Tactical Utility of Tailored Systems

Robert E. Smith, PhD

We have to avoid million-dollar solutions to hundred dollar problems. That doesn't put us at any advantage. That puts us at an economic disadvantage at the strategic level.

—Gen. David G. Perkins,
TRADOC commanding general

The Army has traditionally been equipped to confront what is expected, but winning in today's complex world requires being prepared to fight an unknown enemy. Future enemies will have access to off-the-shelf technologies that previously only large nation-states could afford. Meanwhile, large nation-states are able to duplicate or steal U.S. high-technology investments at a fraction of the research cost. For example, China rapidly duplicates Defense Advanced Research Projects Agency (DARPA) and other U.S. innovations, often improving on designs. One can find evidence of such activities in replicas of the Big Dog robot and the Switchblade tube-launched drones.[1] No longer can the U.S. spend billions to develop the next stealth technology and expect a twenty-year payoff; the return on investment is likely not there.

This article explores the idea of combining virtual environments and rapid manufacturing to create tailored materiel specific to a region or even a battle. The Army needs a powerful innovation process to tilt the cost-effectiveness calculation back in the favor of the United States and drastically increase the rate of materiel innovation.

In the 1970s, the United States chose to offset the Union of Soviet Socialist Republic's superior numbers using technological differentiation (developing weapons with superior capabilities). This led to the development of the Abrams tank and Bradley fighting vehicle (along with precision munitions and stealth technology). However, while the world changed over the years, those vehicles were still expected to perform interchangeably anywhere they were required.

Notwithstanding the changed world, equipment still must provide maximum capabilities for the warfighters. However, the multiplicity of missions that have emerged has led to the development of over-specified *exquisite* systems that require extraordinary (and expensive) technology leaps. The recently canceled Ground Combat Vehicle (GCV) Program provides an excellent example of an exquisite system. GCV requirements included a three-man crew, nine dismounts, and high protection and lethality levels—all bundled into an individual platform. The result was a tactically repulsive 75- to 85-ton vehicle that would have required exotic technology leaps to become useful.

In contrast to exquisite systems, tailored systems focus on specific functions, specific geographic areas, or even specific fights. The narrow focus allows achievement of high performance without the needless development of exotic and expensive technologies that aim to satisfy too many requirements.

The wide range of potential operating environments the Army may encounter requires vehicles with correspondingly different capabilities. For example, a vehicle solution for a megacity may require a small size, much like those driven by the local population. On the other hand, a swamp- or amphibious-entry vehicle may need a screw propulsion system, and a desert environment may require yet a different type of solution. Modularity of components may be possible across these platforms, but the hull structure would likely have to be custom made.

Since the U.S. Army is increasingly becoming a CONUS-based expeditionary force, wherever we

(Photo courtesy of Textron AirLand, LLC)

A Textron AirLand Armored Scorpion ISR-Strike aircraft flies in November 2014. Conceived as a close air support (CAS) aircraft for a low-threat air defense environment, the Scorpion was built from off-the-shelf components in twenty-three months, from concept to first flight, for about $20 million. Its operating cost is about $3,000, compared to about $18,000 for an F-16 performing the same CAS mission.

deploy, the regional actors will already have home-field advantage, including equipment attuned to the operating environment. For example, the South Korean K1 tank is similar to the U.S. M1 tank except that it has a hydropneumatic suspension, which increases the available gun elevation and depression angles. The increased angles provide a greater vertical firing range, an important advantage in Korea's dense urban areas and surrounding mountainous terrain. The United States needs such tailored materiel to attain an affordable capability overmatch of enemy systems by default.

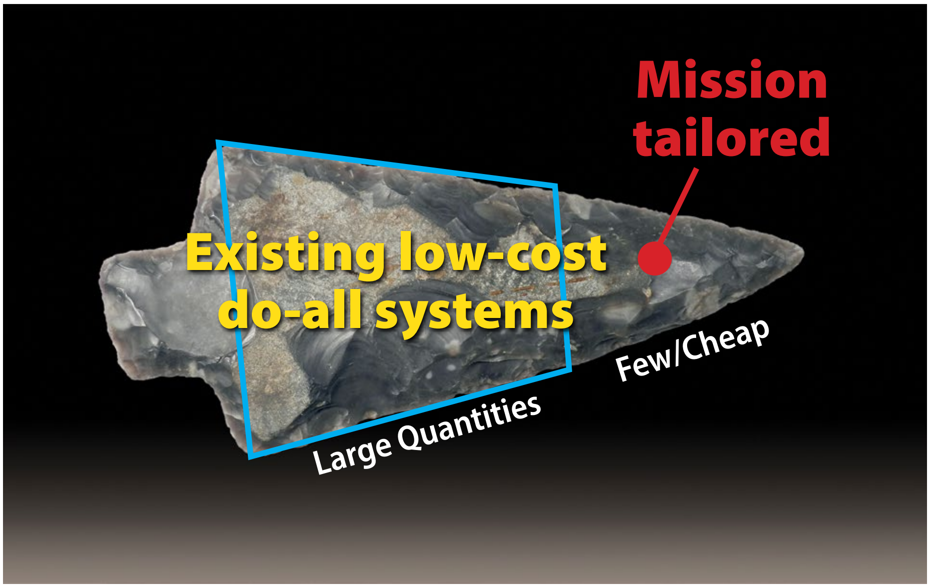
In place of the current one-size-fits-all acquisition approach, since platforms fight in formations, the tip of the future spear (see figure 1, page 110) could be inexpensively "sharpened" by fielding a small quantity of highly tailored systems that perform a limited mission set extremely well. It is also possible that small quantities of regionally tailored equipment could be designed and fielded.

Such a process, capable of rapidly producing tailored and adaptable solutions, would be hard for our enemies to duplicate since it requires a large organization and capital investment. It would create an asymmetric advantage for our forces that most of our adversaries would not be able to counter easily.

Ideally, rapid manufacturing could create a procurement system that produces custom materiel at a cost low enough to make equipment disposable. Further cost savings might be realized by upgrading existing Army assets such as high mobility multipurpose wheeled vehicles (HMMWV) operating at protection levels unsuitable for manned missions with autonomy kits that enable the platform to function robotically without a human operator in the vehicle. Such newly autonomous systems could perform both mundane and dangerous missions.

A further advantage of tailored systems is that they will force the enemy to deal with a variety of unknown U.S. assets, perhaps seen for the first time. Since protection and lethality will be unknown to the enemy, it will be asymmetrically challenging for them to develop in a timely fashion tactics, techniques, and procedures, or materiel, to effectively counter such new capabilities.

For over a decade, the Army has touted modularity as a panacea to achieve system tailoring and flexibility. However, experience has shown that any time something is modularized, it adds some sort of interface burden or complexity. In contrast, a specific-built system will always outperform a modular system for this reason. The disadvantage to a specific-built system is it lacks an inherent adaptive capacity and means for dealing with unknowns. An optimal solution will likely be a combination of modularity and tailoring.



(Graphic by Robert E. Smith, PhD)

Figure 1. How Mission or Regionally Tailored Systems Outperform "Do-all" Exquisite Systems at Lower Cost

Real-World Tailored System Examples

Excellent historic examples of tailored systems were those developed for the amphibious assault phase of the Normandy D-Day invasion during World War II.[2] The failed Allied raid at Dieppe in August 1942 showed how difficult it was to land vehicles and men during an amphibious invasion.[3] One key lesson learned from Dieppe was that specialized armor was needed to get across soft sand and through beach obstacles. British Maj. Gen. Sir Percy Cleghorn Stanley Hobart was responsible for the development of specialized armored fighting vehicles ("Hobart's Funnies") to counter those obstacles. Applying lessons learned from the Dieppe experience, he developed equipment and tactics that not only improved on existing designs, but also created entirely new technologies. These unusual vehicles were key enablers that allowed the Allied forces to break through German coastal defenses to effect a successful landing.

A more recent example is the Scorpion light attack jet.[4] Textron AirLand unveiled the Scorpion at the 2013 Air Force Association's Air & Space Conference. The Scorpion cost about $20 million each. It was built from off-the-shelf components and went from concept to first flight in twenty-three months. Compare this to the exquisite F-35 Lightning, which hit the drawing board in the early 1990s and cost about $157 million per copy. Granted, the Scorpion and F-35 are not an apples-to-apples comparison, but comparison of the two still bounds the problem.

Bill Anderson, president of Textron AirLand, offered a closer comparison by pointing out that the United States is currently using its F-16 superjet on low-end missions in Afghanistan.[5] "There's no air-to-air threat there. They are spending $18,000 an hour running the F-16. You're burning the life of the aircraft on missions it was not designed for," said Anderson.[6] In contrast, Textron is targeting a Scorpion's operating cost at $3,000 per hour.

Enablers

Though tailoring systems offers many advantages, new challenges are created when there is a hugely varied fleet of tailored systems, especially for logistics, training, and maintenance. Capt. Eric Elsmo provides an example of deploying a tailored, modular system:

> A tank, or any other form of modular equipment that is not part of the first wave of combat force, would not necessarily be standard

equipment for a deploying unit. In the Army After Next, modular equipment could be created specifically for the contingency and be assembled during transit. The chassis may come from one location, while the turret may be sent from another, with the two marrying up in the theater of operations. The new piece of armor then would be employed during the logistics pulse or refit phase of the operation.[7]

(Photo by Sgt. J. Mapham, War Office official photographer, Imperial War Museum [H 37859])

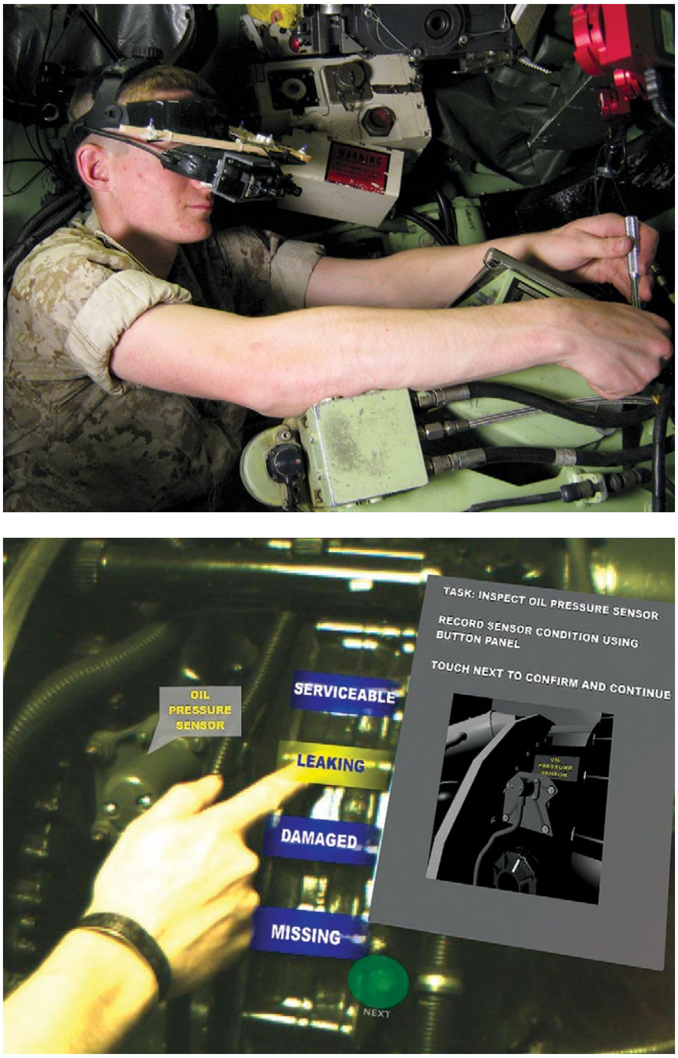
Churchill Armoured Vehicle Royal Engineers (AVRE) Type C mark II "Bobbin" carpetlayer tests laying tracks for armored vehicles to follow across soft beaches in preparation for the Normandy "D-Day" landings that would take place 6 June 1944. This vehicle was one of several tailored solutions to ensure invading armor did not get mired in sand that were developed under the personal direction of British Maj. Gen. Sir Percy Cleghorn Stanley Hobart.

Maintenance and replacement parts. Regarding maintenance, one key is to develop a well-tracked digital manufacturing database of replacement parts. With the advent of 3-D printing and digital manufacturing, a new part may be procured as easily as scanning a bar code and pressing print. The notion of forward manufacturing is not entirely new to the Army. The U.S. Army Tank Automotive Research, Development and Engineering Center had fielded a mobile-parts hospital in the past, the automotive equivalent to the mobile army surgical hospital unit.[8] The Army's Rapid Equipping Force began fielding expeditionary lab mobile units in 2013, which include 3-D printers, computer-assisted milling machines, and laser, plasma, and water cutters, along with common tools like saws and welding gear.[9] The industry is fast approaching a point where even static structures such as buildings may be 3-D printed.[10]

Augmented reality for maintenance and repair. Currently, to do their jobs, mechanics rely on experience with equipment, thick manuals, and rote memorization of many of the maintenance procedures. With new forward manufacturing capabilities, augmented reality goggles can provide mechanics with systematic instructions on how to repair equipment and what tools to use while they perform maintenance procedures.[11]

Training reduction. In order to offset training, imagine a future soldier gets into a vehicle and inserts his or her common access card. First, the seat automatically adjusts. Next, a driving display populates with the soldier's custom widgets, similar to a smartphone display. The display also only lists available weapons on which the soldier has qualified. The displays might also help soldiers understand vehicle performance envelopes. For example, a line might be displayed over the terrain showing how sharp a soldier might turn without a rollover. All this functionality could follow a soldier, no matter what vehicle he or she climbs into, negating a large training requirement.

Early synthetic prototyping. The Army Capabilities Integration Center's Early Synthetic Prototyping (ESP) initiative offers a viable methodology to determine what combination of tactics and materiel is optimal over various scenarios.[12] ESP enables thousands of soldiers to tailor tactics, strategies, force structures, and materiel to try to minimize cost while maximizing mission effectiveness. In this way, ESP may have the potential to harness the free flow of ideas among technologists, program offices, and soldiers to identify and assess concepts early in the design phase at a time when costs are low.



(Photo by Steve Henderson, Computer Graphics and User Interface Lab, Columbia University)

Top: While wearing a tracked, head-worn display, Augmented Reality for Maintenance and Repair (ARMAR) guides a mechanic to complete a maintenance task inside an LAV-25A1 armored personnel carrier. **Bottom:** A user manipulates 3-D virtual buttons while receiving haptic feedback from the underlying grooves of an engine compression section.

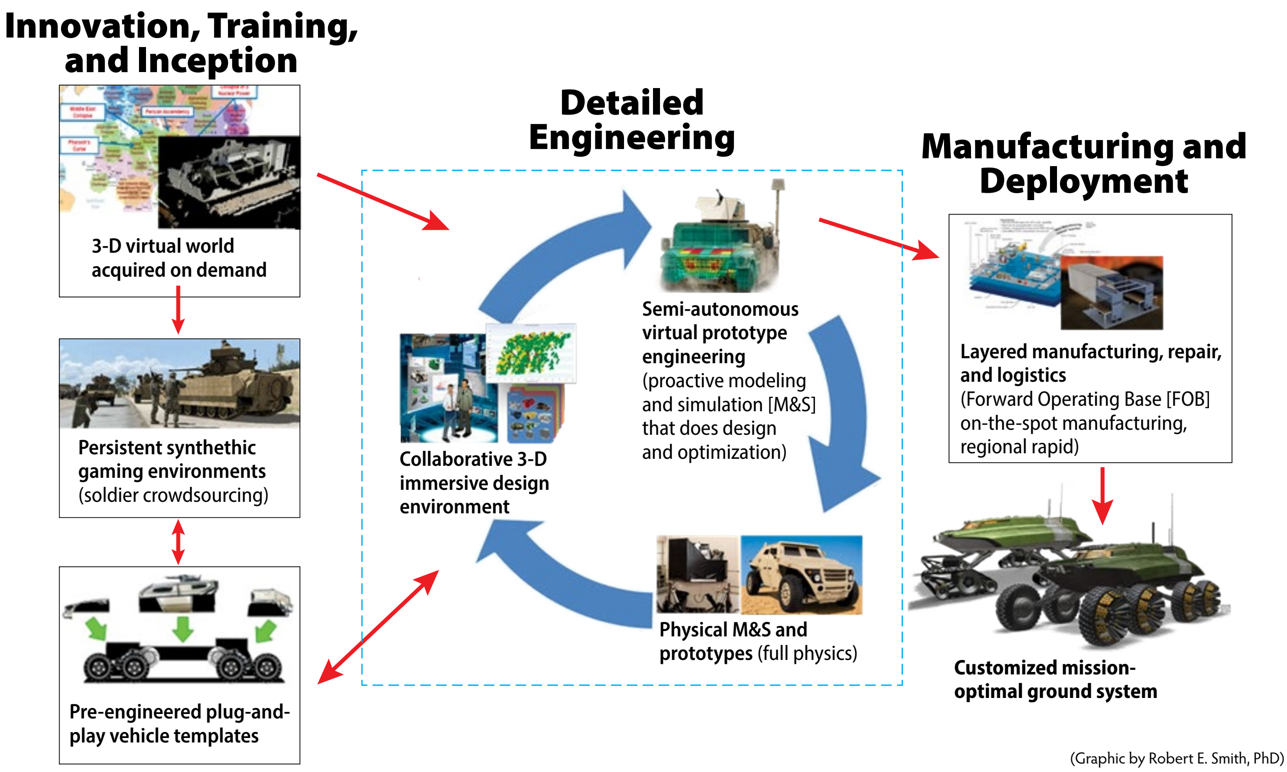
Gaming Is Part of the Process

Gaming is not new to the Army. What is unique about ESP is the idea of launching an ongoing experiment and gaining access to thousands of soldiers' experience and brainpower. ESP players could be anyone from a private fresh out of basic training to a thirty-year veteran with extensive combat experience. Given the dire need of the United States to infuse innovation into its procurement processes and agile responses into acquisitions, the ESP process may lead to a new "revolution in military affairs."[13] The 9/11 Commission Report stated, "Imagination is not a gift usually associated with bureaucracies.… It is therefore crucial to find a way of routinizing, even bureaucratizing the exercise of imagination."[14]

Figure 2 shows a notional future process that uses virtual war-gaming with rapid manufacturing to tailor systems and force structures.[15] The entry point into the process starts with ESP (left center) which allows thousands of soldiers to "kick the tires" of capabilities.[16] Soldiers will pool their collective expertise to codesign vehicles with engineers while simultaneously optimizing the best doctrine including force structure. In this way, soldiers will be able to modify vehicles in this synthetic world before any metal is bent, and they can see how their modifications stack up against realistic mission objectives. Potentially, even real-time scenarios will be rehearsed by using unmanned aerial vehicles and satellites to instantaneously create geo-specific environments as shown in the upper left of figure 2.

In order to avoid overwhelming the users with choices from the infinite combination of vehicle technologies and vehicle templates, capability modules will evolve within the gaming environments as shown at the lower left of figure 2. Among such, vehicle templates are preferred configurations of modules and technology that the "crowd" of soldier-gamers conclude provide robust mission effectiveness. The templates will adapt over time as users share among themselves and piggyback on the best ideas.

The gaming environment will help inform trade space exploration by producing a new *tactical utility* metric, which will measure statistical battlefield effectiveness of various engineering solutions over multiple vignettes. Allowing soldiers to test-drive virtual systems in various operations will enable program managers to compare system versatility and tactical utility against cost, schedule, and risk.



(Graphic by Robert E. Smith, PhD)

Figure 2. Ground Systems SE/2025 Systems Engineering Process

Technology Readiness for 3-D Printing Vehicles

The development of the first crowdsourced military vehicle—the Fypmode by DARPA and Local Motors—gives a glimpse of the potential for SE2025.[17] Jay Rogers, founder of Local Motors, points out conflicts are won not by spending large quantities of time and billions of dollars, but "they win it because they figured out what was going to beat the enemy, and they built that."[18] Rogers adds, "Maybe we did not do the same development that [the contractor] did, to make sure the strut on the vehicle lasts a million miles. But if it saves a life, and it lasts for a whole conflict, haven't we done a better thing?"

President Barack Obama was shown the Fypmode vehicle, which only took four months to produce, and enthusiastically pointed out—

> Not only could this change the way the government uses your tax dollars—think about it, instead of having a ten-year lead time to develop a piece of equipment, if we were able to collapse the pace of which that manufacturing takes place, that would save taxpayers billions of dollars—but it also could get technology out to the theater faster, which could save lives.[19]

The newest developments in 3-D printed vehicles debuted at the 2015 International Auto Show in Detroit, Michigan. Oak Ridge National Laboratories and Local Motors collaborated to print a Cobra replica and the Strati, respectively.[20] Since Rogers claims the carbon-fiber-reinforced material has ballistic properties, the next logical step would be for DARPA to invest in a project to see if 3-D–printed armored ground vehicles can be produced to withstand ballistic and underbody threats. It may be possible to embed armor tiles and plates into the body, build compartments to fill with expedient material such as sand, or provide other innovations. The largest drawback currently to 3-D printing technology is that it is difficult to ensure part quality because every machine and process produces parts at a different standard of precision. However, this should not be an insurmountable challenge.

Conclusion

Winning in a complex world requires a new research, development, and acquisition process to boost the rate of innovation while simultaneously reducing cost. Tailored systems might provide such a capability at a much lower cost by allowing specialized design for regions or possibly for individual battles. Additional utility is gained by making maximum use of modularity to allow systems to adapt. The very nature of this type of vehicle requires an agile systems-engineering and manufacturing process that anticipates many scenarios in advance.

(Photo by Pete Souza, www.whitehouse.gov)

President Barack Obama and Vice President Joe Biden view a 3-D–printed carbon-fiber Shelby Cobra car during a tour of Techmer Polymer Modifiers in Clinton, Tennessee, 9 January 2015.

Using persistent synthetic gaming environments helps achieve this in a cost-effective manner while concurrently considering both tactics and technology. Investment in a new process as described in this article can provide a better return on taxpayer dollars than investing in raw technology. ■

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Biography

Dr. Robert E. Smith is a research engineer in the U.S. Army Tank Automotive Research, Development and Engineering Center's computer-aided engineering group, Analytics. He holds a PhD in mechanical engineering from Michigan Technological University. His research work includes machine-learning, data mining of behavior patterns, systems engineering, and computational fluids. Smith has worked for Ford Motor Company, Whirlpool Corporation, and General Dynamics Land Systems.

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(Photo courtesy of Wikipedia)

The Local Motors' Strati is the world's first 3-D–printed electric car, shown here 20 September 2014. The Strati takes much less time to print and has a rougher finish.

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