Advancing an Understanding of Military, Robotic Exoskeletons

STEVEN YEADON

This article surveys an understanding of robotic exoskeletons in relation to the infantry.

> "Robotic exoskeletons are electronic devices that attach to a human user's body and contain actuators that deliver mechanical power to augment movement. One class of these devices facilitates upper-limb movements such as reaching, grasping, or lifting with the arm or hand. The other primary category of robotic exoskeletons augments lower limb functions such as sitting down, standing up, walking, balancing, and standing. Full body exoskeletons can fulfill a combination of these purposes."[1]

There are three broad types of robotic exoskeletons: assistive devices for those with disabilities, therapeutic robotic exoskeletons for rehabilitation, and human performance augmentation exoskeletons intended to increase strength, endurance, and other physical capabilities of able-bodied people.[2] This last type of exoskeleton is what my analysis will focus on.

In my opinion, robotic exoskeletons represent more than an enhancement to current infantry. Military, robotic exoskeletons can create a distinct kind of heavy infantry unit that can improve current U.S. Army combined arms teams. This objective may be feasible sooner than one may think if robotic exoskeleton-equipped formations have an expanded logistical footprint, which includes the need for a regular supply of charged batteries as well as other logistical concerns. However, this is an untested future military concept, and my analysis is meant only to stimulate discussion on how to employ exoskeletons in military operations.

This article will cover military applications of exoskeletons, current exoskeleton technologies, previous military concepts, possible solutions to potential issues, and other concerns regarding the employment of heavy infantry using robotic exoskeletons.

Soldiers from the 2nd Cavalry Regiment conduct a 12-mile ruck march near Camp Albertshof, Germany, on 9 December 2015. Exoskeletons can be created to augment human performance to increase strength, endurance, and other physical capabilities. (Photo by SSG Jennifer Bunn)

A Soldier wears an exosuit while on a treadmill at a U.S. Army Research Laboratory facility at Aberdeen Proving Ground, MD, on 15 June 2017. The suit is part of the Army's Warrior Web Program. (Photo by David McNally)

Military Applications of Exoskeletons

One of the first planned military applications for robotic exoskeletons gives greater strength and endurance to service members when working with a heavy load.[3] As a logistical and engineering piece of equipment, these exoskeletons would enhance and take the burden off logistics troops performing heavy lifting outside of combat.

A second planned military application for robotic exoskeletons relates to military combat involving Soldiers, Marines, and special operations forces and would provide them relief from the extremely heavy loads they must currently bear in combat situations. The average U.S. Army Soldier must carry around 96-140 pounds of equipment on a three-day mission.[4] The U.S. Marine Corps is adopting a requirement for its infantry to be capable of carrying up to 152 pounds for a nine-mile march.[5]

Four approaches are proposed for solving this problem of the overloaded Infantryman:

- Reduce the weight of the equipment carried by an Infantryman. A caveat of this approach is that ultra lightweight materials are already in use for such equipment, such as Kevlar and carbon fiber.[6]

- Improve human capabilities without more weight. These include new technologies providing superior equipment without more weight, a difficult line of inquiry given the need to develop advanced technologies and medical human enhancement, although the ethics of this area of inquiry are of the utmost importance.[7]

- Use robots as a kind of "pack animal" to carry heavy equipment. The current Squad Multipurpose Equipment Transport (SMET) program aims to develop a robot to carry 1,000 pounds of equipment for an infantry squad of about nine Soldiers.[8] However, problems facing this option include excessive noise generated by the robots and the need for robots to be autonomous enough not to require additional troops to supervise them.[9]

- Increase the carrying capacity of the Infantryman through exoskeletons to reduce the load they feel like they are carrying.[10] Increasing the load-bearing capability of Soldiers, Marines, and special operations forces, however, may translate into even heavier loads of armor, weapons, ammunition, and supplies being required of them.

A third role for military exoskeletons going into the future will be to provide new capabilities for military combat. This was the goal of Special Operations Command's Tactical Assault Light Operator Suit (TALOS) program. TALOS would give special operations Soldiers improved protection, situational awareness, lethality, and human performance.[11] However, the TALOS program was too ambitious and ended in 2019.[12]

Current Exoskeleton Technologies

An understanding of current exoskeleton technology will give some context for more advanced military technologies. Since much of the information on exoskeleton specifications is protected, this analysis will look at the Sarcos Robotics Guardian XO exoskeleton as an example for some key technological takeaways. This is due to a willingness of Sarcos Robotics to release some of the basic specifications of their technology. That said, the Guardian XO is not meant for military combat and is instead for logistical support.

A general engineering problem is that "you can't maximize strength and speed and agility in the same exoskeleton… any more than you can carry Humvees in an F-16 or dogfight in a C-130."[13] The Guardian XO itself has the ability to lift loads of up to 200 pounds, with heavy loads feeling like only one twentieth of the actual weight.[14] Its battery lasts for eight hours under this strain, and the robot carries three batteries that can be changed or "hot swapped" to keep the exoskeleton going.[15] The batteries weigh 12 pounds each, and the Guardian XO weighs approximately 200 pounds without batteries.[16] Each battery requires 500 watt hours to fully charge, which can be accomplished in less than an hour.[17] This means that a high mobility multipurpose wheeled vehicle (HMMWV) towing a 60-kilowatt generator trailer can theoretically recharge up to 120 batteries in less than an hour.

Additional concerns about the Guardian XO is that the "amount of maintenance required will vary based on customer use cases and the operating environment."[18] This may translate into a need for regular maintenance in the demanding environments military personnel work in. The Guardian XO will need military personnel trained to repair the exoskeletons and spare components for repairs.[19]

Returning to the subject of robotic exoskeletons designed for military combat, one necessity for exoskeletons in military combat is that "the military user must have the ability to perform the full range of combat movement, to include agile shifts in position, loading and firing a weapon, and running with a full pack."[20] Thus, exoskeletons for military combat will need to do more than just increase strength and endurance like some commercial exoskeletons promise to do. This problem is ultimately one of improving the control systems and mechanisms on robotic exoskeletons through more research.[21] Another issue is that military, robotic exoskeletons will need batteries that last as long as 24-72 hours for standard infantry missions.[22]

Other examples of exoskeletons under development include the ONYX (left) and the ExoBoot (right).
(Photo courtesy of RDECOM Soldier Center)

There are other exoskeletons in development for military use, however, that may get around the logistical hurdles heavier, hard exoskeletons currently possess. For instance, there are soft exoskeletons that use fabric and other lightweight materials in place of rigid structures made from materials like metal. The Wyss Institute has developed soft "exosuits" that provide mechanical power while walking without need for a heavy, often metallic exoskeleton.[23] The Defense Advanced Research Projects Agency (DARPA) is developing an exosuit called Warrior Web that will function as a conformal under-suit (like a diver's wetsuit) to be worn underneath military equipment and body armor. Warrior Web aims to prevent musculoskeletal injuries during military operations using a system (or web) of actuators, transmission, and functional structures to protect injury prone areas.[24]

Other examples include ONYX, a lower body robotic exoskeleton produced by Lockheed Martin in partnership with B-Temia and based on B-Temia's KSRD Dermoskeleton™ technology; ExoBoot, a lower body exoskeleton produced by Dephy; and ExoBuddy, a load-bearing exoskeleton produced by Intespring. These exoskeletons have the promise of reducing fatigue and increasing endurance for infantrymen when performing overland marches.

A Previous Proposal for Heavy Infantry

In a 2018 *INFANTRY* article, CPT Matthew Allgeyer proposed the idea of a heavy infantryman that would "be fundamentally different than any previous infantryman armed with a gun."[25] Materiel define heavy infantry since they will be a shock unit with heavier ballistic armor to maneuver while under small arms fire and employ heavier weapons than those used by light infantry units common today.[26] Heavy infantry will also have increased protection against shrapnel, reducing the effective blast radius of enemy indirect fires. The heavy infantry concept would require the adoption of new materiel designed for heavy infantry based on testing. However, there will still need to be a balance between protection and firepower with mobility and flexibility. In modern high-speed and kinetic fights, heavy infantry will need to be ready for combat when initial contact is made.[27] This concept of increased lethality and survivability for infantrymen is a surprisingly similar idea envisioned for exoskeleton-equipped soldiers using TALOS. Allgeyer's proposal may indicate where exoskeleton technology is taking the infantrymen of the future.

Additionally, Allgeyer proposed that heavy infantry use Bradley fighting vehicles to transport troops to the point of decision in battle. However, he noted that the Bradley is not a perfect solution since it is not optimized for troops of greater size and weight than normal. Infantry brigade combat teams (IBCTs) may also lack the ability to incorporate such vehicles into their force structure.[28] However, given the U.S. Army's infantry squad vehicle program, light transports for heavy infantry may be purpose-built to keep up with an increasingly mobile IBCT.

Allgeyer noted that heavy infantry may be particularly useful in urbanized terrain due to the increased protection, which will make them more resistant to small arms fire. This will give heavy infantry the opportunity for greater risk against an enemy, and it will provide shock and firepower against individual point targets in an urban environment. Heavy infantry will force an enemy to consolidate heavier weapons and be more deliberate with setting defenses to counter, reducing their freedom of maneuver, making them easier to maneuver against, and constraining them to more readily identifiable points of advantage.[29]

As Allgeyer also noted, an opportunity exists to use exoskeletons in military combat sooner than previously predicted. Batteries need not last three days if the assumption is that exoskeleton units need a continuous supply of charged batteries. Allgeyer proposed that the armored vehicles that carry heavy infantry into combat could recharge their batteries.[30]

Another idea this article proposed is that dedicated trains — "a unit grouping of personnel, vehicles, and equipment to provide sustainment" — could be organic to exoskeleton units.[31] The proposed heavy infantry units will require a kind of fuel — batteries. This means that charged batteries must be provided at regular intervals of time. Such units will be tethered to a logistic supply chain that may require that they not operate for long without resupply. Trains would provide vehicles with towed generators, fuel for both generators and light vehicles, and ammunition. Depending on the weight and reliability of exoskeleton technologies, it may be necessary to include recovery vehicles for damaged or disabled exoskeletons and vehicles with maintenance personnel and lightweight exoskeleton components for repairs. Furthermore, trains will need protection against enemy attack. This may require additional armed vehicles to provide security.

Another possible idea is to incorporate a variant of the Optionally Manned Fighting Vehicle (OMFV) into IBCTs

For dismounted Soldiers in the field, one of the most common injuries is from carrying nearly 100 pounds of gear for extended periods, often over rough terrain. Exoskeletons could help injured warfighters maintain mobility and combat-effectiveness. (Photo by David Kamm)

utilizing heavy infantry. Such an OMFV variant will be designed for larger, heavier infantrymen and would have an alternator capable of recharging exoskeleton batteries. Additionally, the OMFV will have a 50-millimeter automatic cannon with an effective range of 4 kilometers using a variety of ammunition types including armor-piercing rounds and airburst rounds able to defeat enemies in defilade.[32] These capabilities could be as revolutionary to introduce to the IBCT as the planned mobile-protected firepower light tanks.

These two ideas of how to work around limited energy density in current man-portable power sources could allow for military exoskeleton research to aim primarily for advancing and ruggedizing the materials, sensors, actuators, and controllers for robotic exoskeletons.

Further Insights on the Application of Robotic Exoskeleton-Equipped Heavy Infantry

The role of exoskeleton units in need of regular resupply will need further examination. This article will review some of the new capabilities created by such units to incentivize further discussion.

To begin, a problem arises in that, for the near-term, units equipped with exoskeletons will require vehicles to act as a trains for them, or such units will need vehicles to transport them and recharge batteries. This means that units equipped with exoskeletons will need to stay close enough to their vehicles for resupply or will need regular air resupply. This could severely limit the range of foot-mobile troops equipped with exoskeletons. It also means that Soldiers, Marines, and special operations personnel equipped with exoskeletons will be vulnerable to having their resupply cut off if enemy units target their trains or isolate them from resupply, such as through a siege. Units equipped with exoskeletons will also need an assessment as to whether they have too much of a logistical footprint for operations in austere environments such as forcible entry operations.

An important consideration is that a unified force of exoskeleton-equipped heavy infantry will not be as effective as presenting an enemy with a combined arms team. The U.S. Marine Corps tactics manual states that combined arms presents enemy not merely with a problem but a dilemma — a no-win situation. The combination of maneuver, supporting arms, and organic fires combine in such a way that any action the enemy takes to one threat makes him vulnerable to another.[33] The combination of exoskeleton-equipped heavy infantry and traditional infantry serving as light infantry in the maneuver element may add another factor that an enemy must overcome.

As stated earlier, heavy infantry equipped with exoskeletons could be effective in situations where they are rapidly transported to the point of decision in battle. Such exoskeleton-equipped units could also act as support units providing shock and firepower in larger infantry formations, such as infantry battalions. Soldiers, Marines, and special operations personnel equipped with exoskeletons and serving as heavy infantry may present a superior force to using purely light infantry in restricted or severely restricted terrain. Additionally, heavy infantry equipped with exoskeletons may be best for house-to-house, room-to-room combat. Such troops may be effective when sieging enemy forces, such as in an urban area. Two examples in recent memory are the first and second battles of Fallujah. Troops equipped with exoskeletons face the same limitations as infantry units: a limited decontamination capability if exposed to chemical, biological, radiological, or nuclear (CBRN) weapons and a vulnerability to enemy armor, artillery, and air assets when employed in open terrain.[34] This only enhances the role of exoskeleton-equipped units in urban areas or restricted/severely restricted terrain. However, a key restraint of these ideas is the need to not stray far from the vehicles providing logistic support.

It is also prudent to analyze whether it is an effective idea for heavy infantry to "dismount" from their exoskeletons and turn into light infantry if needed, due to such things as damage to the exoskeleton, depleted batteries, or tactical concerns. If exoskeleton-equipped heavy infantry have heavier armor and weapons than light infantry, then it would be prudent to study whether such armor could be modular and quickly taken off except for an armor package like light infantry. The goal would be to radically reduce the weight carried by dismounted infantrymen for improved mobility. It may also be prudent to include a carbine and ammunition as standard equipment for use if dismounted or as a secondary weapon if heavier weapons run out of ammunition.

Mechanized infantry units may benefit by having a mix of light and exoskeleton-equipped heavy infantry with the necessary changes needed for expanded logistic support. Stryker brigade combat teams (SBCTs), which lack the armor or firepower of heavier armored vehicles and are an infantry-centric force, may especially benefit by incorporating heavy infantry. Transporting Soldiers equipped with exoskeletons, along with light infantry to support them, may give an SBCT an even greater advantage against enemy infantry units. This could prove very useful against irregular military forces such as terrorists or insurgents or against the light enemy forces of a nation-state. This improved capability could improve the role of SBCTs in operations to consolidate gains, which are "activities to make enduring any temporary operational success and set the conditions for a stable environment allowing for a transition of control to legitimate authorities."[35] Armored brigade combat teams (ABCTs) may be improved if a mix of heavy infantry equipped with exoskeletons and light infantry can achieve overmatch consistently against enemy mechanized infantry units — thus, helping to mitigate the dilemma presented by mechanized infantry as part of an enemy's combined arms team.

Another possibility is to field heavy infantry equipped with exoskeletons as defensive units by making them protectors of forward operating bases, which can provide fuel and generators to sustain them. This could lead to improved lethality and protection for infantry defending such bases.

Major Concerns Regarding Robotic Exoskeleton-Equipped Heavy Infantry

There are a variety of concerns about the use of heavy infantry equipped with military, robotic exoskeletons. First, a larger logistical footprint may hurt infantry units in regard to one of their capabilities — a smaller logistical footprint in relation to other types of units.[36] One example of how a small logistical footprint can change the course of an operation is during a siege, such as what occurred during the siege of Bastogne in the Battle of the Bulge. Sieges are a real possibility in the future, especially in a war with a near-peer such as Russia, which uses battalion tactical groups that excel at sieges.[37] A key question becomes how infantry units will fare when wedded to robots down to the infantry squad, platoon, and company levels. This is especially troubling if U.S. troops endure a siege. Even attaining a 72-hour battery life may leave U.S. troops at a distinct disadvantage.

Second, exoskeletons affect strategic mobility since a heavy infantry company will need expanded vehicles for their logistical needs. For instance, a U.S. Army infantry company currently requires a Family of Medium Tactical Vehicles (FMTV) truck towing a water buffalo and a HMMWV with towed trailer.[38] However, an infantry company with exoskeletons will likely need an additional HMMWV to tow a generator for recharging batteries and another to tow a trailer for carrying fuel to support it. Depending on the weight and size of the exoskeletons, there may also be a need for a HMMWV to tow a trailer with spare parts, a Soldier (or multiple Soldiers) trained to repair exoskeletons, and at least one more FMTV with equipment to hoist heavy, inoperable exoskeletons for recovery.

This need for additional vehicles should be similar across the joint force. Thus, logistical concerns for exoskeletons mean that a heavy infantry company will require more transport aircraft to deploy to a theater.

Third, Soldiers in exoskeletons that are rendered inoperable in combat are then dismounted cavalry, having lost their amazing edge in the form of their "mount." Suddenly what could be a 150 pounds or more of equipment will put its full strain on a Soldier. This may require infantrymen to make hard decisions, while in combat, about what to take with them or leave behind.

Fourth, if Soldiers, Marines, and special operations forces in exoskeletons weigh considerably more than they currently do, then this may change air assault planning and possibly even planning for ground vehicles. This is because these vehicles may have their range before refueling decreased due to carrying a heavier load. This may also mean fewer troops transported per aircraft or ground vehicle. This could have a major effect on unit organization as compared to current infantry units.

Fifth, when operating in open terrain, one key restraint for exoskeleton-equipped heavy infantry units will be their comparable utility to an armed light vehicle, such as the new Joint Light Tactical Vehicle (JLTV). This is because troops equipped with exoskeletons will likely have the same limitations as small infantry units. These may be limited decontamination capabilities if exposed to CBRN weapons and vulnerabilities to enemy armor, artillery, and air assets when employed in open terrain.[39] A primary issue is that a JLTV, or unit of JLTVs, may also cost less than the exoskeletons needed for a squad. The JLTV's unit cost for a loaded field-equipped model is under $399,000.[40] Depending on the unit cost of exoskeletons, the JLTV may be a bargain for its capabilities in open terrain. For now, the monetary cost of military exoskeletons is unclear, but it is vital information for understanding the comparable role to a unit of JLTVs.

Lastly, there are a variety of threats to infantry wearing heavier armor using exoskeletons, especially when facing a near-peer military. These include grenades and grenade launchers, shoulder-launched missiles, improvised explosive devices, heavy machine guns, medium and large caliber guns, and incendiaries. This means that potential enemies could adapt their tactics and equipment to best counter heavy infantry wearing exoskeletons. However, such an enemy force will require heavier equipment that will then negatively affect their maneuver and require more support requirements for their formations.[41]

Conclusion

In summary, there are three primary military applications for robotic exoskeletons. This article centered on how robotic exoskeletons may improve human performance in combat operations through the concept of modern heavy infantry. In the near term, if trains or transports that can recharge batteries are assumed and current unified infantry are left as a distinct type of light infantry unit, then exoskeletons may be able to help troops in combat sooner as an improved combined arms team. These two solutions to work around limited energy density in current man-portable power sources could allow for military exoskeleton research to aim primarily for advancing and ruggedizing the materials, sensors, actuators, and controllers for robotic exoskeletons.

The combined arms team incorporating both light infantry and exoskeleton-equipped heavy infantry formations may excel in restricted or severely restricted terrain, in military operations on urban terrain, in defensive operations, and as a shock unit against enemy infantry formations. Exoskeleton-equipped heavy infantry formations may also be a highly effective force when transported to the point of decision in battle. However, this will require new materiel for exoskeleton-equipped units from ground vehicles to armor, weapons, sensors, and other equipment.

These new capabilities will require an expanded logistical footprint with current technologies. There will be a need for charged batteries, generators to recharge batteries, fuel for generators, and potentially more and heavier ammunition. Depending on the reliability and weight of robotic exoskeleton technology, there may also be a need for repairs by dedicated personnel with lightweight spare components, recovery when disabled in field, and maintenance.

There are limitations to the use of robotic exoskeleton-equipped heavy infantrymen. Such formations will have a need for more vehicles and heavy equipment, which will affect strategic mobility. Such heavy infantry formations will require more support. Infantrymen that shed their exoskeleton, if rendered inoperable, will drastically reduce their utility in combat and force difficult choices about what heavy gear to take with them. Robotic exoskeletons used by heavy infantry will impact air-assault and ground-vehicle planning due to the increased weight and size of exoskeleton-equipped infantrymen. If near-peers change their tactics and materiel, then they can counter a unified force of heavy infantrymen equipped with exoskeletons; however, this will make their forces heavier and less capable of maneuver. A unified force of heavy infantrymen equipped with exoskeletons will lack the combined arms offered by a combination of light and heavy infantry. JLTVs may represent a superior and potentially more cost-effective force on open terrain. Lastly, a unified force of exoskeleton-equipped heavy infantrymen will lack some of the advantages of infantry formations, such as the ability to continue fighting if cut off from resupply.

However, this analysis is still an untested future military concept, and it is meant to generate discussion further on how to employ military, robotic exoskeletons.

Notes

[1] A.J. Young and D.P. Ferris, "State of the Art and Future Directions for Lower Limb Robotic Exoskeletons," IEEE Transactions on Neural Systems and Rehabilitation Engineering 25, no. 2 (February 2017): 171, doi: 10.1109/TNSRE.2016.2521160.

[2] Ibid.

[3] Sydney J. Freedberg Jr., "Forget The Terminator: Robotics For Logistics 1st, Combat 2nd," *Breaking Defense*, 4 December 2018, accessed from https://breakingdefense.com/2018/12/forget-the-terminator-ii-robotics-for-logistics-1st-combat-2nd/.

[4] Lauren Fish and Paul Scharre, "Super Soldiers: The Soldier's Heavy Load," Center for a New American Security, 26 September 2018, accessed from: https://s3.amazonaws.com/files.cnas.org/documents/CNAS_Super-Soldiers_4_Soldiers-Heavy-Load-FINAL-2.pdf.

[5] James King, "The Overweight Infantryman," Modern War Institute, 10 January 2017, accessed from https://mwi.usma.edu/the-overweight-infantryman/.

[6] David Hambling, "The Overloaded Soldier: Why U.S. Infantry Now Carry More Weight than Ever," *Popular Mechanics*, 26 December 2018, accessed from https://www.popularmechanics.com/military/research/a25644619/soldier-weight/.

[7] Paul Scharre, Lauren Fish, Katherine Kidder, and Amy Schafer, "Super Soldiers: Emerging Technologies," Center for a New American Security, 23 October 2018, accessed from https://s3.amazonaws.com/files.cnas.org/documents/CNAS_Super-Soldiers_5_Emerging-Technologies-FINAL.pdf.

[8] C. Todd Lopez, "New SMET Will Take the Load Off Infantry Soldiers," Army News Service, 8 June 2018, accessed from https://www.army.mil/article/206619/new_smet_will_take_the_load_off_infantry_soldiers.

[9] Hambling, "The Overloaded Soldier."

[10] Scharre et al, "Super Soldiers: Emerging Technologies."

[11] Matthew Cox, "Firms Pitch Exoskeletons and Body Armor for SOCOM's Iron Man Suit," *Military Times*, 21 May 2015, accessed from https://www.military.com/daily-news/2015/05/21/firms-pitch-exoskeletons-and-body-armor-for-socoms-iron-man-suit.html.

[12] Jared Keller, "SOCOM's Iron Man Suit Is Officially Dead," *Task & Purpose*, 15 February 2019, accessed from https://www.military.com/daily-news/2019/02/15/socoms-iron-man-suit-officially-dead.html.

[13] Sydney J. Freedberg Jr, "SOCOM Tests Sarcos Exoskeleton (No, It Isn't 'Iron Man')," *Breaking Defense*, 18 March 2019, accessed from https://breakingdefense.com/2019/03/socom-tests-sarcos-exoskeleton-no-it-isnt-iron-man/.

[14] Ibid.

[15] Ben Wolff (Chairman and CEO, Sarcos Robotics), interview by Steven Yeadon, 4 June 2019.

[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] Scharre et al, "Super Soldiers: Emerging Technologies."

[21] Ibid.

[22] Ibid.

[23] "Soft Exosuits for Lower Extremity Mobility," Wyss Institute, accessed 8 September 2020, accessed from https://wyss.harvard.edu/technology/soft-exosuits-for-lower-extremity-mobility/.

[24] "Warrior Web (Archived)," Defense Advanced Research Projects Agency, accessed 8 September 2020, accessed from https://www.darpa.mil/program/warrior-web.

[25] CPT Matthew Allgeyer, "The New Legionnaire and Modern Phalanx: Modern Ballistic Armor's Role in Returning Heavy Infantry Doctrine to the Battlefield," *INFANTRY* Magazine, 107, no. 2 (April-June 2018): 17. Accessed from https://www.benning.army.mil/infantry/magazine/issues/2018/APR-JUN/PDF/8)Allgeyer-Legionnaire.pdf.
[26] Ibid, 19.
[27] Ibid.
[28] Ibid, 19-20.
[29] Ibid, 21-22.
[30] Ibid, 21.
[31] Army Techniques Publication (ATP) 3-90.5 *Combined Arms Battalion*, February 2016, 7-6, accessed from https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/atp3_90x5.pdf.
[32] Kris Osborn, "The Army is Testing a New 50mm Cannon," *The National Interest*, 12 April 2019, accessed from https://nationalinterest.org/blog/buzz/army-testing-new-50mm-cannon-52182.
[33] Marine Corps Doctrinal Publication (MCDP) 1-3, *Tactics*, 1997, 39-40.
[34] ATP 3-21.10, *Infantry Rifle Company*, May 2018, 1-14.
[35] Army Doctrine Reference Publication (ADRP) 3-0, *Operations*, October 2017, 3-7, accessed from https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/ARN5071_ADRP%203-0%20FINAL%20WEB.pdf.
[36] ATP 3-21.10, 1-14.
[37] Amos Fox, "The Russian–Ukrainian War: Understanding the Dust Clouds on the Battlefield," Modern War Institute, 17 January 2017, accessed from https://mwi.usma.edu/russian-ukrainian-war-understanding-dust-clouds-battlefield/.
[38] Congress of the United States Congressional Budget Office, "The U.S. Military's Force Structure: A Primer" (July 2016), 34, accessed from https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/reports/51535-fsprimer.pdf.
[39] ATP 3-21.10, 1-14.
[40] Christian Seabaugh, "Oshkosh JLTV First Drive Review: Behind the Wheel of America's New Baja-Tuned, Duramax-Powered Humvee Replacement," *Motor Trend*, 3 July 2019, https://www.motortrend.com/news/oshkosh-jltv-first-drive/.
[41] Allgeyer, "The New Legionnaire," 20.

Steven Yeadon is an independent scholar holding a Bachelor of Arts in political science from the University of Central Florida. He is a published author in the field of military operations.