AUTONOMOUS CASUALTY EVACUATION

Demonstrating capabilities and evaluating results is the cornerstone of 6.5 activities on the RDT&E spectrum.

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(Left) Marines assault an enemy position as part of their training scenario. (Below) A team of Marines provides cover for wounded casualties as they are evacuated via our autonomous vehicle out of the firefight to be treated at the Battalion Aid Station.

(Above) The Hunter WOLF, developed by HDT Expeditionary Systems, is prepared for arduous testing in real-world conditions at Range 220 onboard US Marine Corps Base Twentynine Palms. This project was created and led by LT ES Vorm, PhD from the US Naval Research Laboratory's Navy Center for Applied Research in Artificial Intelligence as part of a 6.5 funding activity to demonstrate and evaluate the concept of autonomous casualty evacuation.

(Above) A Marine walks beside the Hunter Wolf as his platoon patrols the open area en route to their objective. The Hunter WOLF is configured here to carry four casualties; two in the center and two on the wings.

In the barren Mojave desert, not far from Joshua Tree National Park, a mock battle rages. Commanders shout orders. The clatter of machine gun fire rings out and echoes off nearby buildings. A squad of Marines presses their bodies against the dirt on the lower edge of a berm and try to return fire against an unknown and unseen adversary. Suddenly a Marine flinches and turns over, yelling for help.

"Corpsman up!" screams another Marine.

Shots ring out from all directions. The air is filled with the sharp tang of gunpowder. Dust wafts through the scene as more Marines dash across the sandy ground, seeking cover. The din of radio chatter mixes with the shouts and cries of the injured Marine who lies writhing on the ground, grasping at his leg in pain.

Twenty-five-year-old Hospital Corpsman Second Class (HM2) Curtis Ikkala, a Fleet Marine Force corpsman, arrives on the scene and begins to treat the wounded.

"It is more than a half-mile to the CCP," he says, referencing the casualty collection point—an intermediate collection spot where wounded Marines can be

The research team consisted of uniformed and civilian scientists and engineers from both industry and the DoD. Right to left: LT E.S. Vorm, PhD, primary investigator; LCDR Brennan Cox, PhD, LT Sarah Sherwood, PhD. Not pictured: LtCol Bryan Patterson, USMC; Kent Massey, HDT Expeditionary Systems; Charlie Deaver, HDT Expeditionary Systems; Michael Hodgson, San Diego State University

treated away from the most intense fighting. “This is gonna suck.”

The Marines maneuver the injured patient onto a litter, then lift him to waist-height and prepare to make the journey overland. Four Marines, one on each corner of the litter, carry the patient and his gear—approximately 240 pounds—while two others and the corpsman provide cover.

These Marines are with the Second Battalion, Fifth Marine Regiment out of Camp Pendleton, California. They have come out to the vast desert area of Twentynine Palms for a month of intense, realistic training. Today’s exercise is specifically focused on casualty evacuation—the ability to coordinate the movement of injured people to higher echelons of care while maintaining tactical superiority.

The unfolding scene looks very familiar to anyone who has experienced ground combat operations over the past decade: difficult, cluttered terrain; multiple moving groups of people; chaotic communications; intersecting fields of fire; limited sight lines; and multiple layers of concealment all combine to make the movement of wounded patients a slow, painstaking process. And there is something else about this scene that is also oddly familiar: the sight of multiple Marines carrying one wounded patient. Although today’s Marines benefit from superior weapons and technology, the process of moving patients from the point of injury to higher echelons of care has barely changed from methods used hundreds of years ago.

The group maneuvers down a narrow alleyway and descends a steep, sandy berm. The Marines holding the litter struggle to manage under the intense weight. Their hands throb and ache. Their movements are jarring and random as the litter carriers jostle and bump against each other in constant motion over the loose, uneven terrain. Sweat pours from their faces. Their heavy, labored breathing is punctuated by the moans of the patient, who may be just role playing, or may genuinely be complaining because of the roughness of the ride; it is impossible to tell.

Suddenly, one of the Marines loses his grip on the litter. His corner of the litter drops, which quickly cascades into the entire litter falling to the ground. The patient bounces violently and rolls partially off the litter, disrupting the sensitive medical interventions--a tourniquet, two pressure dressings, and an IV--that have thus far kept him notionally alive.

In tactical situations such as this, where large vehicles such as HMMWVs are unavailable, carrying patients from one place to another presents a crude, but mostly effective solution. Military conflicts from as far back as the ancient Romans have featured some form of carrying device (i.e., a litter). The American Civil War in the 1860s introduced litter carriers--teams of people that were specifically designated to accomplish this task. World Wars I and II also saw these roles expanded to include more dedicated medical personnel with equipment such as jeeps and field ambulances, and tactics that enabled the strategic and organized movement of patients. The Vietnam war introduced the concept of air ambulances for patient movement, and forward aid stations that acted as intermediate patient collection points to stabilize patients with limited surgical interventions. These casualty evacuation concepts continued to evolve through conflicts in Kosovo and Desert Storm in the 1990s, through more recent conflicts in Iraq and Afghanistan in the 2000s and 2010s. Throughout these conflicts, the case fatality rate (CFR)--which measures the total lethality of the battlefield—has fallen precipitously from a high of 55 in World War II, down to 12

“IF WE HAD TO DO THIS IN REAL LIFE, WE’D IN BE A BAD STATE REALLY QUICKLY.”

for the Iraq and Afghanistan conflicts. Many factors, such as mobile IV fluids and clot-enhancing pressure dressings; improved medical training for every warfighter; and better body armor, have contributed to this improvement in survivability, but one constant has remained—the humble litter.

“If we had to do this in real life, we’d be in a bad state really quickly” says HM2 Ikkala as he readies the patient and prepares to resume the long trek out of the hot zone back to the casualty collection point.

His words echo the concerns of many who study the current state of how the US military goes about the business of evacuating and treating patients on the battlefield. The challenge he is specifically referencing is the fact that one wounded Marine has taken an additional six Marines out of the fight—four to carry the patient, and two more to protect the group as they maneuver. This ratio is a troubling one in light of speculations of what tomorrow’s war against a near-peer adversary would mean for the United States.

Casualty projections in the event of a kinetic fight with a near-peer adversary such as China, based on expert analysis and war gaming, indicate grim statistics: U.S. forces are projected to experience orders of magnitude more casualties than anything the past generation has had to face. The current manpower-to-patient ratio means that a platoon-sized element, roughly 50 people, could only sustain 4-5 casualties before being overwhelmed by the logistical burden of treating and maneuvering patients out of the fight. And the challenges for expeditionary medicine don’t end there.

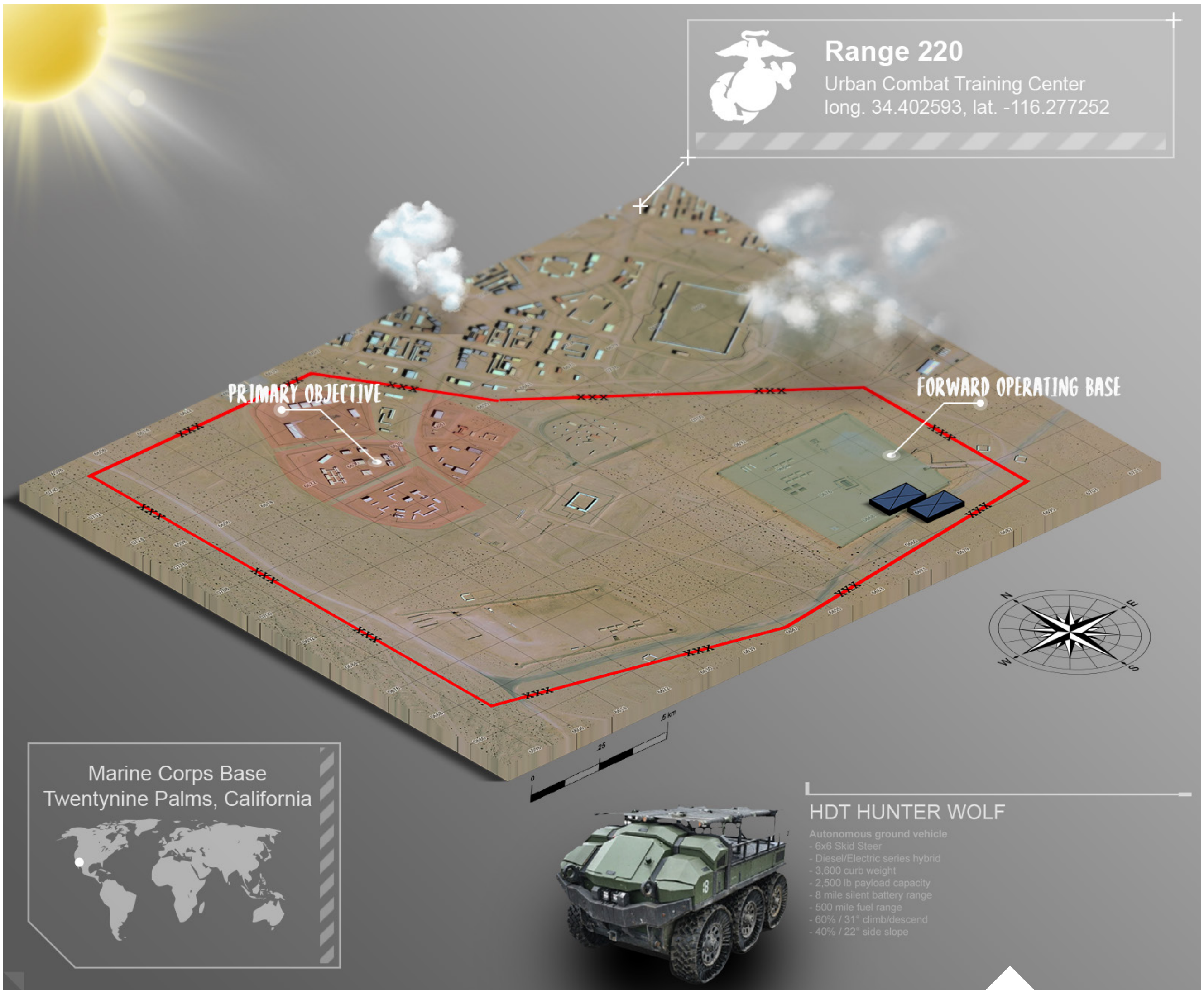
Tomorrow’s battlefields are expected to feature significant use of the electromagnetic spectrum in the form of jamming satellite communications and spoofing radar. This will force a radical change from how the US has coordinated its forces in the past by using large, centralized forces such as a carrier strike group or forward expeditionary force. Instead, units will need to operate more independently from one another, and will be potentially distributed across wide areas. With vast areas of the war zone blanketed in communications-degrading static and GPS-disrupting attacks, units may not have the freedom of movement they have enjoyed in recent conflicts—such as the use of helicopters or convoys of trucks to expeditiously evacuate patients who need advanced medical treatment.

The result of these factors paints a challenging picture for a military force that has grown accustomed to being able to move about freely in contested areas to deliver medical care to those who are injured. Through this speculative lens, the ratio of six Marines for every wounded casualty and the idea of carrying patients on collapsible litters becomes a critical problem in need of an innovative solution.

One such potential solution envisions the use of small, unmanned ground vehicles that are capable of traveling alongside dismounted infantry troops and can fill a variety of roles: logistics, supply, reconnaissance, and even casualty evacuation. Vehicles roughly the size of golf carts, capable of a full range of autonomy, could fill a niche role for isolated and distributed forces in difficult terrain where full-size vehicles like the HMMWV and others may not be able to go. The Hunter WOLF, designed and built by HDT Expeditionary Systems, Inc., was created for this exact scenario.

The WOLF is a six-wheeled vehicle that measures around 7.5 feet long, 4.5 feet wide, and just under 4 feet tall. It weighs around 3,600 pounds, which is around 30% lighter than the HMMWV, but can carry the same payload of 2,500 pounds, allowing it to carry military equipment like weapons and ammunition, weeks’ worth of food rations, or 12 troops fully laden with gear. It has an internal diesel generator capable of outputting 15kW of power—enough to power an entire command operations center and all its associated components. But the WOLF is far more than merely a mobile power generator. Its low center of gravity and extreme torque-to-weight ratio means

LT E.S. Vorm interviews participants in the study while on the march after the conclusion of another simulated combat mission. Over the course of three days the research team conducted 18 individual trials and gathered data from 2,042 active duty participants. Their input is critical to the evaluation and refinement of the ACE concept.



For three days in October 2021 Marines from 2nd Battalion 5th Marine Regiment participated in extended combat training on Range 220 at Marine Corps Base Twentynine Palms. Scenarios dedicated to casualty evacuation enabled the research team to compare Marines' performance in evacuating casualties using traditional litters, and an autonomous ground vehicle built by HDT Expeditionary Systems called the Hunter WOLF.

that it can tow more than three times its own weight, while its small compact size and zero-turn radius means that it can maneuver through the narrowest alleyways with ease. It is fitted with innovative features like Michelin airless radial "Tweels" that conform to terrain and never go flat, and a hybrid diesel-electric motor that can go for hundreds of miles silently on battery power. The WOLF was designed to support a platoon-sized group of dismounted infantry for five days with no resupply; to move alongside troops and be adaptive to a variety of roles; and is an ideal solution for scenarios where regular and extensive supplies like fuel, ammunition, and food may not be available for days or even weeks.

I have come to this exercise in the desert training grounds of Twentynine Palms to evaluate how vehicles such as the WOLF can help accomplish a new, emerging concept in military medicine: autonomous casualty evacuation (ACE). In scenarios where operating rooms and extensive medical infrastructure are not available, units will need to be able to provide both critical, life-saving interventions and also sustain patients for prolonged periods of time under difficult conditions. Automation of monitoring and treatment is the cornerstone of the ACE concept, in which machines driven by artificial intelligence could lessen the burden on medical providers by autonomously monitoring patient vital signs and providing limited clinical interventions such as administering fluid resuscitation or medications. Other necessities such as IV warmers, powerful suction, and mechanical ventilation would enable medical providers a broad range of treatment options in a field environment. And of course, the most radical of the ACE concept involves using autonomous or semi-autonomous vehicles like the WOLF to transport patients, with or without a human "at the wheel."

Vehicles like the WOLF are obviously well-suited to provide the logistical means and power to integrate all of the monitoring and treatment technology necessary to accomplish the ACE concept in a small-enough footprint to remain viable in austere environments. More importantly, however, is the exponential value they could add by flipping the 6:1 ratio of current manpower requirements of casualty evacuation on its head. One WOLF could easily transport four patients on litters, and could potentially do so with a minimal amount of human supervision. Utilizing the same kinds of technologies that are enabling self-driving cars to enter public roadways today, vehicles like the WOLF could lessen the burden of transporting patients on the battlefield, resulting in more fighters staying in the fight.

To empirically demonstrate and evaluate the WOLF in a casualty evacuation role, we designed a simple factorial design. Each platoon in the battalion, one at a time, would execute the same objective of assaulting an area in order to capture and control a collection of buildings. Some groups would be given the WOLF as an asset to evacuate patients, while some groups would only be allowed to use traditional hand-carried litters. The traditional litter groups would serve as a control group against which the performance of the WOLF groups would be compared. This resulted in a two by five-way factorial design. Two experimental conditions: traditional litter carry for evacuation, and using the WOLF for evacuation were compared across five groups of people: drivers are those are have been designated to control the vehicle; security are those have been designated to provide physical security during the evacuation; corpsman are those who are designated to provide medical aid to the patient; patients are those who are designated with mock injuries; and for the traditional condition we have litter carriers, those individuals tasked with carrying the patient on a litter. Performance would be measured in two general ways: the subjective workload experienced by participants, and the quality and efficiency of teamwork as measured by structured observations.

To estimate workload, we used the NASA-developed Task Load Index (TLX), originally created to evaluate the workload of operators interacting with new spacecraft and robotics. Workload can be physical, as in the physical effort necessary to carry a patient on a litter, but also can be mental. For example, how much mental effort does it take to determine the best route the WOLF should take when moving patients? How difficult are its controls? How much time does it take to get the WOLF to do what you want it to do? How quickly can a person learn to control a vehicle like the WOLF, and at what point are they considered proficient? These are all branches off the tree of mental workload, and these questions are important to answer in order to ensure the WOLF fully meets the needs of the units it seeks to support.

Each platoon was allowed to develop their own plan of action (known in infantry terms as their scheme and maneuver). Each group chose to incorporate the WOLF in their own way, which included who would be designated to control it, where the vehicle would be stationed, and how it would move with the unit during their assault. The time it took for each platoon to execute their mission ranged from 1.5 to 3 hours, depending on the speed and efficiency of their coordination. My team would pay close attention to how each platoon conducted themselves, and would document decisions and actions in order to correlate those to each platoon's overall performance. Each day ran three platoons through the assault over three days' worth of testing, for a total of 9 evolutions; two using traditional litter evacuation, and seven using the WOLF.

A total of 2,042 Marines took part in our exercise. 116 Marines directly participated in the evacuation of casualties and chose to participate in our study. A breakdown of participants by their role is available in the table below.

To best understand how the WOLF improved or hindered each group's ability to evacuate their mock casualties, we examined measures of workload as measured by NASA TLX. We used independent samples t-test wherever appropriate to determine if workload differed significantly between the two groups. To augment these measures, we used structured observations with time-stamped photographs and notes. We also solicited feedback using a structured interview format.

Corpsman from 2nd platoon Golf Company of 2nd Battalion 5th Marines respond to a mock casualty while their platoon sergeant communicates with headquarters. Over this three-day evolution, Marines from 2/5 received dedicated training in casualty treatment and evacuation in urban combat scenarios in preparation for their upcoming deployment overseas.

MENTAL WORKLOAD

Both the WOLF group ($M = 18.09$, $SD = 19.59$) and the traditional litter carrying group ($M = 13.28$, $SD = 11.43$) reported relatively low mental workload for the task of evacuating patients. The differences between the two groups was not significant, $t(114) = 1.64$, $p = .057$, $d = 15.8$. It is worth noting, however, that the traditional litter carrying group reported slightly lower mental workload than the WOLF group, and there were notable outliers in the WOLF group, all of which were Drivers. This could be interpreted that operating the WOLF required higher mental workload for those operators, which makes logical sense. Each designated operator of the WOLF received approximately one hour of practice and instruction before taking part in the assault exercise. This was the minimum necessary time to ensure the safe and effective operation of the vehicle, but was evidently not enough time to eliminate the extra burdens that remotely controlling a full-size vehicle adds.

Changing the control interface, for example, may help alleviate some of the mental demands that operators of the WOLF reportedly experienced. For example, during the evolutions, we heard feedback from multiple operators who said that controlling the WOLF with the thumbstick was difficult to accomplish while wearing gloves. The relatively low force-feedback of the thumbstick made it very easy for the operator to over-torque the WOLF, which would cause it to lurch forward and could potentially create an unsafe condition. The WOLF's control interface is very intuitive to use, and provides extremely fine degrees of control, but with the addition of gloves and operators who are moving alongside the vehicle, many of those degrees are lost. All of this means operators have to think more carefully about what they are doing, which results in more mental workload.

While training would likely alleviate much of this mental demand, it bears consideration that operating vehicles like the WOLF inevitably add a degree of complexity to the equation of evacuating patients in combat situations, which can have an effect on the overall performance of the team and its mission. If vehicles like the WOLF will be operated or controlled by a single, designated operator, then this finding may not ultimately be that important as that person would likely receive adequate training and experience operating the vehicle.

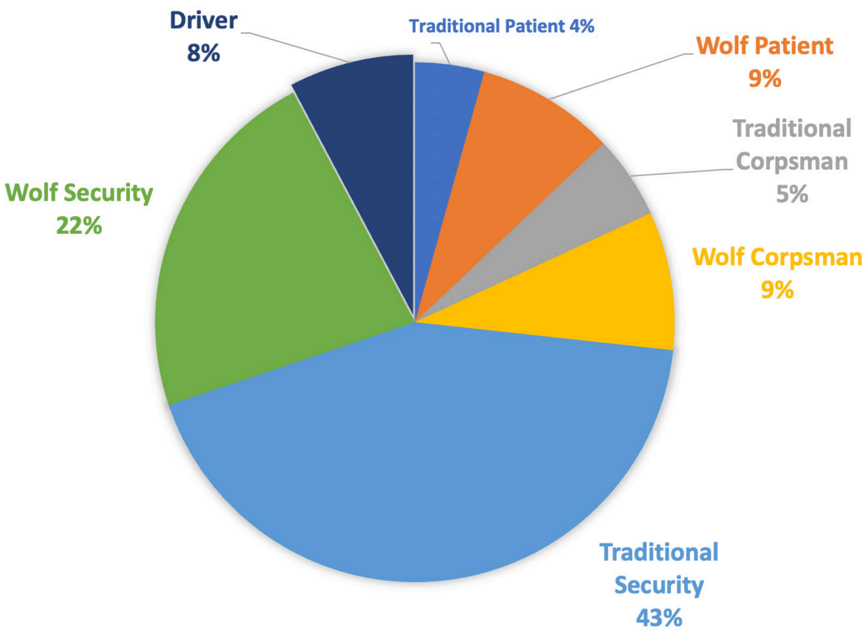


Figure 1: Demographics of participants in our study

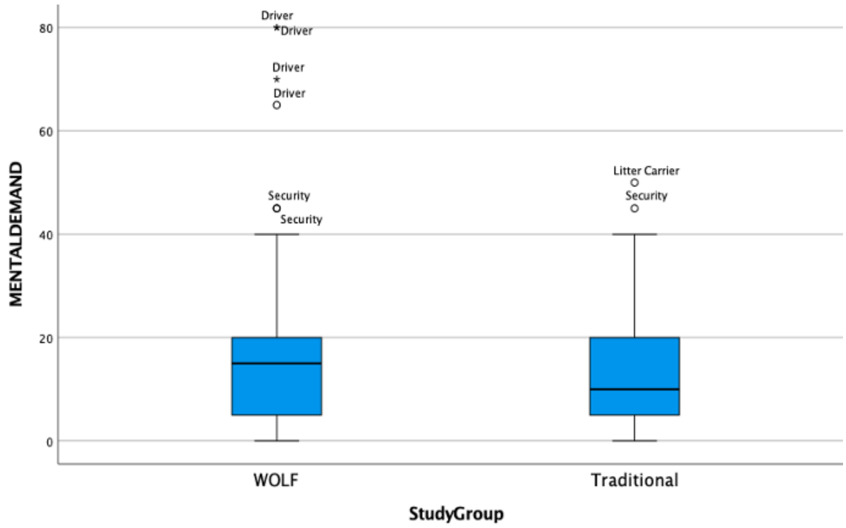


Figure 2: Box and whisker plot reporting the results of the mental demand experienced between two groups while evacuating casualties under battlefield conditions.

If the WOLF will be operated or controlled by multiple people, however, where some or all members of a unit have some cross-training but not necessarily extensive familiarity or experience with the system, then this finding becomes more critical. Findings like this help the design team to identify task and functional areas that can be improved.

PHYSICAL DEMAND

Physical demand was much higher for the traditional group than for the WOLF. Results showed that mean score for the WOLF group (M =13.2, SD = 19.8) was significantly lower than mean physical demand for those evacuating patients using the traditional litter method (M = 62.05, SD = 28.5), t(114) = 10.47, $p < .001$, d = 24.77. This result is not surprising and was predicted. The WOLF makes light work of carrying patients off the battlefield, while carrying them by hand is physically arduous. As before, we can see that while the overall average physical workload was lower for the WOLF groups over the traditional litter carrying groups, there are notable outliers. The single WOLF driver that reported 100 physical demand did so because he was the only person who had to respond to all of the casualties taken during his platoon's assault (there were four casualties for his exercise), whereas everyone else only had to evacuate a single patient before returning to the fight. The security participants that reported high physical demand explained their ratings as being related to lifting and positioning the patient onto the WOLF. We configured the WOLF to accommodate four patients on litters; two on top, and two on the sides of the vehicle, but the majority of the time patients were loaded onto the top of the vehicle. This means that a patient and all of their gear would have to be lifted approximately four feet high to be placed on top of the WOLF's bed. Even when spread across four people, this task takes a good deal of physical effort to accomplish. The personnel who were tasked with providing security tended to be the personnel who were responsible for loading and unloading the patient, hence their ratings of high physical workload.

Again, this data is valuable from a design improvement standpoint. A number of potential solutions could be developed, for example, a modular ramp system

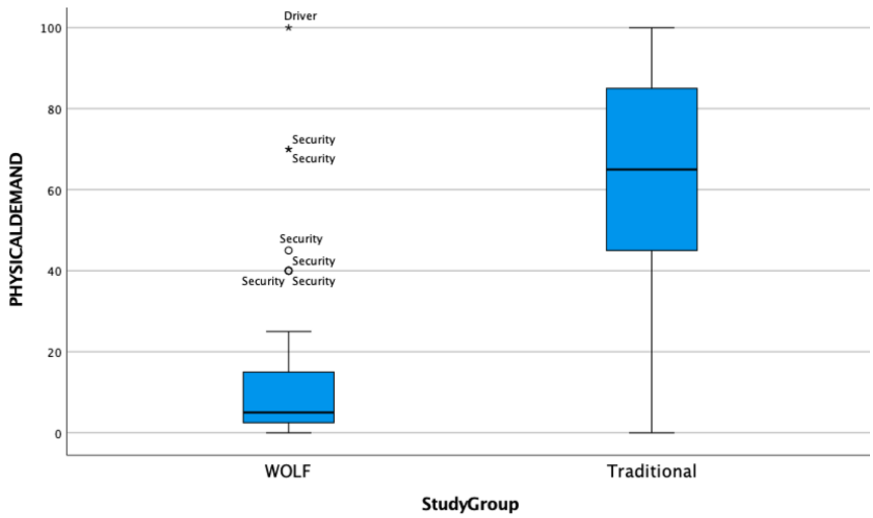


Figure 3: Physical demand was understandably much lower for the group using the Hunter WOLF, but there were some notable exceptions. These findings help to refine the WOLF's design and improve its usability for future operators.

that would enable a smoother and easier loading of patients onto the WOLF. By evaluating the WOLF under these realistic conditions with real operators, we can better evaluate and iterate on its design, which will result in a better overall product to meet the needs of our customers.

EFFORT

The perceived effort, as measured by NASA TLX was significantly different between the two groups, $t(114) = 10.192$, $p < .001$, $d = 23.186$. This means that the participants who were able to use the WOLF to evacuate their casualties thought the total effort involved, from physically moving the patient to transporting them to the casualty collection point, was less than those who had to perform the evacuation manually using a foldable litter. Effort can sometimes be thought of as a combination of physical and mental workload, in which case we see similar trends between our two groups reflecting perhaps the total effort it took to successfully evacuate patients using the WOLF versus using a traditional litter.

FRUSTRATION

The NASA TLX defines frustration as how insecure, discouraged, irritated, stressed, or annoyed a participant was when trying to accomplish the task. The WOLF group expressed significantly less frustration ($M = 14.91$, $SD = 14.83$) than the traditional litter carrying group ($M = 55.41$, $SD = 22.12$), $t(114) = 11.45$, $p < .001$, $d = 19.01$.

One way we can evaluate the differences in overall effort and frustration is to consider how many of the decisions made by different platoon leaders contributed to an easier or more difficult scenario involving the WOLF. For example, our team observed that many platoon commanders designated the lowest ranked person or a person who was not considered integral to any fire team to control the WOLF. Other platoon commanders did the opposite: they designated a staff sergeant or gunnery sergeant (E6 or E7) to control the WOLF. With higher rank also comes more experience leading troops, more authority to make decisions, and better decision making abilities. Thus, teams who used higher ranking people as operators had more coherent plans, communicated more efficiently, and executed their plans more successfully than teams with a very low ranking, less experienced individual at the controls.

Our team also observed a difference in how the platoons approached the WOLF as a strategic asset. Some platoons immediately saw the potential benefits of the WOLF, and worked to incorporate it into their scheme and maneuvers. These platoons used the WOLF in a variety of roles, expanding beyond only using it for casualty evacuation. For example, the WOLF was used to provide physical cover for moving troops on multiple occasions. It was used as a decoy and a distraction to fool enemy troops. It was also used to ferry supplies and people from location to location during the firefight, in terrain and under conditions that traditional vehicles would not have been able to afford. Conversely, some platoons appeared reluctant to use the WOLF and treated it as if it were a burden to them; some went so far as to leave it in the rear to wait until casualties were designated. These platoons appeared to think of the WOLF as a distraction to their overall mission, rather than a tool they could creatively use. Platoons who conceptualized the WOLF as a multipurpose asset and who saw it as a tool that could be creatively employed were more successful and required less

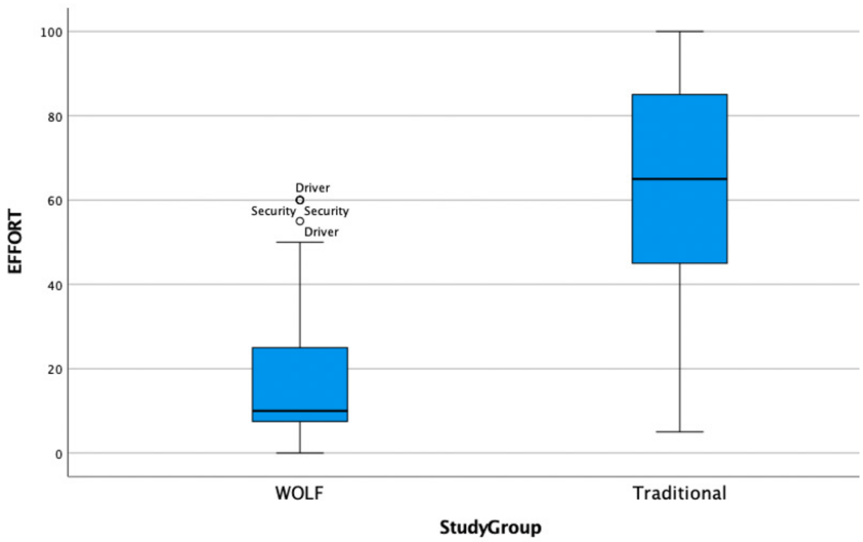


Figure 4: The overall effort it took to evacuate patients was lower for the Hunter WOLF group than using a traditional litter, but some roles experienced more effort than others.

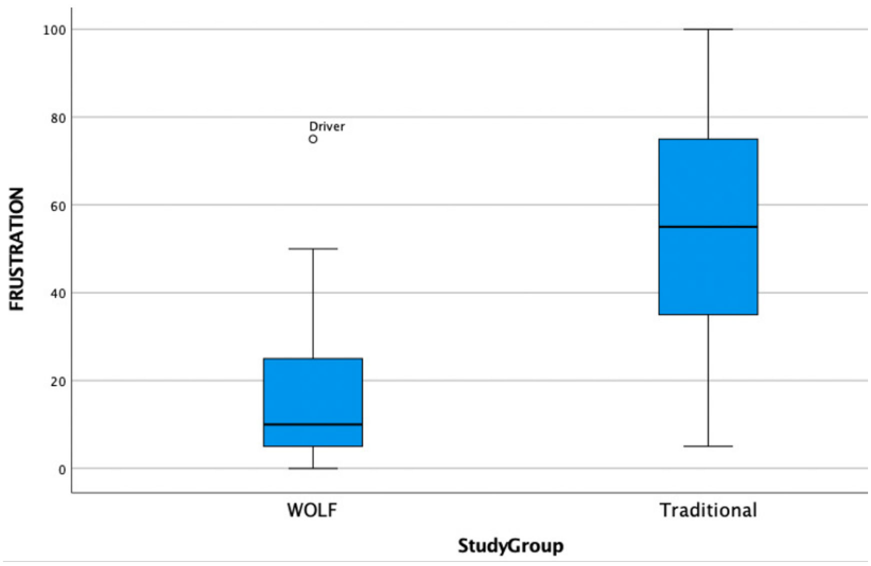


Figure 5: Frustration is a form of workload. Here we see the WOLF group had much less frustration than the traditional litter carrying group.

overall effort than other platoons.

This is an important finding if we consider a slightly broader scope. Technology is only useful when it is used, and used appropriately. How users think about and approach technology—seeing it through an adversarial lens or conceptualizing it as a teammate—makes a tremendous difference on the benefits that technology brings to bear. The overall effort these groups experienced was influenced, at least in part, by how they thought about and approached using the WOLF in their mission planning and execution. Future generations of Marines will no doubt be more familiar and comfortable with autonomous vehicles as they become more mainstream, but there will still need to be dedicated efforts to appropriately socialize these technologies in ways that engender trust and encourage them to be used. Failing to do so may result in technologies that ultimately hinder or slow performance, rather than speeding it up and making it easier.

TEMPORAL DEMAND

In dynamic situations with complex tasks, high physical and mental workload, and high levels of overall effort and frustration all tend to result in one thing: excessive time. The time it takes to accomplish a series of tasks is evaluated using NASA TLX, and is an important metric in our evaluation because when it comes to patients' lives, time is precious.

Due to the highly dynamic nature of each assault, we were unable to precisely measure how much time it took each group to evacuate patients from the point of injury to the casualty collection point. The perception of time as experienced by those involved in the exercise, however, was measured by NASA TLX. The participants' experiences differed significantly between the WOLF group ($M = 18.2$ $SD = 18.9$) and the traditional litter carrying group ($M = 62.2$, $SD = 27$), $t(114) = 10.17$, $p < .001$, $d = 23.49$. Along with being less physically challenging, participants using the WOLF for casualty evacuation appeared to experience quicker results. From our observations, it appeared that Marines using the WOLF for evacuation were indeed better able to move patients once they were loaded, but the coordination involved in moving the WOLF to the patient's location was sometimes slow and difficult, which sometimes slowed things down. Both the drivers and patients presented as outliers in these findings, which again makes sense in context. Both the drivers and patients needed to wait while patients were maneuvered over to the vehicle, and then again wait while they were loaded and unloaded. From the drivers' and patients' perspectives, these steps must have felt like they were taking a long time.

It is also worth noting that although physically carrying a patient on a litter may be tiring, it is a simple exercise—a physical action that all humans are familiar with—whereas maneuvering and controlling a vehicle from a third-person perspective and ensuring that patients are loaded appropriately so that the vehicle does not inadvertently dump them off if it turns too quickly are variables that few people are used to worrying about. It is important to examine these outliers in order to best understand the "pain points" of using vehicles like the WOLF. The best predictor of success in complex sociotechnical systems is the goodness of fit between the technology and its intended audience. Even the most sophisticated running shoe is of no benefit to a runner if it doesn't fit. Similarly, it is imperative that we design vehi-

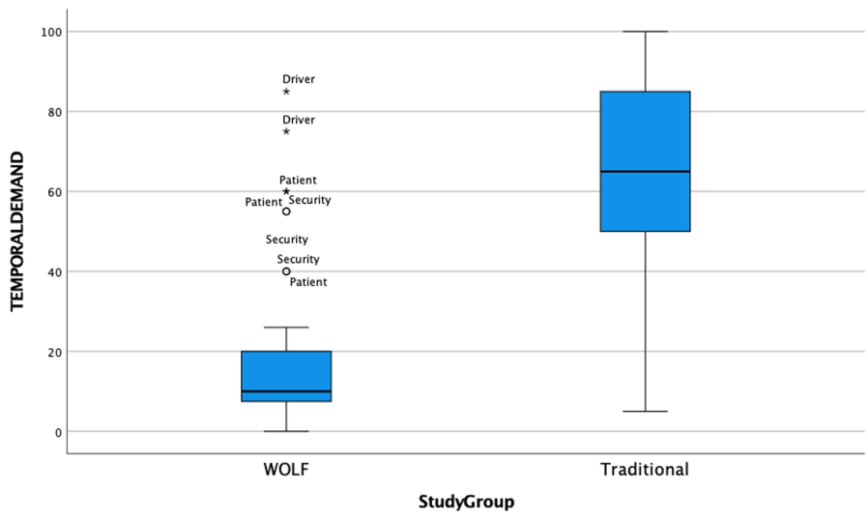


Figure 6: The time it took for patients to be evacuated off the battlefield was significantly shorter for the WOLF group, but it FELT longer to some of those group members, according to our findings. This indicates that some functions of interaction with the Hunter WOLF can be improved and made smoother to improve the overall experience.

cles like the WOLF so that they "fit" our customers well. Improving the loading and unloading of patients, for example, might very well improve the current findings of high temporal demand in addition to the physical demand experienced by our participants.

OVERALL PERFORMANCE

At the end of each exercise, we asked each individual how they thought they did overall in performing their mission of evacuating patients safely. Overall performance, as measured by each participant's self-assessment using NASA TLX, differed significantly between the two groups, $t(114) = 10.17$, $p < .001$, $d = 23.49$. Based on observations and discussions with training staff, the groups who evacuated patients using the WOLF were more likely to reach their objectives with less safety issues, and had greater overall communication and teamwork than the groups who evacuated patients using traditional litters. We infer from these anecdotal observations that the WOLF afforded teams greater freedom of movement with less overall effort, which resulted in better overall performance.

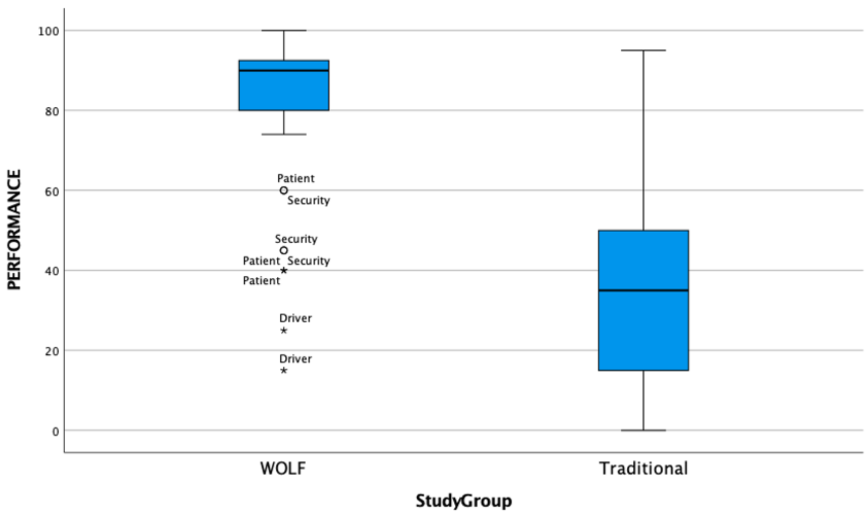


Figure 7: Overall performance, as measured by each group's ability to evacuate their patients to the designated location.

We can also consider patient survivability as a measure of overall performance. When Marines and corpsman failed to effectively treat their wounded patients, or when they took too long to administer aid or move their patients to safety, the Coyotes would mark the mock patient as deceased. Three WOLF patients were designated as deceased, or around 11% of the total of 28 patients of the WOLF evolutions, whereas two patients during the traditional litter carrying evolutions were designed as deceased, which was 25% of the 8 patients involved in the traditional litter evolutions. It is nearly impossible to directly correlate the mock patient outcomes to the presence or absence of the WOLF. The factors we have measured above (i.e., physical workload, mental workload, effort, frustration, and time), however, do allow us to infer some relationship between the manner in which patients were evacuated during our exercise, and whether or not they survived the evolution.

CONCLUSION

The purpose of 6.5 activities on the RDT&E spectrum is to demonstrate the possible in order to inspire what can be done, and refine designs so that they best meet the needs of the operational customer. Evaluations are guided by questions to be answered rather than research hypotheses. The methods we employed for this evaluation of the autonomous casualty evacuation concept, therefore, reflect our interest in understanding where benefits can be attained with vehicles like the WOLF in dynamic operational settings, and likewise where situations favor other technologies or analogs.

Our evaluation of the WOLF for casualty evacuation demonstrated several benefits over traditional methods. Future conflicts may feature situations in which capabilities afforded by autonomous vehicles may be a significant factor in determining successful outcomes. As is common in robotic and autonomous systems, however, the manner in which these systems are designed and employed can play a large role in their effectiveness, and this evaluation demonstrated several examples of this as well. Getting the technology right is only half the battle.

Ultimately, how the US Navy and Marine Corps plan to manage casualty evacuation in future conflicts is partially informed by results from studies such as this. Taking science and technology out of the constraints of laboratory environments and into environments that mimic real life is critical to the success of fielding innovative solutions. This is the purpose of 6.5, system development and demonstration activities on the RDT&E spectrum.