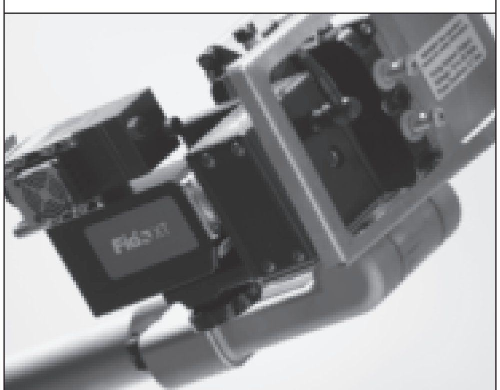
The newly formed Joint IED Defeat Task Force (JIEDDTF) in the Office of the Secretary of Defense was briefed on the concept at the Detect Sub-Integrated Process Team level, and funding was requested to conduct a concept demonstration. They liked the idea, especially the proposed 90-day delivery schedule of producing 10 integrated systems in theater, including testing at YPG with training manuals and videos as well as a safety release for each system. Potential robotic platforms were assessed in a single half-day session involving a group comprised of customer, user and stakeholder representatives from diverse organizations. iRobot's® PackBot was selected for its ruggedness, versatility, reliability, availability and requirements fulfillment as expressed in the ONS. Along with contractors Nomadics Inc. and iRobot, the platform decision also brought new team members from the acquisition community — the Robotic Systems Joint Project Office (RSJPO) in Huntsville, AL; a representative from DOD's Joint Robotics Office; and the U.S. Army Research, Development and Engineering Command NVL. The 90-day clock would start ticking the day the Army received JIEDDTF funding, which arrived in early July 2005.



The Fido XT provides a wide-view camera and an explosives sensor on its highly maneuverable and extendable arm. It is ideal for "sniffing" out explosives from under vehicle chassis, car trunks and inside vehicles. Soldiers can operate the device from a safe distance. (U.S. Army photo.)

The Prototype Integration Facility (PIF) at Redstone Arsenal, AL, was selected by the Deputy Assistant Secretary for Research and Technology to manage the program. The PIF, through careful analysis based upon extensive experience with comparable efforts, developed the rationale and delineated the key assumptions associated with the ambitious 90-day schedule. An Executive Steering Board (ESB) was formed with the ASAALT

Research and Laboratory Management Director as Chair and lead spokesperson for the effort. The ESB was comprised of team members and included stakeholders from other organizations such as JIEDDTF, Rapid Equipping Force, U.S. Army Test and Evaluation Command (ATEC), Navy Explosive Ordnance Disposal, Army Research Laboratory and the Technical Support Working Group.

A Fido/PackBot proposal for a concept demonstration, reviewed by the full ESB, was briefed up the JIEDDTF chain, approved and funded. Per JIEDDTF direction, ATEC conducted a survey with troops in theater after the initial prototype systems were deployed and operated in theater for several months. A team of government explosives experts and Army S&Es collaborated with ATEC in preparing the original YPG test program and the theater survey to assess its operational effectiveness. Based upon these experiences, it is clear that much mutual benefit can be derived from more direct collaborations between ATEC and Army S&Es.

But the idea of a robotic dog remotely sensing IEDs turned out to be a much greater challenge than the originally expected no-brainer. Staying within both the 90-day schedule and cost became a formidable challenge. The cost estimate turned out to be off by a factor of two, so only half of the original 10 prototype units were eventually produced, tested and fielded. Completed prototypes sent to theater were inadvertently misdirected by the commercial shipper, traveling a circuitous route from the U.S. to South America and Europe before finally arriving in the Middle East.

Once in theater, several unexpected operational issues with the integrated system emerged that had not been experienced in prior successful testing at YPG and subsequent demonstrations at FLW. Contractor engineers were eventually sent in theater to support the Joint Robotics Repair Facility by identifying and solving Fido/PackBot technical issues amidst an escalating war and many other robots waiting for repair. At the same time, a red team of S&Es from various Army laboratories was quickly formed in the U.S. to augment and interact with the engineers in theater working to solve the operational Fido/PackBot issues. Costs increased because of these technical problems and underestimates of actual YPG testing costs, thus reducing the number of prototype systems procured for theater from 10 to 5.

Within a few weeks, however, all Fido/PackBot technical solutions were identified and repairs made. Throughout this period, the ESB continued to meet regularly, providing the team with guidance and support. Regular briefings to JIEDDTF also provided useful suggestions in advancing the effort's goals and objectives as well as troubleshooting. Positive feedback regarding the robotic dog's capability was received from theater through anecdotal e-mails and the official ATEC operational survey, which included urgent requests for additional systems. All of this created a ground swell of support for the system and the approach taken in managing this complex fast-moving effort.

PackBots have been deployed to Iraq and Afghanistan to support Soldiers fighting the global war on terrorism. Here, a 184th Explosive Ordnance Disposal Detachment technician prepares to launch a PackBot against a suspected IED in Baghdad, Iraq, May 18, 2007. (U.S. Army photo by SPC Jonathan Montgomery.)

Joint IED Defeat Organization (JIEDDO)

In the meantime, the JIEDDTF was reestablished by the Deputy Secretary of Defense (DEPSECDEF) as the JIEDDO and governed by an entirely new set of people who had never heard of Fido/PackBot. To proceed to a larger procurement required going back up the JIEDDO chain starting at the bottom and, because this second funding request exceeded $25 million, required final DEPSECDEF approval.

Within 2 months, approval for the additional buy was received and FY07 funding provided to procure systems for the MP and USMC in theater and for training centers in the U.S. and abroad. After satisfying the requirements for the initial planned fielding of Fido/PackBot to units in theater, the RSJPO returned 25 percent of the money that was provided by JIEDDO for this project. This was a result of creative negotiation by RSJPO with the suppliers for spare parts for the units ordered. Delivery to theater of all the units procured was made by the end of July and are being deployed incrementally. Execution of this phase of the Fido/PackBot program has transitioned from the PIF to the RSJPO with ASAALT and ESB leadership and management remaining the same. The PIF remains an integral Fido/PackBot team member and a key technical advisor.

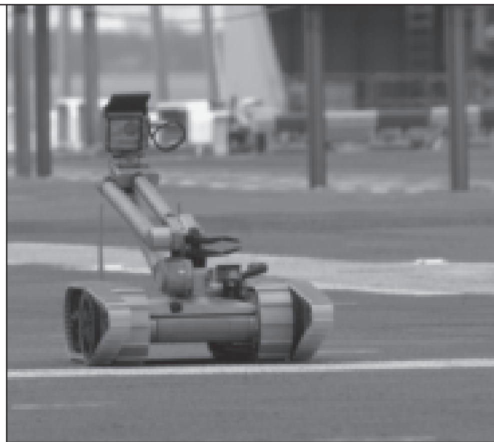
Historical Example

An interesting pertinent historical example of technology transition is the introduction of interchangeable parts in manufacturing by Thomas Jefferson, a capability that today we take for granted. In 1785, while Ambassador to France, Jefferson met Honore Blanc, a French mechanic who was building muskets using handcrafted parts of such precision that they could be interchanged. Unable to persuade Blanc to move to America to demonstrate his techniques, Jefferson influenced inventors and musket producers such as Eli Whitney and Roswell Lee to incorporate the innovation. Both tried but failed because of cost and schedule overruns.

Approximately 25 years later, in 1826, John Hall — who headed the Harper's Ferry Armory — built the first rifles from interchangeable parts. Eight years later a private contractor was able to use the methods, tools and technologies developed by Hall to produce parts in his factory that could also be used interchangeably with those manufactured by Hall. Now, parts from multiple sources could be used to assemble rifles and for field repair of any rifle manufactured at any location. For a more complete discussion, go to: **http://www.virtualschool.edu/cox/pub/PSIR/PSIRResponse.html**.

The challenges Jefferson faced have counterparts in the Fido/PackBot fielding experience. The major lessons learned for successful transition that parallel Jefferson's interchangeable parts transition experience are:

- Effort supported by a very high-level executive for introduction of the innovation despite lack of measurable results on which to base judgment on operational effectiveness.
- Promoted by respected, well-connected technologists even though the idea had not been successfully demonstrated operationally yet.
- Determined and highly motivated "change agents" work together over a considerable time period, falling short of the goal of adoption.
- Major effort is undertaken to promote the innovation, combining all circumstances to achieve success.
- Replication of the success by someone else demonstrates to all concerned that the innovation is not a fluke.
- A "champion" pushes for adoption once success has been established.



A PackBot remote-controlled robot from the U.S. Navy (USN) Explosive Ordnance Mobile Unit 2 is put through its paces during an IED drill aboard the Wasp Class Amphibious Assault Ship USS Bataan (LHD 5). (USN photo by MC2 Elizabeth R. Allen.)

Additionally, there were some lessons learned such as:

- A user agrees to the technology insertion to meet a yet-to-be-defined requirement.
- In early stages of transition, technologists are in the lead with the fielding organization in a subordinate role and customers/users as integral team members.
- The fielding organization takes lead role (still with same team) after innovation has been successfully tested, demonstrated in operation and acquisition funds for a major buy identified.
- Technologists continue to assist to ensure that any technical issues are resolved expeditiously.
- Technical requirements must remain stable throughout; otherwise additional costs and risks are incurred.
- Getting the problem properly formulated and exercising informed judgment to understand uncertainties is very important.
- Imagination is needed to deal with the unpredictable, which the transition process is often fraught with.

The outstanding success of Fido/PackBot fielding earned the project one of the U.S. Army Awards for the Top 10 Inventions of 2006 as well as a 2007 Army Research and Development Award. These accomplishments should be attributed to the people involved in the program. They are an extraordinarily talented group of experts who believed in the concept from the beginning, even in the presence of possible failure, and were determined to make it work in an expeditious manner. There was no preplanned process outlined on how to do it, no regulation to follow. But together, as an enthusiastic and highly dedicated team, they accomplished an extraordinary transition from concept to fielding in very short time. Transition of technology, therefore, is really all about strong dynamic leadership, people, passion, conviction, tenacity, knowledge, informed judgment and imagination.

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