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Form Approved  
OMB No. 0704-0188

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<b>1. REPORT DATE (DD-MM-YYYY)</b> 07-MAY-2021	<b>2. REPORT TYPE</b> Master of Military Studies (MMS) thesis	<b>3. DATES COVERED (From - To)</b> AY 2020-2021
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<b>4. TITLE AND SUBTITLE</b> Unmanned Logistics System - Air: A Family of Systems with a Wide Range of Requirements and Possibilities	<b>5a. CONTRACT NUMBER</b> N/A
	<b>5b. GRANT NUMBER</b> N/A
	<b>5c. PROGRAM ELEMENT NUMBER</b> N/A

<b>6. AUTHOR(S)</b> Watts, Chester J. T. (Major)	<b>5d. PROJECT NUMBER</b> N/A
	<b>5e. TASK NUMBER</b> N/A
	<b>5f. WORK UNIT NUMBER</b> N/A

<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> USMC Command and Staff College Marine Corps University 2076 South Street Quantico, VA 22134-5068	<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b> N/A
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<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> N/A	<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b>
	<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b> N/A

**12. DISTRIBUTION/AVAILABILITY STATEMENT**  
Approved for public release, distribution unlimited.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**  
The Marine Corps aviation community must prepare to operate unmanned aircraft systems (UAS) that will support the logistics functions of supply and transportation. Logisticians will be responsible for small- and medium-sized cargo UAS, but professional aviators from the Aviation Combat Element must fly large cargo UAS. Based on the relatively low requirements for maintenance, planning and airspace deconfliction, risk management, and operator capabilities, Small ULS-A and Medium ULS-A will be maintained and operated by Marines within the Logistics Combat Element and Ground Combat Element. In contrast, the same factors for Large ULS-A indicate that it must be maintained and operated by units within the aviation combat element. Thus, the Marine Corps must prepare for Large ULS-A in future appropriations documents and develop plans to fit Large ULS-A into the Aviation Combat Element.

**15. SUBJECT TERMS**  
unmanned aircraft systems, UAS; Unmanned Logistics System, ULS, ULS-A; K-MAX; cargo resupply UAS, CUAS, CRUAS

<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>	<b>18. NUMBER OF PAGES</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b>
<b>a. REPORT</b>	<b>b. ABSTRACT</b>	<b>c. THIS PAGE</b>			USMC Command and Staff College
Unclass	Unclass	Unclass	UU		<b>19b. TELEPHONE NUMBER (Include area code)</b> (703) 784-3330 (Admin Office)

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MASTER OF MILITARY STUDIES

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Unmanned Logistics System – Air:  
A Family of Systems with a Wide Range of Requirements and Possibilities

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

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AY 2020-21

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Approved: \_\_\_\_\_

Date: \_\_\_\_\_

## Executive Summary

**Title:** Unmanned Logistics System – Air: A Family of Systems with a wide range of requirements and possibilities

**Author:** Major Chester James Todd Watts, United States Marine Corps

**Thesis:** The Marine Corps aviation community must prepare to operate unmanned aircraft systems (UAS) that will support the logistics functions of supply and transportation. Logisticians will be responsible for small- and medium-sized cargo UAS, but professional aviators from the Aviation Combat Element must fly large cargo UAS.

**Discussion:** The Marine Corps continues to acquire a wide variety of UAS that vary in size, weight, capability, mission, and autonomy. Each variant requires its own degree of expertise. On one end of the continuum, Marines in ground units operate and maintain small UAS (sUAS) as a collateral responsibility after only a few days or hours of training. At the other end of the continuum, the Air Force’s MQ-1 Predators, MQ-9 Reapers, and RQ-4 Global Hawks require operators and maintainers who have expertise similar to manned aircraft. The family of cargo UAS known as Unmanned Logistics System-Air (ULS-A) will also span this continuum. Large ULS-A will be analogous to Predators, Reapers, and Global Hawks, and thus the people who operate and maintain it will require more intensive and specialized training on the system. Small ULS-A and Medium ULS-A will be in the middle of the continuum based on weight and flight parameters, and the expertise required will be similar to current sUAS. As such, the maintenance, planning and airspace deconfliction, risk management, and operator capabilities will mirror that of sUAS.

**Conclusion:** Based on the relatively low requirements for maintenance, planning and airspace deconfliction, risk management, and operator capabilities, Small ULS-A and Medium ULS-A will be maintained and operated by Marines within the Logistics Combat Element and Ground Combat Element. In contrast, the same factors for Large ULS-A indicate that it must be maintained and operated by units within the aviation combat element. Thus, the Marine Corps must prepare for Large ULS-A in future appropriations documents and develop plans to fit Large ULS-A into the Aviation Combat Element.

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THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

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## *Preface*

The object of my research was to learn about the future of unmanned aircraft systems in the Marine Corps and provide analysis of how I think the Marine Corps should exploit emerging technologies. My original intent was to focus on intelligence, surveillance, and reconnaissance aircraft and how their advancements will integrate with the future force. However, with the help of Major Daniel Lewis, I realized the potential for significant friction as the Marine Corps attempts to acquire cargo systems that support sustainment requirements of widely dispersed ground units. That line of inquiry took me down a path reading about very interesting projects, emerging concepts, and potential problems, which I look forward to following over the next several years.

I want to start off by thanking my family for their love and support throughout this academic year at the Marine Corps University. Next, I would like to acknowledge Dr. Brandon Valeriano for patiently mentoring me through this research and writing process. Mr. Thomas “Brain” Heffern, of the Logistics Innovation Office in Headquarters Marine Corps Installations and Logistics, was integral to helping me understand current and future efforts to integrate unmanned cargo aircraft into the Marine Corps. LtCol Jeremy Thompson rounded out my thinking with respect to the logistics community, and I greatly appreciate his inputs and thought-provoking questions.



## INTRODUCTION

As the Marine Corps modernizes to become more lethal and survivable, it continues to acquire a wide variety of unmanned aircraft systems (UAS) that vary in size, weight, capability, mission, and autonomy. Each variant requires its own degree of expertise. Table 1 shows this continuum from Group 1 through Group 5. Marines in ground units operate and maintain small UAS (sUAS) as a collateral responsibility after only a few days or hours of training. These aircraft typically fit into Group 1. At the other end of the continuum is Group 5, which consists of the United States Air Force’s MQ-1 Predators, MQ-9 Reapers, and RQ-4 Global Hawks. These highly complex aircraft have engines, sensors, and controls that require operators and maintainers with expertise similar to that of manned aircraft.





UAS Groups	Maximum Weight (lbs) (MGTOW)	Normal Operating Altitude (ft)	Speed (kts)	Representative UAS	
Group 1	0 – 20	<1200 AGL	100	Raven (RQ-11), WASP	
Group 2	21 – 55	<3500 AGL	< 250	ScanEagle	
Group 3	< 1320	< FL 180		Shadow (RQ-7B), Tier II / STUAS	
Group 4	>1320		> FL 180	Any Airspeed	Fire Scout (MQ-8B, RQ-8B), Predator (MQ-1A/B), Sky Warrior ERMP (MQ-1C)
Group 5		Reaper (MQ-9A), Global Hawk (RQ-4), BAMS (RQ-4N)			

Table 1. DoD UAS Group Descriptions<sup>1</sup> (altitudes reference above ground level (AGL) and flight level (FL))

The Department of Defense (DoD) UAS Groups were created for UAS that conduct Intelligence, Surveillance, and Reconnaissance (ISR), communications relay, and airstrike missions. The groups were developed in coordination with the Federal Aviation Administration (FAA) based on the systems at the time, their typical flight profiles, and how they interact in airspace with manned aircraft. The groups do not readily account for cargo UAS, also known as cargo resupply UAS (CRUAS), because historically weight increased with the complexity of the aircraft and the amount of interaction they had with manned aircraft. CRUAS, however, are designed to be heavy regardless of the flight profile or how much they interact with manned aircraft. In 2004, the FAA reassessed the limitations and requirements for ultralight and light sport aircraft due to technological advancement and proliferation.<sup>2</sup> With the advent of CRUAS, the DoD and the FAA need to reassess the specifications and requirements of the UAS groups.

The family of CRUAS known as Unmanned Logistics System-Air (ULS-A) may span at least four of the five groups. Though Small ULS-A and Medium ULS-A meet the current definition for Group 3 based on weight, the flight parameters and the expertise required will be analogous to current Group 1 and Group 2 systems. Since the maintenance, planning and airspace deconfliction, risk management, and operator capabilities for Small and Medium ULS-A will be similar to Group 1 and 2 systems, Group 3 Cargo UAS should be incorporated into logistics and ground combat units. This means that the ULS-A planners must overcome the obstacle of the requirements outlined by the Naval Aviation Maintenance Program. Large ULS-A will be more analogous to Predators, Reapers, and Global Hawks, and thus the people who operate and maintain it will require more intensive, specialized training. The Marine Corps UAS community needs to think seriously about how it would incorporate Group 4 Cargo UAS into squadrons and the rest of the aviation community.

## **BACKGROUND**

### A history of Cargo Resupply UAS

The Marine Corps started flying UAS in 1984, and for nearly thirty years they were exclusively used for ISR. The first deployed CRUAS for the Marine Corps was an unmanned variant of the Kaman K-MAX. An article from December 2012 reports that K-MAX was operated by Marine Unmanned Aerial Vehicle Squadron – 1 (VMU-1) and VMU-3, as they each rotated through deployments to Afghanistan. Major Kyle O’Connor, the officer in charge of VMU-1’s CRUAS, justified its use by saying, “The need... came about because the Marine Corps wanted to get trucks off the road.”<sup>3</sup> Convoys of trucks were highly susceptible to improvised explosive devices, but that threat was avoided by flying supplies to combat outposts.

VMU-2 wrote an after action report about their experiences with K-MAX in Afghanistan from May 2012 to September 2012, and they made four recommendations for future operations. First, it was essential to maintain good relationships with the Combat Logistics Battalion (CLB), the unit in charge of logistics and resupply operations. Second, “the CRUAS should either be tasked via the [Air Tasking Order] as the other rotary-wing assets, or it should be in direct support of the CLB and get its tasking directly from the CLB.” Presumably, there was confusion about command relationships between the CRUAS operators and the rest of the aviation and logistics units in Afghanistan. Third, the report identified a need to adjust the standard operating procedures (SOPs) to load and unload cargo. It appears that a different set of procedures was followed with K-MAX than with manned helicopters. The report says their request to change the procedures “met with some resistance...” possibly due to a lack of trust in unproven unmanned systems. Finally, VMU-2 observed that K-MAX’s limit of one hour of flight time hindered

operational effectiveness. They recommended adjusting the process to refuel the aircraft while the engines were running or allowing a fuel bladder to be attached.<sup>4</sup>

In October 2013, an internal document from Naval Air Systems Command (NAVAIR) described historical concepts of CRUAS dating back to 1998.<sup>5</sup> The authors analyzed and summarized multiple student theses, Universal Needs Statements, and articles about logistics and UAS. The document described then-current concepts from the other military branches and provided detailed analysis about the cost-saving and risk-mitigating advantages of CRUAS over ground transportation and manned aviation. The document leveraged training and administrative documents from logistics units and helicopter units to provide multiple lists of Mission Essential Tasks and a notional Table of Organization for future CRUAS units.<sup>6</sup> While the merits of CRUAS are still applicable today, some of the cost analysis may have been overly optimistic in favor of CRUAS.

In 2014, Major Thomas J. Denevan, USMC also analyzed the operating costs of manned and unmanned logistics aircraft in the Marine Corps, but he came to a very different conclusion from the NAVAIR document. Of the aircraft that could take off and land vertically, he found that MV-22s were the cheapest per mile, followed by K-MAX (1), CH-53E, and K-MAX (2). Though Denevan listed maximum payloads for each aircraft, he failed to calculate the cost per mile per pound; how much it cost to move a certain amount of cargo a certain distance. If he had done that, the manned and unmanned platforms' differences would have been stark due to the manned platforms' significantly larger payloads. According to Denevan's charts, the K-MAX (1), the cheapest UAV analyzed, would cost \$3.31 per pound of cargo per 25 miles. The most expensive manned aircraft, the CH-53E, was cheaper than the K-MAX (1), costing 5.7¢ per pound of cargo per 25 miles. CRUAS should become more economical in the future, but more

analysis is required to rectify the difference between Denevan's assessment and the NAVAIR document.

In the commercial sector, UAS are emerging as an enhancement to logistics and supply chains. To this end, researchers from Dortmund University in Germany attempted to determine the best combinations of manned ground vehicles, unmanned ground vehicles, and UAS in parcel delivery.<sup>7</sup> They recognized the complexity of simulating delivery operations and UAS operations, and they modeled delivery schemes that split-up tasks between UAS and delivery trucks. "It was shown that drone usage in parcel delivery can reduce the time taken to complete a delivery tour by up to 80%."<sup>8</sup> The researchers determined that UAS drastically increased workflow efficiency and reduced delivery times.<sup>9</sup> They recommend that further analysis be done to compare energy efficiency between UAS and trucks, and to add real-world friction like traffic, weather, and communications interference with the UAS.

Adding to the analysis about commercial applications for UAS in logistics, researchers from the United Kingdom and Turkey took a look at the best way to manage airspace with a significant number of UAS. They compared the use of UAS "highways," which consolidate the aircraft to a few flight paths, with the use of individually optimized flight paths that allowed each aircraft to fly directly to its destination.<sup>10</sup> They looked at how these schemes affect operations within a warehouse as well as parcel delivery over large distances. They found that the ideal organization of the flight paths is dependent on several variables including the number of aircraft, number of deliveries to be made, size of the airspace, and distance between pick-up and delivery locations. They intend for their research to be applied by government organizations that regulate airspace and UAS, companies designing UAS, and companies that plan to use UAS for logistics and deliveries.

## Unmanned Logistics System, MAGTF UAS Expeditionary, and ULS-A

In October 2016, the Joint Requirements Oversight Council approved the Marine Corps' initial capabilities document for the MAGTF UAS Expeditionary (MUX) program. As outlined by USNI News, the goal was to merge two sets of requirements and provide seven distinct capabilities with just one platform. The desired capabilities were "MAGTF C4 (Command, Control, Communications and Computing with Spectrum Agile Data Routing); early warning; persistent fires; escort; electronic warfare; Reconnaissance, Intelligence, Surveillance and Target Acquisition (RISTA); and tactical distribution."<sup>11</sup> Because the Marine Corps wanted a UAS that could take off and land on ships and confined terrain, they were primarily interested in rotary-wing and tilt-rotor UAS, including K-MAX and the Bell V-247. However, Marine Corps aviation planners gradually realized that it was impractical to expect one platform to meet all of those requirements. In March 2020, LtGen Steven Rudder, Deputy Commandant of the Marine Corps for Aviation, told Congress and journalists that the Marine Corps would no longer be pursuing a single aircraft for MUX. Instead, MUX would be a family of systems.<sup>12</sup>

While Marine Corps aviators were figuring out how to make MUX a reality, Marine Corps logisticians thought of their own innovations and future concepts. In October 2017, LtGen Michael Dana wrote an article for the Marine Corps Gazette that espoused Hybrid Logistics.<sup>13</sup> In the article, Hybrid Logistics consist of additive manufacturing, "smart" logistics via predictive software and artificial intelligence, and unmanned platforms in the air, on the land, on the sea, and under the sea. That last concept, unmanned vehicles would become Unmanned Logistics System (ULS). After LtGen Dana's article, several people wrote articles for the Gazette and Professional Military Education programs about the possibilities and visions of Hybrid Logistics, including ULS.

Although LtGen Michael Dana described what the future of logistics could or should be, he did not identify problems to be solved. In 2018, Major Leo Spaeder used his Master's thesis at the Marine Corps School of Advanced Warfighting and an article in the Gazette to identify problems with current logistics processes and platforms that could be fixed by hybrid logistics.<sup>14</sup> He analyzed the logistics problems posed to a distributed company landing team (CLT) during the Rim of the Pacific Exercise in 2014, which, among other things, highlighted a lack of available manned aviation.<sup>15</sup> Major Spaeder proposed the addition of a Logistics Platoon to the CLT, and he detailed specific MOSs and qualifications of the Marines in the Logistics Platoon. Notably, he expected relatively junior Marines to be responsible for operating and repairing ULS-A systems that provide aerial medical evacuation.<sup>16</sup> The ULS-A he described resembles current concepts of Medium ULS-A.

In addition to these Marine Corps-specific theses, there have been many students and innovators positing ideas in the last few years about combining UAS and artificial intelligence to enable more autonomous systems and decrease the workload for logisticians in the military and in the civilian sector.<sup>17</sup> Another seemingly futuristic concept is “swarm logistics,” the idea of having myriad small resupply vehicles that can disperse or concentrate as required based on the end user's needs.<sup>18</sup> These concepts are interesting but are overused and may not be that novel. All modern aircraft have a certain level of “artificial intelligence” in the form of autopilot or “pilot assistance.” There may not be as much expertise required to operate the joystick and throttle, but CRUAS will require expertise to determine where it will fly safely without interfering with manned aircraft. Swarm logistics is a broader philosophy about how and where to stage supplies and coordinate the push and pull of resources. It could be accomplished at any

scale with nearly any method of transportation. However, CRUAS may make it more feasible and less dependent on external factors like the availability or prioritization of manned aircraft.

### Research Methodology

As a hypothesis-generating case study, this project began with exploratory research to determine potential uses of UAS in the Marine Corps in the future and what issues may arise. The case study research design of process tracing included current Marine Corps periodicals, student theses, and interviewing officers in the Marine Corps UAS community. By comparing and contrasting the information in these documents and interviews, it emerged that there is potential for friction between the UAS and logistics communities as they determine manning requirements, roles, and responsibilities for CRUAS. These two communities are receiving renewed emphasis due to the Commandant's Planning Guidance, and it makes sense that emerging technologies will bring them together and cause some growing pains.

The Marine Corps logistics community makes a compelling case for unmanned systems in the air, on the ground, and on the water, but each domain has unique considerations, and as the research continued a few questions came to mind centered around one primary question: what is the most effective way for the Marine Corps to manage the UAS that will support logistics? Should the Marine Corps aviation community provide squadrons, manpower, and equipment for these UAS? Can logistics units handle a wide range of aviation planning, deconfliction, maintenance, and operational considerations? Is there a threshold that separates the aircraft that can be operated by aviation novices within the logistics community from the aircraft that must be operated by more highly trained experts?

Networking emails and phone calls included the Marine Corps Warfighting Lab (MCWL); the Logistics Innovation Office within Headquarters Marine Corps, Installations and

Logistics; and the UAS Cell within Headquarters Marine Corps, Aviation. Reading and qualitative analysis included after action reports from UAS and logistics units, working papers from each of the groups mentioned above, and academic theses from various military postgraduate schools. The research drew from experience with manned aviation training, operations, and maintenance; sUAS training, operations, and maintenance; and some knowledge of Navy and Air Force UAS training, operations, and maintenance. Additional analysis included U.S. military doctrinal publications and training manuals for manned aviation, sUAS, Group 3 UAS, and logistics.

Throughout the research, four broad categories emerged for comparison across the continuum of CRUAS: maintenance requirements, planning and deconfliction, risk management, and operator requirements. This paper reviews historic and projected use of CRUAS in the Marine Corps, and then discusses each of the four categories as they apply to the aircraft that will make-up the ULS-A family of systems.

#### Small, Medium, and Large Unmanned Logistics System - Air

When LtGen Rudder announced that MUX would be a family of systems, it meant that ULS-A could also have multiple CRUAS rather than a single platform to fit all scenarios. As currently envisioned, ULS-A will consist of three categories, shown in Table 2: Small ULS-A and Medium ULS-A will be Group 3 UAS due to their weight, and Large ULS-A will be a Group 4 UAS based on its weight and flight profile. MCWL and the Logistics Innovation Office identified representative systems for the Small ULS-A and Medium, the TRV-150 and TRV-400, respectively. A pamphlet from the manufacturer, SURVICE Engineering Company, advertises that the TRV-150 has successfully carried up to 150 pounds. Depending on the weight of the payload, it can resupply a unit 8-45 kilometers away. The advertised, but not tested, capability of

the TRV-400 is to carry 400 pounds to a unit 20 kilometers away, but its maximum range is only 45 kilometers with lighter payloads.<sup>19</sup> Mr. Thomas Heffern, who is exploring the applicability of TRV-150 and TRV-400 on behalf of HQMC, Installations and Logistics, said that the user interface will mimic the equipment that is already used by Group 1 UAS.<sup>20</sup> In that case, they will be highly automated systems, and operators could be trained relatively quickly.

UAS Group	ULS-A Category	Basic Performance Goals	Description
Group 3	<b>Small ULS-A</b> Sized for Squad	<ul style="list-style-type: none"> <li>▪ 60 - 150+lb payload</li> <li>▪ 10 - 20+ km radius</li> <li>▪ ~1,000 lbs/day/sys</li> </ul>	<ul style="list-style-type: none"> <li>▪ Organic logistics for any ground unit.</li> <li>▪ Highly automated to enable simple operations for a wide range of users.</li> <li>▪ Provides emergent and routine distribution</li> </ul>
	<b>Medium ULS-A</b> Sized for Platoon	<ul style="list-style-type: none"> <li>▪ 300 - 500+lb payload</li> <li>▪ 35 - 200+ km radius</li> <li>▪ ~5,000 lbs/day/sys</li> </ul>	<ul style="list-style-type: none"> <li>▪ Logistics and potentially limited CASEVAC/Emergency Extract (1-2 pax)</li> <li>▪ Automated &amp; Autonomous</li> <li>▪ Operated &amp; managed by logistics personnel in coordination with air C2</li> </ul>
Group 4	<b>Large ULS-A</b> Sized for low cost and longer range <ul style="list-style-type: none"> <li>▪ Emergency resupply</li> <li>▪ CASEVAC</li> <li>▪ Personnel Transport</li> </ul>	<ul style="list-style-type: none"> <li>▪ 1,000 - 3,000+lb payload</li> <li>▪ 300+ km radius</li> <li>▪ ~15,000 lbs/day/sys</li> </ul>	<ul style="list-style-type: none"> <li>▪ Logistics and potentially personnel transport (4-8 pax)</li> <li>▪ Automated and Autonomous</li> <li>▪ Operated from small austere landing zones and small ships with limited manning requirements.</li> </ul>

Table 2. ULS-A Category Descriptions<sup>21</sup>

Table 2 shows that MCWL and the Logistics Innovation Office’s vision for Small ULS-A and Medium ULS-A is to employ them at the squad and platoon levels, respectively. Table 3 shows examples of cargo that a single aircraft could carry in a single trip. MCWL and the Logistics Innovation Office want each aircraft to reliably conduct eight to ten trips per day, which hints at the amount of congestion that could occur in the airspace around a logistics hub.

	Description	Weight
Small ULS-A	Two 5-gallon plastic jugs, full	100 lbs
	Four cases of meals ready to eat (MREs)	88 lbs
	Two full cases of 5.56mm ammunition (3,200 rounds, metal cans, and wooden crates)	140 lbs
	Fourteen 3-liter hydration pack reservoirs, full	93 lbs
	One MEP-531A 2-kilowatt Generator, dry	143 lbs
Medium ULS-A	Twelve cases of MREs	264 lbs
	Four full cases of 5.56mm ammunition (6,400 rounds, metal cans, and wooden crates)	280 lbs
	Forty-two 3-liter hydration pack reservoirs	279 lbs
	Army “Steady State” Load – three cases of MREs, thirty-six 2-quart canteens, 240 AA batteries, twenty-four conformal batteries, six individual first aid kits	295 lbs
	One MEP-531A 2-kilowatt generator, dry Two 5-gallon plastic jugs of fuel	243 lbs

Table 3. Example ULS-A Loads<sup>22</sup>

There has not been a specific platform identified for Large ULS-A, yet. A potential option for Large ULS-A is to convert retired helicopters into unmanned aircraft using the Autonomous Aerial Cargo Utility System (AACUS), which also boasts of being very simple to operate. “AACUS is a package of sensors and software that can be integrated into any existing rotary-wing aircraft to provide autonomous capabilities, including flight, fight route, obstacle avoidance, approaches, landings and takeoffs.<sup>23</sup> AACUS was designed for simple use. With minimal training, and using an intuitive handheld tablet, the user can call up needed supplies very quickly. That capability was on display in December 2017 when AACUS successfully completed its final demonstration—featuring a UH-1 “Huey” helicopter—at Marine Corps Base Quantico, Virginia. This demonstration allowed a Marine, with no prior experience, to program a

resupply after only 15 minutes of training.” There is also an intent to put AACUS on K-MAX to modernize it and improve on its previous performance in the Marine Corps.

AACUS may provide additional capabilities to the entire family of ULS-A. Mr. Heffern mentioned that in addition to experimenting with AACUS on large helicopters, the system and its sensors are now small enough to put on Small and Medium ULS-A, improving their effectiveness. “AACUS gives revolutionary capability to our fleet and force,” said Dennis Baker, AACUS program manager. “It can be used as a pilot aid to operate in GPS- and communications-denied arenas, or allow fully autonomous flights in contested environments—keeping our pilots and crews out of harm’s way.” These capabilities that Mr. Baker mentions would increase the survivability and effectiveness of ULS-A in a combat environment where the enemy will try to degrade Marines’ ability to navigate and communicate.

### **MAINTENANCE REQUIREMENTS**

A major dividing line between Small/Medium ULS-A and Large ULS-A will be the maintenance requirements for the systems, which is one factor that supports placing Small and Medium ULS-A in the logistics combat element and Large ULS-A in the aviation combat element. Small and Medium ULS-A will be relatively simple machines with parts that can be replaced with common tools. Like manned aircraft, however, Large ULS-A will be more complex machines with a variety of internal systems, and each internal system may require maintainers with their own training and expertise. Within manned aviation, it is common for engine mechanics or electricians to transition from one type of aircraft to another, but they remain aviation engine mechanics or aviation electricians. Their expertise would likely transition to the Large ULS-A in the aviation combat element.

Due to traditional policies, the Navy and the Marine Corps treat all Group 3 UAS as if they were manned aircraft, which currently includes all ULS-A systems when loaded with cargo. The Naval Air Forces 4790.2C *Naval Aviation Maintenance Program* (NAMP) has very high standards to ensure manned aircraft are as safe as possible. Historically, aviation was very dangerous, but better maintenance practices have significantly increased the reliability of aircraft and reduced the danger. The legacy policies, designed for manned aviation, affect the way that investigations are conducted when there is a crash or other incident and they significantly affect the maintenance requirements and many operating practices. In his thesis for Naval Postgraduate School, Major John Park pointed out many inefficiencies, including the requirement for everyone who will control the UAS to sign the maintenance logbook and different systems that required duplicate maintenance records.<sup>24</sup> Group 1 and Group 2 sUAS are exempt from the NAMP, and Major Park recommends new maintenance policies for Group 3 UAS as part of his thesis.<sup>25</sup> The Logistics Innovation Office also wants to requirements imposed by the NAMP. If Major Park's recommendations are not adopted, Group 3 CRUAS will place a significant burden on the ground or logistics unit that operates them simply because of the maintenance paperwork and practices.

If Major Park's recommendations are adopted, the Small ULS-A and Medium ULS-A may be supplied and maintained by logisticians in the LCE and the GCE. However, Large ULS-A will still need to be part of the ACE due to the unique and complex nature of aviation maintenance and aviation supply. UAS with fuel-burning engines and complex avionics will rely on aviation technicians and aviation logistics.

The TRV-150 and TRV-400 fit the weight specifications for Group 3 UAS, but their maintenance requirements are very similar to current Group 1 and Group 2 sUAS. The TRV-400

is advertised to be extremely simple to maintain, like Puma, Stalker, and various quadcopters.<sup>26</sup> Based on trends in the industry, the TRV-400 is likely to come with a Field Repair Kit that has all the necessary tools and parts to make rapid repairs, and the operators will be trained to maintain, repair, and inspect the aircraft before each flight. Broken parts and components will be considered consumable or be sent to higher echelons for one-for-one replacement.

There are two major components that the RQ-21, a group 3 ISR UAS, has that the TRV-400 does not have, which simplify the TRV-400's maintenance requirements: electronic combat systems and a fuel-burning engine. Marines who maintain, repair, and inspect RQ-21 Blackjack have a separate set of skills from the Marines who fly and operate the systems. The technicians are all from one primary Military Occupational Specialty (MOS), 6314 "Avionics/Maintenance Technician, Unmanned Aircraft System."<sup>27</sup> Without the electronic combat systems or a fuel burning engine, the Small ULS-A and Medium ULS-A are much simpler to maintain. Like sUAS operators, Small ULS-A and Medium ULS-A operators will need to learn how to repair and maintain their systems during their training pipeline.

The Large ULS-A, on the other hand, is likely to be very similar to manned rotary wing or tiltrotor aircraft in form and function. It will need fuel-burning engines to provide the required power to lift 2,000-3,000 pounds and fly 150-300 nautical miles. It will also need more complex avionics and combat systems to be survivable in combat and to coordinate and deconflict with other aircraft and airspace controllers. If the AACUS is adopted, the maintenance requirements for ULS-A will be identical to the manned versions of those aircraft.<sup>28</sup> Thus, Large ULS-A will need maintainers and technicians who are specially trained on internal systems of the aircraft.

Each manned vertical lift aircraft in the Marine Corps has maintainers from four different primary MOSs, each focused on a portion of the aircraft. Helicopter Mechanics inspect, service,

maintain, and repair engines, transmissions, drivetrains, fuel systems, flight control systems, and rotor systems. Helicopter Airframe Mechanics inspect, service, maintain, and repair aircraft airframe structures, composite material, hydraulic systems, and landing gear systems. Aircraft Avionics Technicians install, remove, inspect, test, maintain, and repair systems, components, and ancillary equipment of installed aircraft communications/navigation/electrical systems to include deceptive electronic countermeasures (DECM) systems. Aircraft Ordnance Technicians conduct duties incident to the inspection, maintenance and repair of armament equipment and loading of aviation ordnance on Marine Corps aircraft. The Aircraft Ordnance Technician performs a variety of duties and tasks such as inspecting ammunition, testing aircraft systems, performing preventive maintenance and effecting repairs, loading and fusing ammunition and arming/de-arming aircraft.

The Large ULS-A will need specialists who can focus on its engines and fuel systems, avionics and electronics, and its airframe structures. Due to the potential to carry personnel, the Large ULS-A may also have crew-served weapons, in which case it will need ordnance technicians. These MOSs would be a significant burden on the Marine Corps logistics community, which lacks the appropriate background knowledge and support structure to field these MOSs. As such, the Large ULS-A's maintenance requirements indicate that it will need to be maintained and supplied through the Marine aviation logistics system, and be subject to requirements set forth in the Naval Aviation Maintenance Program (NAMF.)

Furthermore, the Marine Corps aviation community needs to think critically about how it might man, train, and equip the units that fly the Large ULS-A, and how it might maximize those units' support to the LCE and the GCE. Perhaps VMUs of the future could fly multiple large

UAS, with operators and maintainers trained on each aircraft. Alternatively, new squadrons may need to be commissioned and designated that are specific to cargo, ISR, and airstrikes.

## **PLANNING AND AIRSPACE DECONFLICTION**

Another dividing line between Small/Medium ULS-A and Large ULS-A forms along planning and airspace deconfliction requirements. As long as the air controllers in logistics and ground units communicate effectively with the rest of the aviation community, just like they would for unmanned ISR and manned aviation, the requirements for Small and Medium ULS-A will be within the capabilities of logistics and ground units to plan and provide airspace deconfliction. Small and Medium ULS-A, supporting small units away from major logistics hubs, are less likely to interfere with other aviation operations than Large ULS-A, which by their mission will need to operate in congested airspace around more manned and unmanned aircraft.

When deconflicting and coordinating air operations, there are three ways to separate aircraft: horizontally, vertically, and by time. Airspace Coordinating Measures (ACMs) are horizontal and/or vertical specifications that create a three-dimensional location, known by all aircrew in the area, that either separates or integrates air operations based on their mission and situational awareness. JP 3-52, *Airspace Control*, describes the importance of ACMs, their influence on effective air operations.

Airspace control is essential to overall military effectiveness and in achieving JFC objectives. Given the speed, range, and physical characteristics of air operations, airspace coordinating measures (ACMs) are integrated into operations to deconflict airspace users and decrease the potential for unintended engagements against friendly, civil, and neutral aircraft. Available technical capabilities such as surveillance radars, navigation aids, and communications between airspace users and airspace control, AMD, and air traffic control (ATC) agencies often determine the required ACMs... Airspace control is extremely dynamic and situational, and it needs to be flexible and responsive enough to

accommodate users with varied technical capabilities and to mitigate technical failure or adversary action in order to optimize airspace use.<sup>29</sup>

Ideally, the ACMs that are described in JP 3-52 are pre-planned and published for all aircrew so that they can plan their missions with the ACMs in mind. However, they can also be created in real time, at which point the airspace controllers must notify all aircraft in the area and ensure the aircraft adhere to the new ACM.

Additionally, airspace controllers in the joint force use two methods of control: positive control and procedural control. With positive control, airspace controllers use sensors, typically radar, to track aircraft by position and altitude. They can see any potential conflicts between the aircraft on their screens and give directions to the aircrew to ensure safe separation. In contrast, JP 3-52 describes how procedural control “relies on comprehensive air defense identification procedures and ROE; voice and digital communications between aircraft and airspace control elements; ACMs... aircraft identification maneuvers; and FSCMs such as restrictive fire areas and no-fire areas.”<sup>30</sup> Generally, multiple forms of separation are combined to keep aircraft as safe as possible, especially in terminal areas like airports, forward arming and refueling points (FARPs), and landing zones (LZs). Controllers and aircraft in terminal areas rely on procedural control even if positive control is available. Aircraft follow pre-planned routes in order to help controllers and other aircraft predict where they will be in space and time. ULS-A operators must understand how their aircraft fit into the flight patterns and procedures of the terminal areas and be aware of the dynamic and flexible nature of aviation operations.

Planning and deconfliction requirements for Small ULS-A will be minimal, as these aircraft will fly relatively short distances at relatively low altitudes. This means that they will generally be separated from other aircraft laterally and by altitude as long as planners are careful to ensure the flight path does not cross any other planned routes. Since Small ULS-A will be

employed at smaller units who are widely distributed, the aircraft will not add to the congestion of terminal areas. However, an increased number of aircraft in friendly airspace means that planners and operators must do their due diligence to provide the aircraft with corridors that keep them away from any manned aircraft in the area. If Small ULS-A are operated in or around terminal areas, the operators must adhere to the ACMs, assigned routing, and directions from local airspace controllers.

Due to their ability to fly further and potentially cross more flightpaths of manned aircraft, Medium ULS-A operators will require a greater degree of coordination with aviation planners and airspace controllers. Pre-coordinated flight corridors would still keep them safe from most manned aircraft enroute, but Medium ULS-A will probably operate more frequently in congested terminal areas than Small ULS-A. The operators may not need to communicate directly with airspace controllers, but a supervisor or Officer in Charge will need to make sure everyone has high situational awareness about the UAS's location and the locations of all the other aircraft in the area.

TRV-150 and TRV-400, the two Cargo UAS that may become Small ULS-A and Medium ULS-A, are primarily operated through tablets. The recommendation is for the aircraft to fly pre-planned routes, relying on onboard navigation, with operators monitoring their progress. This should work well when the aircraft is operating at distributed locations, away from most other aircraft. In terminal areas, though, operators will need to take more direct control in order to ensure the ULS-A are maintaining safe separation from manned aircraft.

Like the other similarities to manned aircraft, Large ULS-A will fly in and out of the same terminal areas and probably use a lot of the same altitudes and routes as manned aircraft. This factor means that planners and operators have to participate in detailed planning, follow the

flight patterns and procedures just like manned aircraft, and communicate directly with airspace controllers in real time. Large ULS-A may need to be sequenced in and out of terminal areas with manned aircraft, and they will be subject to the same positive control and procedural control. All of this will be easier to synchronize and deconflict if the planners and operators are working within the rest of the aviation community.

## **MANAGING RISK**

Risk, particularly severity, is another reason why it makes sense for the aviation community to operate Large ULS-A and for logistics and ground units to operate Small ULS-A and Medium ULS-A. The Marine Corps describes the associated degree of risk for a given incident in terms of probability and severity. Probability is the likelihood that an incident will occur based on “location, exposure (cycle or hours of operation), affected populations, experience, or previously established statistical information.”<sup>31</sup> Severity is the worst credible consequence that can occur, and is defined in terms of potential injury, damage, or effect on the task or mission. As the size and weight of the associated aircraft and payloads increases, so does the potential severity of an incident. The Risk Assessment Matrix in Figure 1 shows how severity and probability are combined to determine a risk assessment code for a given incident. This section covers both severity and probability across each ULS-A size, but it would be foolish to try to assign specific risk assessment codes, 1 through 5, without much more analysis and observation.

## Marine Corps Risk Assessment Matrix

			PROBABILITY			
			Likely	Probably	May	Unlikely
			A	B	C	D
SEVERITY	Catastrophic	I	1	1	2	3
	Critical	II	1	2	3	4
	Moderate	III	2	3	3	5
	Negligible	IV	3	4	5	5

Figure 1. Marine Corps Risk Assessment Matrix<sup>32</sup>

The ULS-A will provide a low-risk alternative when compared to other means of transporting cargo due to the fact that aviators and logisticians will not have to physically transit the battlespace, on the ground or through the air. As mentioned in the Background, CRUAS were envisioned specifically to avoid the threats to ground convoys. Automation and advances in sensor technology should decrease risk even further. The risks outlined below should not be overly emphasized or cause reservations about the systems’ employment. All aviation operations carry some risk, though, and it takes time to find and eliminate the shortcomings of new technology.

There will be a potential for ULS-A to damage infrastructure or to injure or kill personnel in the terminal area, but it will vary significantly based on the size and weight of the aircraft. Similarly, there will be the potential to lose or crash ULS-A, thus losing or damaging the payload. The larger the ULS-A, the more significant the loss or damage, though some small objects are also very important and expensive. Medium ULS-A will carry up to 500lbs, which could include humans. This significantly raises the stakes.

Small ULS-A will pose the least severe risk, carrying only 50 pounds. The lower weight means that the aircraft will cause less damage if it runs into infrastructure, though it will still be heavy enough to severely injure or kill someone. The lower weight also means that there will be

less material loss if the aircraft is lost or crashes. Small ULS-A will have competing factors that affect the probability of an incident. The Small ULS-A will be operated away from the congested terminal areas, which decreases the probability of it causing damage or injury. However, the Small ULS-A will not have many redundant components for power, flight controls, navigation, and computing, which means an increased probability of the aircraft crashing or being lost.

Carrying 500 pounds, the Medium ULS-A will pose a more severe risk than the Small ULS-A. The size and weight will cause more damage to infrastructure, and if the aircraft is lost or crashes, the material loss of the payload would be significant. With respect to probability of an incident, it is not clear whether the TRV-400 will have any more redundancy in its components than the TRV-150. Conceivably, carrying ten times more weight would necessitate more robust and redundant systems. Regardless, Medium ULS-A is more likely to operate around terminal areas, which increases the probability of a collision with another aircraft, infrastructure, or personnel on the ground. Ultimately, the risk posed by Small and Medium ULS-A is on par with other the other equipment and activities of the Logistics Combat Element, and it is appropriate for well-trained logisticians and staff to manage and mitigate that risk for the commander.

If a Large ULS-A crashed in a terminal area, it could cause catastrophic damage and loss of life on the ground. Any loss or crash of a Large ULS-A would also be catastrophic for the payload. The Large ULS-A will operate almost exclusively in typical terminal areas, alongside manned aircraft. However, the probability of an incident should be very low, despite its operating in congested areas. The aircraft should be extremely reliable, with redundant components for its key systems, just like manned aircraft of the same size. Despite the low probability, it makes sense for dedicated operators, who are intimately familiar with aviation, and the staff of the Aviation Combat Element to mitigate that risk on behalf of the commander

because the types of hazards posed by Large ULS-A, and their severity, are on par with manned aviation.

## **OPERATOR CAPABILITIES AND QUALIFICATIONS**

Small and Medium ULS-A operators' capabilities and qualifications will be very similar to current sUAS operators in ground units, while the requirements for Large ULS-A operators will be similar to those levied on Group 3 and Group 4 ISR operators in the aviation community. There will be plenty of cross-over in the requirements for all three ULS-A because any of them could operate in complex airspace and their operators must understand how to safely and effectively load cargo for flight. However, most Small ULS-A operations will be in remote areas with lighter cargo, so most of the operators will be able to accomplish their missions with fewer qualifications. Large ULS-A, on the other hand, will regularly operate from well-established airports, so their operators will need more qualifications based on the airspace where they will operate.

### **Basic UAS Qualification and Joint Mission Qualification**

*Joint Unmanned Aircraft Systems Minimum Training Standards (JUMTS)* from the Chairman of the Joint Chiefs of Staff provides four qualification levels for UAS operators in the armed services. The document was last updated in 2012, it focuses on Intelligence Surveillance Reconnaissance (ISR) and Fires missions, and it does not account for logistics.<sup>33</sup> Though cargo and resupply missions are arguably simpler than ISR and Fires missions, TRV-150 and TRV-400 are Group 3 UAS, as previously discussed. Thus, the operators will require Basic UAS Qualification (BUQ) Level III training unless the Marine Corps argues for a change to the criteria or for an exception to the policy. Because the flight altitude and airspace requirements

will be more similar to traditional sUAS, BUQ Level I or BUQ Level II makes sense for the Marine Corps' Small and Medium ULS-A operators.

Current UAS training manuals are worth referencing when thinking about appropriate standards and requirements for ULS-A operators. NAVMC 3500.107C is the Small Unmanned Aircraft Systems Training and Readiness Manual (sUAS T&R Manual).<sup>34</sup> It provides details about specific skills and flight parameters that must be accomplished to be considered qualified on particular systems, ultimately achieving the BUQ Levels as described in JUMTS. TRV-150 and TRV-400 will technically be Group 3 UAS, but their flight characteristics will more closely resemble Group 1 and Group 2 ISR UAS.

According to the sUAS T&R Manual, Group 1 UAS operators are required to meet all requirements for BUQ-1, which gives the operator “required aviation and SUAS knowledge-based skills to fly Visual Flight Rules (VFR) in Class E and G, and restricted/combat airspace <1200’ above ground level (AGL).”<sup>35</sup> Group 2 UAS operators are required to meet all requirements for BUQ-2. According to *JUMTS*, operators who are BUQ-2 qualified, “Possess required aviation knowledge and UAS knowledge-based skills to fly under VFR in Class D, E, G, and restricted/combat airspace <18,000’ mean sea level (MSL).”<sup>36</sup> Class D airspace surrounds some airports from the surface to 2,500’ AGL. Quantico Marine Corps Air Field has Class D airspace.

According to Mr. Heffern, the Logistics Innovation Office envisions two sets of Small ULS-A operators. Basic operators will meet BUQ-1 requirements, and they can be trained more quickly and used widely.<sup>37</sup> Another set of operators will meet both BUQ-1 and BUQ-2 requirements, and thus they will be expected to think and perform at a more advanced level. The BUQ-2 qualified operators will oversee the training and standardization for the unit, and provide

additional capability if the Small ULS-A needs to fly about 1,200 feet AGL or in Class D airspace. Thus, the people currently trying to design force structure and training requirements for Small ULS-A envision a straight-forward training regimen that meets BUQ-1 requirements, and follow-on training that meets BUQ-2 requirements. Medium ULS-A are likely to be employed in similar conditions, and thus the BUQ-2 requirements will provide all the necessary knowledge and skills for Medium ULS-A operators to use the system safely.

BUQ-3 and BUQ-4 qualifications may also provide utility to ULS-A operators. BUQ-3 qualified operators “possess required aviation knowledge and UAS knowledge-based skills to fly under VFR in all classes of airspace except U.S. and ICAO Class A.” This additional qualification would allow Small and Medium ULS-A to fly into and out of larger airports that are surrounded by Class B or Class C airspace. This may be a necessity if the logistics hub is based out of a large airport that accommodates fixed wing cargo planes. The important distinction for BUQ-4 qualified operators is the added capability to fly in all weather conditions, which is not necessary for Group 1 and Group 2 UAS.

The Marine Corps could benefit from BUQ-4 qualified operators flying Small, Medium, and Large ULS-A. Group 1 and Group 2 ISR UAS typically have sensors that require them to see the ground in order to conduct their mission and did not have instruments that allowed them to reliably operate in clouds or fog. TRV-150 and TRV-400, on the other hand, may be affected by wind and precipitation, but should be able to operate without visibility since they are simply trying to transit from one location to another. Large ULS-A should also be able to fly through poor weather to conduct their missions. Resupply can and should happen in any weather conditions.

In addition to BUQ Levels, *JUMTS* also lays out Joint Mission Qualifications (JMQs), which all focus on Fires, ISR, Combat Search and Rescue, and Personnel Recovery tasks. In order for UAS operators to deploy to a combat zone, they must meet the requirements for both the appropriate BUQ and the appropriate JMQ. However, there are not any JMQs that apply to cargo UAS or logistics tasks, so these must be developed.

### Air Delivery and ULS-A operations

For logistics training requirements, NAVMC 3500.27D and NAVMC 3500.39D refer to *Logistics* and *Motor Transport*, respectively.<sup>38</sup> There are likely to be several essential tasks related to managing cargo, using helicopter support for logistics, and managing loading areas and drop zones, just like VMU-2 discussed in their After Action Report. If logistics units operate TRV-150 and TRV-400 organically, then it will be necessary to write out training requirements in the same style and format as the other logistics requirements, using analogous terms and tasks where appropriate. Personnel from the Logistics Innovation Office are looking at ways to fit Small ULS-A into an Air Delivery/ULS-A Sections within the General Support Company of future combat logistics battalions (CLBs).<sup>39</sup> These sections would use Marines with the traditional PMOS of 0451, Airborne and Air Delivery Specialist, to operate Small ULS-A. Most of these Marines would train to BUQ-1 requirements. A few would also train to BUQ-2 requirements and receive a Necessary MOS as Air Vehicle Operators.<sup>40</sup>

There is already a precedent for using MOS designations to keep track of UAS operators as collateral responsibilities. Enlisted Group 1 and Group 2 UAS operators are eligible for the Free MOS (FMOS) of 8623, Small Unmanned Aircraft System Specialist.<sup>41</sup> It is a FMOS

because it can be filled by any Marine, and the skills are not related to the Marine's primary skills. Small ULS-A operators, however, will need to have background knowledge and skills in preparing, packing, loading, and attaching cargo. Thus, it makes sense for the BUQ-2 qualified Small ULS-A operators to receive a NMOS that has a prerequisite MOS of 0451.

These same Air Delivery Specialists will be needed to work with Large ULS-A. In this case, their skillset will be more similar to their traditional skills, since the size, weight, and type of cargo will be similar to what is loaded on, or hung from, manned aircraft. Additionally, if Large ULS-A are really as easy to operate and control as advertised with the AACUS, there may be a role for BUQ-1 or BUQ-2 certified operators to take control of the aircraft in and around the terminal area.

## **CONCLUSION**

Based on the relatively low requirements for maintenance, planning and airspace deconfliction, risk management, and operator capabilities and qualifications, Small ULS-A and Medium ULS-A can be maintained and operated by Marines within the Logistics Combat Element and Ground Combat Element. In contrast, the same factors for Large ULS-A indicate that it must be maintained and operated by Marines with dedicated expertise in the aviation combat element.

The first factor that supports placing Small and Medium ULS-A in the logistics combat element and Large ULS-A in the aviation combat element is the maintenance requirements for the systems. Small and Medium ULS-A will be relatively simple machines with parts that can be replaced with common tools. This is predicated on the Marine Corps finding a way to avoid NAMP requirements, and treat the Small and Medium ULS-A like Group 1 and 2 UAS. Large ULS-A, on the other hand, will be more complex machines with a variety of internal systems,

and each internal system may require maintainers with their own training and expertise. A lot of these experts could be pulled from the larger aviation community who already understand engines, fuel systems, and avionics.

Planning and airspace deconfliction requirements form another dividing line between Small/Medium ULS-A and Large ULS-A. Air controllers in logistics and ground units can plan and provide airspace deconfliction, just like they would for unmanned ISR and manned aviation. Small and Medium ULS-A supporting small units away from major logistics hubs, are less likely to interfere with other aviation operations than Large ULS-A, which by their mission will need to operate in congested airspace around manned and unmanned aircraft. The aviation community will need to operate Large ULS-A to ensure adequate planning and airspace deconfliction.

The third factor that supports the need for the aviation community to operate Large ULS-A and for logistics and ground units to operate Small ULS-A and Medium ULS-A is the potential severity of an accident. Severity is the worst credible consequence that can occur, and is defined in terms of potential injury, damage, or effect on the task or mission. As the size and weight of the associated aircraft and payloads increases, so does the potential severity of an incident. Logistics and ground units are accustomed to the severity and types of risks associated with Small and Medium ULS-A, but only the aviation community is accustomed to the types and severity of incidents associated with large aircraft, their cargo, and personnel.

Finally, Small and Medium ULS-A operators' capabilities and qualifications will be very similar to current sUAS operators in ground and logistics units, while the requirements for Large ULS-A operators will be similar to those levied on Group 3 and Group 4 ISR operators in the aviation community. There will be plenty of cross-over in the requirements for all three ULS-A based on any of them operating in complex airspace. Also, all ULS-A operators will need to

understand how to safely and effectively load cargo for flight. However, most Small ULS-A operations will be in remote areas with lighter cargo, so the operators will accomplish their missions with fewer qualifications. Large ULS-A, on the other hand, will regularly operate from well-established airports, so their operators will need more qualifications based on the airspace where they will operate.

The logistics community is well-suited to operate Small and Medium ULS-A based on the requirements for planning and deconfliction, risk, and operators' capabilities and qualifications. As long as it can avoid the overly burdensome requirements of the NAMP, the community is also well-suited to perform maintenance on Small and Medium ULS-A. The Large ULS-A, though, will need to be operated and maintained in the aviation community, where Marines are more familiar with the nuances and requirements of large aircraft. Thus, the Marine Corps must project the Large ULS-A in future appropriations documents and start figuring out how to fit Large ULS-A into the Aviation Combat Element

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<sup>1</sup> Department of Defense. "Unmanned Aircraft System Airspace Integration Plan" ([https://web.archive.org/web/20160121155841/http://www.acq.osd.mil/sts/docs/DoD\\_UAS\\_Airspace\\_Integ\\_Plan\\_v2\\_\(signed\).pdf](https://web.archive.org/web/20160121155841/http://www.acq.osd.mil/sts/docs/DoD_UAS_Airspace_Integ_Plan_v2_(signed).pdf)) (PDF). Archived from the original ([http://www.acq.osd.mil/sts/docs/DoD\\_UAS\\_Airspace\\_Integ\\_Plan\\_v2\\_\(signed\).pdf](http://www.acq.osd.mil/sts/docs/DoD_UAS_Airspace_Integ_Plan_v2_(signed).pdf)) (PDF) on 21 January 2016. Accessed 27 February 2021.

<sup>2</sup> General Aviation Certification and Operations Issue Area, Part 103 (Ultralight Vehicles) Working Group, "14 CFR Parts 1, 21, et al.: Certification of Aircraft and Airmen for the Operation of Light-Sport Aircraft; Final Rule," *Federal Register*, Federal Aviation Administration, Aviation Rulemaking Advisory Committee, July 27, 2004. [https://www.faa.gov/regulations\\_policies/rulemaking/committees/documents/media/GACOp103T1-09071993.pdf](https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/GACOp103T1-09071993.pdf)

<sup>3</sup> Regional Command Southwest. "USMC Cargo Resupply UAS in Afghanistan." *Second Line of Defense*. <https://sldinfo.com/2012/12/usmc-cargo-resupply-uas-in-afghanistan/>

<sup>4</sup> VMU-2. "After Action Report For Operation Enduring Freedom For The Period Of May 2012 - September 2012." pp. 23-24

<sup>5</sup> Naval Air Systems Command. "United States Marine Corps Cargo Unmanned Aircraft Systems Program of Record Study." October 31, 2013.

<sup>6</sup> *Ibid.*

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<sup>8</sup> *Ibid.*, 8.

<sup>9</sup> *Ibid.*

<sup>10</sup> K. Kuru, D. Ansell, W. Khan and H. Yetgin, "Analysis and Optimization of Unmanned Aerial Vehicle Swarms in Logistics: An Intelligent Delivery Platform," in *IEEE Access*, vol. 7, pp. 15804-15831, 2019.

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- <sup>25</sup> Ibid., v
- <sup>26</sup> SURVICE Engineering Company.
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- <sup>28</sup> Sierra Jones, "Rewarding Work: ONR Autonomous System Finalist for Aviation Award," Office of Naval Research website, February 13, 2018, <https://www.onr.navy.mil/en/Media-Center/Press-Releases/2018/AACUS--Robert-Collier-Trophy>.
- <sup>29</sup> Chairman Joint Chiefs of Staff, *Joint Airspace Control*, Joint Publication 3-52, November 13, 2014, I-2
- <sup>30</sup> Ibid., x
- <sup>31</sup> Headquarters Marine Corps, *Risk management*, MCO 3500.27C, November 24, 2014,
- <sup>32</sup> Marine Corps Risk Assessment Matrix, Online, Accessed 28 March, 2021. [https://www.trngcmd.marines.mil/Portals/207/Docs/safety/usmc\\_risk\\_assessment\\_matrix.jpg?ver=MgaLpHgbRWyh9qjFdwt88A%3d%3d](https://www.trngcmd.marines.mil/Portals/207/Docs/safety/usmc_risk_assessment_matrix.jpg?ver=MgaLpHgbRWyh9qjFdwt88A%3d%3d)
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<sup>40</sup> Heffern, “ULS-A JCTD.”

NAVMC 1200.1F says that a Primary MOS (PMOS) is used to identify the primary skills and knowledge of a Marine. A Free MOS (FMOS) is a non-PMOS that can be filled by any Marine regardless of primary MOS. A free MOS requires skill sets unrelated to primary skills.

<sup>41</sup> NAVMC 1200.1F, 3-482.

## Glossary

**airspace coordinating measures (ACM).** Measures employed to facilitate the efficient use of airspace to accomplish missions and simultaneously provide safeguards for friendly forces. Also called ACMs. (JP 1-02. SOURCE: JP 3-52)

**free military occupational specialty (FMOS).** Non-PMOS that can be filled by any Marine regardless of primary MOS. A free MOS requires skill sets unrelated to primary skills. (NAVMC 1200.1F Military Occupational Specialty Manual)

**necessary military occupational specialty (NMOS).** A non-PMOS that has a prerequisite of one or more PMOSs. This MOS identifies a particular skill or training that is in addition to a Marine's PMOS, but can only be filled by a Marine with a specific PMOS. When entered as a requirement into the Total Force Structure Management System (TFSMS), a billet bearing a necessary MOS must identify a single associated PMOS even if several PMOSs are acceptable prerequisites. (NAVMC 1200.1F Military Occupational Specialty Manual)

**positive control.** A method of airspace control that relies on positive identification, tracking, and direction of aircraft within an airspace, conducted with electronic means by an agency having the authority and responsibility therein. (JP 1-02. SOURCE: JP 3-52)

**procedural control.** A method of airspace control which relies on a combination of previously agreed and promulgated orders and procedures. (JP 1-02. SOURCE: JP 3-52)

**primary military occupational specialty (PMOS).** Used to identify the primary skills and knowledge of a Marine. (NAVMC 1200.1F Military Occupational Specialty Manual)

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