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Introduction

The Marine Corps fights in accordance with the doctrine of maneuver warfare. Per Marine Corps Doctrinal Publication 1, *Warfighting* (MCDP 1), this doctrine is based on “rapid, flexible, and opportunistic maneuver.”1 Particularly important is the idea that time is an element of maneuver and that by generating a quicker operating tempo one can gain a “temporal advantage” over the enemy. Another important concept taken from MCDP 1 is the concept of combined arms, which is the “full integration of arms in such a way that to counteract one, the enemy must become more vulnerable to another.”2 The infantry is the key component of the combined arms team and all other aspects of the Marine Air Ground Task Force (MAGTF) are built around the infantry as support. Yet despite the infantry being the most important component of the MAGTF and therefore the instrument that will be used to conduct maneuver warfare, it has several limitations that are keeping it from realizing its true potential: limited survivability, speed, and firepower. In order for infantry to execute maneuver warfare, they often must be carried into battle by armored vehicles that possess the speed to rapidly move about the battlefield, heavy armor for protection, and the firepower to decisively defeat the enemy. However, technology is currently being developed that will augment the individual infantryman and allow him to be highly mobile, highly protected, and employ greater firepower than ever before. This technology is the Armored Powered Exoskeleton. Armored Powered Exoskeletons will provide infantry with superior protection, speed, and firepower on the battlefield and by doing so will bring the doctrine of maneuver warfare closer to its full potential.
The Marine Corps Tank/Infantry Team and the Need for an Armored Powered Exoskeleton

In order to achieve success in maneuver warfare as explained in MCDP 1, infantry must be able to move rapidly throughout the battlefield and bring superior firepower to bear on the enemy at the decisive point. The current method for employing speed and firepower across the battlefield is the tank/infantry team. The venerable "Team Mech" and "Team Tank" concepts, in which an infantry unit is mounted in Amphibious Assault Vehicles (AAV) and paired with a tank unit to form a ground combined arms team, is how the Marine Corps employs the tank/infantry team. These formations have the capability to conduct operations requiring a high degree of firepower, mobility, armor protection, and shock effect. Tanks and infantry share a symbiotic relationship. The tanks provide the heavy firepower and shock effect to support the infantry and the infantry can clear terrain the tanks cannot operate in, secure prisoners, dig in and hold decisive terrain, attack enemy antitank defenses, and protect the tanks from close-in assault. Together, they have the survivability, mobility, and firepower to break through and tactically exploit using opportunistic maneuver to gain the temporal advantage over the enemy.

This capability, however, is wholly dependent upon the infantry being mounted in AAVs in order to be able to keep pace with the tanks. Additionally, the infantry is dependent on the armored capability of the AAVs for survivability as well as the carrying capacity of the AAVs to transport heavy infantry weapons such as machineguns and mortars. The infantry also rely on the AAVs' mounted weapons for heavy fire support. When the infantry dismount, the survivability, mobility, and firepower the infantry enjoyed from the AAV decreases. Dismounted infantry are more susceptible to small arms fire, machine gun fire, and blast and fragmentation from grenades and Improvised Explosive Devices (IED). Dismounted infantry can go many places that vehicles cannot but they give up speed and the ability to outmaneuver enemy infantry forces when
separated from their armored carriers. Lastly, the heavy firepower an infantryman can employ in the form of machineguns and mortars is much more cumbersome to employ while dismounted and foot mobile for extended periods of time.

An additional limitation to the employment of Team Tank or Team Mech is the limited numbers of AAVs available to Marine Corps infantry. Currently, 1st Marine Division has two battalions of AAVs and 2nd Marine Division has one. An AAV battalion can lift approximately one regiment of infantry. The ramifications are apparent: 1st Division can mount two of its three regiments in AAVs and 2nd Division can only mount one of its regiments, leaving a significant number of units less than capable of conducting true maneuver warfare.

If only there were a way for the infantry to be able to retain the survivability, mobility, and firepower of the AAV when dismounted. Clearly an enhancement for the individual infantry Marine infantryman is necessary. Fortunately, the emerging technology of the Armored Powered Exoskeleton will be able to overcome many of the limitations listed above and will provide additional capabilities to the infantry in order for them to fulfill their role as the centerpiece in maneuver warfare.

**Emerging Exoskeleton Capabilities**

Before exploring the future possibilities of Armored Powered Exoskeletons and their implications on the battlefield, it is necessary first to briefly explain what an exoskeleton is, the current level of the technology, and feasibility for the Armored Powered Exoskeleton to be further developed and fielded. Normally the mention of an Armored Powered Exoskeleton for military application conjures up images of Marvel’s Iron Man, the Mobile Infantry from Heinlein’s *Starship Troopers*, or even Space Marines from Warhammer 40,000 (see Figure 1). In fact, science fiction is full of images and stories of super-powered soldiers in powered armor
dominating their foes on battlefields of the future. The basic premise of these science fiction characters though, is actually becoming reality with modern exoskeleton technology. An exoskeleton is defined as "an active mechanical device that is essentially anthropomorphic in nature, is 'worn' by an operator and fits closely to his or her body, and works in concert with the operator's movements." This mechanical device is essentially a wearable robot that a person dons and operates simply by moving as normal. The exoskeleton does not require a user interface such as a keyboard, mouse, or joystick, but rather responds to the wearer's movements. The input to control the actuators of the exoskeleton is the normal movement of the human body, meaning there is no special training to teach a user to operate an exoskeleton.

There are several types of exoskeletons currently in existence and being developed and refined. The two most mature areas of exoskeleton development are for the health and rehabilitation industry and exoskeletons for military application. Exoskeletons in the health industry focus mainly on augmenting the strength of workers dealing with elderly or infirm patients, or restoring mobility to patients. Military exoskeletons have so far focused on increasing the mobility and performance of the individual warfighter by providing a load-carrying capability to reduce fatigue.

Lockheed Martin's Human Universal Load Carrier (HULC) and Raytheon's XOS Exoskeleton have been the longest in development for military use. The HULC is a battery powered, lower-body-only exoskeleton that is intended to reduce soldier fatigue and injuries. The HULC transfers the carried weight to the ground through powered titanium legs and can operate for four hours on one battery pack at a walking speed of three miles per hour and bursts of speed up to 10 miles per hour. The XOS is a full-body exoskeleton powered by an external power source via an umbilical that greatly enhances the user's strength, at a ratio of
approximately 25:1. The primary application of the XOS is work augmentation in a logistics support role, allowing the operator to act as a “human forklift.”

Beyond the HULC and the XOS, the Defense Advanced Research Projects Agency (DARPA) is currently working on “Warrior Web”, a small powered exoskeleton imbedded in a garment that can be worn beneath a camouflage uniform. The function of Warrior Web is to significantly reduce musculoskeletal injury associated with the greater loads of today’s infantryman. The garment would protect injury-prone areas by stabilizing and reducing stress on joints and promoting efficient and safe movement over a wide range of activities (walking, running, jumping, crawling, etc.). The suit would also include technologies to augment the wearers’ muscles, helping reduce fatigue during endurance-related tasks.

HULC, XOS, and Warrior Web are examples of the current state of exoskeleton technology and from them the realistic possibilities for the future can be extrapolated. In fact, the U.S. Army Research, Development and Engineering Command (REDCOM) has already done just that. REDCOM has responded to a request from U.S. Special Operations Command (SOCOM) to develop an advanced infantry uniform that promises to provide superhuman strength with greater ballistic protection. This new uniform has been designated the Tactical Assault Light Operator Suit, or TALOS. US Army Lieutenant Colonel Karl Borges, a REDCOM science advisor described the TALOS as “a comprehensive family of systems in a combat armor suit where we bring together an exoskeleton with innovative armor, displays for power monitoring, health monitoring, and integrating a weapon into that.” TALOS is clear evidence that the Armored Powered Exoskeleton is feasible and within the realm of the possible. Lieutenant Colonel Joseph Hitt, US Army, a Ph.D. in Mechanical Engineering and program manager for Warrior Web says, “we are a lot closer than you think.” Currently, the limiting
factor in creating an Armored Powered Exoskeleton, or what Hitt calls a “hard-shell suit” is the power source. Current power technology does not have the energy density in a small enough package to power a hard-shell suit for any usable duration. However, the technology is expected to mature to the point that the Armored Powered Exoskeletons a reality within 10-15 years.17

**Armored Powered Exoskeleton Requirements**

The infantry’s speed, survivability and firepower must be enhanced by Armored Powered Exoskeletons in order for the Marine infantryman to fulfill his role as the centerpiece of maneuver warfare. It follows then that the Armored Powered Exoskeleton must be able to move rapidly and with agility on the battlefield. Foot-mobile forces have the inherent advantage of being able to operate in restricted terrain but have lost the ability to “out-tempo” the enemy owing to the weight of body armor, heavy weapons, electronics, communications equipment, etc. Thus the Armored Powered Exoskeleton must be able to both bear the load of the infantryman as well as enhance his ability to move at a high rate of speed for a sustained period of time. While no exoskeleton will match the speed of a vehicle, infantry equipped with Armored Powered Exoskeletons will be able to move as if unencumbered and sustain a high rate of march with minimal metabolic tax on the Marine. Increased speed alone will give the infantry a tempo advantage over the enemy.

The Armored Powered Exoskeleton must also enhance the Marine’s survivability. The hard shell armor must be able to withstand small arms fire and provide increased protection from blast and fragmentation. To that end, emergent materials science will develop lighter armor and the load of the armor will be borne by the exoskeleton. Such enhanced protection will allow the infantry to fight and survive on the battlefield.
Finally, the Armored Powered Exoskeleton must enhance the infantryman’s ability to bring overwhelming firepower to bear quickly at the decisive point. The Armored Powered Exoskeleton must make it easy to carry weapons already in the rifle squad’s inventory as well as greater quantities of ammunition, and yet at the same time allow ease of movement and emplacement of medium and heavy weapons.

These enhancements of speed, survivability, and firepower that Armored Powered Exoskeletons will give to the Marine infantry will provide a decisive tactical asymmetry over the enemy that will move the Ground Combat Element closer to tapping the full potential of maneuver warfare.

**Armored Powered Exoskeleton Implications**

The need for the Armored Powered Exoskeleton has been discussed, as has the feasibility of developing this technology and the requirements that it must fulfill. Now the implications of infantry units equipped with Armored Powered Exoskeletons will be explored focusing on the following four areas: tempo, increased survivability and firepower, economy of force, and expeditionary operations.

**Tempo**

The need to operate faster than the enemy and generate a temporal advantage is a central tenet of maneuver warfare. As already noted, one easy way to achieve this is to have the capability to literally move faster than the enemy on the battlefield. The advantage of having a higher relative speed of movement than the enemy has been demonstrated throughout the history of warfare. Napoleon outmarched his opponents, conducting wide sweeping turning movements and cutting off his enemy.\(^{18}\) Stonewall Jackson did the same at Chancellorsville, securing victory by marching his corps rapidly around the Union flank and conducting a successful flank
attack. As motorization and mechanization became commonplace, vehicles took the lead role in exploiting speed. The German breakthrough and exploitation in France in 1940 introduced the world to the concept of "blitzkrieg". While seemingly a new phenomenon using new weapons such as panzers and dive bombers, blitzkrieg was nothing more than operating faster than the enemy could react.

Motorization and mechanization seemed to relegate the foot-mobile infantry to a second place role in maneuver warfare. This is due to the decreased operational speed of foot-mobile infantry in the modern era. The infantryman is so encumbered with body armor, electronics, and weapons that his operational speed has greatly decreased. The current Approach March Load, defined as that load for conducting a 20-mile march within eight hours maintaining 90% combat effectiveness, is recommended to be approximately 76 lbs, or 45% of the body weight of the average Marine.\(^1\) However, the Naval Research Advisory Committee study, *Lightening the Load*, determined that the actual Approach March Load is currently 123 lbs, or 73% of the body weight of the average Marine (see Figure 2).\(^2\) The same study showed a direct correlation between weight carried and a drop in marching rate and combat effectiveness derived from the Goldman Metabolic Energy Cost Model (see Figure 3).\(^3\) Because of the load they carry, foot-mobile infantry have lost the ability to create a temporal advantage.

As discussed earlier, there are not enough assets to mount every infantryman in an AAV or transport them in trucks. This leaves foot-mobile infantry units lagging behind the fight, waiting on limited assets to move them about the battlefield. Infantry equipped with Armored Powered Exoskeletons would be able to move greater distances without relying on other assets. While not moving as rapidly as mounted troops, they would still be able to maneuver and make
use of their enhanced speed over non-similarly equipped troops, providing the commander with
greater use of all of his forces and more options.

The Armored Powered Exoskeleton will be able to carry the armor, electronics,
sustainment, and weapon systems with a greatly decreased metabolic tax on the Marine. The
Marine will be able to march faster than the enemy at a sustained rate and be combat effective
upon arriving at the fight. By operating as if unencumbered, coupled with the augmented speed
the Armored Powered Exoskeleton can provide, the foot mobile infantry will possess the
capability to turn their legs into weapons.

**Survivability and Firepower**

The Armored Powered Exoskeleton will provide the infantryman with greater
survivability and firepower which will make him a greater asset in the combined arms team. As
previously discussed, the infantry in the tank/infantry team often dismount from their AAVs to
conduct operations. During these periods of dismounted activity, they are more vulnerable to
small arms fire and blast and fragmentation from grenades and IEDs. The armor protection
provided by the Armored Powered Exoskeleton will increase the survivability of the infantry,
allowing them to more easily accomplish their mission. This will, in turn, increase the
survivability of the tanks the infantry are operating with, leading to reduced risk to the force.

Along with increased survivability, the Armored Powered Exoskeleton-equipped infantry
will be able to employ greater firepower. Integrating weapons into an exoskeleton is one of the
goals of the TALOS project. But even without an integrated weapon, Armored Powered
Exoskeleton-equipped troops can bring heavy weapons to bear on their enemies more easily than
“straight-legged” infantry. Due to their augmented strength, they will be able to more rapidly
move, emplace, and employ heavy infantry weapons currently in the inventory. Marching with
the components of a heavy machine gun or mortar will be much less of a burden and
emplacement and displacement times will be shortened. This will allow Armored Powered
Exoskeleton-equipped troops to apply greater firepower at the decisive point and achieve fire
superiority over a numerically similar or even a numerically superior enemy.

Economy of Force

Armored Powered Exoskeleton troops will provide an economy of force as their
survivability and firepower will allow them to engage forces significantly above their "weight
class." This will provide the commander with more options at the tactical level. A unit of
Armored Powered Exoskeleton infantry can fix a larger force for a longer period of time than
non-equipped troops. Delaying actions can be conducted by smaller units equipped with
Armored Powered Exoskeletons. In both examples, the bulk of the force is free to be employed
elsewhere, providing for economy of force.

Expeditionary Operations

The capabilities of the Armored Powered Exoskeleton will make infantry inherently
expeditionary. Infantry equipped with Armored Powered Exoskeletons will be uniquely suited
to conduct many of the missions that Marine Expeditionary Units (MEUs) currently execute.
They will be particularly effective in conducting missions that normally would require armored
vehicles, such as a mechanized raid. A mechanized raid usually calls for the mobility,
survivability, and firepower that an AAV can bring to bear along with delivering the infantry to
the objective. This requires the amphibious ship delivering the AAVs to conduct well deck
operations and maneuver the ship to the launch point. The ship is vulnerable while launching the
AAVs and the AAVs themselves are vulnerable during their swim to the beach. This is a
logistically intensive operation with significant risk to the force. Armored Powered
Exoskeleton-equipped infantry will eschew these “luxuries”. They can be inserted via helicopter, maneuver to the objective, and use their survivability and overwhelming firepower to accomplish the objective. An infantry unit equipped with Armored Powered Exoskeletons negates the need to launch AAVs, keeps the amphibious shipping protected, and increases the expeditionary options of the MEU commander to conduct maneuver warfare.

Vertical envelopment will also become a more viable expeditionary option when employing Armored Powered Exoskeleton-equipped infantry. The Armored Powered Exoskeleton unit can protect and sustain themselves for longer durations because of their ability to carry heavy loads alongside their built in survivability. Lifting a battalion into an objective to secure a lodgment becomes a more promising option with the knowledge that they will be better able to withstand enemy counterattack, engage numerically superior forces, and survive and sustain themselves for a longer duration while waiting for link-up with follow-on forces.

Embassy reinforcement is another mission where Armored Powered Exoskeleton troops would excel. Many U.S. embassies are located in dense urban environments with no available landing zones, requiring Marines to land outside the compound and then conduct a movement through a potentially hostile environment to the embassy. Marines equipped with Armored Powered Exoskeletons would be more protected while moving through such a hostile environment and would be well armed and equipped to withstand a siege of the compound if necessary. Alternatively, the exoskeleton would provide the capability to easily absorb a 20-30 foot jump from a hovering helicopter directly onto the grounds of the embassy thus removing the need for either a landing zone or a potentially dangerous fast roping operation.23

These three scenarios of raid, vertical envelopment, and embassy reinforcement demonstrate the innate expeditionary nature of Armored Powered Exoskeletons, how they nest
with the current doctrine of maneuver warfare, and enhance the infantry to be the central figure in maneuver warfare.

Challenges

There are several potential pitfalls and questions that will need to be addressed in order the make Armored Powered Exoskeletons an operational reality. Maintenance, power consumption, and cost are chief among them. Like a vehicle or an aircraft the introduction of the Armored Powered Exoskeleton is going to bring with it new maintenance requirements for the user, and require an established maintenance and supply chain. It would be imprudent to field this new gear until the technology allows for simple first and second echelon maintenance by the infantry units themselves. Third and fourth echelon maintenance chains can be established following existing models of new equipment fielding protocols. Preventive Maintenance Checks and Services (PMCS) can be established that the individual infantryman can conduct himself and maintaining an Armored Powered Exoskeleton suit will be a requirement similar to weapons maintenance.

Power consumption has already been discussed as the major hurdle to exoskeleton development. Energy density technology is being rapidly researched and improved and the requirement for an Armored Powered Exoskeleton would be for a long sustaining power source that could be rapidly swapped out with a replacement, similar to the current battery system in use today.

The cost of an individual Armored Powered Exoskeleton would be determined and managed like any other large procurement project. If the cost of the system is prohibitive to fielding each infantryman with an Armored Powered Exoskeleton, an alternative could be to procure enough to create an Armored Powered Exoskeleton unit in each battalion. Similarly to a
weapons company in an infantry battalion, this unit could be structured to give the battalion commander the best options of employing exoskeleton-equipped troops as the mission and situation dictates. By having the option to mass and employ Armored Powered Exoskeleton-equipped troops at the decisive point or reinforce a line company with a detachment, the commander would have access to the enhancing effects an Armored Powered Exoskeleton provides the infantry to maximize the use of maneuver warfare.

**Conclusion**

Infantry has been the centerpiece of armies throughout history and remains so today. As fighting techniques and doctrine have changed the infantry has been forced to evolve and adapt its battlefield role. While the infantry remains the centerpiece of the Ground Combat Element that the MAGTF is built around, the infantry possesses several limitations that keep it from realizing the full potential of maneuver warfare. Enhancing the survivability, speed, and firepower of the infantry would not necessitate a shift in doctrine but would allow the current doctrine to be more fully realized. The way to do this is with the Armored Powered Exoskeleton. The options that Armored Powered Exoskeleton-equipped troops will provide to commanders are the next evolutionary step in maneuver warfare.

Exoskeleton technology exists today and is rapidly developing for the future. It is a logical deduction that the Armored Powered Exoskeleton could become a reality in the next 10-15 years. This technology would provide for improved survivability, speed, and firepower to the infantry that would allow them to fulfill their centerpiece role in maneuver warfare. The Department of Defense and the Marine Corps should continue to develop this technology in order to maximize the ability to operate according to the tenets of the doctrine of maneuver warfare and be successful on the battlefield of today and those of tomorrow.
Endnote

2 Ibid, 94
3 “Team Mech” and “Team Tank” is a concept of task organizing a force of tanks and infantry together. Team Mech would consist of more AAVs than tanks, usually at a ratio of 2:1. Team Tank would be the inverse.
5 Ibid, 1-8 and 1-9
6 C. Travis Reese, “Exoskeleton Enhancements for Marines: Tactical-Level Technology for an Operational Consequence” (master's thesis, SAW, 2010), 10
9 Reese, 11
10 John McHale, “Exoskeleton Technology Reduces Soldier Fatigue and Injury,” Military and Aerospace Electronics, No 20.6 (June 2009) 6,12, http://search.proquest.com
11 Ibid
12 Reese, 11
15 Ibid
16 LTC Joseph Hitt (Ph.D. Mechanical Engineering, Warrior Web Program Manager), interview by Andrew Roberts, October 31, 2013.
17 Ibid
19 Lightening the Load January - September 2007 NRAC 07-02, Naval Research Advisory Committee 875 North Randolph Street Arlington, Virginia 22203-1993
20 Ibid
21 Ibid
22 Based on the rates of march of the HULC, future Armored Powered Exoskeletons can be expected to be able to sustain a march rate of 4-5 MPH with bursts up to 10 MPH.
23 LTC Joseph Hitt
Figure 1. This Figure shows three types of fictional Armored Powered Exoskeletons. Left to right are Marvel’s Iron Man, James Warhola’s cover art to *Starship Troopers* by Robert Heinlein, and Space Marines from Warhammer 40,000 by Games Workshop.
Load Description | Recommended Load | Current Rifleman's Load
---|---|---
**Assault Load** (in the Fight) Conduct combat operations indefinitely with minimal degradation in combat effectiveness | 50 lb 30% of body wt based on Avg Marine (169 lb) | 97 lb 67% of body wt

**Approach March Load** (Getting to the Fight) Conduct 24-mile march within 8 hours maintaining 50% combat effectiveness | 76 lb 46% | 123 lb 73%

**Existence Load** Limited movement within confines of transportation platforms and limited marching from landing zone into secure area | 127 lb 75% | 167 lb 99%

* MIL-STD-1173F  **Information received from MCCDC, Quantico*

**Chart 2** Marine Rifleman Loads

Figure 2. This Figure shows the comparison between recommended weights for various load types based on the average weight of a male Marine and those actually carried in combat. (Source NRAC Lightening the Load Study, September 2007)

**Marching Distance in 8 Hours**

Figure 3. This Figure shows the results of an Army study developed from the Goldman Metabolic Energy Cost Model indicating that as weight increases a soldier's ability to march a given distance over 8 hours is decreased. This study was done on dirt with a 1% grade. (Source NRAC Lightening the Load Study, September 2007)
Figure 4. This Figure shows three current exoskeletons being developed for military application. Left to right are the Human Universal Load Carrier (HULC) by Lockheed Martin, the Raytheon XOS, and DARPA’s Warrior Web.
Bibliography


