Resilient, Efficient, and "Dumb"

An expeditionary rail system for the Joint Force

by Maj Daniel C. Walker

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Future operating environments (FOE) will require the joint force to be increasingly agile and expeditionary to accomplish a wide array of missions across the range of military operations. Given this, forces must be properly equipped to provide responsive transportation and sustainment as a key component of success. Current and future logistical capabilities are largely based on rail and motor transport, with emerging vehicle autonomy offering possibilities for significant developments in the latter. Though they do serve an important role, over-reliance on these capabilities will degrade joint force flexibility resulting from three specific platform weaknesses. First, rail transportation is limited to existing infrastructure, most notably the established rail network. Second, traditional motor transportation is inherently inefficient, requiring significant fuel and manpower to operate at scale. Third, the rise of vehicle autonomy is currently limited in its application because of the reliance on technological systems that are vulnerable, costly, and complex in their maintenance requirements. This triad of challenges is significant, yet the development of a new, alternate transportation platform—the expeditionary rail system (ERS)—can overcome these challenges and serve as a low-tech autonomous platform that will address transportation challenges in the near term.

Though traditional rail will continue to play a key role in future operational-level logistics, its inherent limitations are distinct in light of the growing anti-access/area denial (A2/AD) challenge. This is even more true given naval concepts like expeditionary advanced base operations (EABO), which require logistics capabilities to be rapidly deployable and moveable once established. By definition, railways are not expeditionary because a significant amount of time, resources, and manpower are required to establish an operational capability. Viewed through an operational lens, the most significant observation is that the benefits of rail extend only to the last mile of track.

Past this last mile of railroad track, both military and civilian trucking fulfill much of the transportation and distribution requirement. Unfortunately, military trucking requires an inordinate amount of fuel and manpower for large-scale operations. World War II's Red Ball Express serves as a case study for the massive requirements associated with sustained motor transport operations during a high-end conflict.[1] Even if comparable fuel and manpower costs were accepted in a future scenario, it is unclear if such scale would even be feasible given the significant A2/AD capabilities held by U.S. adversaries and the limited resources within the logistics force structure.[2]

To mitigate some of these manpower and fuel inefficiencies, recent progress has been made within both the public and private sectors to partially fulfill transportation requirements with autonomous vehicles. Although autonomous vehicles will surely play a role in the logistical sustainment of tomorrow's force, they also create three significant challenges for that same force. First, the current military experimentation effort is largely focused on a "leader-follower" concept in which numerous autonomous vehicles drive behind a manned vehicle.[3] Although this manned-unmanned teaming (MUM-T) concept does provide some potential benefits, it presents additional force protection concerns that exist with neither a completely unmanned convoy nor a completely manned convoy. Second, whether using MUM-T or a fully autonomous convoy, success requires technological resilience and the ability to operate in a contested information environment. Third, even if dominance in the information environment is gained and maintained, autonomous vehicles remain costly in terms of fuel and technological systems.

While each of these platforms—rail, manned trucks, and autonomous vehicles—have a place in the FOE, each also presents its own challenges. It is at the convergence of these challenges where an opportunity emerges for the ERS to transport supplies in a more efficient and resilient manner than either traditional trucking or autonomous vehicles. It is the ERS' deployable nature, lack of reliance on technology, and modularity that provide its relative advantage to other current transportation platforms.

The ERS: A Vignette

South China Sea. Initial U.S. security forces landed at a remote island a few hours ago to further distribute lethal, land-based capabilities beyond the upper limit of naval platforms. Given mission *requirements, there is no time to waste. The initial forces must quickly prepare the island to serve as an austere and temporary forward mobile base providing essential logistics capability. Given sensitive political considerations and tactical necessity, the force's primary forward arming and refueling point (FARP) must be positioned about three miles from the landing beach. Poorly maintained, fuel-inefficient roads and the lack of a rail network characterize the area between the beach and FARP.*

Although the autonomous vehicles previously used by the force would normally save vital manpower, fuel, and time, the adversary has recently begun conducting operations in the information environment throughout this island chain, most significantly electronic warfare against friendly forces. The result is a localized, yet significant, disruption in friendly communications, GPS capability, and other assets requiring positioning, navigation, and timing technology.

Once U.S. forces establish initial command and control (C2) ashore and achieve localized security, a task-organized element departs the beach in a twelve-vehicle mounted patrol. In addition to the standard security vehicles in the front and rear of the mounted patrol, the remaining vehicles are medium- and heavy-lift trucks with modular spools of metal rope on the back of each truck. As the patrol slowly moves from the beach to the FARP site, each of these trucks lays this metal rope—the guide*—along the ground, creating a track from the beach to the FARP. Within mere hours, the ERS has full operational capability.*

The next morning, as additional forces land, vehicles carrying an array of supplies from the beach are driven to the ERS track, where a tow bar-like device—the guide rider*—connects the front of the vehicle to the* guide*. Within minutes, the vehicles then autonomously idle to the FARP. Over the course of the day, more than 100 vehicles successfully travel autonomously to the FARP, creating significant fuel and manpower efficiencies using a new low-tech form of ground vehicle autonomy.*

Operational Applications of the ERS

While the ERS's value is located at the convergence of existing transportation platform limitations, it is important to note that the ERS will replace neither trains nor trucks. However, in certain situations—characterized by a short-duration (90-150 days) and short-distance (2-10 miles) transportation requirement that necessitates many round trips—the ERS will provide a more efficient transportation alternative to both rail and truck.

There are two optimal applications for the ERS: the first is a joint force's reception, staging, onward movement, and integration (RSO&I) into a campaign's theater; the second is a use during EABO. In both scenarios, supplies will travel repeatedly between key locations (e.g., landing beaches, aerial/sea ports of debarkation, combat service support areas, etc.), but only for a short duration, nullifying the value in building long-term infrastructure—especially a railroad. Once the mission has been met, forces and the associated ERS can be quickly removed and reallocated given the system's temporary nature. As the transportation requirement's duration lengthens, the value of the ERS will decrease. This is because, in such a scenario, the relative value of laying a traditional railroad increases given its expected payoff of high fixed costs. Similarly, if the mission requires fewer trips between two locations, traditional trucking will likely be more desirable, given the higher fixed costs of an ERS compared to a traditional motor transport solution.

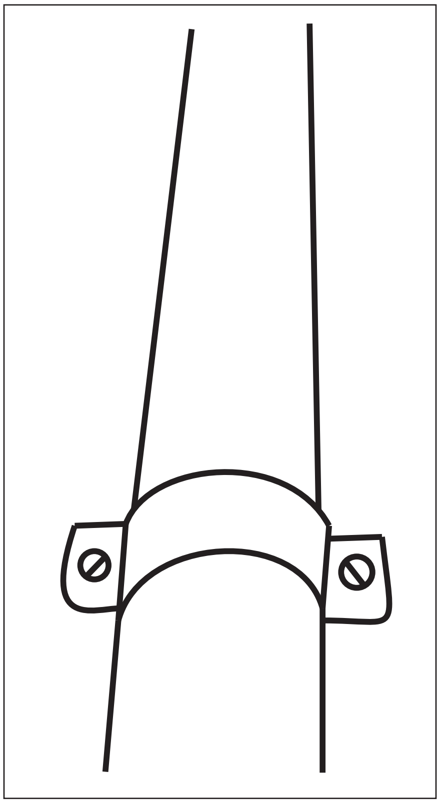

Figure 1. Guide with securing bracket.

Components of the ERS

As defined, the ERS consists of three primary components: the *guide,* which establishes the ERS track; the *guide truck,* which lays the *guide* along the desired route; and the *guide rider,* an attachment which attaches the ERS vehicle to the *guide*.

The Guide: An Overview.

The guide is a non-weight-bearing, surface-laid metal wire rope that spans end-to-end and creates the ERS track. To ensure durability and rigidity in guiding idling vehicles along its path, the guide will be secured to the ground with a bracket and stakes (See Figure 1).

Given various applications and ground surface characteristics, the guide may require differing degrees of rigidity once established; however, this can be managed by adjusting the number of stakes securing it to the ground. By adjusting the guide's tension with the number of stakes, the requirement for a more expensive, thicker, and less expeditionary guide is avoided.

The Guide Truck: An Overview.

To ensure the ERS's advantage over traditional rail transport, the guide must be rapidly deployable. The guide truck provides this capability and will hold one or more spools of guide in a modular attachment on the back of the truck (see Figure 2). Once a desired location for the ERS is determined, the guide truck will simply drive slowly along the desired ERS track and lay the guide. Though manpower will be required to secure the guide at each terminus, once started with the initial anchor end secured, the spool will freely spin to allow for efficient laying of the ERS track. As this guide is laid, it must also be manually secured to the ground at given intervals. This will both ensure the guide's placement and rigidity required to guide heavy vehicles.

Most critically, the modularity of the guide spool on the back of the truck ensures that any medium or heavy vehicle can transform into a guide truck and perform this critical application. Such a spool module will look similar to Marine Corps' hose reel system which is already used in support of bulk fuel operations.

The Guide Rider: An Overview.

Once the guide is laid and the track established, the ERS is nearly immediately operational. The last required component is the guide rider, which is a modified version of a current military tow bar. This attachment will connect the front of any vehicle to the guide, allowing for autonomous idling along the ERS track (see Figure 3). Because of the simplicity of the ERS concept, numerous vehicles are compatible with the ERS. Given that the guide-rider is a modified tow bar, this single attachment can either attach to the guide directly or attach to the vehicle in front of it, creating an ERS convoy.

The ERS: Flexible, Modular, Scalable

The greatest benefits of the ERS—flexibility, modularity, and scalability—can be seen when contrasted with other transportation platforms. Indeed, the ERS can be adapted to ensure its optimal use in numerous applications.

ERS compatibility.

Because the vehicle is guided along the track via the guide rider, the only requirement for a vehicle's compatibility with the ERS is its ability to attach a guide rider. Currently, all military vehicles that have organic tow bars will be able to attach the guide rider. This flexibility also enables future contracted or host-nation vehicles to integrate into the ERS, simply requiring the attachment of a guide rider to the front of the vehicle.

ERS convoy capability.

Another critical capability of the ERS is the ability for vehicles to operate individually or coupled together to form an ERS convoy (see Figure 4).

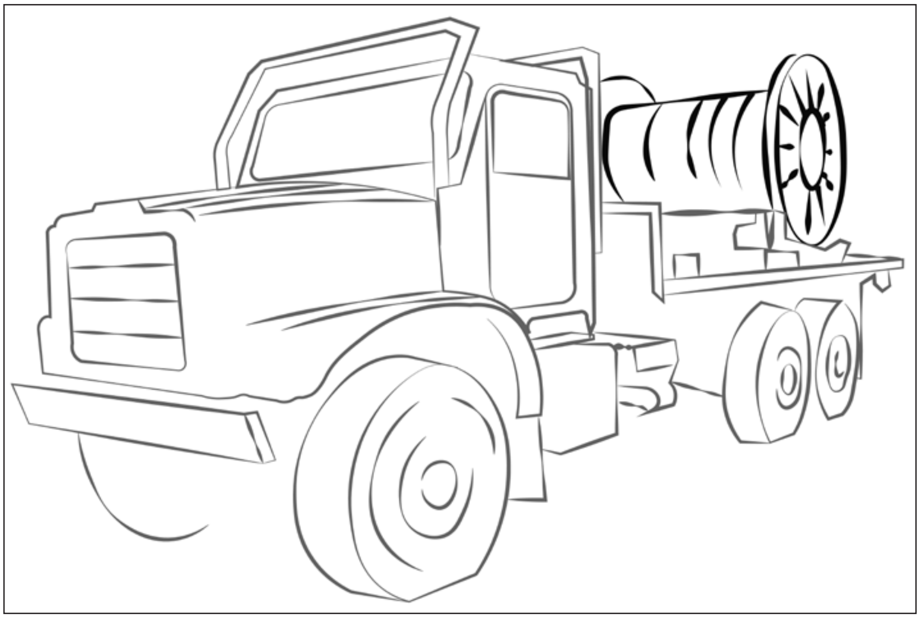

Figure 2. Guide truck. *(Figure by author.)*

The ERS provides an analogous capability to the Australian Road Trains in which a tractor-trailer pulls six, eight, or more trailers along the characteristically straight roads of Australia.

If operating as a single vehicle along the ERS, the vehicle simply attaches its guide rider to the guide and moves along the ERS track. When operating as an ERS convoy, the first vehicle's guide rider will attach to the guide, while all other vehicles or trailers simply attach their guide rider as a tow bar to the vehicle or trailer immediately in front of it. Thus, the ERS provides the capability for a heavy-lift military truck (e.g., LVSR) to *autonomously* pull six or more trailers, creating valuable fuel and manpower efficiencies.

ERS track scalability.

The ERS also provides the ability to gradually improve its track as resources become available, resulting in scalable

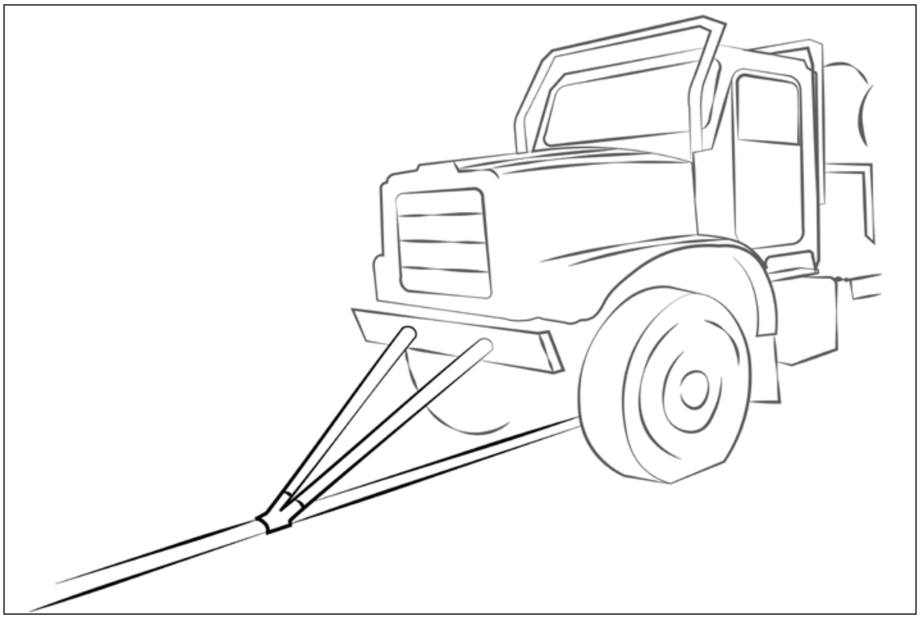

Figure 3. Guide rider. *(Figure by author.)*

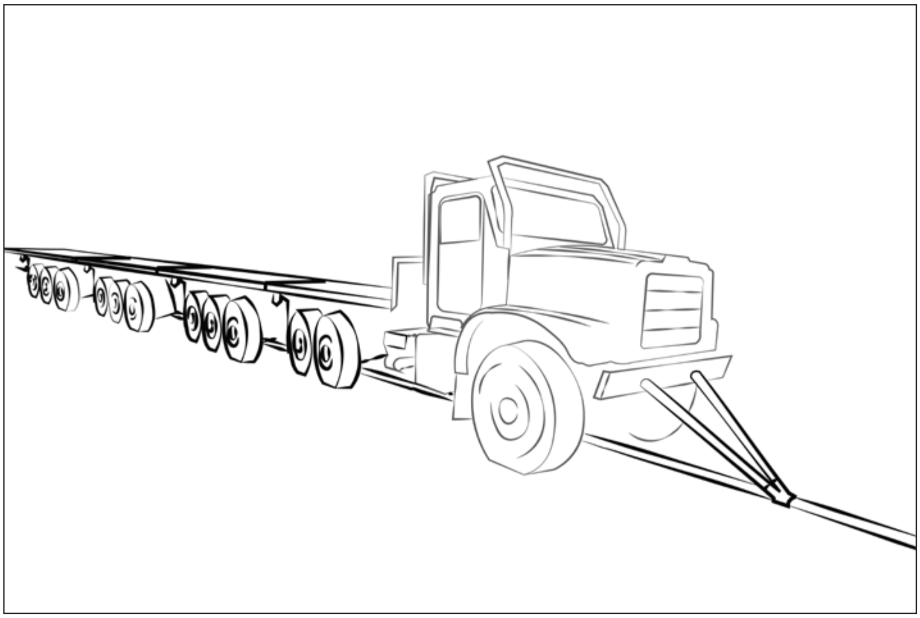

Figure 4. ERS convoy. ***(Figure by author.)***

fuel efficiency. When initially laying the guide, units will likely lay it on an unimproved ground surface because of time considerations as mentioned in the vignette. Such a method captures the expeditionary benefits of the ERS. However, as time, manpower, and horizontal construction assets become available, the ERS track can be improved in a number of ways to capture fuel efficiencies inherent in the ERS.

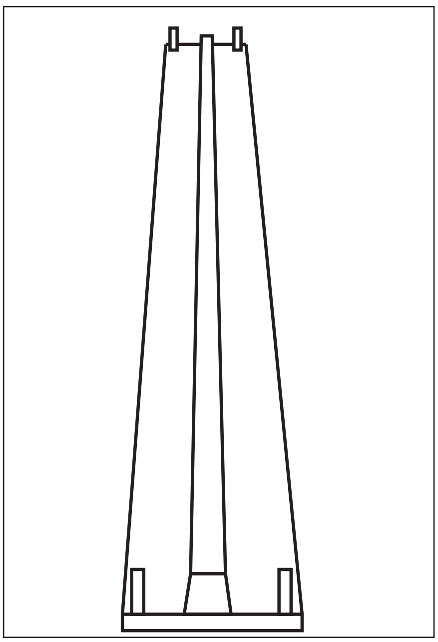

Figure 5. Rail mat. ***(Figure by author.)***

First, the ground surface along both sides of the ERS track can be graded and compacted for a more durable, fuel-efficient operating surface. Second, if the ERS will be used for a longer period of time than originally planned and even greater fuel efficiency is desired, a modular rail-mat can be laid down on each side of the guide (see Figure 5).

This rail-mat would also replace AM2 matting currently used for expeditionary airfields given rail-mat's dual-use as an ERS component and modular airfield matting. If properly engineered, one side of this new rail-mat would continue to be a smooth surface to allow use on airfields and tarmacs. However, on the reverse side, a low-profile track would be engineered in the metal, providing a grove along which a vehicle's tires will travel.

ERS wheel and tire modularity.

Given this new rail-mat, the ERS also allows for a variety of vehicle tire and wheel combinations to improve the stability, cost efficiency, and fuel efficiency of the ERS. If, in an expeditionary setting, no time is available for the ERS' track to be leveled, graded, or compacted, traditional all-terrain vehicle tires will continue to be used. However, as the surface along the ERS track is improved, a more cost- and fuel-efficient tire can be used on vehicles.

Once the rail mat is laid and the ERS meets a longer-duration requirement, rubber tires can be replaced altogether with railroad-type wheels to ride along the rail mat's low-profile track, further enhancing the fuel efficiency of the ERS, and adding to the stability of the vehicles traveling along the track (see Figure 6). Such interoperability between vehicles and railroad tracks has been previously used in both the civilian and military sectors and proven viable.[4]

ERS and autonomous vehicle compatibility.

The final benefit of the ERS is its compatibility within the future vehicle autonomy family of systems. Essentially, the ERS serves as a "bridging platform" between the current traditional motor transportation assets and the fully autonomous convoys of tomorrow. Additionally, the ERS allows for a gradual increase in the amount of autonomy in a given logistics convoy, likely beginning with local, low-cost sensors that aid the ERS vehicles in starting and stopping at each track's terminus.

In the future, if a future transportation requirement is along a complex route in a permissive information environment, such autonomous vehicles can leverage their high-tech autonomous technology. However, if the transportation requirement is a short- or medium-distance movement along a straight route or the information environment is contested, the ERS provides a more resilient capability, presenting commanders with an additional system for risk mitigation—all by simply attaching a guide rider to any vehicle.

Advantages of the ERS

A new concept like the ERS requires significant resources to bring to fruition. Its associated fixed costs are only acceptable if the ERS presents significant benefits compared to available alternatives. Costs and benefits can be analyzed by contrasting this new platform with rail, traditional trucking, and autonomous vehicles. The following five ERS advantages are most relevant in such an analysis.

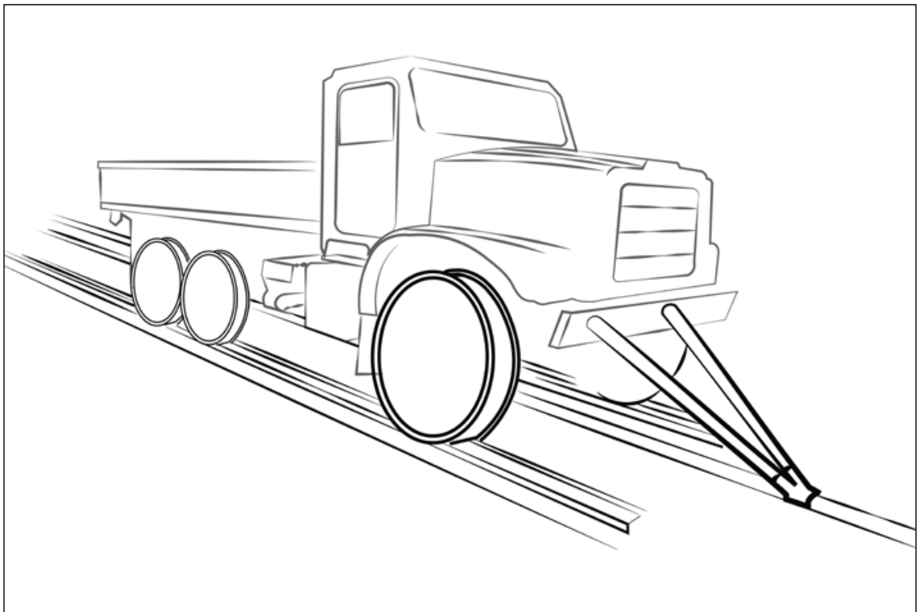

Figure 6. ERS with rail-mat. *(Figure by author.)*

ERS advantages over rail.

The ERS's most valuable contribution is that it will be more deployable than traditional rail. While traditional railroads require significant time, manpower, and fixed costs to establish, the ERS track is laid in mere minutes when the guide truck slowly travels along the desired path laying the guide.

Because of its lighter weight and lower cost, the ERS can also be used in many more applications than traditional railroads. Once the ERS requirement has ended, the guide can be rapidly re-spooled on the guide truck and prepared for its next application. Additionally, because of locomotives' and railcars' specialized nature, they are unable to serve multiple purposes and must be moved into location for operational viability. However, because any military vehicle can be made ERS-compatible by merely attaching the guide rider, significant flexibility is added. Military trucks can be driven across great distances in the absence of established infrastructure when a short-distance ERS track is established and the vehicles are quickly converted to serve as low-tech autonomous vehicles.

ERS advantages over motor transportation.

In the appropriate situations, the ERS will save significant manpower and fuel resources compared to motor transportation. Though manpower will be required to lay the ERS guide, load/unload trucks, and service trucks at each end of the track, ERS autonomy relieves the requirement for vehicle drivers and assistant drivers. This autonomy also minimizes the force protection risk normally associated with drivers and assistant drivers conducting convoy operations across the battlefield. Additionally, because the guide provides the truck a linear path on which the truck will travel, fuel-inefficient lateral movements are reduced. Additional fuel savings are captured by the inherent slow, but continuous speed of the ERS vehicles idling along the track. Though the ERS does not provide the fuel efficiency of traditional rail, it does increase fuel efficiency when compared to traditional trucking.

ERS resiliency.

Because the ERS operates with a type of "dumb" autonomy—one in which no navigational technology is required—the ERS is more capable and resilient in an information- degraded environment. While the autonomous vehicle does provide some benefits over the ERS, once its core capability—high-tech autonomy—is degraded by enemy actions or technological failure, it simply becomes another truck that is both fuel and manpower inefficient.

Additionally, the ERS's low-tech requirements present significant benefits and reduced risk when compared to current vehicle autonomy's technology. Autonomous vehicles' robotic applique kits (RAKs [i.e., navigational systems]) are expensive to acquire and maintain.[5] This maintenance includes ensuring systems are properly patched and configured to mitigate any known cyber vulnerabilities[6] As such cyber threats evolve, so must the patching and configuration updates. Because of the ERS's lower-tech solution, such a maintenance requirement is eliminated, further mitigating operational risk and support requirements.

ERS reduced signature.

The ERS also has the potential to reduce friendly force signatures within an operational setting. In the FOE, adversaries will use friendly force's signature and emissions to find, track, and target adversarial forces.[7] Viewed through this lens, another potential weakness of future "smart" autonomous systems is their signal emissions. Whether communicating to other vehicles in a MUM-T configuration or using GPS navigational systems, such signals create risks. In contrast, because the ERS executes "dumb" autonomy by merely operating along a fixed track, its autonomy creates no additional signals or emissions for an adversary to detect.

Additionally, in an A2/AD environment, especially while conducting EABO, once an adversary has taken advantage of a friendly force signature, logistics capabilities must be able to be quickly displaced and moved elsewhere. The ERS provides such a capability in its ability to be moved rapidly, ensuring a distributed net of logistics capability while minimizing friendly force vulnerabilities.

Less Technology = Faster Development.

Though the ERS will require time to further develop and test, its minimal technology requirements will result in expedited testing and fielding as compared to development of fully autonomous convoys. The potential for this more rapid acquisition is a significant benefit to a "low-tech" solution and one which is explicitly supported by current DOD acquisition initiatives.[8] In essence, the ERS provides a "bridging" solution between current transportation platforms and future fully autonomous convoys that are very much in their "operational infancy."[9] The ERS's compatibility with future autonomous vehicles ensures that development of the ERS is not a detriment to the long-term development of autonomous vehicles. Additionally, such a "bridging" solution will not simply serve as a link from current trucks to fully autonomous convoy capabilities; rather, it will serve as a bridge along each iterative enhancement of autonomous capabilities, all the way to fully autonomous convoys.

The ERS's Challenges

As established above, the ERS presents a valuable capability in the FOE. However, in examining the way forward, three notable challenges are quickly evident, all of which must be properly addressed to ensure this project's success. First, the ERS does require some technological and engineering refinement to ensure the system's technological viability. Second, although the ERS will likely be considerably cheaper than both traditional rail components and a fully converted fleet of autonomous vehicles, the ERS will still have significant fixed costs above and beyond additional required experimentation and testing. Third, the ERS program will have impacts across the doctrine, organization, training, materiel, leadership, personnel, and facilities spectrum. Perhaps the most significant of these relates to organization and personnel. If fully fielded, selection of the proper organizations to manage ERS manning, training, and equipment maintenance is vital for its successful future use.[10]

Conclusion

The FOE continues to challenge the joint force as it seeks heightened readiness across the range of military operations. Despite the variety of future mission sets, transportation will be a requirement to ensure flexible sustainment to relevant forces. In this context, the transportation challenges created by the weaknesses of traditional rail, manned trucks, and vehicle autonomy lend themselves to the creation of a new transportation platform: the ERS. Such a system is not only a significant benefit over the long term, but also serves as a crucial bridging technology that ensures heightened flexibility over the medium term. With proper advocacy and sponsorship, the ERS can reduce costs, gain manpower and fuel efficiencies, and ensure joint force agility in future operational scenarios.

Notes

1. At its peak, this amalgamated American convoy system employed 132 truck companies, consisted of more than 5,900 tucks, and used more than 300,000 gallons of fuel daily in support of U.S. First and Third Armies in France. See Bradley E. Smith, "The Influence of Railroads upon Campaign Plans" (Master's Thesis, U.S. Army Command and General Staff College, 1989). Additionally, such a significant fuel requirement for operations requires addition transportation assets to move that same fuel. In other words, it takes a significant amount of fuel to move fuel.

2. Joint Staff, *Joint Concept for Logistics*, (Washington, DC: September 2015).

3. Sydney J. Freedberg Jr, "Army Wants 70 Self-Driving Supply Trucks by 2020," *Breaking Defense*, (August 2018), available at https://breakingdefense.com.

4. For historical military applications, see Denis Bishop and W.J.K. Davies, *Railways and War since 1917*, (London, UK: Blandford Press, 1974). For a current civilian application, see HARSCO website available at http://www.harscorail.com.

5. According to the Army Capabilities Integration Center (ARCIC), the upcoming Army RAK testing is scheduled to be completed in 2020 and will cost between $30-45 million for 150 vehicles. Personal exchange between author and MAJ Todd McMillan, USA, (ARCIC Sustainment Division) on 17 November 2018.

6. Department of Defense, *Unmanned Systems Integrated Roadmap: 2017-2042*, (Washington, DC: 2018).

7. Headquarters Marine Corps, *Marine Corps Operating Concept*, (Washington, DC: 2016).

8. Department of Defense, *A Blueprint for Winning* (Annotated Summary), (Washington, DC: 2017). This document lays out six "tenants for modernization" for ensuring new capabilities are in line with "an operational definition of modernization."

9. Robert O. Work and Shawn Brimley, *20YY: Preparing for War in the Robotic Age,* (Washington, DC: Center for a New American Strategy, 2014). This assessment is shared by MAJ Todd McMillan, ARCIC. Following the leader-follower testing through 2020, those vehicles' operational viability is still "years away." This time would likely be spent refining technology based on testing results and adding similar technology to more of the Army's approximately 30,000 RAK-compatible vehicles. MAJ Todd McMillan, discussion with author, 17 November 2018.

10. Systems maintenance remains a key consideration for the implementation of any new technology. Given the future operating environment's austere and distributed nature, maintenance planning should account for active duty service members conducting all maintenance. This is a marked difference from the current leader/follower testing which is heavily reliant on contractors for the foreseeable future to ensure RAK maintenance.