2010 NDIA GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM
MODELING & SIMULATION, TESTING AND VALIDATION (MSTV) MINI-SYMPOSIUM
AUGUST 17-19 DEARBORN, MICHIGAN

BASIC TRAINING FOR ROBOTS: A DIFFERENT PERSPECTIVE AT DESIGNING ROBOTS FOR MILITARY APPLICATIONS

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ABSTRACT

Designing robots for military applications requires a greater understanding between the engineer and the Soldier. Soldier considerations result from experiences not common to the engineer in the lab and, when understood, can minimize the design time and provide a more capable product that is more readily deployed into the unit.

INTRODUCTION

The science, technology and engineering community is postured to make rapid advances in the field of robotics. One of the areas of opportunity is with military applications and operations. While many tasks within military operations overlap with commercial and civilian tasks, certain functions lend themselves more toward the military because of their inherent military nature.

As suggested in the title of this paper, certain considerations must be taken into account when designing robots for military applications. This paper is intended to identify and encourage an improved understanding in the science, technology and engineering community of military operations and possible applications for robotics in this field.

Clarifying Unmanned

Before addressing concerns regarding military operations, it is necessary to define for the context of this paper, a few key terms. The first term to define is unmanned.

Contrary to what it would seem, an unmanned system may or may not have humans included in its operations. The term more appropriately reflects that there is no person located on the vehicle or sensor when in operation. Human operators in this case are removed from the vehicle/sensor by means of tele-operations such as wire, radio or preprogrammed control. It is also important to identify that unmanned systems may either decrease or increase the personnel requirement to conduct operations. This is based on the maintenance required, supervision, or complexity of the device. The personnel requirement of unmanned systems must be included in the analysis prior to the design phase because increasing personnel requirements, even if they are out of direct harm's way, may be counterproductive in the long run.

Tasks and Functions

A Soldier has both internal and external factors working on them. In this paper, the term 'tasks' will be solely defined as an external requirement imposed upon the Soldier or system. Meanwhile the term 'functions' will be used to describe the capabilities or actions taken internally by the Soldier or system.

Redefining Autonomy

The next term requiring clarification is autonomy/autonomous. One definition of autonomous is "not subject to control from outside".[1] It is of critical importance at this point to clearly emphasize that the United States military does not make it a practice of allowing individuals to act without being part of the overall team mission. This implies that there is always an 'outside', usually in the form of a higher commander, providing command and control or at a minimum, rules of engagement within which the Soldier operates. According to this definition, there can never be complete autonomy within a structured military. This even applies to Soldiers.

Additionally, every Soldier is assigned a battle buddy whom they can rely on for security, assistance and accountability if needed. In terms of a network, all Soldiers are nodes that perform individual functions, but usually as a part of the system. Yet, their value is greatly increased when combined with others.

However, other definitions of autonomous include "Not controlled by others" and "Self-governing with respect to local or internal affairs".[2] These definitions can apply to both robotic systems and Soldiers. The first definition applies if we assume the definition of 'controlled' is 'physically manipulated'. The Army refers to both command and control, but with extremely different definitions than the technology field. For the Army, the term command and control (C2) is the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of a mission. Commanders perform command and control functions through a command and control system. [2] In this definition, 'systems' is used to describe a process that commanders use.

The second definition of autonomy creates a very interesting perspective with regards to both robotics and Soldiers with the phrase 'respect to local or internal'. This is essential since both 'local' and 'internal' apply to the operational environment that both Soldiers and robots operate. The operational environment will be addressed later in this paper.

A slightly different perspective of autonomy may be more comprehensive by defining it as how much flexibility is provided to/by the node (either Solder or system). Flexibility has two major subcomponents – external and internal.

The first component, external, is comprised of conditions imposed upon the Soldier or robot. These conditions are commander's guidance and the local environment. The second subcomponent is a result of the node's capability. In the context of Soldiers, their capability is their preparedness, directly related to their training, thought processes, equipment, experience and many other factors. With robots, their internal flexibility is a direct result of the design of the system and the programming emplaced upon creation. Unfortunately with robots, increased flexibility usually has increased complexity which can be both unnecessary and costly.

As discussed above, autonomy may be more effectively defined as a combination of the external inputs (commander's guidance, environment) and the internal capabilities of the Soldier or robot.

All three factors combined serve as a guide for a Soldier to execute their functions. For example, a Soldier that is ordered to cross a river has been provided the initial factor – commander's guidance. The next step is to assess the environment. This requires telemetry on the Soldier's part to adequately understand the environment. There is a large variation between frozen or warm, fast or slow-moving, even depth and width of the river may come into play. Additionally, the recognition of a bridge nearby may enable success of the mission without unnecessarily increasing the risk and complexity of task.

The final factor in determining the autonomy of the Soldier is assessing their capabilities. If the Soldier cannot swim or does not know how to operate a boat, then their flexibility is reduced. And if their flexibility is reduced, they lose some autonomy since they no longer can 'self-govern' and require external assistance.

These same factors can be applied to robots and are essential when designing and defining the level of autonomy of a system.

Autonomy Versus "Independent" Operations

Even though Soldiers are completely immersed as members of a team, they must perform individual functions, sometimes independently, to ensure success. As an example, the delivery of artillery rounds onto a target requires the teamwork of generally three components. These components are the observer, fire direction center and the gun crew. Outward appearance may present the forward observer as acting autonomously. But those actions are still executed within the commander's guidance, Soldier's capability (from training) and as applicable within environmental constraints. As only one node in the system, the forward observer is required to perform their specific tasks in support of the overall mission.

For purposes of this paper, independent operations will be broken down into a three step process. The three steps required are: 1) receiving initial command guidance, 2) executing functions to complete tasks without required further command input, and 3) reporting completion of required tasks.

The final step, reporting, is essential for independent operations. This feedback enables the force to continue with missions by providing information to either validate or negate assumptions made about the current situation. At a minimum, feedback provides a starting point to develop alternate courses of action.

PERSPECTIVES OF TECHNOLOGY

There are many perspectives and viewpoints on technology's role and usefulness within the military. However, there are three predominant communities that deal almost expressly with this topic. These communities can be broken down into Entertainment, Engineering and the Military.

Entertainment's Perspective and Influence

It's very easy to see robots today. Robots are everywhere in popular culture and have been imagined to do everything possible. Print media, television, movies and video games are filled with autonomous robots that perform myriad functions. Recent movies and video games depict robots that fight, drive, fly, navigate, target, engage and destroy, and possess a sentience that is sometimes equal or greater to humans.

These robots, though cleverly created and designed for believability, are primarily images that bring to life the artists' imagination. And in many of these cases, the imagination is only loosely based on current technologies.

Robot armies that fight wars are nothing new to the entertainment industry. And these images, intentionally or not, shape perceptions and expectations of military robotic capabilities.

These military robots are born deep within the science fiction realm. They capture the imagination of countless viewers and spur many to pursue their development and creation. And this may be the maximum extent of their contributions to the real world robotics industry.

Regardless of how well researched, planned, imagined, discussed or even war-gamed, these robots remain mostly imagination and images that never are realized in the physical world.

Out of the Laboratory

The next community is the science, technology and engineering community. It is from this group that real robots are made. They are the physical constructions that perform functions and actions for which they are designed. These robots are a physical manifestation of knowledge and application of the scientific rules and laws which govern nature.

The building blocks for these robots primarily arise from the physical sciences that mankind has discovered. Electronics, hydraulics, processing, stress and strain are all factors that build from the bottom up. Unlike their entertainment counterparts, engineers start with facts (and sometimes theories) and build from there.

However, designing robots solely from this background of what can be done may induce risks of delivering robots that don't perform what needs to be done.

There is a hazy area inherent in the creation of robots that requires a transfer of understanding from the user/employer to the engineer. In the case of military applications, the users are the Soldiers.

It is of critical importance to synchronize efforts between the user community and the engineering community. This synchronization helps focus developmental efforts. There is a risk of building technically capable systems that do not accomplish the users' tasks without this collaboration.

This very fact was mentioned twice in the May 2010 issue of Discover Magazine in the article "Machine Dreams". Feedback from the Soldiers in Afghanistan and Iraq said a certain robot "sucked". The solution to help realign the capabilities of the robots to the tasks and requirements of the Soldiers, as explained by Rodney Brooks, "required a different way of thinking on our part about how someone was going to interact with that robot and what they were going to bring to the interaction, not what an engineer wants to do." [3]

The second instance of needing to redesign a robot was referenced by Robin Murphy with rescue robotics. [4] Regardless of the robot in question, the need to re-engineer and redesign the system was a result of engineers not understanding the true requirements of the user.

It is the engineers that are at the forefront of robot creation, but without the focus of the Soldier, these efforts may be scientifically satisfying, but operationally wasteful. A better means to collaborate is the method to prevent this type of unguided development.

Onto the Battlefield

The current Army Field Manual 3-0, Operations, dated February 2008, states "Technology will be another double-edged sword. Often, innovations that improve the quality of life and livelihood are also used by adversaries to destroy those lives. It would seem as though technology is an asymmetric advantage of developed nations." [5] From this statement it is fairly evident that the sentiment of doctrine writers is one of cautious skepticism.

A much longer discussion was included in the prior version dated 14 June 2001. In this earlier release, the recurring theme about technology was "Technology enhances leader, unit, and soldier performance and affects how Army forces conduct (plan, prepare, execute, and continuously assess) full spectrum operations in peace, conflict, and war." [6]

It further developed this concept with the view of technology as a means to augment Soldiers. "Even with its advantages, the side with superior technology does not always win in land operations; rather, the side that applies combat power more skillfully usually prevails. The skill of soldiers coupled with the effectiveness of leaders decides the outcomes of engagements, battles, and campaigns. This fact does not lessen the positive effects of advanced technologies. It does, however, challenge soldiers and leaders to realize and use the potential of advanced technologies in the conduct of full spectrum operations." [7].

As seen in this excerpt, the doctrine writers remain cautious by stating there will be challenges in both understanding and applying technology to achieve its potential from the Soldier's perspective.

A final excerpt from the early FM 3-0 clearly and plainly shows military sentiment for technology when compared to Soldiers. "Current and future technology requires skilled soldiers who understand their systems. Regardless of the importance of equipment or the expansion of technological capabilities, *soldiers are more important than machines. Soldiers, not equipment, accomplish missions and win wars.*

Leadership links soldiers' technical and tactical competence to operational success. Achieving combined arms effectiveness with complex systems demands adaptive and flexible soldiers." (Italics added for emphasis) [8]

In summary, Soldiers' expectations of technology are cautiously optimistic. The military seemingly understands the benefits technology can bring but also understand the costs required to implement and use it. Effective technologies improve the capabilities of the Soldier and overall force.

But to optimize the design of robots, Soldiers should be included from the beginning.

CAPABILITY AND CONDITIONS FOR SUCCESS

Quantifying success is difficult at best because of the multitude of variables and methods involved in a task. But to try and demonstrate this in a logic and math formula, I propose a very simple equation to define task accomplishment or success.

Success is defined as the "favorable or prosperous termination of attempts or endeavors".[9] The attempt or endeavor in military operations is the task to be accomplished. And "favorable or prosperous termination" is when it has been accomplished to or above the standard.

Most actions in the army are defined in the context of Task, Condition and Standard. These actions can range from the very simple to very complex and can be directly translated into the design of robots.

The task is what must be done and is usually very clearly articulated by the leader. For example, 'load the truck', 'clean the latrine' and 'dig a fighting position' are all tasks. Military operations, however, tend to have many variables and operating conditions which can complicate matters. The operating conditions (or operational environment) is correlated to the external environment in which a unit operates. Day, night, cold, fog, high altitude, dusty, windy and any other climatic or environmental condition is only part of this operational environment. Other considerations include possible enemy or civilian activity, terrain in the area of operations, other friendly forces that are nearby or in support, and even time.

To simplify the logic of success, one can state that an operational environment requires a certain level of capability (ENV_{req}). For example, if the environment is a stair and success is reaching the top of the stair, then the operational capability (CAP_{op}) required must meet or exceed that height. This can be achieved by stepping, jumping, launching or any other means to reach the top of the stair.

Success is then achieved when the operational capability meets or exceeds the environmental requirement. Expressed as an equation, $CAP_{op} > ENV_{req}$.

At its lowest level the operational capability can be expressed as,

$$CAP_{op} = S_{cap} * (1 + Tech_{cap}) \quad (1)$$

Equation (1) states that operational capability is equivalent to the capability of the Soldier (S_{cap}) multiplied by the quantity one plus the capability provided by technology ($Tech_{cap}$). The Soldier will always be able to provide only their base level of capability and are therefore multiplied by one. Although there is a wide variation on the Soldier capability, this cannot be affected by the technology except through simplifying the design or additional training.

The interesting factor in this equation is the effect technology will have on the overall operational capability.

Complex technologies that require higher maintenance, disrupt operations, or require greater operator training and/or involvement will reduce the overall operational capability and induce risk of failure.

RE-DEFINING THE SOLDIER AS A CAPABILITY

Soldiers themselves can be viewed as a functional system of components, peripherals and programming. A closer correlation between robots and Soldiers may be achieved by viewing Soldiers as systems. This may lead to a better design process.

Basic training should not be confused with initial programming, however. Life experiences serve as the initial programming that continually redefine the capabilities found within a Soldier. Much like a personal computer arrives with an initial 'operating system', Soldiers come to basic training with a lifetime's worth of programming on communication, mobility, motor coordination. But at basic training these skills are honed.

Functions and Skills/Equipping and Training

There are many things that people do before they become Soldiers. To be more precise, there are many functions that people perform that enable them to become Soldiers. These functions range from simple actions such as eating, sleeping and breathing to more complex functions which include communicating, moving and thinking. These functions serve as a baseline to help the person to continuously learn and develop skills.

A Different Six 'P's

An analysis of these functions yields four major areas under which most other functions fall. These include Power, Processing, Propulsion and Payload.

Power is the area dealing with generating energy for all functions and activities. Humans eat food to get energy. Additionally, humans are able to continue operations for days with minimal food. While food is the fuel that humans consume, robots, however, require different power sources. They do not utilize the same energy source as humans. This is one of the initial challenges to designing robots.

The second area is processing. Humans think. This is usually a result from some sort of stimulus, but not always. A subset of the processing is perception. Perception is the means to gather or collect stimulus. This is provided by telemetry in robots. Humans can increase their perception through the use of tools. These can range from simple tools such as binoculars to complex systems that translate the natural world into understandable inputs to which a person can respond.

An interesting difference between robotic systems and humans relating to perception is that human perception is passive whereas robotic sensing can be either passive or active. A passive perception is one where existing sound, light, vibration, etc reaches the human and they ascertain facts upon reception. An active perception would be one such as echolocation where the initial action is taken by the entity and a response is then awaited. Active perception can be both a benefit and a liability and must be carefully analyzed when designing a system.

The third area is propulsion. This is the means by which a human traverses the land. There are many different means by which a human can propel themselves, but the most basic is walking. This function is an enabler for the other areas. It enables a human to gather more food for power and it allows humans to observe different perspectives of the environment by enabling closer and alternate viewpoint observation.

Within the propulsion area, positioning is a critical piece and the focus of much emphasis for both Soldiers and robots. Positioning can be classified as either internal or external and also applies to both Soldiers and robots.

Internal positioning in Soldiers is a result of visual, vestibular and proprioceptive systems. Aviators are trained in these systems to help them understand potentially confusing environments such as flying in clouds, or at night when ground lights may be confused with stars. These systems allow the being to understand their positioning in relationship to the earth. Within robots, gyros or attitude reference systems may be used to help maintain a sense of balance.

The external positioning relates to the location relative to other geographic locations. For Soldiers this occurs fundamentally by map reading or looking around at what can be seen. Soldiers can look at maps and, through analysis, determine nearby terrain features. Additionally, Soldiers can look at the road ahead and recognize the difference between smoke and a wall or grass and a fence. These capabilities found within Soldiers are not taught at basic training, but are gained through years of experience in the physical world. Global Positioning System navigation has become a tool that assists (or hinders) Soldiers by providing exact coordinates of their location. However, this position is only valuable when it can be translated into the local terrain. A difference in one horizontal foot can be a tremendous difference in vertical feet when standing at the edge of a cliff. In this case, one foot away isn't really that close.

For Soldiers and robots to be successful at navigation, both internal and external navigation are needed. It is therefore critical to synchronize the capabilities to determine position and understand local terrain for successful operations. This capability is essential in terms of autonomous navigation.

The final area is payload. In the analysis of people or Soldiers, payload is the set of peripherals with which a human can interact with the environment. Most humans are born with a full complement of senses, fingers and toes. These are the baseline package that allows them to interact with the world. But people are able to perform many additional functions with additional equipping and training.

Once selected to become a Soldier, people begin training to develop additional skills. These skills are inherently related to the tasks required to be completed in the military.

Form Following Function

As Soldiers continue to train, they learn specialties in their chosen career field. At the same time, they are equipped to perform these duties.

As an example, mechanics are given tool boxes and training and tank drivers are given training and access to tanks.

Through the equipping and training process, Soldiers are transformed from an everyday individual to a tailored fighting force.

Drawing a relation to computers, when a system is purchased, it may not contain programs or peripherals necessary to accomplish specific tasks. By adding certain software packages (training), the system can perform different tasks, such as money management, word processing or design. In addition to having the capability to process and perform these tasks, sometimes peripherals are needed (scanners, light pens, web cams, etc). Adding peripherals is similar to equipping and training Soldiers.

Fitting Into the Force

To make a cohesive and comprehensive team, there must be a plan in place before the training begins. A force comprised of solely infantry would have weaknesses that other branches normally compensate for. Therefore, a well-rounded unit is predetermined. It is predetermined, planned, trained and equipped to accomplish tasks as part of the whole.

OPERATIONAL CONCERNS

Although tele-operation and unmanned systems have been in the military for a fairly long time, much of the plan is still in development.

We are currently at a time when the science and technology field is moving faster and starting to shape the force structure instead of the force structure being defined and then created. Rapid fielding initiatives are developing systems that are being pushed to Soldiers for use in the combat environment without having been formally tested.

Deploying systems directly into a combat zone has pros and cons and must be carefully considered based upon the level of effort required to deploy the capability but also on the return provided to the Soldiers.

Robots TO Soldiers

Soldiers are pretty decisive and mission focused. Much like the discussion earlier in this paper, many Soldiers are cautiously skeptical yet optimistic about fielding autonomous capabilities. Soldiers will not hesitate to disregard a system if the promised capabilities take too long to learn or the Soldier can perform the actions faster or better. The classic 'Paul Bunyan' or 'John Henry' conflict of man vs. machine occurs every time something new is introduced to Soldiers.

But, there can be no argument that tele-operated systems have saved lives. Finding just one Improvised Explosive Device (IED) without requiring a Soldier in a bomb suite to directly probe is a huge success. But to reach that point, there were a lot of actions required.

Once a system has been built and (preferably) tested in the laboratory, it is fairly easy to say that it is 'battle ready'. Unfortunately several considerations must be taken into account. First and foremost should be "What impacts does this have on the current operation, both negative and positive?"

New equipment training (NET) is essential when a system is introduced to Soldiers. And the unit's operational tempo is always disrupted when Soldiers must stop what they are doing to learn the new system. This disruption usually means that some operations are put on hold and the larger force is accepting risk by the trainees not performing their normally assigned missions. However, an even greater danger to Soldiers is that only a portion of the force is identified for training while the remainder continues performing the same amount of operations with a smaller force. This can cause Soldier fatigue and be even more damaging on the morale.

Today's complex systems are not always as intuitive to Soldiers as they are to those who created it. Again quoting Rodney Brooks, "We got word back from the field in Afghanistan and Iraq that the soldiers didn't like the menu system our engineers had designed.".[10] Greater coordination up front will reduce the training time and expedite usage from the Soldier.

Fitting into the force does not only deal with the operational capability provided to the force, but also the logistics and maintenance requirements imposed by the new system.

Space is a premium in a forward operating base (FOB). Fuel is also another factor that must be considered. Unnecessary burdens may be placed on Soldiers by introducing a system from the laboratory without adequately explaining requirements upfront.

Robots FOR Soldiers

Time is one constraint we cannot control. But technology can free the Soldier to perform tasks quicker and sometimes simultaneously.

Soldiers generally appreciate anything that reduces their workload. Digging a fighting position requires moving dirt and stone. Soldiers possess the strength and knowledge to do this, but it will take a lot of time unless they are properly equipped. Soldiers can perform this task much quicker if they are given a shovel. They can do it even faster if you provide them training and a tractor.

The two key benefits robots can bring to Soldiers are capability augmentation and/or execution.

Soldiers can be augmented by robots to enhance skills. Lifting, viewing, listening and many other skills can be technologically enhanced. Tele-operated counter IED systems extend the reach of ordinance technicians. This technology enhances existing operator's skills.

But designing robots for Soldiers becomes an interface drill requiring an understanding of both sides. The first side is the Soldier who interacts with their environment through their five senses. They are again constrained by their human limitations of sight, sound, touch, taste and smell. And these senses must serve as the input for the Soldier to take action.

Many designs begin at this point. They take an existing example and expand upon it or even worse, they force the processing requirement back to the Soldier. For example, on a mine detecting robot, a camera is attached. This enables the Soldier to see what is there and make judgments based on their visual perception.

But science can provide a much greater picture of the world though different telemetries. There are spectrums the human eye cannot see, but science can harness them through other tools. There are also differing characteristics that science can detect and may increase effectiveness of the Soldier by augmenting their senses. Thermal, chemical, acoustic, electromagnetic, infrared and ultraviolet spectra are all areas that science is defining. This same science can enhance the situational awareness of the Soldier but requires the translation from scientific detection to practical understanding. It is up to the engineer and scientist to de-humanize the design of robots to leverage our scientific understanding of the world.

But technology can also execute in place of Soldiers.

Robots AS Soldiers

The range of tasks that Soldiers perform varies from simple to extremely complex. And even with the amount of quality training provided, there are still challenges in accomplishing tasks correctly every time.

The familiar phrase, 'the fog of war' describes the uncertainties that Soldiers encounter when conducting operations. The confusion and chaos during combat operations, in addition to the complexity of the tasks required creates infinite opportunities for error.

The current level of technological processing and telemetry does not currently provide the capabilities required to handle this amount of input. But there still are plenty of opportunities to integrate robots into the force.

Instead of creating robots that completely replace Soldiers or that perform a very large subset of tasks, a design opportunity is to focus on a very small subset of tasks that are either very dangerous or so repetitive and monotonous, that an autonomous robot could perform over and over more effectively than a Soldier.

One of these tasks has already been identified as Autonomous Navigation. But there are still many other possibilities for robots to augment the force. Loading bay, refueling, retransmission site, and area clean-up operations are just a few of the tasks that require extensive manpower but may be accomplished through robotics.

However, to ensure the use of robots to augment Soldiers is truly worthwhile, a comprehensive business case must be completed to identify the costs and benefits.

From a business overhead perspective, Soldiers are a relatively inexpensive cost. The amount of flexibility they provide in capability is staggering. But they still have human limitations.

Robots can exceed these human limitations and increase or exceed the strength, speed, and precision of humans. But only in a limited set of capabilities.

Robots VERSUS Soldiers

Will technology ever mature to the point that Soldiers can be completely replaced by robots? This is an interesting question that spans the technical, business and ethical fields.

The complexities of human thoughts and actions when coupled with confusing environments create infinite choices a Soldier can perform. And many of these choices can have costly results.

For robots to begin to replace Soldiers, even for limited tasks, they must be able to exceed the capability of Soldiers in these critical areas.

THE CHALLENGE

Engineers face two major challenges. The first challenge is to understand their own fields within the sciences. It is imperative that they continue to push the envelope of understanding and then applying laws of nature to create better technological solutions that improve society. This in itself is extremely challenging.

The other major challenge is to understand their customer – in this case, the military. As a culture and society within itself, the military is not always understood. Sometimes the translation of military to engineer language can be the greatest challenge.

Risks

There are many risks when developing robots for military applications. These risks are shared by many and range from lack of funding, failure to perform, too dangerous to operate, to cost prohibitive designs.

Although these represent post development risks, there are other, more critical risks to avoid. These risks can be avoided up front and early in the design phase if appropriate effort is applied.

As mentioned earlier, the first major challenge faced by engineers is the application of laws of nature to the design of their system. This challenge is one of the primary sources of design risk. At times, scientists and engineers may focus too closely on solving the technical problems that they forget the end state or neglect second order effects of their design.

Focusing on the design rather than holistically looking at the application can lead to an excellent technical achievement with limited practical application.

Informed Design – Invention or Innovation?

Engineers are generally inventors. They create things using their knowledge of science and math. But the ultimate design must remain attached to something. It cannot be a self-licking ice cream cone. The question at the root for the Soldier ultimately is "What good does it do for me?"

Innovation can be an iterative process that involves the user and the maker. It requires both sides to communicate what is needed, but also what is possible. A common understanding is the baseline for moving forward.

The Chasm, The Course, and the Correction

The fact remains there is a chasm between the military and engineering communities. Steps must be taken to bridge the gap and are required of both sides.

From the engineering community, efforts must be taken to seek information on the true requirements and capabilities required. This may even require an understanding of the tasks requiring completion and the current methods to achieve. This knowledge will better equip the engineers to focus their efforts toward a solution that fits the force with minimal disruption and minimizes multiple iterations to provide needed capabilities.

From the military, there are two primary efforts that must be continued and emphasized. The first is provide visibility to leadership so they have a better understanding of current and future capabilities and how they will positively impact the force and how we conduct operations. The second effort is to provide a unified voice to the engineer on the capability requirements and not the design. The critical piece to understanding the requirements is to capture the voice of the customer accurately.

Refining the processes to increase collaboration between the engineering community and the military user is only the first step in bridging the chasm and leveraging our scientific and engineering community to support the Soldier.

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