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14. ABSTRACT This paper presents a transportation solution to the challenges facing the joint force—the Expeditionary Rail System (ERS). The ERS provides the commander a deployable, scalable, and modular solution; one that is more expeditionary than rail; more fuel- and manpower-efficient than traditional motor transport; and one that uses a low-tech form of autonomy resulting in greater resilience in the face of a contested information environment. Because the ERS' low-tech nature, and its reliance on many existing technologies currently in the joint inventory, this system will able to be rapidly fielded and a low-cost resulting in advantages for the force today and tomorrow.					
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FUTURE WAR PAPER

*Resilient, Efficient, and “Dumb”:
An Expeditionary Rail System for the Joint Force*

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF OPERATIONAL STUDIES

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FOREGOING STATEMENT**

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 (ROMO). Given this, future 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 reliance on technological systems that are vulnerable, costly, and complex in their maintenance requirements. This triad of challenges is significant, yet the development of an 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.

Current strategic guidance makes clear estimates of the FOE and provides a roadmap for operating in such a setting. The *National Defense Strategy (NDS)* recognizes that the future will be characterized by great-power strategic competition.¹ The competitive environment, and its associated multi-domain threat, will extend inside the United States’ geographic borders in the event of conflict. Therefore, the Joint Force must modernize key capabilities, including the ability to conduct “forward force maneuver and posture resilience,” as well as “resilient and agile logistics.”² In this scenario, the entire Joint Force must be more expeditionary than ever,

especially while “closing the force.” The *Joint Concept for Rapid Aggregation* (JCRA) details “the challenges to aggregation when supporting crisis response or limited contingency operations in the current and future security environments.”³ This Joint Supporting Concept repeatedly stresses the importance of a force that is able to ensure timely aggregation in support of operations—regardless of established infrastructure in the operational theater. Similarly, the *Joint Concept for Logistics* (JCL), which proposes the concept of “globally integrated logistics,” explicitly states the Joint Force needs “an improved ability to construct, improve, and maintain forward base infrastructure.”⁴ Within this strategic framework, transportation play a major role in determining success in future conflicts, providing both required sustainment to friendly forces and credibility to deterrence.⁵

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 truer 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—significant 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. Conceptually, while rail may move supplies into an operational theater, motor transport assets often move supplies from ports, beaches, and railheads forward toward the end-user. 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.⁶ 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.⁷

To mitigate some of these manpower and fuel inefficiencies, recent progress has been made within both the public and private sector 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.⁸ Though 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 which provide its relative advantage to other current transportation platforms.

The ERS: A Vignette

South China Sea--Initial U.S. security forces have landed at the remote island a few hours ago to further distribute lethal, land-based capabilities beyond the upper limit of naval platforms. Given mission requirements, there's 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, Global Positioning System (GPS) capability, and other assets requiring Positioning, Navigation, and Timing (PNT) 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 12-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.

Differing operational theaters will surely affect the utility of the ERS, as adversary threat and the quality of existing infrastructure can impact the ERS's viability and relative utility. Regardless of the nature of the threat, the ERS requires friendly observation and fires capability to ensure the maintenance of this newly-established line of communication. While tactical-level solutions can support the ERS's viability, a lack of local infrastructure will further prove the ERS's utility.

Currently, there is a large differential in the quality and quantity of established railroads throughout the world. Many Western European countries, like Germany, have a well-developed rail network that not only connects sea ports, but also traverses the entire country. Other locations, especially in various Pacific island chains, are characterized by a lack of quality

railroads. Those railroads that do exist in less developed regions often have short-length tracks, leaving much of the country without a network to support efficient transportation of goods.⁹

Whether in these locations or those in the vicinity of a well-established rail network, the ERS provides the capability to extend the operational reach of an efficient mode of transportation. In this situation, the ERS's ability to range from the end of the railroad track to a nearby military logistics hub would result in manpower and fuel savings—resources that could be more effectively used elsewhere within the theater.

There are two optimal application 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 naval EABO. In both scenarios, supplies will travel repeatedly between key locations (e.g. landing beaches, Aerial/Sea Ports of Debarkation [A/SPODs], Combat Service Support Areas [CSSAs], 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 re-allocated 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.

Though not the optimal application as described above, the coalition military presence at Camp Bastion and Camp Leatherneck, Afghanistan, serves as a case-study in the value of the ERS in particular environments. From 2009, when the US "surge" began, until 2014, when US Forces handed over the base to the Afghan National Security Forces, tons of cargo were

delivered everyday by plane and truck to support a force of approximately 20,000 residents.¹⁰ Coalition forces and supplies would fly into one side of the base (Bastion) and were transported to the other side (Leatherneck). As these forces and supplies were received at the airfield, a significant number of contracted and military motor transport assets continuously transported baggage, supplies, and personnel across base. Because of the short distances and routine routes, such trips were inefficient in terms of both fuel and manpower. Given the nature of this type of transportation requirement, an autonomous, expeditionary transportation system like the ERS would have saved significant coalition resources.

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 desire route; and the *Guide Rider* attachment which attaches the ERS vehicle to the *Guide*.

The Guide: An Overview

The most important component of the ERS is the *guide*, which, once laid, serves as the ERS track along which vehicles will travel. Because the ERS is required to be expeditionary, the *guide* itself must also be rapidly-deployable.

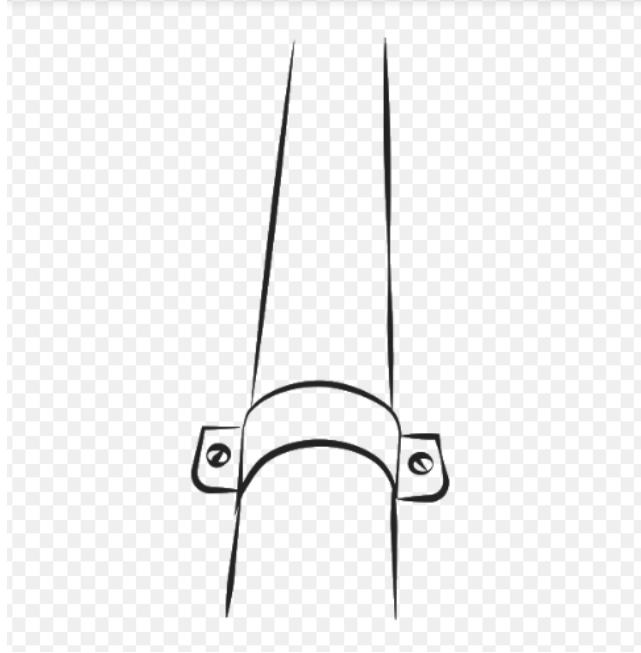


Figure 1: Guide with Securing Bracket

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 via 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 allowing 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 for guiding heavy vehicles.

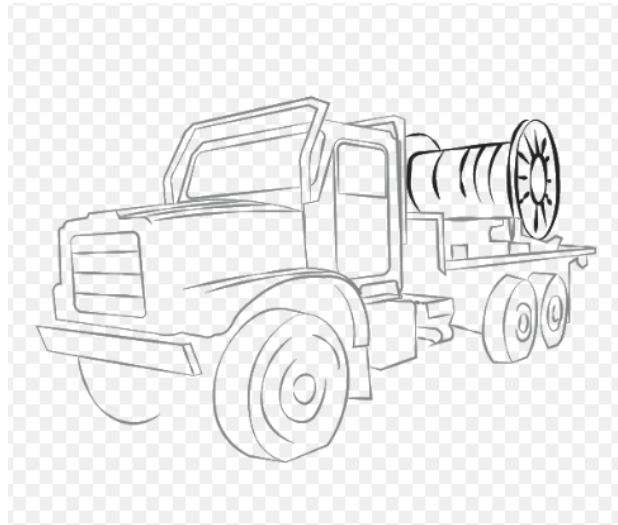


Figure 2: Guide Truck

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 to 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 serve two purposes—attach to the *guide* directly or attach to the vehicle in front of it, resulting in an ERS convoy.

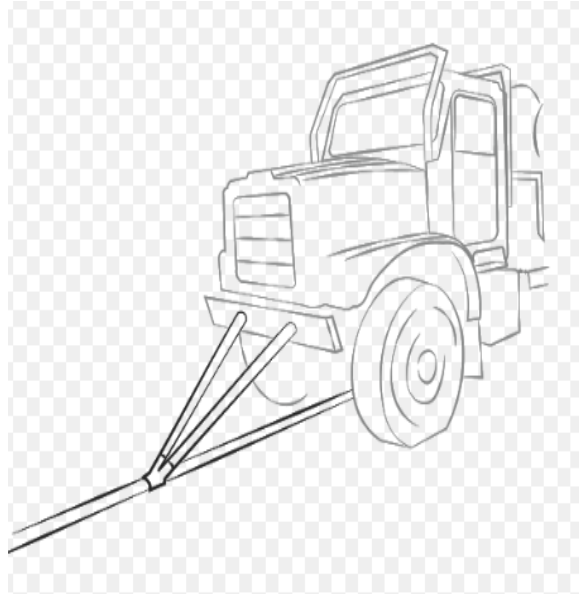


Figure 3: Guide Rider

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 as one of many, coupled together, to form an ERS convoy (See Figure 4). 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 Australian roads.

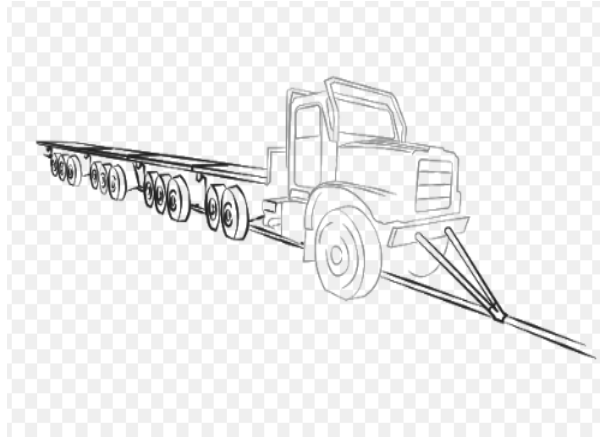


Figure 4: ERS Convoy

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 fuel efficiency. When initially laying the *guide*, units will likely lay it on an unimproved ground surface due to 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.

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).

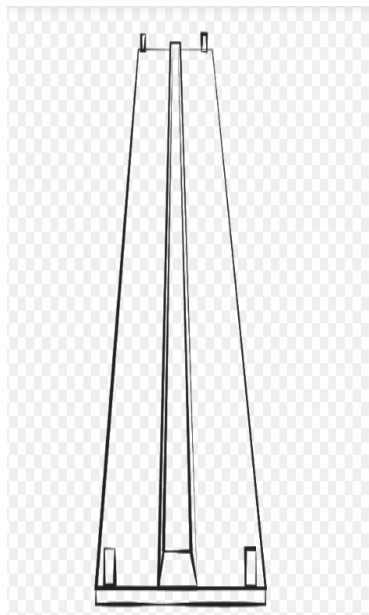


Figure 5: Rail-Mat

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 groove 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 placed onto vehicles.

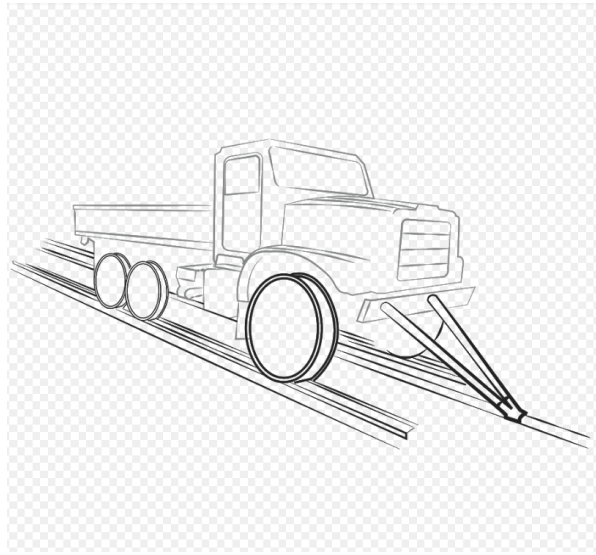


Figure 6: ERS with Rail-Mat

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.¹¹

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 in a straight-line 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 seven ERS advantages are most relevant in such an analysis.

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—with merely the attachment of 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

As mentioned in the Camp Bastion-Camp Leatherneck case study above, 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 is 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.¹² This maintenance includes ensuring systems are properly patched and configured to mitigate any known cyber vulnerabilities.¹³ 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.¹⁴ 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 Department of Defense acquisition initiatives.¹⁵ 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.”¹⁶ 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, but rather will serve as a “bridge” along each iterative enhancement of autonomous capabilities, all the way to fully autonomous convoys.

ERS Deterrence Capability

Because of the ERS’s expeditionary nature, the lightweight system components can also be viewed as a component of a deliberate deterrence package. In this case, the ERS—primarily the *guide* and *guide trucks*—can be forward-staged as part of strategic material reserves, like the

Marine Corps Pre-positioning Program-Norway (MCPN). Even if not required for a current operational requirement, ERS components can be rapidly-deployed and laid to not only prepare for RSO&I of potential follow-on forces, but also as a flexible deterrent option, clearly signaling to potential adversaries both capability and credibility.

ERS Public-Private Development Potential

Though this paper's concern is solely the military application of the ERS concept, it is important to note two other possible civilian ERS applications which could encourage a public-private partnership and development of this concept. Such a partnership will minimize development and experimentation risk for both the DOD and industry partners.¹⁷

The first potential civilian application of the ERS concept is agricultural farming. In this setting, harvest time provides a requirement for a significant volume of goods (e.g. grain) to be transported short- or medium-distances many times over, but only for a short duration (i.e. harvest time itself). In the vast expanses of large-scale Midwestern crop fields, an ERS *guide* could be quickly laid, preparing for harvest, while crop-carrying semi-trucks simply attach a *guide rider* to the front of the truck. Those trucks could then autonomously make repeated low-cost trips from the crop field back to the silo or processing plant. Because of the ERS's expeditionary nature, once harvest is complete, the *guide* can be easily removed with minimal ground surface damage along the ERS track.

The second possible application exists in mining. In this context, the ERS could be quickly established from the processing plant to the extraction site itself, enabling raw materials to be easily transported with minimal manpower. Once a mine is no longer viable, the ERS *guide* can quickly be picked up and moved to another work site as required.

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.

Further Development and Testing

Though conceptually strong, the ERS does require some technological and engineering refinement to ensure the system's operational viability. Further research should focus primarily on two aspects of the ERS.

First and most importantly, "traffic management" warrants significant development and is currently the ERS's central technical challenge. Because much of its value is the result of its minimal technology requirement, supplementary technological systems must be cautiously accepted. However, at the same time, solutions must be developed for ensuring ERS vehicles start and stop along the track efficiently and effectively. However, because the ERS is compatible with autonomous vehicles throughout their future development, some of these "traffic management" concerns can be mitigated through the use of low-cost and more secure short-range sensors which aid in the ERS vehicles starting and stopping. The use of such sensors conforms to the overall ERS concept as they are low-cost, relatively resilient, and compatible with both ERS vehicles and RAKs.

Second, engineers must further examine the optimal diameter of the *guide*. This vital component to the ERS must be large enough to ensure vehicle stability and system durability, yet small enough to ensure that a *guide spool* is light and expeditionary. Initial estimates have shown that this dual requirement can be met simultaneously.¹⁸

Fixed Costs of the ERS

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. Because the *guide rider* will be merely a new version of existing towbars and can be phased in through gradual acquisition, the two largest costs of fielding the ERS will be the numerous spools of *guide* and the modular *guide truck* component which will house the *guide* spool itself. Additional costs will also be seen in the required training of units assigned to the ERS mission.

Comprehensive Implications

In addition to the challenges listed above, the ERS program will have impacts across the Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities (DOTMLPF) 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.¹⁹ Although each service will likely benefit from the ERS, currently both the Army and Marine Corps appear to be the most prepared for ERS integration within existing logistics organizations.

The Army's Rapid Port Opening Elements or the Marine Corps' Transportation Support Battalions should be considered for such duties, given their existing competency and familiarization with port operations, transportation, and distribution operations. However, as the ERS concept matures and is proven operationally viable, other services can field this system at marginal additional costs.

Above and beyond the organizational implications of the ERS adoption, significant training and personnel considerations will surely be required. Proper entry-level and operational force training must be made to ensure the ERS is properly understood and safely used. Personnel requirements and potential reallocation of organizational structure due to manpower efficiencies will also need to be considered prior to adoption of the ERS.

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.

¹ Department of Defense, *National Defense Strategy*, 2018, 2.

² Department of Defense, *National Defense Strategy*, 2018, 6-7.

³ Joint Chiefs of Staff, *Joint Concept for Rapid Aggregation*, 2015, IV.

⁴ Joint Chiefs of Staff, *Joint Concept for Logistics*, 2015, 17.

⁵ Credibility is a foundational concept in traditional deterrence theory. According to Thomas C. Schelling, "It is the *threat* of damage, or of more damage to come, that can make someone yield or comply." See Thomas C. Schelling, *Arms and Influence* (Yale University Press, New Haven, 2008), 3. Thus, because deterrence is a function of the adversary's own cognition, a force must demonstrate enough force projection and sustainment (e.g., transportation and distribution) capability to demonstrate that explicit or implicit threats of violence can be successfully carried out against the adversary. In other words, the ERS and its deployment, can serve as a non-lethal signal of both enhanced capability and credibility, respectively.

⁶ At its peak, this amalgamated American convoy system employed 132 truck companies, consisted of more than 5,900 trucks, and used more than 300,000 gallons of fuel daily in support of US 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), 9. Additionally, such a significant fuel requirement for operations requires additional transportation assets to move that same fuel. In other words, it takes a significant amount of fuel to move fuel.

⁷ *Joint Concept for Logistics*, 3.

⁸ Sydney J. Freedberg Jr, "Army Wants 70 Self-Driving Supply Trucks by 2020," *breakingdefense.com*, August 20, 2018, <https://breakingdefense.com/2018/08/army-wants-70-self-driving-supply-trucks-by-2020/>.

⁹ The World Bank, Rail Lines Database, December 26, 2018, https://data.worldbank.org/indicator/IS.RRS.TOTL.KM?view=map&year_high_desc=true. The Open Railway Map also provides a valuable visual depiction of global rail networks (<https://www.openrailwaymap.org/>).

¹⁰ *The Military Engineer*, "Troop Surge Master Planning." (Nov-Dec 2009): 73, http://themilitaryengineer.com/tme_past_issues/2009-06-NovDecTME-SM.pdf.

¹¹ For historical military applications, see Denis Bishop and W.J.K. Davies, *Railways and War since 1917* (London, Blandford Press, 1974), 114. For a current civilian application, see HARSCO website, accessed December 26, 2018, <http://www.harscorail.com/equipment/hy-rail.html>.

¹² 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. MAJ Todd McMillan (ARCIC Sustainment Division), discussion with author, November 17, 2018.

¹³ Department of Defense, *Unmanned Systems Integrated Roadmap: 2017-2042*, 2018, 25.

¹⁴ United States Marine Corps, *Marine Corps Operating Concept*, 2016, 6.

¹⁵ Department of Defense, *A Blueprint for Winning* (Annotated Summary), 13. This document lays out six "tenants for modernization" for ensuring new capabilities are in line with "an operational definition of modernization."

¹⁶ Robert O. Work and Shawn Brimley, *20YY: Preparing for War in the Robotic Age*, 22. 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, November 17, 2018.

¹⁷ Elon Musk and The Boring Company serve as a relevant reference. Not only would this type of company be a likely industry partner to future DoD efforts to develop the ERS, but also this company's current efforts demonstrate the validity in a dual-use (an autonomous vehicle's use on a track system) concept which is analogous to the ERS and its compatibility with future autonomous vehicles.

¹⁸ When conducting preliminary research, the assumption of a 1.5" guide was made. If this assumption remains, one generic guide spool (20" barrel diameter; 60" flange diameter; 30" drum length; and ½" freeboard) could hold more than 2400 feet of guide. *Ingersoll-Rand Drum Capacity Estimator*, accessed November 17, 2018, https://myir.com/lifting/winches/drum.htm?_ga=2.121457100.512227702.1543089060-1055402167.1543089060#modal=70%,90%,true.

¹⁹ 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.

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