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As the Marine Corps pursues the *Marine Corps Operating Concept's (MOC)* critical tasks, Marine logisticians must exploit automated and unmanned technology to enhance Marine Air Ground Task Force (MAGTF) maneuver and sustainment. Unmanned and autonomous logistics systems are on the horizon for the Marine Corps. These systems will enhance maneuver and sustainment in distributed operations while reducing risk in force protection. Teaming humans and unmanned logistics systems (ULS) will enable MAGTF logisticians to keep maneuver elements supplied while reducing the weight individual Marines carry and reducing the proverbial "Iron Mountain" of supplies ashore. Ultimately, the value of ULS will be smaller, but more capable logistics forces that will enable distributed operations in the future operating environment. ULS will be a critical capability to support maneuver and sustainment in the future operating environment. Logisticians must aggressively develop platforms and concepts of operations to be ready for implementation. Ultimately, this will lead to a lighter, faster, and more lethal MAGTF.

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Unmanned Cargo Systems for Expeditionary Forces:
Exploiting Automation for MAGTF Logistics

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

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Executive Summary

Title: Unmanned Cargo Systems for Expeditionary Forces: Exploiting Autonomy for MAGTF Logistics

Author: Major Jay L. Montgomery, United States Marine Corps Reserve

Thesis: As the Marine Corps pursues the *Marine Corps Operating Concept's (MOC)* critical tasks, Marine logisticians must exploit automated and unmanned technology to enhance Marine Air Ground Task Force (MAGTF) maneuver and sustainment.

Discussion: Unmanned and autonomous logistics systems are on the horizon for the Marine Corps. These systems will enhance maneuver and sustainment in distributed operations while reducing risk in force protection. Teaming humans and unmanned logistics systems (ULS) will enable MAGTF logisticians to keep maneuver elements supplied while reducing the weight individual Marines carry and reducing the proverbial "Iron Mountain" of supplies ashore. Ultimately, the value of ULS will be smaller but more capable logistics forces that will enable distributed operations in the future operating environment.

Conclusion: ULS will be a critical capability to support maneuver and sustainment in the future operating environment. Logisticians must aggressively develop platforms and concepts of operations to be ready for implementation. Ultimately, this will lead to a lighter, faster, and more lethal MAGTF.

DISCLAIMER

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Preface

The object of my research was to learn about unmanned logistics systems from many sources and provide analysis of what I think is possible by the year 2025 when the *Marine Corps Operating Concept* matures. My original intent was to focus on ground vehicles, but I determined that air systems are further in development and there will be opportunities to team air and ground systems to maximize both efficiency and effectiveness in sustainment operations. While I cannot predict exactly 2025 capabilities, I believe there is an opportunity for the Marine Corps to fundamentally change sustainment operations into a system that is more effective for distributed operations while providing better force protection by that time.

I would like to acknowledge Dr. John Gordon who graciously and patiently mentored me through this process. The Marines and civilians at Headquarters Marine Corps, Installations and Logistics, Next Generation Logistics section were instrumental in providing material for my baseline research that provided the bulk of my writing. The Marines of the Ellis Group and Dr. Benjamin Jensen provided much useful insight during the Fight Club 2.0 wargame elective where we worked through some of the advantages and challenges of unmanned technology. Dr. Michael Qin of the Office of Naval Research was a key contributor to the technology aspect of the wargame and provided key insight as a developer.

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Introduction

As the Marine Corps pursues the *Marine Corps Operating Concept's (MOC)* critical tasks, Marine logisticians must exploit automated and unmanned technology[1] for logistics forces to enhance Marine Air Ground Task Force (MAGTF) maneuver and sustainment. The recently released *Littoral Operations in a Contested Environment (LOCE)* requires the following capabilities for success: battlefield awareness, particularly with regard to improvised explosive devices (IED) and naval mines; understanding natural and man-made terrain; establishing expeditionary advanced bases to support sustainment operations; sustaining amphibious operations; defending forward logistics capabilities and providing redundancy for select critical capabilities; establishing mobile logistics bases; providing logistics forces the mobility, protection, and agility to support widely dispersed forces with diverse support requirements; leveraging logistics at-sea forces to sustain forces in the contested littorals; using auxiliary platforms to augment logistics sustainment capacity; spreading sustainment risk; enhancing operational tempo; achieving battlespace awareness; managing signal control and conducting dynamic maneuvering; and conducting casualty evacuation.[2] Though quite a daunting list, properly designed unmanned logistics systems (ULS) will provide at least part of the solution for each of these required capabilities. While the *LOCE* is focused on amphibious operations, the majority of these capabilities have merit across the range of military operations (ROMO). As autonomous and unmanned vehicles continue to develop, the Marine Corps must decide what systems to acquire and determine how those systems will affect combat service support operations.

Unnamed Logistics Systems

IEDs were effective in Iraq and Afghanistan,[3] and future opponents will no doubt maximize their use among other asymmetric tactics, especially in irregular war. Fortunately, the non-state actors in Iraq and Afghanistan had limited technology and resources to supply insurgents with effective IEDs, but the low technology hidden bombs still proved effective in restricting maneuver and sustainment. As such, it should be a priority to limit the number of Marines on supply routes to the extent possible. While new technology investments are costly, life and limb are not replaceable and ultimately cost the US more in resources and less measurable effects such as domestic resolve and international support.

Generally, there are several distinctions to make between unmanned, autonomous, and semiautonomous logistics systems. First, there are Unmanned Logistics Systems-Air (ULS-A) and Unmanned Logistics Systems-Ground (ULS-G) being developed. Secondly, there is no official Department of Defense terminology distinguishing between unmanned and autonomous technology, but there is a significant technology gap between a fully autonomous ULS and a semiautonomous ULS requiring human input such as leader-follower technology or remote piloting. Recently, Secretary of Defense Mattis expressed his opinion that the name unmanned aerial system (UAS) is a misnomer because there is ultimately a human in the loop controlling the drone. He went on to suggest that artificial intelligence and autonomy could change not only the character of war, but also its very nature.[4]

ULS-A programs are significantly further in development than ULS-G mainly because, counter to common perception, the ULS-A operational environment is significantly less complex than the ULS-G terrestrial environment.[5] Although there are air space coordination considerations with ULS-A, the systems are less complex to operate because they simply fly over or around obstacles and can operate at low enough altitude to reduce collision risks with other aircraft. Slight or even gross deviations from a set path are not problematic as long as they reach the point of delivery. In contrast, ULS-G must operate on predetermined routes, interact with other traffic, humans, and obstacles, and face more complex enemy threats. Furthermore, ULS-G do not address the problem of crowded routes not only adding to the traffic problem, but also inducing wear and tear to infrastructure which is likely already in poor condition. Lastly, ULS-A will cost significantly less than ULS-G allowing commanders to assume more risk in employing ULS-A.

For clarity, it is important to draw distinction between unmanned and autonomous technology. Unmanned systems simply operate without an operator onboard. The remotely piloted UAS currently in operation are a good example of unmanned systems. Autonomous systems can perform at least some operations without human input.[6] ULS-A and ULS-G will both likely be unmanned or semiautonomous in the near future. The goal of full autonomy is important because if human input is needed, there will remain a requirement for communications with the systems both creating electronic signature and receiving signals making it vulnerable to cyberspace and electromagnetic threats. A fully autonomous ULS would operate completely independent of human interaction by incorporating artificial intelligence capable of making complex decisions such as best routes and delivery points in a changing environment. Personnel reductions are also not possible until reliable full autonomy is achieved.

<u>Unmanned Logistics Systems-Air</u>

ULS-A are a rapidly approaching capability allowing increased distributed operations as they are fielded. ULS-A will allow sustainment from a sea base and provide on-demand resupply without burdening critical amphibious connectors or exposing personnel to the enemy ashore.[7] Multiple sizes of ULS-A will provide capability to efficiently resupply Marines while unburdening traditional, manned rotary-wing platforms and reducing the need for ground vehicles and secure ground lines of communication. Small ULS-A will carry about fifty pounds of payload[8] and are intended for just-in-time delivery of mission critical items. This will be a powerful tool to lighten the load of the individual Marine and give him confidence that supplementary equipment and supplies are rapidly deliverable.

Medium ULS-A will be the workhorse of the logistics combat element providing 500 or more pounds of capacity.[9] An infantry squad requires roughly 800-pounds of sustainment per day, so medium ULS-A are ideal for sustaining squad to company sized elements. Additionally, medium ULS-A could be used to evacuate casualties without exposing additional personnel or manned aircraft to hostile fire. Marines could also use medium ULS-A to transport weapons and equipment to and from key terrain like rooftops of high-rise buildings[10] and ridgelines, allowing combat power to quickly mass where the enemy least expects it. The Marine Corps Warfighting Laboratory experimented with a 300-pound payload variant called the Picatinny Pallet: Sustainment Aerial Mobility Vehicle in 2016.[11] The Army is now working with this "hoverbike" under the name Joint Tactical Aerial Resupply Vehicle (JTARV). Program objectives are an 800-pound payload with 125-mile range and 60 miles per hour.[12] While the prototype helps prove the concept, it also reveals opportunities for improvement such as load packaging and implementation challenges as discussed below.

Large ULS-A will be capable of transporting 5,000 pounds[13] and used for sustaining company or larger units and sustainment intensive elements such as armor and artillery. Large ULS-A will also be useful as amphibious connectors in forcible entry operations, further reducing risk. Packaging for all sizes of ULS-A will be a critical component of the concept. It should be modular, lightweight, and disposable. External sling loads will enable rapid loading and automatic unloading while reducing the size and weight of each ULS-A and allow the load to simply detach automatically without a human exposing himself to unload to platform. The exact capacity of each ULS-A category is still up for debate, but turn-around time due to maintenance and loading are key determining factors in their performance.[14] Lastly, ULS-A sensor packages will contribute to MAGTF intelligence, surveillance, and reconnaissance (ISR) efforts by filling critical coverage intelligence gaps.

As discussed, due to the less complex operating environment, the Marine Corps is closer to acquiring autonomous ULS-A than ULS-G. Recognizing this early, Installations and Logistics focused effort on air systems and allowed the U. S. Army and private to sector pursue ground systems. One of the most significant developments is an applique kit called Autonomous Aerial Cargo/Utility System (AACUS). As an appliqué kit, AACUS is essentially a bolt on modification for existing platforms such as the UH-1 Huey that flies and lands a helicopter autonomously. Previously, unmanned helicopters were controlled on landing by a trained operator, but AACUS can be controlled with an Android application by any Marine with fifteen minutes of training and a network connected tablet. Furthermore, the sensors that allow AACUS to avoid buildings, terrain, and other obstacles also create a three-dimensional terrain model that can pair with artificial intelligence to find the best routes.[15] While still in the prototype phase, the Marine Corps and Army expect to begin experimentation in Fiscal Year 2018.

Work to date with AACUS is with existing platforms, which is interesting because retired UH-1 Hueys and fitted with AACUS[16] is a possible bridging technology. This approach gains the Marine Corps experience in ULS-A and can increase to significant numbers in a contingency, but it will be expensive and maintenance intensive as well as consume personnel resources and take significant space aboard ship or at an air field. Efforts to acquire low-cost ULS-A must answer these challenges.

In addition to reducing throughput requirements for manned rotary-wing aircraft, ULS-A will cost significantly less to acquire and operate. With this lower cost in mind, commanders will have the freedom to employ ULS-A when weather and enemy threat ground manned aircraft. This is particularly important for medium and large ULS-A which, as discussed, will be capable of evacuating casualties without endangering more personnel. MAGTFs have already employed ULS-A,[17] and full integration will enhance operations beyond this discussion especially once innovative Marines employ and experiment with them.

Unmanned Logistics Systems-Ground

ULS-A will have the throughput capacity to sustain dismounted infantry in the near future,[18] but the future sustained major combat operations will require more sustainment than aerial systems can reasonably provide. Specifically, mechanized and fire support units consume fuel and ammunition at rates ULS-A will not adequately resupply. It may be possible for ULS-A to exclusively provide sustainment during the first few days of an amphibious operation, but as combat power builds ashore and moves inland, the carrying capacity and range of ground vehicles will be necessary. ULS-G will provide the heavy lift required for sustained major combat operations while taking many and eventually all Marines out of logistics vehicles.

ULS-G development is currently moving in two directions. The first is modifying existing platforms to operate unmanned, and the second is acquiring new unmanned platforms. Modifying existing platforms is more cost effective than new acquisitions. Optional manning also supports this method because the platforms are already designed for humans with the accompanying armor packages. New acquisitions will cost more,[19] but there could be efficiencies in size, weight, fuel economy, and maintenance requirements especially if systems are exclusively unmanned.

Developing appliqué kits for current platforms such as the Medium Tactical Vehicle-Replacement (MTVR) will more than likely result in the fielding of a leader-follower system which requires a manned vehicle to lead between three and seven unmanned vehicles.[20] This is a realistic approach to field ULS-G by 2025 and is in keeping with the Commandant's manned/unmanned teaming (MUM-T) concept. Commanders will be more confident employing systems like this because it allows humans to escort vehicles and make decisions that artificial intelligence does not currently have the capacity for. The escorts would need to act as convoy commander and recovery/contact vehicles. Additionally, in practice, the manned vehicles would act as armed security as commanders are unlikely to send unprotected supplies in any but the most permissive environments.

One example of an appliqué kit is TERRAMAX from Oshkosh Defense. It is currently in testing with the Medium Tactical Vehicle Replacement (MTVR) and other platforms and is semi-autonomous, optionally manned, leader-follower capable, optionally remote-controlled, and can navigate without global positioning systems (GPS).[21] Optional manning leaves the traditional controls in the vehicle allowing the commander to choose to operate manned or unmanned depending on the tactical situation. Leader-follower technology allows a single manned vehicle to lead one or more unmanned vehicles. TERRAMAX can drive autonomously or remote controlled as the situation dictates. Navigating without GPS is a necessary requirement in the future operating environment as satellite signals will likely be disrupted or denied by the enemy in the future operating environment.

As compared to modifying existing equipment, acquiring a completely new platform has several advantages and disadvantages. If an unmanned vehicle cannot operate across the ROMO, manned platforms will remain a requirement meaning the total amount of equipment the Marine Corps owns would increase substantially. Operating among civilians and in network denied areas are two challenges that must be solved before fully unmanned platforms can replace manned platforms completely. The most significant disadvantage is the resources an all new platform will take to procure while existing platforms such as the MTVR still has many years of service life ahead. Secondly, the lead time required to field such a platform is considerably longer than modifying an existing platform.[22]

Disadvantages notwithstanding, a new platform would be tailored to fit the mission envisioned for it. For example, a new platform without an operator would be smaller, lighter, and more efficient than a manned system of similar capability because an occupant compartment and armor are not required. This means it would occupy less transport space aboard ship, on amphibious connectors, and on aircraft. A goal for newly procured systems could be the cargo capacity of an MTVR but at a weight within the external lift capacity of the upcoming CH-53K King Stallion[23] or even the height, width, and length to be internally transportable on a KC-130 Hercules. Furthermore, significant improvements in maintenance and loading/unloading procedures would necessarily be designed into the system. A goal of unmanned systems is to reduce personnel, so designing advantages in load handling and maintenance requirements is critical to gain personnel efficiencies.

Without human occupants to target, the enemy will have less incentive to attack logistics convoys as destroyed equipment will not impact US domestic opinion like American casualties. Furthermore, ULS-G do not require supple suspension systems for the comfort of occupants which further reduces weight and complexity. Reducing speed requirements is also possible since ULS-G can operate longer shifts than humans. Lower speed requirements will also reduce power requirements having an exponential effect on weight, efficiency, and maintenance. Incorporating composites and alloy metals can further displace weight requirements. Ford Motor Company demonstrated the advantages of this in the F-150 when it changed to aluminum bodies and high strength steel frames on the popular pickup trucks. The reduced weight of the body and frame allowed efficiencies in other components, reduced corrosion issues, raised cargo capacities, and increased fuel efficiency.[24] A new acquisition could also target alternative fuel sources such as all-electric, diesel-electric hybrids, or multifuel engines. All-electric and hybrids are attractive not only for fuel efficiency, but also for quiet operations when the tactical situation warrants. Artificial intelligence controlled vehicles will also be more disciplined than humans in efficient driving techniques to gain even more efficiency. Whether existing platforms are modified or new are acquired, ULS-G are an opportunity to remove personnel from dangerous ground lines of communication while enhancing maneuver element operations.

Material Handling Equipment

Autonomous material handling equipment (MHE) will be useful for loading aircraft and trucks, keeping warehouses and supply lots organized and consolidated, and constructing force protection measures. While ULS will likely increase workloads and personnel requirements as they are implemented, autonomous MHE operations could be a first step in reducing the workload and support personnel requirements. Autonomous MHE is also lower risk considering operations are in more permissive environments such as supply lots and flight lines. Artificial intelligence can create more efficient load and storage plans than humans. Autonomous MHE could then pull the required materials and pre-stage them on the supply lot or flight line ready for the next convoy or sortie. Autonomous MHE could also reorganize and consolidate storage space according to upcoming missions, incoming deliveries, and space available. MHE installing concrete or HESCO barriers for perimeters will enhance force protection without exposing Marines to the enemy. Similarly, autonomous earthmoving heavy equipment is used in the commercial sector for building roads and site preparations.[25] Commercial construction companies using autonomous bulldozers can precisely calculate the amount of material needed to spread over a given area. This would be particularly valuable in a combat zone where gravel is costly to procure and transport over dangerous supply routes. Autonomous MHE could be an opportunity to reduce personnel and streamline operations in more passive environments.

ULS Coordination

There is significant room for ULS-A and ULS-G to work in coordination. For example, ULS-G could deliver multiple ULS-A to a central hub along a main supply route (MSR) and the ULS-A could then deliver sustainment the last tactical mile or several miles. This method complements the ULS-G's inherent capacity for heavier loads while exploiting ULS-A's ability to cross any terrain. Much is written about the potential for ULS-A in amphibious operations working from a sea base;[26] however, these studies show a concept of logistics for a dismounted understrength infantry regiment with minimal fuel requirement and assumes the sea base is reasonably close to shore. While these studies are valuable, in large scale forcible entry operations fuel and ammunition requirements for wheeled vehicles, armor, and power generation will quickly exhaust capacity for ULS-A resupply and require to teaming with ground vehicles.

Another opportunity to partner ULS-A and ULS-G is to leverage ULS-A as an ISR system ahead of ULS-G operations. For example, AACUS sensors are capable of mapping terrain to gain detailed route reconnaissance and provide commanders with route recommendations according to the type of ground vehicle employed.[27] Sensors can also penetrate vegetation to provide imagery of the ground in forested terrain. Additionally, ULS-A can provide bathymetric and mining data for amphibious operations at relatively little cost without exposing aircrews or other UAS platforms to risk, filling gaps in information from other ISR systems, and give logistics combat element commanders an organic ISR platform. Coordinating ULS-A, ULS-G, and logisticians will improve the performance of each exponentially.

Lighten the Load

In addition to lightening the MAGTF, easing the burden on the individual Marine is critical for the future operating environment to make Marines more mobile and more effective on the objective. While efforts continue to lighten individual equipment such as body armor and helmets,[28] the weight and requirement for water remain constant. Additionally, consumables such as food, ammunition, and batteries continue to weigh down Marines. ULS will be a capability to reliably resupply Marines at the right time and place to prevent them from carrying more than what is absolutely needed. This predictability will give Marines confidence to leave contingency items in the rear. In other words, if Marines have confidence in the logistics system, they will carry less supplies and leave just in case items behind. ULS-A could also assist Marines by moving heavy or bulky weapons, equipment, and ammunition to key terrain such as ridgelines and rooftops. These advantages will have a compound effect on sustainment needs because Marines carrying less weight consume less energy and require less food and water. Besides physical endurance, cognitive resiliency will also be enhanced in Marines less burdened by unnecessary weight. Properly employed, reliable ULS will significantly lighten the load for individual Marines.

Concept of Operations

A concept of operations for ULS with currently available technology is to team manned and unmanned vehicles in a convoy with ULS-A. The lead vehicle or first several vehicles could be unmanned operating semi-autonomously with remote input from a human operator either in the convoy or at an operations center with manned vehicles spread throughout the convoy from a one to three up to a one to seven ratio of manned to unmanned vehicles.[29] A convoy commander, security element, and recovery team would be in optionally manned vehicles with operators who are not necessarily driving. Operators attention would be on security and communications but could take control of the vehicle if necessary. Ideally, the convoy would move mostly on primary MSRs and detach unmanned vehicles along the route as the convoy passes near distribution points.

For smaller distribution points, ULS-A would detach from a ground vehicle, make the delivery, and return to the convoy for another load. The Singaporean Armed Forces’ V-15 ISR UAS is capable of launch and recovery from a moving vehicle,[30] so the concept is certainly possible for ULS-A. For improved situational awareness and communications, ULS-A or dedicated UAS could provide over watch for the convoy while relaying communications from low altitude. Such a UAS could scan for signs of IEDs at a level of fidelity much greater than the human eye. In open terrain, this UAS would be tethered to a vehicle to provide it constant power and a direct data link to the tethered ground vehicle.

For security, vehicles would be mounted with remotely operated crew-served weapons at a ratio appropriate to the threat. As with the remote-control option for driving, either from the manned vehicles or at the operations center, human operators would have the ability to take control of the crew-served weapons with views from the weapon’s optics and a bird’s eye view from the convoy's UAS. A single operator could control multiple weapons and create interlocking fields of fire due to his operational picture and situational awareness.[31] Current Department of Defense policy requires a human decide to engage a target,[32] but as artificial intelligence improves, that policy may change. Once the threat is suppressed, the convoy commander could decide whether to bypass the threat, call for fire to destroy or neutralize the threat, or even launch the convoy's own micro-bots to destroy the target. About the size of a hummingbird, micro-bots are miniature UAS programmed to seek out enemy personnel and attack with a miniature shape charge.[33] They share much of the same technology with ULS-A, but are a low cost combined-arms solution that would be more responsive and cost effective than precision guided munitions with less collateral damage.

As described above, unmanned UH-1 Hueys fitted with AACUS could not only deliver cargo, but also be an effective military deception. Flying unmanned traditional aircraft across a likely beach landing zone would be an effective feint or first wave, especially if it draws fire and enemy electronic signatures to locate and target enemy positions. Using mothballed airframes would be a cost-effective way to entice the enemy to reveal his positions and attrite his defenses. This concept, teamed with unmanned armored amphibious vehicles using similar technology to ULS-G, would simulate an amphibious assault, providing an effective distraction to give a MAGTF both time and space to maneuver.

<u>Packaging</u>

For any ULS to work, packaging is a major consideration to make loading and unloading practical and efficient. Packaging for ULS-A must be lightweight and disposable. ULS-A cargo capacity is limited, so every extra pound of packaging is wasted throughput. For example, small ULS-A are designed to carry about fifty pounds,[34] so just ten pounds of packaging would take nearly 20% of capacity. Disposable packaging eliminates the workload and risk of returning packaging and the material could potentially be repurposed by the receiving unit. One possible use for repurposing is recycling plastic packaging for use in three-dimensional (3D) printers.[35] External sling-loads could be staged on a landing zone to reduce turnaround time, and those loads would easily automatically detach at the point of delivery. This both reduces turnaround time and prevents receiving personnel from exposing themselves to enemy observation and fire.

ULS-G packaging has different considerations from ULS-A packaging. Reusable systems allow for reduced loading times and provide mobile storage solutions. Current systems such as International Organization for Standardization (ISO) container and flat racks will continue to prove invaluable, but this adds an additional requirement for unmanned Logistic Vehicle System-Replacement (LVSR) to load and unload autonomously. SIXCON tank and pump modules will also continue providing mobile fuel and water capacity, which will only be enhanced by autonomous capability because the 900-gallon modular systems are easily loaded and unloaded and turn any flatbed cargo vehicle into a fuel or water tanker. The 5000-gallon M970 fuel tanker will provide robust carrying capacity if ULS-Gs are successful in towing large trailers.[36] Material packaging for ULS-G becomes a significant consideration to reduce manpower needed for sustainment operations.

Manned/Unmanned Teaming

Fully autonomous ULS-G are probably a distant reality, but for now, artificial intelligence capabilities do not allow the ability to make all the decisions involved in commanding a convoy or make decisions about firing weapons.[37] MUM-T will not only be necessary, but a force multiplier as technology evolves. The task of commanding a convoy in a hostile environment is too complex for current artificial intelligence to reliably execute. A realistic intermediate goal is the ability to remotely command a semiautonomous convoy from an operations center. Similarly, the decision to fire weapons should remain in human hands until there is confidence in artificial intelligence to prevent friendly fire and fire on noncombatants.[38]

Additionally, robotics are not advanced enough to provide anything but a rudimentary vehicle recovery capability. Tasks as simple as turning a door knob are challenging for today's robotics whose physical dexterity could be likened to that of a young toddler. For recovery, an autonomous tow vehicle would not be difficult to engineer, but towing is not the solution for every vehicle problem on a convoy. Flat tires, loose loads, and other correctable problems will continue to need human hands and reasoning until artificial intelligence can reason through the problems and robotics can perform complex tasks requiring the mobility and dexterity of a human. MUM-T should emphasize that robots should be developed to do things better than humans can. If a human can perform a task better than a robot, resources are better spent on capabilities that humans have difficulty performing. Otherwise, robotics will hinder military operations as opposed to enhancing them. Examples of this are the large, heavy, and loud cargo carriers designed to follow foot-mobile troops that cannot traverse terrain like a human can such as the Multifunction Utility/Logistics and Equipment (MULE) autonomous vehicle.[39] Such vehicles could have utility as an ULS-G, but persistent presence with a combat unit would potentially limit operations more than enhance them. In summary, the concept of MUM-T is that machines should be used for tasks machines can do better than humans and humans should continue performing tasks where machines are a hinderance.

Civilian Interaction

In addition to the challenges listed above, autonomous vehicles will necessarily avoid collisions with other vehicles and pedestrians. The private sector has identified this as a major problem for civilian autonomous vehicles because pedestrian behavior could change. Pedestrians, knowing programming will not allow self-driving cars to hit a pedestrian, will be emboldened to cross in front of them or even harass vehicles.[40] While this could amount to little more than mischievous harassment and increased traffic in a permissive civilian environment, it is a serious consideration for autonomous military vehicles across the ROMO. A crafty enemy could easily pose as civilians to delay supplies and clog vital supply routes or even halt a convoy before an attack. Furthermore, pedestrian interaction with traffic has localized patterns based on culture and social norms.[41] Visiting any large city will quickly confirm this phenomenon if one observes resident pedestrian actions as compared to tourists. As such, operating ULS-G in different areas and in various threat levels will require different pedestrian interaction protocols or advanced machine learning to perceive the nuance and overcome the challenge. Lastly, urban operations will further be affected due to infrastructure changes such as barricades designed to keep pedestrians off streets. These could channelize vehicles and add additional obstacles to contend with in urban operations. More challenges with civilian interaction will certainly arise, but the preceding is a starting point to understand and work through those challenges.

Capacity

A ULS-A study shows that the exact capacity of ULS is almost irrelevant, but that medium capacity from 500-1200 pounds is optimum for sustaining dismounted operations.[42] Maintenance and loading time are more important than identifying an optimum capacity or speed. Small ULS-A with a fifty-pound capacity are useful for just in time logistics, but substantial throughput is not possible due to limited capacity, range, and speed. If the Marine Corps uses existing platforms for ULS-G, size is fixed, but some capacity could be regained by removing armor. Removing armor is unlikely, as capacity would be relatively small and commanders will want to retain optional manning capability. Follow-on generations of ULS-G will likely be exclusively unmanned which will provide multiple benefits by eliminating the passenger compartment and need for armor. This will result in significantly reduced weight, height, and length of each vehicle unburdening capacity on amphibious ships and connectors where space and weight are at a premium. Decreased energy consumption is another benefit of smaller platforms.

Conversely, regulation of commercial UAS is driving the development of ULS-A toward a fifty to fifty-five-pound capacity because commercial drones under this weight avoid registration with the Federal Aviation Administration.[43] While the previously discussed study shows small ULS-A as less than optimal for efficiency,[44] the low cost and availability of small ULS-A will make them attractive in the near-term. An operational model using small ULS-A could partner manned or unmanned ground vehicles to deliver supplies to a central hub and distribute supplies in fifty-pound bundles to points of delivery. The shorter range required in this system has the added benefit of requiring less air space coordination, less risk of enemy interference, and less power required for the ULS-A.

Personnel and Maintenance

ULS could provide an opportunity to improve tooth to tail ratios, but it is not a forgone conclusion. While these personnel would operate in lower risk environments, significant work remains in ensuring ULS do not create more burden than they eliminate, and acquisitions should include goals to reduce personnel or at least remain neutral.[45] Loading and maintenance of ULS are just two significant factors to consider. With a plethora of sensors and other electronics added on to existing systems, it is easy to imagine the manpower these systems will require particularly in austere environments. Motor transport operators are trained to perform preventative maintenance checks and services on traditional vehicles, but as vehicles have become more technologically complex in recent decades, reliance on contracted logistics support has increased at an unsustainable rate and left operations dependent on civilian contractors.

While cost and personnel increases in the near term make acquiring ULS more difficult, the force protection and freedom of maneuver the systems will provide in the future is worth pursuing. The return on investment will be increased force protection, reduced overall cost, less personnel, and less vehicles required for operations. Clearly, force protection is the priority. Even a basic leader-follower system would significantly reduce personnel on the road and a fully autonomous system, while probably a distant reality, will eventually take all personnel off the supply routes. Initial increases in acquisition, personnel, and maintenance costs will be offset by future personnel reductions. Personnel are about 50% of the costs of the military,[46] so reducing personnel pays dividends. Killed and wounded Marines are a substantial financial cost which would certainly be reduced by taking Marines off the road. Lastly, unmanned vehicles will require maintenance and loading time like manned vehicles, but they will not need operator rest time. Less down time will enable fewer vehicles to perform the same work, resulting in more cost savings and reducing the MAGTF’s footprint and weight. There are too many variables to calculate initial costs and eventual savings, but investing now will result in financial savings sooner, not to mention lives protected.

Challenges

Implementing ULS will pose challenges to the Marine Corps. Logisticians must make a concerted effort to demonstrate how unmanned technology will save lives and resources, making ULS worth the investment. As with any procurement, the Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities and Policy (DOTMLPF-P) process must be considered.[47] Initially, ULS will likely add to maintenance and personnel requirements, but manned ground vehicles and rotary-wing aircraft will realize immediate efficiency and force protection improvements. Nonetheless, maintenance requirements must be carefully weighed against benefits as personnel increases will result from buying the wrong platform. Phasing systems in will avoid overwhelming the organizational structure and provide lessons learned for subsequent systems. Recognizing that ULS are largely untested, using a baby-step approach is necessary to find the right systems and operational models.

Command and control of ULS will challenge existing networks,[48] so network improvements and resiliency are a necessary condition for unmanned system proliferation. Doctrine will change, but doctrinal updates may not keep pace with developments in technology, requiring Marines to remain innovative to stay ahead of the enemy. Emphasizing simplicity will reduce the need for excessive training or organizational changes such as new military occupational specialties. Procuring systems with common control architecture with common fuel or power systems will reduce materiel considerations. Besides additional storage and maintenance facilities, training ranges must also accommodate ULS, particularly those with lethal capabilities.[49]

Network resiliency is a critical vulnerability for current and future operations especially against peer and near-peer adversaries that will require nearly impervious networks to confidently employ. The cyber domain is emerging as an area the US cannot exclusively dominate. Unmanned systems requiring constant communication and GPS guidance are obviously vulnerable to network outages, and remotely controlled systems are susceptible to interference or takeover by the enemy. Even if the enemy can only disrupt ULS, the requirement for backup manned systems would negate most advantages. Total cost, manpower, and theater lift for separate manned and unmanned systems would far exceed current requirements. This is an argument in favor of small ULS-A and optionally manned ULS-G to minimize risk, but this approach does not help reduce personnel requirements and adds to the total amount of equipment in the MAGTF. More work is required, but networks could build in resiliency by using UAS and balloons to relay communications either as a primary system or as a backup to satellites. Much as wired communications find a route through their network,[50] wireless communications using a network of UAS could find a path around interference which could restrict the enemy's ability to impact communications in a limited area and add capacity to overburdened networks.

A possible solution for network issues is to use technology similar to the Air Force's Gray Wolf missile program which networks a group of missiles in a swarm that share information so each missile does not require every sensor.[51] Using this approach, ULS would cost less per unit and have access to more sensors from the aggregate of its formation's shared sensors. Furthermore, the data transfer ability will enable group behavior and maintain communications with greater fidelity. For example, one master ULS-A would travel at higher altitude and maintain communications with the controlling unit while providing guidance to and receiving information from four other ULS-A at lower altitude. All five could have different destinations in the same general area, make their separate deliveries, and regroup to return to base. Additionally, this concept lowers the cost of each ULS-A, so a commander can swarm ULS-A. Swarming will assume more risk to individual ULS-A, but ensure more supplies reach their destinations. Although these challenges will make acquiring and implementing ULS more difficult, Marines must adapt and innovate to overcome them.

The Commercial Sector

The commercial sector is making much progress in self-driving cars, but there remains a divide between driver assisted vehicles and fully autonomous vehicles.[52] In 2016, 34,349 people were killed in automobile accidents in the U.S. Alcohol was involved in 21% of cases, and excessive speed was a factor 27% of the time. Automobile accidents are the leading cause of death in young people age sixteen to twenty-three. In addition to the lives lost, estimates show that the economy losses nearly a trillion dollars each year to automobile accidents.[53] These statistics show the moral imperative to develop self-driving technology, but fully autonomous driving is still several years if not more away. Despite suggestive terms like “Autopilot” and “ProPilot,”[54] technology currently available is better categorized as driver assistance than self-driving. Adaptive cruise control, lane holding, crash avoidance, and self-parking are helpful safety features, but all require driver input and supervision. While some of these features would certainly aid vehicle operators, the risk of cyber-attack on the systems must be weighed against improvements that do not actually remove operators from vehicles. Unmanned vehicles will face the same threat, but they will have the benefit of removing a human from the vehicle and could be worth the additional risk of vulnerability. Another drawback is that many of these systems work by following the lines on the road, so they do not have military utility where unmarked pavement and off-road terrain are the norm. In fact, self-driving systems have difficulty distinguishing between a boulder which must be avoided and a tumbleweed that can be driven over. These challenges notwithstanding, the Marine Corps must continue working closely with the commercial sector and seize true unmanned opportunities as they arise.

<u>Conclusion</u>

Exploiting automated and unmanned technology for logistics will enhance Marine Air Ground Task Force (MAGTF) maneuver and sustainment capabilities. Marines must remain innovative to overcome challenges to provide effective logistics support in the future operating environment. Lighter, faster, and more lethal MAGTFs will result from logisticians employing and teaming with ULS to provide future expeditionary logistics. Ideas in this paper are not predictive of the future, but merely input on how the Marine Corps could implement future technology. It is certain that the logistics community in conjunction with other functional areas will implement new and better ideas as technology is developed and Marines continue innovating. Lastly, the Commandant of the Marine Corps, General Neller, speaking about the future operating environment, stated, "It will involve rapidly changing and evolving technologies and concepts, which will force us to be more agile, flexible, and adaptable."[55] ULS are a key development for logisticians to make critical contributions to the future fight.

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