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1. AGENCY USE ONLY (LEAVE BLANK)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED STUDENT RESEARCH PAPER	
4. TITLE AND SUBTITLE OVERMANNED AND UNDERTRAINED: PREPARING UAS CREWMEMBERS FOR UNMANNED CLOSE AIR SUPPORT		5. FUNDING NUMBERS N/A	
6. AUTHOR(S) Maj Rodney C. Rodriguez, USMC			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) USMC COMMAND AND STAFF COLLEGE 2076 SOUTH STREET, MCCDC, QUANTICO, VA 22134-5068		8. PERFORMING ORGANIZATION REPORT NUMBER NONE	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) SAME AS #7.		10. SPONSORING/MONITORING AGENCY REPORT NUMBER: NONE	
11. SUPPLEMENTARY NOTES NONE			
12A. DISTRIBUTION/AVAILABILITY STATEMENT NO RESTRICTIONS		12B. DISTRIBUTION CODE N/A	
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14. SUBJECT TERMS (KEY WORDS ON WHICH TO PERFORM SEARCH) UAS CAS Unmanned Training Simulator RQ-7B Shadow VMU		15. NUMBER OF PAGES: 51	
		16. PRICE CODE: N/A	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE: UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT

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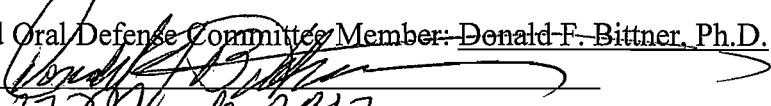
TITLE:
OVERMANNED AND UNDERTRAINED:
PREPARING UAS CREWMEMBERS FOR UNMANNED CLOSE AIR SUPPORT

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

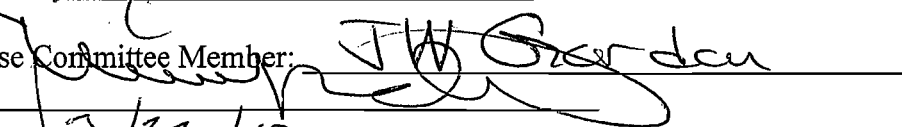
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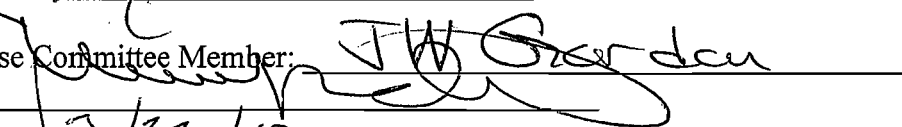
AY 11-12

Mentor and Oral Defense Committee Member: Donald F. Bittner, Ph.D.

Approved: 

Date: 22 March 2012

Oral Defense Committee Member: 

Approved: 

Date: 3/22/12

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Executive Summary

Title: Overmanned and Undertrained: Preparing UAS Crewmembers for Unmanned Close Air Support

Author: Major Rodney C. Rodriguez, United States Marine Corps. Operations Officer VMU-2 from November 2009 thru July 2011. Deployed with VMU-2 twice in support of Operation ENDURING FREEDOM (OEF), once in support of Weapons and Tactics Instructor (WTI) Course, and once in support of Joint Task Force – North (JTF-N). Qualified F/A-18D Weapons and Sensors Officer (WSO) as C-130J Pilot.

Thesis: Marine Fixed-Wing Unmanned Aerial Vehicle Squadrons (VMUs) are not postured to achieve Headquarters Marine Corps' newest tactical or operational goals and capabilities due to underutilized and undervalued Unmanned Aircraft System (UAS) flight simulation, inefficient crew composition, and lack of organic Close Air Support (CAS) subject matter experts.

Discussion: Since 1782 aviation, particularly unmanned aviation has grown exponentially, including the growing demand for Close Air Support (CAS) on the battlefield. During World War II Germany took the lead in weaponized unmanned technology with the development of "Vengeance Weapons". Throughout the last 28 years the Marine Corps' UAS program evolved from an intelligence collection and artillery observation platform to a much more sophisticated mission platform capable of unmanned cargo delivery, laser designation, electronic warfare, advanced target acquisition, and now: The weaponization of the RQ-7B Shadow in order to meet the growing demand for CAS.

Within the standard VMU RQ-7B flight crew, there exists numerous training and manning shortfalls. As of January 2012, the new Primary Military Occupational Specialty (PMOS) of 7315 has been approved and should provide a much higher quality professional UAS Aircraft Commander (UAC). However, this only exacerbates the gap that has developed in training. Of the numerous challenges that face the VMUs regarding training and manning, the most vital are UAS flight simulator usage, placing the best possible aircrew skill sets in the most advantageous position, and providing the VMUs with the necessary CAS subject matter experts.

Conclusion: The VMUs are not currently postured correctly. The following recommendations will help ensure they are. An emphasis on UAS flight simulation, including the required contractor support, will ensure cost effective advances in tactical acumen. Detailed examination of the current crew composition, from a skill set perspective, will identify areas of redundant training and inefficient crew coordination. Finally, introduction of UAS into the CAS environment without the requisite subject matter expertise residing in each VMU will result in the underutilization of this crucial asset. Without the necessary changes, the investment into leading edge technology for Marine Corps UAS may result in underutilization of this enhanced battlefield capability.

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Preface

During my most recent billet assignment in the Marine Corps, I served as the Operations Officer at Marine Unmanned Aerial Vehicle Squadron Two (VMU-2). In this assignment it became evident to me that many Marines in the VMUs are not prepared for the employment of rapidly fielded technological advancements in the Marine Corps Unmanned Aircraft Systems (UASs) field. I believe this shortfall to be the biggest hurdle to the future of Marine Corps Aviation. As the last manned aircraft (The Lockheed Martin F-35 Lightning II) enters production, we need to ask the hard question: Are the VMUs currently postured to best execute the mission requirements from Headquarters Marine Corps (HQMC)? Or, have our efforts become too narrowly focused solely on systems acquisition while gaps have grown in other areas? This paper will thus provide insight into newly identified problem areas and postulate feasible solutions. It is not intended to cover all problem areas associated with UAS Close Air Support (CAS); only those that I view as having the most potential for negative impact if not addressed are discussed here.

During the lengthy process of research and writing numerous individuals provided noteworthy contribution, direction, guidance, and support. I would like to thank Lt Col Mikel Huber for acting as a sound board and valued source for the information in this paper. I would also like to extend my sincere appreciation to the following individuals who took the time to meet with me during the research phase Col Dan Lathrop, LtCol George Beach, Maj Lawrence Green, Maj William Hendricks, and Capt Dale Fenton. I would like to emphasize that the opinions and recommendations in this paper are mine, and not all of the ideas included were supported by the above individuals. The Leadership Communication Skills Center (LCSC) deserves my gratitude for assistance with numerous revisions and initial guidance. I would also

like to thank Dr. Donald F. Bittner for his mentorship and guidance throughout this process.

Finally, and most importantly, I would like to thank my wife Sara. Without her loving support and hours of proof reading, this would not have been possible. Short of listing her as my co-author; I dedicate this paper to her.

General: History of UAS Development

Unmanned Aircraft Systems (UAS) played a vital role in the early development of aircraft starting in France with the Montgolfier brothers in 1782 and their experimentation with balloons.¹ Since that time aviation, including unmanned aviation has grown exponentially. This includes meeting the growing demand on the battlefield. It can be argued that UAS's impact on the battlefield really commenced during the Civil War with the formation of the aerial balloon corps, as early pioneers used unmanned balloons in an attempt to drop ordnance on the enemy and acquire intelligence.²

In 1917 the United States Navy began funding the development of the first military UAS designed from the ground up as an unmanned attack platform. The Curtiss N-9 seaplane "flying bomb" program would eventually fail to meet expected performance goals due to numerous technological problems. However, it did succeed in the further evolution of unmanned aviation development for military application.³ During World War II Germany then took the lead with unmanned technology in the development of "Vengeance Weapons". The V-1, which many military historians consider the first cruise missile, was also known as a "pilotless plane" or "robot bomb".⁴ Although numerous navigation and flight control issues had to be resolved the program resulted in nearly 30% of the launched V-1s reaching their target.⁵ The V-2 program, concurrently developed by the Germans, used similar missile guidance technology with a much higher success rate of about 50% resulting from a larger payload capacity, increased invulnerability to interception, and overall reliability.⁶ Ultimately the effectiveness of the "Vengeance Weapons" is debatable; however, the technological success of the various programs should not be understated.

With the early development of the Global Positioning System (GPS) in the 1970s came the answer to one of the biggest UAS development hurdles: navigation.⁷ Along with advances in light weight dependable engine design and advanced computers, the birth of modern UAS technology commences in the 1970s and 1980s (Reference Appendix B: General Timeline of Significant Events). Although not very successful in its infancy, the evolution, and ultimate success of UAS technology, recently placed unmanned aviation at the forefront of military aviation.

Overview: VMU Squadrons in the Marine Corps

Starting in 1984 with the formation of Detachment "T", Target Acquisitions Battery⁸, the Marine Corps has invested both time and money in the development of unmanned aviation. In addition to vast improvements in intelligence collection and dissemination, the Marine Corps placed great emphasis on effectively employing UAS in ordnance delivery. The end state of such endeavors is improved accuracy and decreased "time to kill". This is accomplished by shortening the kill chain, decreasing collateral damage, improving the timeliness and accuracy of Bomb Hit Assessments (BHA), and increasing the amount of available Close Air Support (CAS) and Strike Coordination and Armed Reconnaissance (SCAR) aircraft.⁹ Throughout the last 28 years the Marine Corps' UAS program evolved from an intelligence collection and artillery observation platform to a much more sophisticated mission platform capable of unmanned cargo delivery, laser designation, electronic warfare, and advanced target acquisition. Over the past few years the Marine Corps placed great emphasis on weapons delivery from the workhorse of Marine Corps UAS: the RQ-7B Shadow.¹⁰

Currently the Marine Corps benefits from UAS at the strategic, operational, and tactical levels of war; however, the Air Force fills the majority of the strategic and operational level

flights for the Marine Corps. The focus of organic Marine Corps UAS remains at the tactical level via supporting the Marines on the ground at the lowest level (see appendix D: Chart of UAS Groups). In the 21st century the Marine Corps UAS program has grown exponentially to meet the demand signal. The Marine Corps currently has four Marine Unmanned Aerial Vehicle Squadrons (VMUs) with plans to stand up VMU-5 within the next few years. The Marine Corps continues to wrestle with the issue of proper placement of the VMU which continues to be a controversial topic during Operational Advisory Groups (OAGs).¹¹ In early 2000 the VMUs were reassigned to the Marine Air Control Group (MACG) where they presently reside.¹² The future of Marine Corps UAS looks bright with the July 2010 \$43.7 million dollar contract award for design, development, integration, and test of the Small Tactical Unmanned Aircraft System (STUAS)¹³ as well as plans for future acquisition of an organic Marine Corps group 4/5 UAS similar in capability to the Air Force's MQ-1 Predators and MQ-9 Reapers (see appendix I: USAF Predator and Reaper).

VMU Squadrons: Aircraft, Operations, and Missions

The VMU currently deployed to Afghanistan operates three different Type Model Series (TMS) aircraft in support of combat operations (see appendix H: UAS of VMU): RQ-7B Shadow, Insitu ScanEagle, and Kaman K-MAX. The focus of this paper is the tactical employment of the RQ-7B Shadow. Each VMU squadron is task organized into three detachments capable of employing an RQ-7B Shadow system. In generic terms, a Shadow detachment consists of approximately 53 Marines and can provide 10-14 hours of Intelligence, Surveillance, and Reconnaissance (ISR) coverage. The Operations Section of each detachment consists of three UAS Aircraft Commanders (UACs) and 12 UAS Air Vehicle Operators (AVOs) and UAS Mission Payload Operators (MPOs). For the majority of UAS missions the crew is

comprised of one UAC, one AVO, one MPO, and one Intelligence Marine.¹⁴ See appendix E for duties and responsibilities of the individual crew members.

The current mission of the VMU (which presently does not include CAS) is to “conduct day and night unmanned aerial Reconnaissance, Surveillance, and Target Acquisition (RSTA) in support of a Marine Air-Ground Task Force (MAGTF).”¹⁵ Prior to a VMU receiving authorization to deploy, it must successfully demonstrate proper execution of its core mission sets with the minimum number of qualified crews (see appendix F: VMU Mission Essential Task List). The Mission Rehearsal Exercise (MRX) occurs during Block IV of the Pre-deployment Training Plan (PTP). This assessment evaluates the squadron in Aerial Reconnaissance (AR), Analyzing and Synthesizing Information, Control of Indirect Fires (IDF), Terminal Guidance Operations (TGO), Convoy Escort, and Strike Coordination and Reconnaissance (SCAR).¹⁶

Considering the current POI and the expanding mission requirements for VMU aircrew, a gap in tactical knowledge has emerged. The Training and Readiness Manual (T&R), designed to provide standardized training and evaluation of all crew members, attempts to bridge the gap dependant on the target audience’s proficiency, experience, and background.¹⁷ The diverse background of officers assigned to the VMU creates a myriad of additional training hurdles considering the breadth of tactical employment requirements and the associated tactical knowledge requirement.¹⁸

VMU Squadrons: Crew Composition

The crew composition currently in place to operate the RQ-7B Shadow consists of one UAC, one AVO, and one MPO (see appendix E: Crew Member Responsibilities). In basic terms the UAC is overall responsible for mission coordination and execution, the AVO controls the flight of the Air Vehicle (AV), and the MPO controls the sensor or camera. An additional

qualification is the UAS Mission Commander (UMC). A UMC is a highly qualified UAC capable of performing the job of UAC for multiple crews at the same time.

In most cases, the existing crew configuration physically places the UAC apart from the remainder of the crew in the Command Operations Center (COC). The COC provides the UAC with increased situational awareness based on the great number of assets available in the COC vice the GCS. However, the physical separation from the remainder of the crew increases friction with a resulting decrease in responsiveness to tasking.

In standard practice, an enlisted Marine assigned to the VMU will first qualify as an MPO; this is more often than not followed very quickly by AVO qualification. Every individual training plan is unique. Under typical circumstances, the average Marine will be qualified to sit the MPO and AVO crew position within four to six months of reporting to the VMU squadron.

UAS Aircrew Training: Officers

Currently the UACs are comprised of various officers from around the Marine Corps with MOSs of 75xx and 72xx. This provides the VMU with a mix of aviation experience and Air Control/Air Support/Anti-Air Warfare/Air Traffic Control experience. Over the past few years this mix of officers has proven problematic and challenging for numerous reasons, the most significant of which is training.¹⁹ With such a diverse background in aviation experience it has proven difficult to agree upon a common syllabus in an effort to produce a known quantity.²⁰ Establishing a common background amongst the officers prior to training is crucial.²¹ More often than not, officers graduate from their initial training at Fort Huachuca, designated as UACs, with as wide a skill set as when they started. The resulting variance in product requires the instructor cadre organic to the VMU to tailor the follow-on instruction for each UAC.²² The second issue regarding UAC training is the lack of depth in the instructor corps as a result of the

18-24 month tour length for most officers.²³ This is further compounded by the fact that most officers never come back to the VMU for a second tour.

UAS Aircrew Training: Primary MOS 7515

As of January 2012, the new Primary Military Occupational Specialty (PMOS) of 7315 has been approved and should provide a much higher quality professional UAC with the eventual depth of experience so drastically needed.²⁴ Although the Program of Instruction (POI) is currently being developed and no firm timeline has been established, it is estimated that the first Marine to select the new PMOS from The Basic School (TBS) will be late 2012.²⁵

The challenge the Marine Corps UAS program currently faces regarding training is finding the most cost effective and efficient method available to increase the initial skill set of aircrew, the goal of which is to provide the VMU squadrons with more capable aircrew from the start. At present both the officers and the enlisted Marines attend training at the U.S. Army's UAS schoolhouse in Fort Huachuca, Arizona. In recent years the officer's training syllabus has undergone dramatic revisions in an effort to increase the quality of graduates, with great success; however, the relatively short course (3 weeks) remains inadequate to meet growing requirements.²⁶ The addition of a formal POI for the new officer PMOS will continue that positive growth trend.

The United States Air Force now has more unmanned aircraft than manned aircraft in its inventory. Along with this influx of aircraft has come the growing demand signal for Remotely Piloted Aircraft (RPA) Pilots. The efficiency with which the U.S. Air Force has implemented the change required to train the vast number of pilots is a model the Marine Corps is attempting to duplicate. One possible solution is to leverage joint training opportunities by sending Marine

Corps UACs to the first three phases of U.S. Air Force RPA training, followed by the Army course at Fort Huachuca.

If approved, the new POI will add an additional six months of training prior to the Fort Huachuca course. For the first phase of training Lieutenants from TBS would travel to Pueblo Colorado for Initial Flight Screening (IFS); this will include approximately 40 hours of flight instruction in the Diamond DA-20. The training will be extensive and leaves the students just shy of a Private Pilot's License. The second phase of training is RPA Instrument Qualification (RIQ) at Randolph Air Force Base; this will focus on flying with the use of instruments only when the pilot lacks outside visual reference. This phase is particularly relevant to UAS aircrew who rely on instruments throughout the majority of flights. RPA Fundamentals Course (RFC) is the final phase of Air Force instruction; it will concentrate on countering threats to UAS, communications, and a basic introduction to tactics. Upon completion of training with the Air Force, the students would then travel to Fort Huachuca, Arizona, to learn RQ-7B Shadow specific procedures and tactics. Although the Marines run the Fort Huachuca course in an Army facility with Army assistance, the Marines receive additional Marine Corps specific tactical instruction in the areas of CAS and SCAR. Upon completion of this course the Marines will be designated UACs and receive the new PMOS.²⁷ Although the above conceptual POI has not been officially approved, it has received positive feedback from numerous Marines involved in the decision and is expected to receive approval soon.

It is important to emphasize that the current approved POI includes only the Fort Huachuca course. Once the proposed POI referenced above is approved, the caliber of UAC arriving at the VMU will be better trained and a more professional and capable Marine Corps

aviator. Although not being considered at this time, discussions have arisen regarding flight pay and UAS Naval Aviator Insignia or “wings” are gaining momentum.

The Weaponization of the RQ-7B and the Demand for Organic UAS CAS

As the Marine Corps enters the next logical phase of UAS evolution, the VMUs will be tasked to successfully add an additional mission: Close Air Support (CAS). As military aviation evolves with regard to unmanned aviation technology, scholars have begun to discuss unmanned aviation taking the lead. In 2009 the United States Air Force has passed the milestone of having more unmanned aircraft in its inventory than manned.²⁸ With the influx of advanced unmanned aircraft such as the Predator and the Reaper able to carry thousands of pounds of ordnance into combat, there arise numerous challenges associated with adequate training and proper employment. Over the past decade the Air Force has taken a very detailed and more deliberate approach to training UAS aircrew in the delivery of ordnance that the Marine Corps must capitalize on.

Joint Pub 1-02 (*DOD Dictionary of Military and Associated Terms*) defines CAS as “air action by fixed- and rotary-wing aircraft against hostile targets which are in close proximity to friendly forces and which require detailed integration of each air mission with the fire and movement of those forces.”²⁹ Although many variations of the definition exist throughout the lexicon of military aviation, the above definition provides the key elements of CAS that all can agree upon: the close proximity to friendly troops and the resulting detailed integration required to perform this varsity mission.

The evolution over the past five years of Marine Corps UAS in the close-knit Marine Air Ground Task Force (MAGTAF) resulted in a steep learning curve for the Marines of the VMUs. Starting in 2008, the VMUs transitioned from the RQ-2 Pioneer to the RQ-7B Shadow, a much

more capable aircraft than its predecessor.³⁰ Along with the new airframe came new tactical requirements and upgraded systems. Over the past three deployments the VMUs developed the Tactics Techniques and Procedures (TTPs) for employing the RQ-7B's newest payload the POP-300LD (see appendix J: POP-300LD).³¹ The "LD" is the identifier for the laser designation capable camera which is the latest in a line of payload upgrades that enables the RQ-7B Shadow to designate targets for strike aircraft and laser guided ground fires. This difficult tactical transition occurred while the VMUs were the most deployed aviation unit in the Marine Corps fighting in both Iraq and Afghanistan on constantly rotating deployments.

As the relentless deployment cycle continues, a new requirement has developed: organic UAS CAS. Throughout deployments to Iraq and Afghanistan, the Air Force has proven the usefulness of UAS CAS. Armed USMC UAS provide the MAGTF with a multi-function ACE asset capable of providing Aerial Reconnaissance and Persistent OAS. The USMC is in the process of weaponizing 2 x RQ-7B Shadow systems for a Field User Evaluation (FUE) in response to Urgent Universal Needs Statement 10172UA.³² Ground forces in Afghanistan want more UAS coverage and the ability to strike targets of opportunity with those assets before the target can blend back in with the surrounding environment. Weaponizing the RQ-7B meets that need by bringing enhanced responsive organic strike capability to the battlefield.

Since the birth of Marine Corps Aviation in 1912, Marine Corps pilots have honed their skills in order to support the Marines on the ground. Over the years the terminology may have changed but the intense focus on the primary mission remains constant: support. Today the Marine Corps utilizes the MAGTF concept to take the fight to the enemy, and for the aviation element the skillful execution of CAS is a hallmark. As the next logical step in response to the urgent request from ground forces, the Marines of the VMUs need to prepare to carry on the

tradition of close air support which has been the greatest attribute of Marine Corps manned aircraft.

Identified Deficiencies in Training

Gaps in tactical knowledge in the VMU started to appear with the introduction of new technology, namely the Communications Relay Payload (CRP) and the Laser Designation (LD) capable payload. The pace at which the Air Vehicle (AV) has changed has not been well addressed from a training perspective.³³ This has occurred because of the focus being almost solely on getting the new payload capability and technology out to the deployed VMU as fast as possible. Little if any thought was placed on appropriate manning and training.³⁴ In late 2010 prior to deployment to Afghanistan, VMU-2 received the laser designation capable payload; however, numerous deficiencies with the fielding of the upgrade ensued.³⁵ Acceptance of the new systems came with training for all operators and maintainers; unfortunately, the training only covered how to perform pre-flight checks and how to physically turn the laser on. Zero instruction was provided regarding tactical employment of the new asset. This occurred because of a miscommunication between VMU-2, the contractor, and the program office regarding the new requirement for additional tactical instruction.³⁶

In response to the situation, numerous RQ-7B subject matter experts from the VMUs worked closely with MAWTS-1 in an attempt to resolve this problem via development of the required TTPs. VMU-2 forward deployed to Afghanistan with the new laser designator and only two aircrew with CAS or laser designation profile experience.³⁷ Making the best out of a bad situation, the VMUs conducted as much training as possible; however, all three VMUs were using different tactics for laser designation employment. This resulted in a dangerous lack of standardization.³⁸ As a result, after two deployments with the new payload, only two crews

successfully designated a target; both were practice engagements for training. This lack of opportunity and missed opportunities can be attributed to a number of different issues. These included: technical issues with communications, lack of training with CAS aircraft, and insufficient trust and comfort level in the VMU from Forward Air Controllers (FACs) on the ground.³⁹ The implementation of the laser designator on the RQ-7B provides an example of how a gap in tactical expertise can make a much needed piece of technology useless on the battlefield. Although the ineffectiveness of the laser designation upgrade in Afghanistan is not monocausal, and many of the compounding issues are not discussed in this paper, it was clear that changes to training and manning are required. This is especially important as VMU prepares to execute close air support in the near future. As the squadrons enter 2012, they bring with them almost two years of target designation experience utilizing the POP-300LD, the vast majority of which is training only. As they enter 2013, the RQ-7B will be able to designate and deliver precision guided munitions on the battlefield, a true unmanned CAS asset.

Recommendations for the Future Training of UAS Crew Members

In order to continue in the right direction with UAS, the Marine Corps needs to ensure advancements are made in all areas of UAS employment. This is not solely a technology gap with hardware solution. As technology evolves and new systems, including weapons, are acquired for existing platforms, a corresponding increase in required tactical proficiency will be required. The proposed POI for future officers is certainly a step in the right direction; however, if implemented into the current VMU operational structure the basic educational foundation will not produce the desired results. In order to successfully fulfill the battlefield needs, changes must be made in UAS flight simulation, crew composition, and the level of tactical expertise organic to the VMU.

Recommendation 1: Improvements to UAS Flight Simulator Operations

From a training perspective an emphasis on UAS flight simulation is crucial to tactical advancement. The vast majority of military and civilian aviators agree in the significant value of incorporating an advanced simulator in flight training to reduce cost, provide better training, and maintain currency.⁴⁰ Although it cannot completely replace live flights, today's advanced simulator are ideal at providing the aircrew with a very close approximation of actual flight conditions and required procedures at a fraction of the cost. The benefit of flight simulators is well documented, but to appropriately quantify the value in flight simulation for UAS aircrew the current flight simulator in use at the VMUs must be understood. AAI (formally, Aircraft Armaments, Inc) produces the RQ-7B Shadow with an accompanying flight simulator. The Ground Control Station (GCS) is a modified High Mobility Multipurpose Wheeled Vehicle (HMMWV) used by the aircrew to control the Air Vehicle (AV).⁴¹ To simplify the equipment, it can be thought of as a cockpit situated on the back of a HMMWV.⁴² Each GCS is built with software capable of simulating an actual flight. Within the last two years a more advanced stand-alone simulator has been procured and distributed to all VMUs.

The ability for these flight simulators to replicate actual flight is far greater than any manned aircraft simulator. This is due to the fact that the only distinguishable difference between an actual UAS flight and a simulated UAS flight is the background noise of the engine being started and the "live" video feed. The video feed in the simulator more closely resembles video game animation than video camera. Although this may seem significant, the quality of the video feed has little to do with actual flight instruction or tactical execution. In order to receive quality instruction in the UAS simulator the crew members only require sufficient fidelity to drive their decision making process. Additionally, the learning environment created by the

simulation is more beneficial than actual flight in many ways. During a period of instruction the instructor can select a number of different tactical scenarios and locations within minutes, thus providing learning opportunities that cannot be replicated during live flight. In addition, the instructor can simply pause a scenario to review TTPs and lessons learned. If mistakes are made, the instructor can simply re-run the exercise time and time again until executed successfully.⁴³

With these clear benefits of UAS flight simulation, why is the simulator underutilized? The underutilization of UAS flight simulation can be attributed to a culture within the VMU that does not properly value the benefits of flight simulation and the lack of adequate contractor support.⁴⁴ Further compounding the issue of proper contractor support is the complexity of computer programming knowledge required to properly utilize the simulator.⁴⁵ The concept of negative culture towards UAS flight simulation can only be fixed by shifting the organization's culture.

According to Alan Murray, the first step in successfully executing a culture shift is to "...start with people who have disproportionate influence in the organization. Get them committed to the change, or, failing that, get them out."⁴⁶ Within the VMU the center of gravity preventing such a significant paradigm shift regarding UAS flight simulation is the individuals who have not been exposed to the benefits of properly executed flight simulation and have only experienced the frustrations surrounding operating the simulator software.⁴⁷ In order to shift the momentum of culture change in the right direction, this frustration must be removed through contract support and the addition of aircrew that are familiar with tactical flight simulation instruction. This plan will be most effective if initiated with the senior instructors and staff. The VMUs need more tactical aviation flight experience now. This can be accomplished, prior to the implementation of the 7315 POI, by selecting more Unmanned Aircraft Commanders (UACs)

with tactical flight experience from F/A-18s, AH-1s, and AV-8Bs. This will also pay huge dividends during the implementation of weapons on the RQ-7B and the development of TTPs associated with that implementation.

A discussion on UAS flight simulation value would not be complete without addressing the actual “dollars and cents” of flight operations. In today’s fiscally constrained military, very few program budgets are actually growing; UAS is one of the few. With the increase in funding comes increased financial scrutiny. In order to continue successful employment of evolving unmanned systems, it is essential to reevaluate current flight operations and utilizing best business practices. Flight hour cost comparison at the squadron level and cost per sortie are two reasons why UAS flight simulation remains undervalued. If not addressed, this could lead to devaluation of not only UAS flight simulation but UAS operations as a whole.

One major constraint the operations department of an aviation squadron confronts is the flight hour program. This is essentially the funding available (or budget) for flight operations. The flight hour program drives many of the decisions in operations, just as a budget drives the decisions in any organization. The flight hour program is significant when discussing the fiscal benefits of flight simulation because when funding for flight operations runs out, the only remaining option for maintaining flight proficiency is the simulator. Currently in the VMU there is not a true flight hour program and thus no cost comparison to actual flight operations. The VMUs are authorized to fly as many hours as they determine necessary.⁴⁸ It is not hard to imagine that this practice will come to an end as budgets constrict and efficiencies are sought out.

The second fiscal consideration to address is the cost of training with live weapons. As the Marine Corps gets closer to weaponizing UAS, the value in UAS flight simulation for

weapons currency and proficiency will become more apparent. The Marine Corps will fund the (FUE) in response to the Urgent Universal Need Statement (UUNS) which requests weapons modifications to the RQ-7B Shadow UAS. This funding will only cover a finite number of initial weapons.⁴⁹ Although the quantity of weapons has yet to be determined, the importance of flight simulation in the development of tactics and training of aircrew is readily apparent. If successful, the FUE may result in additional weapons acquisition and possibly an official program of record. In either case the importance of UAS flight simulation cannot be overemphasized.

In summation, the value of UAS flight simulation has gone undervalued due to underutilization, a culture that has not embraced the benefits of flight simulation, and a lack of proper cost comparison. Although substantial, these hurdles can be overcome relatively easily and cost effectively with the addition of properly trained contractor support for the existing simulators.⁵⁰

Recommendation 2: Additional Funding for Contractor Support of Simulators

If approved, the proposed addition of an RQ-7B simulator in Yuma, AZ will be upgraded in order to facilitate the development of TTPs and a formalized POI necessary to instruct UAS CAS procedures to the fleet.⁵¹ This is a crucial step in the fielding of the initial systems if the FUE is to be successful.⁵² Sufficient resource allocation to the simulator in Yuma is crucial in order to ensure adequate tactical support for weaponizing the RQ-7B. However, if overlooked the remaining simulators (resident at each squadron) may not be upgraded in time for the fleet to execute training. Furthermore, the assumption that the current simulator support to the fleet squadrons is adequate could result in additional shortfalls and underutilization.

The simulator in Cherry Point NC (supporting VMU-2) suffers from underutilization as a result of insufficient knowledge and experience organic to the squadron. Although the simulator has the potential to become a great asset to the VMU squadrons, without proper training and support this asset is a wasted asset. Upon initial installation of the simulator a support team was available for basic training and initial instruction. Today, the majority of the aircrew still do not know how to perform the basic operation of the device and only a select few are capable of executing a useful period of instruction. The squadrons are forced to educate themselves on simulator operation, and they depend solely on organic personnel for its operation.⁵³ As a result the squadron continues to rely on actual flight time for a vast majority of its education.

In order to resolve this potential shortfall, funding needs to be identified early for continued contractor support for all the RQ-7B Shadow simulators. If the allocation of funding only covers the initial weapons upgrade for the simulator, a drastic reduction in its use and effectiveness will ensue after the support expires. This previously happened when support was received for the initial simulator install and the POP-300LD and CRP upgrades.⁵⁴ In order to further maximize training dollars and efficiently train our aircrew, contracted simulator support must be available at the discretion of the squadron Operations Officer up to 24 hours a day including weekends. Simulator operations, including sufficient support to run tactical missions, can be modeled after manned aviation squadrons and respond to the squadron's training plan.

Recommendation 3: Changes to Crew Composition

As discussed previously (reference pg 4, discussion on Crew Composition), in its current configuration the crew composition of the RQ-7B results in duplication of training, underutilization of aircrew, unnecessary friction, and miscommunication. Current changes underway in the crew composition include the approval of the 7315 PMOS for the UACs/UMCs.

Starting near the end of this calendar year, students from TBS will be selected for this new career path. In addition a transition and conversion board will most likely be announced to select currently qualified UACs/UMCs to convert to the new PMOS.⁵⁵ If approved, the Program of Instruction (POI) currently under review by Marine Aviation Weapons and Tactics Squadron One (MAWTS-1) would produce a more highly trained and professional UAC/UMC. This issue has been at the forefront of Marine UAS conversation for years and its approval is welcomed news to the VMUs. However, if implemented in its current configuration this will only exacerbate the above crew coordination problems.

Considering the current POIs for the enlisted crew positions, the duplication in training is astonishing. Although training to both the AVO and MPO crew position provides flexibility in scheduling, the duplication of training results in wasted training hours and a diluted product. If the crew members were to focus on one crew position (vice two), it would result in a much higher level of proficiency, a true subject matter expert, and a decrease in the required time to train.

Taking into account the current POI for the UAC/UMC crew positions, a similar duplication in training is apparent. A fully qualified UAC knows many of the functions performed by the AVO and MPO. Although it is difficult to estimate the degree of knowledge overlap, it is estimated that a qualified UAC could gain his/her MPO qualification in approximately 15 flight hours of instruction.⁵⁶

Within the last two years a new qualification for enlisted crew members has been established and implemented in varying degrees within the different VMUs. The new qualification is an enlisted UAC. Supporters of the concept, which resulted in the formation of the enlisted UAC qualification, contend that “the goal is to increase unit war fighting capabilities

by capitalizing on existing senior enlisted manpower resources – personnel possessing advanced training and years of Unmanned Aircraft Systems (UAS) subject matter expertise.”⁵⁷ To date, no data has been collected to prove the effectiveness or ineffectiveness of the enlisted UAC crew position. If approved, the new POI which supports the new PMOS will increase the amount of training given to the officer UAC/UMC. Unfortunately, this would exacerbate the issue based on the inherent widening of the knowledge gap between the enlisted and officer UACs. The risk involved with assuming years of UAS subject matter expertise is adequate enough to perform the job of UAC grows as the training for the PMOS increases. At the very least these two changes are at odds with each other and are only exacerbated with the addition of weapons systems.

Considering the above data and observations, the MPO position should be eliminated and filled by the UAC/UMC. Consolidating the crew positions would eliminate much of the friction that has a negative impact on crew coordination and eliminate much of the duplication in training.⁵⁸ Additionally, if the FUE for weaponization of the RQ-7B is a success and converted into a Program of Record, this new crew configuration would increase overall crew situational awareness and communication.

Currently, tasking received by the UAC is transmitted via headset to the GCS for the AVO and MPO to execute. The result: Adding an unnecessary middleman! Placing the UAC in the GCS would allow the UAC to make seamless changes in camera and laser designation position, and improve the crew coordination with the AVO sitting right next to him.⁵⁹ Imagine attempting to talk a camera onto a target through a headset vice simply completing the action yourself.

A large portion of the UAC’s duties are directing the AVO and MPO in the execution of their duties. This task execution style creates a micro-management feeling of friction between the

UAC and the remainder of the crew. Moving the UAC into the GCS to perform the duties of the MPO would eliminate this “voice activated auto-pilot” problem and increase execution speed. In addition, during most missions the UAC is underutilized which exacerbates the micro-management and friction.

Dislocating the UAC from the numerous assets in the COC is one possible disadvantage of moving the UAC into the GCS; however, experience in Iraq and Afghanistan have provided many lessons learned for UAS operations that help to solve this issue. Recent combat operations resulted in one of the greatest improvements in UAS operations: The extensive changes to the COC and the GCS (see appendix K: VMU COC Diagram). Many of the systems, previously only available in the COC, including mIRC Chat, FalconView map software, and access to classified shared drives, are now available in the GCS. With the addition of a more capable Universal GCS in the coming years the GCS will have access to even more capabilities that were previously only available in the COC. For missions requiring extensive coordination with the COC, a UMC could be scheduled as a COC watch officer and provide the crew with assistance when required. Considering the upcoming decrease in manpower and budget, the above consolidation would result in an estimated decrease of 36 Enlisted Marines per VMU; an obvious advantage during the upcoming manpower and funding constrained environment.⁶⁰

Recommendation 4: Assignment of Highly Qualified Tactical Aviators to the VMU

One of the more popular plans to handle the implementation and training aspects of weaponizing the RQ-7B includes the formation of a “tiger team”.⁶¹ If approved, the team would be tasked with all aspects of training a VMU to utilize the new system and possibly deploying with the squadron. This team will most likely be comprised of a number of tactical aviators with CAS experience in order to develop the required TTPs, perform operational testing, and assess

the FUE. As identified earlier, there is a significant gap in knowledge at the VMU regarding CAS execution. If sufficient numbers of tactical aviators with CAS experience are not identified for this implementation, significant issues could arise.

It would be a considerable mistake not to consider the important lessons learned from the implementation of the Harvest Hawk program. Very similar to the weaponization of UAS in the Marine Corps, Harvest Hawk was an organic Marine Corps solution in response to an UUUNS detailing the need for a persistent ISR/CAS capability with long time on station similar to the US Air Force's C-130 Gun Ship.⁶² In the most simplistic form, both UUNs identified the same capability gap which allows for excellent comparison. An ISR/Weapons system was designed, tested, and deployed successfully. The aircrew designated to deploy with the new system was in concept very similar to the planned tiger team for UAS weaponization. Subject matter experts came together from KC-130s, MAWTS-1, F/A-18s, and AV-8Bs. The crew developed TTPs, tested those TTPs, and then trained and deployed together. This addition of CAS expertise to the KC-130 community was crucial to the program's success.

On the surface the proposed UAS tiger team sounds very similar, but upon closer examination there is a significant exception. The Harvest Hawk FUE deployed with one aircraft and an experienced crew capable of flying all the required tasking for that aircraft. In order to match that success, the weaponized RQ-7B system would need to deploy with an adequate number of crew members having extensive CAS experience. For the Harvest Hawk the crew members selected to operate the ISR pod and execute targeting all had tactical aviation experience. For the RQ-7B, the MPO has extensive ISR experience but very limited targeting experience.⁶³ As discussed earlier the new POP-300LD is equipped with a laser designator that has seen limited use in an operational environment.

Without knowing the specifics of the weapons system that will be selected it is difficult to recommend precisely which crew position in the RQ-7B would require the additional CAS expertise. At a minimum, every mission flown with the new weapons capability must have this expertise, much like the Harvest Hawk FUE. The VMU-3 Fiscal Year 2012 Table of Organization (TO) lists four UAC billets per detachment.⁶⁴ In order to make a reasonable assessment of the required amount of CAS experienced augments needed, Headquarters Marine Corps first needs to determine the number of sorties the new system will provide. Given the mission requirement and tasking, one augment per sortie plus one additional as backup should suffice.⁶⁵

It is worth noting that during the implementation of the new POP-300LD, the VMUs had very limited laser designation experience organic to the squadron. MAWTS-1, which is traditionally tasked with developing tactics for the fleet, used all available resources to help test and design TTPs for the new payload. Unfortunately, MAWTS-1 UAS department had no laser designation or CAS experience and no organic RQ-7B Shadow system to utilize for testing.⁶⁶ Out of necessity, the individual squadrons independently developed a majority of the TTPs (with MAWTS-1 assistance); ultimately resulting in a dangerous lack of standardization between the VMUs and very limited testing.

Conclusion

HQMC responded quickly to the demand signal from Afghanistan regarding weaponized UAS; however, the addition of laser designators and weapons to the RQ-7B resulted in an unforeseen complication. Within the next year the RQ-7B Shadow will fly with weapons on board. Much of the success of this program depends upon the training and readiness of the aircrew within the VMU.

In order to prepare the VMUs for the tactical challenges associated with weaponizing the RQ-7B, significant changes need to be implemented as soon as possible. HQMC, TECOM, and MAWTS-1 are leading the way with the newly approved PMOS for UACs and the proposed POI. An emphasis on UAS flight simulation, including the required contractor support, will ensure cost effective advances in tactical acumen. Detailed examination of the current crew composition, from a skill set perspective, will identify areas of redundant training and inefficient crew coordination. Finally, introduction of UAS into the CAS environment without the requisite subject matter expertise residing in each VMU will result in the underutilization of this crucial asset.

For the past ten years the preponderance of resources has focused on technological advancement and system acquisition vice appropriate manning and training. Marine Corps UAS technology has grown leaps and bounds with the addition of RQ-7B, Cargo UAS, laser designation capabilities, and soon advanced weapons systems; however, parallel changes have yet to be implemented in manning and training. Without the necessary changes, the investment into leading edge technology for Marine Corps UAS may result in underutilization of this enhanced battlefield capability.

APPENDIX A

List of Acronyms and Definitions of Terms

ACE – Aviation Combat Element
AR – Aerial Reconnaissance – Intelligence gathering from the air, typically using a camera
ATO – Air Tasking Order – gives each flight of the day their mission and airspace
AVO – Air Vehicle Operators – UAS pilot
AVPLAN – Deputy Commandant for Aviation annual Marine Aviation Plan
BDA – Battle Damage Assessment
BHA – Bomb Hit Assessment
CAS – Close Air Support
COC – Combat Operations Center
CONOPS – Concept of Operations
CRP – Communications Relay Payload – allows radio transmissions to be relayed from the AV
in order to increase range of transmission
DCA – Deputy Commandant for Aviation, USMC
DoD – Department of Defense
EA – Electronic Attack
EMV – Enhanced Mojave Viper
EW – Electronic Warfare
FAC – Forward Air Controller
FMF – Fleet Marine Force
GCS – Ground Control Station – the ground unit that controls the AV
GPS – Global Positioning System
HIMARS – High Mobility Artillery Rocket System
HQMC – Headquarters Marine Corps
IDF – Control of Indirect Fires
ISR – Intelligence, Surveillance, and Reconnaissance
JTAC – Joint Terminal Attack Controller
JPUB – Joint Publication
LD – Laser Designator
MACC – Marine Air Command and Control
MACG – Marine Air Control Group
MAG – Marine Aircraft Group
MAGTF – Marine Air-Ground Task Force
MAWTS-I – Marine Aviation Weapons & Tactics Squadron - One
MCTUAS – Marine Corps Tactical Unmanned Aircraft System
MOS – Military Occupational Specialty
MPO – UAS Mission Payload Operators (MPOs)
MUG – Marine Unmanned Group (conceptual only)
NTISR – Non-Traditional Intelligence, Surveillance and Reconnaissance
OAG – Operational Advisory Group – representatives from across the UAS community gather to
discuss the future of the program and determine the top priorities for funding.
POI – Program of Instruction – a syllabus for instruction
POP – Plug-in Optical Payload – the variant of camera on the RQ-7B

PID – Positive Identification
PTP – Pre-Deployment Training Plan
RSTA – Reconnaissance, Surveillance, Target Acquisition
SATCOM – Satellite Communication
SCAR – Strike Coordination Aerial Reconnaissance
STUAS – Small Tactical Unmanned Aircraft System
T&R – Training and Readiness
TACAIR – Tactical Aviation, usually referring to marine fixed-wing aviation
TACC – Tactical Air Command Center
TBS – The Basic School
TGO – Terminal Guidance Operations
TIC – Troops in Contact
TIM/S - Type/Model/Series of an Aircraft; (ex: type, fixed-wing fighter-attack; model, FA-18; series, FA-18C)
TTP – Tactics, Techniques and Procedures
T&R – Training and Readiness (Manual)
UAC – UAS Aircraft Commander
UAS – Unmanned Aircraft System(S)
UAV – Unmanned Aerial Vehicle (or AV) – the unmanned aircraft
UMC – UAS Mission Commander
USAF – United States Air Force
USMC – United States Marine Corps
VMO – Marine Fixed-Wing Observation Squadron
VMFA – Marine Fixed-Wing Fighter-Attack Squadron
VMU – Marine Fixed-Wing Unmanned Aerial Vehicle Squadron

APPENDIX B

General Timeline of Significant Events⁶⁷

1884	Nikola Tesla, father of remote control, immigrates to the United States, arriving in New York City reportedly with plans for a remotely controlled airplane. He begins working for Thomas Edison's company.
1898	Tesla submits a paper describing a remotely controlled aircraft that "...could change its direction in flight, explode at will, and ...never make a miss" to the <i>Electrical Engineer</i> magazine. Its editor, T.C. Martin, refuses to publish it due to its outlandishness.
May 1898	Tesla demonstrates his "telautomaton," a remotely controlled boat, at an Electrical Exposition in New York City's Madison Square Garden. This led to tests of a radio-controlled torpedo with the U.S. Navy in 1914-16.
Sep 1916	The Hewitt-Sperry Automatic Airplane, with a safety pilot onboard, successfully flies a level flight over a preset distance using Sperry's gyroscope and distance measuring system.
1917	The British Army (A. M. Low) attempts the first radio-controlled flight of an unmanned aircraft; it crashes.
6 Mar 1918	A Curtiss-Sperry <i>Aerial Torpedo</i> , a modified Curtiss <i>Speed Scout</i> , makes the world's first successful flight by an unmanned aircraft at Copiague, Long Island, New York. Catapulted into the air, it flies its planned 1000 yards, is recovered, and flown again.
4 Oct 1918	An unmanned Army/Dayton-Wright <i>Liberty Eagle</i> makes its first flight from South Field near Dayton, Ohio, and is ordered into production by the U.S. Army.
17 Oct 1918	An unmanned Navy/Curtiss N-9 seaplane successfully flies an 8-mile course at 4,000 ft off Long Island.
22 Oct 1918	An unmanned Army/Dayton-Wright <i>Liberty Eagle</i> successfully flies a 1500-ft course at 200 ft, diving into its target near Dayton, Ohio.
1922	First launch of an unmanned aircraft (RAE 1921 <i>Target</i>) from a ship (HMS Argus).
3 Sep 1924	A Royal Aircraft Establishment 1921 <i>Target</i> flies for 39 minutes and is successfully recovered the world's first radio-controlled unmanned flight.

- 15 Sep 1924 The U.S. Navy conducts the first successful “NOLO” (no live operator) U.S. radio-controlled unmanned flight with a Curtiss N-9 seaplane, which lands after flying for 40 minutes and executing 49 of the 50 commands sent to it.
- 1933 The first use of an unmanned aircraft as a recoverable target drone is made by the Royal Navy using a radio-controlled Fairey IIF. This leads to the production of over 400 DeHavilland Queen Bee target drones.
- 12 Jun 1944 The world’s first cruise missile, the German Fi 103 (or V-1), is launched against England. It would be followed by 10,500 more before 3 Mar 1945, of which 2,400 reached their intended targets.
- 19 Oct 1944 The world’s first UCAV, a U.S. Navy/Interstate TDR-1 assault drone, successfully bombs Japanese gun emplacements on Ballale Island in the South Pacific. It crashes on its return flight due to having been damaged by anti-aircraft fire.
- 5-6 Aug 1946 Under Operation Remote, two U.S. Army Air Force unmanned B-17s fly from Hilo, Hawaii, to Muroc (now Edwards AFB), California, covering the 4200 km in 14 hours and 55 minutes.
- 1959 U.S. Army fields the Northrop SD-1 (later the MQM-57) *Observer*, the first unmanned reconnaissance aircraft. A total of 1,445 were built.
- 12 Aug 1960 The world’s first unmanned helicopter, the Gyrodyne QH-50, makes its first untethered flight at the Patuxent River Naval Air Test Center, Maryland.
- 20 Aug 1964 Teledyne Ryan unmanned *Firefly* and *Lightening Bug* reconnaissance drones, based on their *Firebee* target drone, began flying missions over China and Vietnam. A total of 3,435 sorties are flown before missions end in Jun 1975.
- 4 Nov 1974 The world’s first solar-powered flight was made over Bicycle Lake, California, by Robert Boucher’s 26-pound *Sunrise I*.
- 20-21 Aug 98 The first successful unmanned trans-Atlantic flight is made by the Insitu *Aerosonde* “Laima” from Bell Island, Newfoundland, to Benbecula, Outer Hebrides, Scotland, covering 2,031 miles in 26 hours 45 minutes.
- 22-23 April 01 The first successful unmanned trans-Pacific flight is made by the Northrop Grumman *Global Hawk* “Southern Cross II” from Edwards AFB, California, to RAAF Edinburgh, Australia.

APPENDIX C

Records Current as of 05 March 2012⁶⁸

Fastest: D-21 (Mach 4)—USA

Highest: Helios (96,500 ft)—USA

Biggest (size): Helios (246-ft wingspan)—USA

Biggest (weight): RQ-4 Global Hawk (25,600 lbs)—USA

Smallest (size/weight): Black Widow (6-inch diameter/2.0 oz)—USA

Longest flight (duration): Heron UAV (52 hours)—Israel

Longest flight (distance): RQ-4 Global Hawk (8,580 miles) - USA

Most expensive: RQ-4 Global Hawk (\$40 million)—USA

First Trans-Atlantic flight: Aerosonde (Aug. 20-21, 1998)—USA

First Trans-Pacific flight: RQ-4 Global Hawk (Apr. 22-23, 2001)—USA

APPENDIX D

Chart of UAS Groups⁶⁹

UAS Category	Maximum Gross Takeoff Weight (lbs)	Normal Operating Altitude (ft)	Speed (KIAS)	Current/Future Representative UAS
Group 1	0-20	< 1,200 AGL	100 kts	WASP III, Future Combat System Class I, TACMAV RQ-14A/B, BUSTER, BATCAM, RQ-11B/C, FPASS, RQ-16A, Pointer, Aqua/Terra Puma
Group 2	21-55	< 3,500 AGL	< 250	Vehicle Craft Unmanned Aircraft System, ScanEagle, Silver Fox, Aerosonde
Group 3	< 1,320	< 18,000 MSL		RQ-7B, RQ-15, STUAS, XPV-1, XPV-2
Group 4	> 1,320		Any Airspeed	MQ-5B, MQ-8B, MQ-1A/B/C, A-160, MQ-8B
Group 5		> 18,000 MSL		MQ-9A, RQ-4, RQ-4N, Global Observer, N-UCAS

NOTE: THE ABOVE INFORMATION IS PROVIDED FOR COMPARISON AND BACKGROUND INFORMATION ONLY. THE FOCUS OF THIS PAPER IS THE RQ-7B “SHADOW” UAS, WHICH CAN BE FOUND UNDER GROUP 3.

APPENDIX E

RQ-7B Crew Member Responsibilities⁷⁰

1. UNMANNED AIRCRAFT COMMANDER (UAC) AND UNMANNED AIRCRAFT SYSTEM MISSION COMMANDER (UMC): The UAC/UMC is **overall responsible for the safe conduct of the mission**, to include:
 - a. Mission planning and **coordination with supported unit** and airspace controlling agencies.
 - b. Identify the primary and alternate missions.
 - c. Mission brief and de-brief. The crew will assist with preparing and briefing the sortie, but the UAC/UMC is overall responsible for the conduct for the brief and de-brief.
 - d. Pre-flight of all system components.
 - e. Air vehicle acceptance.
 - f. Review and sign the Risk Assessment Worksheet (RAW).
 - g. Ensure understanding of, and compliance with: local course rules, range restrictions, applicable SPINS, the ACO, and the ATO.
2. AIR VEHICLE OPERATOR (AVO): The AVO is responsible for the safe conduct of the flight and **navigation of the Air Vehicle (AV)**, to include:
 - a. Determine the Electronic Line of Sight (ELOS) and Minimum Safe Altitude (MSA).
 - b. Plan fuel requirements to include: JOKER, BINGO, and Time on Station.
 - c. Determine the flight profile to include inbound and outbound routing as well as **AV positioning while on station**. Factors that will be taken into account include: supported unit requests, MPO input, input from Intel, sun position, wind direction and velocity, picture quality, audible signature, Fire Support Coordination Measures (FSCMs), and range restrictions. The UAC/UMC has overall approval of flight profile.
 - d. Ensure understanding of, and compliance with: local course rules, range restrictions, applicable SPINS, the ACO, and the ATO.
 - e. With the assistance of the other crew members, plan and plot the following information on briefing charts and on the Ground Control Station (GCS) overlays: routes, return home point/route, all applicable Airspace Control Measures (ACMs) and range boundaries, threat locations, artillery positions, gun target lines, position of friendly and enemy forces.
 - f. Conduct preflight inspection of the AV and all system components.
3. MISSION PAYLOAD OPERATOR (MPO): The MPO crew position is responsible for the **operation of the AV payload** and assisting with AV navigation, to include:
 - a. Obtain mission requirements from S-2 and the UAC/UMC.
 - b. Provide input to the AVO's flight profile, to include the best altitude and positioning of orbit points to achieve the best product given the scenario and mission requirements.
 - c. Ensure accurate completion of all required checklists.
 - d. Assist the other crew members with preflight planning.

APPENDIX F

VMU Mission Essential Task List⁷¹

MCT	MET	OUTPUT STANDARD	CMMR CREWS
2.2.5.2	Conduct Air Reconnaissance	(2) Sorties with surge of (3) sorties (of (6) hours each for a daily maximum of 12/18 hours during contingency/ combat operations). Sorties are based on 85 NM range from primary Ground Data Terminal (GDT).	7
		Y/N: Able to provide real-time and/or near real-time battlespace information products (video).	
		Y/N: Able to communicate relevant reconnaissance information using line-of-sight (LOS) / beyond-line-of-site (BLOS) means.	
2.4.3	Analyze and Synthesize Information	Y/N: Able to generate precision coordinates near real-time from UAS sensor point-of-interest to support acceptable Circular Error of Probability (CEP) in order to meet weapons employment criteria.	7
		Y/N: Able to provide a Mission Report (MISREP) per sortie and associated imagery products.	
		Y/N: Able to provide Intelligence Summary (INTSUM) input	
3.2.7.2	Control Indirect Fires	(2) Sorties with surge of (3) sorties (of (6) hours each for a daily maximum of 12/18 hours during contingency/ combat operations). Sorties are based on 85 NM range from primary Ground Data Terminal (GDT).	4
		Y/N: Able to function as airborne supporting arms observer or spotter	
		Y/N: Able to conduct Call-For-Fire (CFF) and subsequent adjustments in Grid, Polar, and/or Shift-From-Known-Point format IAW MCWP 3-16.6	
3.2.7.3	Conduct Terminal Guidance Operations (TGO)	(2) Sorties with surge of up to (3) sorties (of (6) hours each for a daily maximum of 12/18 hours of operations).Sorties are based on 85 NM range from primary Ground Data Terminal (GDT).	7
		Y/N: Able to provide targeting information consisting of target elevation (meters or feet), description of target, and target location (Lat/Long, MGRS, or UTM coordinate format).	
		Y/N: Able to report targeting information to weapons release authority and/or airspace control agency.	
		Y/N: Able to provide limited mark during hours of darkness for strike package.	
		Y/N: Able to report effects of weapons employment on target.	
		Y/N: Able to maintain PID chain of custody from point of hostile action or intent until target is engaged IAW ROE.	
		Y/N: Able to provide real-time and/or near real-time battlespace information products (video).	
Table 1-1. CORE METL OUTPUT STANDARDS FOR VMU (From Chapter 1 of the UAS T&R, NAVMC 3500.34A)			

APPENDIX G

Characteristics of the RQ-7B “Shadow”⁷²

Basic Brigade Tactical Unmanned Aircraft System (TUAS) consists of:



Two Ground Control Stations with Ground Data Terminals



Two GCS Support Vehicles



Two Equipment Trailers with 10-Kilowatt Generators



One Air Vehicle Transport (AVT) with Hydraulic Launcher



One AVT Support Vehicle with Equipment Trailer

Four Aircraft with Payloads



Four One System Remote Video Terminals (OSRVTs)



One Portable Ground Control Station (PGCS)/One Portable Ground Data Terminal (PGDT)

Maintenance Section:



Maintenance Section Multifunctional (MSM) with Equipment Trailer



MSM Support Vehicle with Equipment Trailer

RQ-7 TUAS Features and Accomplishments

- Deployed in Operations New Dawn and Enduring Freedom
- More than 600,000 hours flown worldwide
- More than 100 systems delivered
- More than 115 systems under contract
- Worldwide performance based logistics support
- Automatic launch and recovery from small clearings
- Trainer embedded in GCS
- Emplace or displace in less than one hour
- Flexible design facilitates future enhancements
- In operational use by U.S. Army and Marine Corps

SHADOW RQ-7B SYSTEM



PROVIDING CRITICAL BATTLEFIELD INTELLIGENCE



AAI's One System[®] is the U.S. Army's premier ground control station (GCS), able to collect battlefield intelligence from mu
unmanned aircraft and deliver it to warfighters.

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AAI Corporation
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RSC_AAIReg@aai.textron.com

SHADOW TACTICAL UNMANNED AIRCRAFT SYSTEM



One System Ground Control Station

- Common systems integration, or CSI
- Command and control for various aircraft
- Modular software
- Based on commercial, off-the-shelf components
- Redundant hardware
- Embedded training
- Joint Variable Message Format/NATO format compatible



Air Vehicle Operator (AVO) Display

- Flight and situational awareness
- Full mission and payload planning
- Integrated automatic launch and landing
- Electronic pre-flight and aircraft status monitoring

Mission Payload Operator (MPO) Display

- Autosearch, point-at-coordinates, rate/position and autotrack
- Automated marking of searched areas
- Integration into any C4I system
- Artillery adjust-fire feature
- Laser designator control
- Searchable digital archive and retrieval system

Plug-In Optronic Payload (POP-300D)

- Electro-optic/infrared/laser designation, or EO/IR/LD
- Detect, recognize and identify moving and stationary vehicles
- Artillery adjustment feature
- Target autotrack feature
- Laser designator for laser-guided weapons
- Laser range finder and laser pointer



Shadow Hydraulic Launcher

- Hydraulic launcher mounts on standard HMMWV trailer
- Four 10-foot sections fold for transport
- One-man deployable in less than 10 minutes
- Launches in sustained 20-knot crosswinds

Shadow RQ-7B with Extended Wings

- Length 11.8 feet (ft.)
- Wingspan 20.4 ft.
- Maximum gross weight 460 pounds (lb.)
- Payload capacity 45-80 lb.*
- Data link range 125 kilometers (km)
- Single Channel Ground and Airborne Radio System or SINGARS; communications relay
- Maximum speed 110 knots
- Loiter speed 65 knots
- Cruise speed 90 knots
- Maximum altitude 15,000 ft. mean sea level, or MSL
- Endurance nine hours
- 38 brake horsepower, or bhp, engine with electronic fuel injection upgrade
- More than 85 percent composite material

*depending on mission profile and payload options

Tactical Automatic Landing System (TALS)

- Inclement weather and day/night performance
- Meets U.S. Army field requirements for automatic recovery, mobility and two-person transportability
- System components:
 - Portable ground tracking subsystem
 - Small airborne transponder
- Recovery in sustained 20-knot crosswinds



Shadow TUAS Arrested Landing



APPENDIX H
UAS of VMU⁷³

RQ-7B Shadow
(The focus UAS of this paper)



ScanEagle



K-Max



APPENDIX I

USAF Predator and Reaper⁷⁴

MQ-1 Predator



MQ-9 Reaper



APPENDIX J

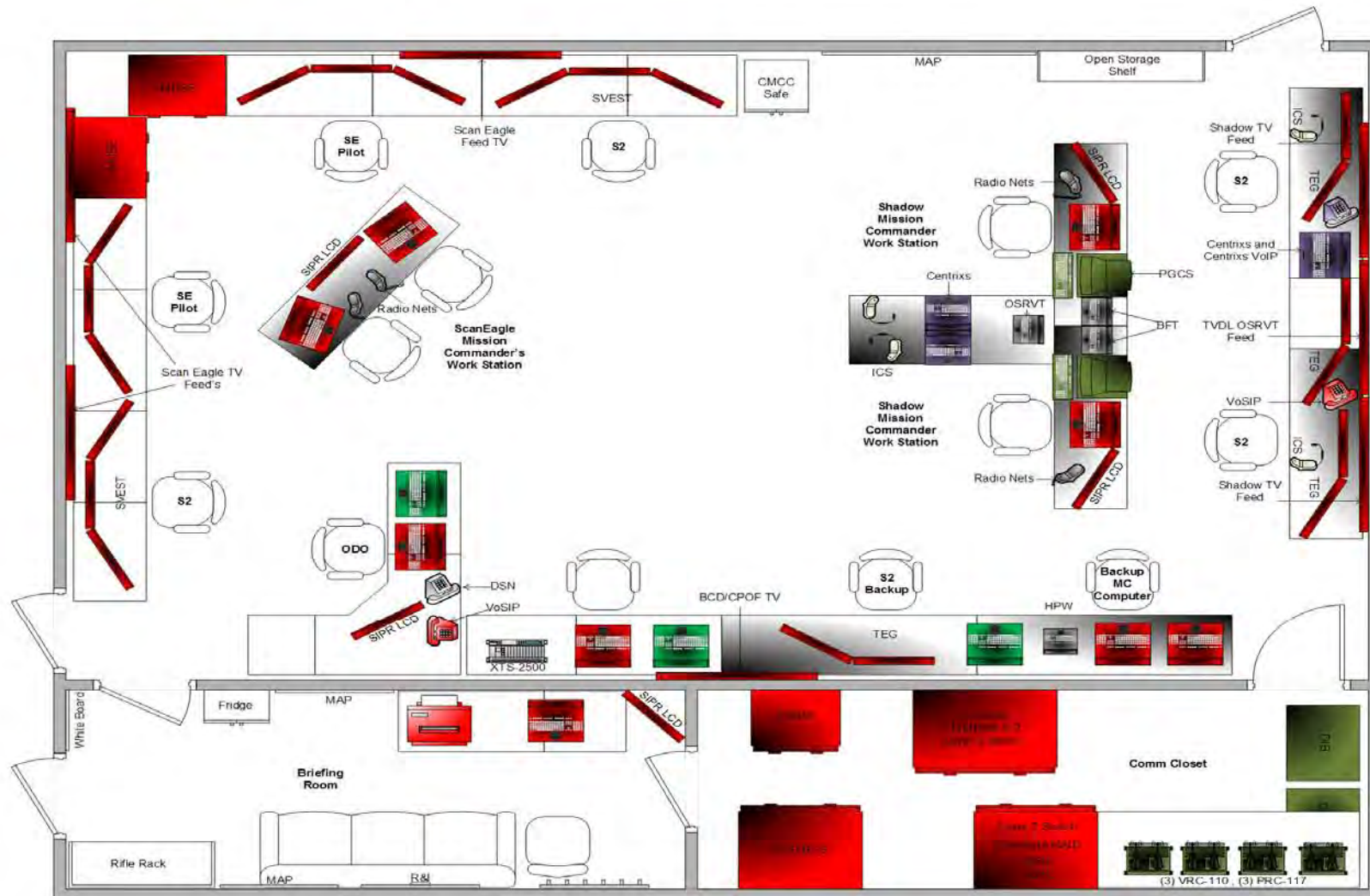
POP-300LD⁷⁵



- Diode Pumped Laser
- Can designate for Hellfire, JCM, Laser Maverick, Copperhead, and other NATO munitions
- Designation to 3.5 Km slant range (90% energy on Target)
- Integrated Laser Range Finder, decreases TLE to 20m (goal)
- PRF and PIM code compatible

APPENDIX K

VMU COC Diagram⁷⁶



BIBLIOGRAPHY

All email correspondence, as well as author's notes from phone and personal interviews, are in the author's possession. All unpublished papers can be located at the General Alfred M. Gray Marine Corps Research Center aboard Marine Corps Base Quantico, Virginia.

PRIMARY SOURCES

- Commandant of the Marine Corps, General James T. Conway, *Marine Corps Vision and Strategy 2025*. Washington, D.C.: Headquarters United States Marine Corps, 2008.
http://www.onr.navy.mil/~media/Files/About%20ONR/usmc_vision_strategy_2025_0809.aspx (accessed October 28, 2011).
- Beach, George, LtCol USMC, telephone conversations and emails with author, October 2011 – March 2012.
- Fenton, Dale, Capt USMC, interview and emails with author, October 2011 – March 2012.
- Gates, Robert, US Secretary of Defense. "2010 Quadrennial Defense Review."
<http://www.defense.gov/qdr/> (accessed November 12, 2011).
- Green, Lawrence B., Maj USMC, telephone conversations and emails with author, October 2011 – March 2012.
- Hendricks, William, Maj USMC, telephone conversations and emails with author, October 2011 – March 2012.
- Huber, Mikel, LtCol USMC, interview and emails with author, October 2011 – March 2012.
- Lathrop, Dan, Col USMC, telephone conversations and emails with author, October 2011 – March 2012.
- Office of the Under Secretary Of Defense (Comptroller) / CFO, "United States Department of Defense Fiscal Year 2012 Budget Request: Program Acquisition Costs By Weapon System."
http://comptroller.defense.gov/defbudget/fy2012/FY2012_Weapons.pdf (accessed February 08, 2012).
- Trautman, George J. Ill., "FY2011 Marine Aviation Plan."
http://www.aviationweek.com/media/pdf/Check6/FY11MarineAviationPlan.pdf?bcsi_scan_6D1A198076EBD3B6=0&bcsi_scan_filename=FY11MarineAviationPlan.pdf (accessed October 28, 2011).

U.S. Army UAS Center of Excellence, "U.S. Army Roadmap for Unmanned Aircraft Systems (UAS) 2010-2035."
http://www.aviationweek.com/media/pdf/UnmannedHorizons/US%20Army%20UAS%20RoadMap%202010%202035.pdf?bcsi_scan_E804B318397B4D5A=0&bcsi_scan_filename=US%20Army%20UAS%20RoadMap%202010%202035.pdf (accessed January 18, 2012).

SECONDARY SOURCES

Borin, Elliot. Better Bombing Through Technology. March 2004,
<http://www.wired.com/science/discoveries/news/2004/03/62704> (accessed November 12, 2011).

Callicoatt, J.D., "Needless Incentives For Unmanned Aerial System Controllers." Unpublished paper, Marine Corps University, 2009.

Chapman, Col Robert E. II, USAF, "Unmanned Combat Aerial Vehicles, Dawn of a New Age?" *Aerospace Power Journal*, Summer 2002.
<http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/sum02/chapman.html> (accessed November 12, 2011).

Defense Industry Daily, "Arming RQ-7 UAVs: The Shadow Knows..."
<http://www.defenseindustrydaily.com/Mortars-from-Aircraft-The-Shadow-Knows-05226/> (accessed February 08, 2012).

Defense Industry Daily, "Laser Designators for RQ-7 Shadow UAVs."
<http://www.defenseindustrydaily.com/Laser-Designators-for-RQ-7-Shadow-UAVs-05260/> (accessed February 08, 2012).

Goebel, Greg, "US Unmanned Aerial Vehicles" Version 2.0.0 Updated 01 February, 2012
<http://www.vectorsite.net/twuav.html> (accessed March 05, 2012).

Gosik, Geoffrey Z. "USMC Electronic Warfare 2025: Trading Expertise for Advanced Technology." Masters of Military Studies Thesis, Marine Corps University, 2010.

Hough, Ryan J., "It's MUG Time: The VMU community lacks a senior advocate who can harness the ever-growing capabilities of unmanned systems to support the future MAGTF ." <http://www.mca-marines.org/gazette/article/it%E2%80%99s-mug-time> (accessed January 18 2012).

Krock, Lexi, "Timeline of UAVs." <http://www.pbs.org/wgbh/nova/spiesfly/uavs.html> (accessed 05 March, 2012).

Sears, Stephen, W. *Chancellorsville*. Boston: Houghton-Mifflin, 1996.

- Singer, P.W., “In the Loop? Armed Robots and the Future of War.”
<http://www.defenseindustrydaily.com/In-the-Loop-Armed-Robots-and-the-Future-of-War-05267/> (accessed February 08, 2012).
- Stout, LtCol Jay, USMC (Ret), “Close Air Support Using Armed UAVs?” *Proceedings*, July 2005. http://www.military.com/NewContent/0,13190,NI_0705_Air-P1,00.html (accessed October 28, 2011).
- Tufvesson, Seth E., Capt USMC, emails with author, 23 Jan 2012.
- U.S. Centennial of Flight Commission, “Joseph Michael and Jacques Étienne Montgolfier”
<http://www.centennialofflight.gov/essay/Dictionary/Montgolfier/DI35.htm> (accessed January 20, 2012).
- Warwick, Graham, “Shadow Punches Above its Weight.”
<http://www.aviationweek.com/aw/blogs/defense/index.jsp?plckController=Blog&plckBlogPage=BlogViewPost&newspaperUserId=27ec4a53-dcc8-42d0-bd3a-01329aef79a7&plckPostId=Blog%3a27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post%3a8e57cb19-ae90-4a9e-8708-092a825d9330&plckScript=blogScript&plckElementId=blogDest> (accessed February 08, 2012).
- Watner, Gary Y. “Unmanned Aerial Vehicles: Where Are They Going and Where Do They Belong.” Masters of Military Studies Thesis, Marine Corps University, 1995.
- Wirth, Justin R., “Unmanned Aircraft System Procurement: Inter-Service Unity of Effort Still Lacking.” Unpublished paper, Expeditionary Warfare School, 2011.

ENDNOTES

-
- ¹ “U.S. Centennial of Flight Commission, *Joseph Michael and Jacques Étienne Montgolfier* <http://www.centennialofflight.gov/essay/Dictionary/Montgolfier/DI35.htm> (accessed January 20, 2012).
- ² Stephen W. Sears, *Chancellorsville* (Boston: Houghton-Mifflin, 1996), 69
- ³ Kendra L. B. Cook, “The Silent Force Multiplier: The History and Role of UAVs in Warfare” <http://www.mendeley.com/research/silent-force-multiplier-history-role-uavs-warfare/#> (accessed November 12, 2011).
- ⁴ The other side, “World War 2: German "vengeance weapons" - V1, V2 and V3” <http://www.theotherside.co.uk/tm-heritage/background/v1v2.htm> (accessed January 20, 2012).
- ⁵ World War 2: German "vengeance weapons"
- ⁶ World War 2: German "vengeance weapons"
- ⁷ Radio Shack, “A Guide to the Global Positioning System (GPS): GPS Timeline”, http://support.radioshack.com/support_tutorials/gps/gps_tmline.htm (accessed February 15, 2012).
- ⁸ United States Marine Corps, “2nd Marine Aircraft Wing”, <http://www.marines.mil/unit/2ndMAW/macg28/vmu2/Pages/history.aspx> (accessed January 03, 2012).
- ⁹ Maj Lawrence B. Green, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ¹⁰ Maj Lawrence B. Green, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ¹¹ Ryan Hough, “It’s MUG Time: The VMU community lacks a senior advocate who can harness the ever-growing capabilities of unmanned systems to support the future MAGTF” <http://www.mca-marines.org/gazette/article/it%E2%80%99s-mug-time> (accessed January 18, 2012).
- ¹² United States Marine Corps, “VMU-2”, <http://www.marines.mil/unit/2ndMAW/macg28/vmu2/Pages/history.aspx> (accessed February 15, 2012).
- ¹³ Naval Air Systems Command, “Small Tactical Unmanned Aircraft System” <http://www.navair.navy.mil/index.cfm?fuseaction=home.display&key=4043B5FA-7056-4A3A-B038-C60B21641288> (accessed November 12, 2011).
- ¹⁴ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ¹⁵ VMU-2 SOP.
- ¹⁶ Capt Seth E Tufvesson, USMC, emails with author, 23 Jan 2012.
- ¹⁷ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ¹⁸ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ¹⁹ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ²⁰ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ²¹ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ²² Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ²³ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ²⁴ Lt Col George Beach, USMC, telephone conversations and emails with author, October 2011 – March 2012.

-
- ²⁵ Lt Col George Beach, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ²⁶ Maj Lawrence B. Green, telephone conversations and emails with author, October 2011 – March 2012.
- ²⁷ Maj Lawrence B. Green, telephone conversations and emails with author, October 2011 – March 2012.
- ²⁸ Cooney, Michael, “Air Force: More unmanned aircraft than manned in 2009” <http://www.networkworld.com/community/node/37275> (accessed March 05, 2012).
- ²⁹ Department of Defense, “Department of Defense Dictionary of Military and Associated Terms”, http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf (accessed December 02, 2011)
- ³⁰ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ³¹ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ³² Maj Hendricks, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ³³ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ³⁴ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ³⁵ Col Dan Lathrop, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ³⁶ Col Dan Lathrop, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ³⁷ Col Dan Lathrop, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ³⁸ Maj Lawrence B. Green, telephone conversations and emails with author, October 2011 – March 2012.
- ³⁹ Col Dan Lathrop, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ⁴⁰ McAndrews, Laura, “Flight simulators help AMC to 'maximize value, minimize waste'.” <http://www.af.mil/news/story.asp?id=123172892> (accessed February 15, 2012).
- ⁴¹ AAI Corporation, “Shadow® Tactical Unmanned Aircraft Systems (TUAS)” http://www.aaicorp.com/products/uas/shadow_family.html (accessed November 16, 2011).
- ⁴² AAI Corporation, “Shadow® Tactical Unmanned Aircraft Systems (TUAS)” http://www.aaicorp.com/products/uas/shadow_family.html (accessed November 16, 2011).
- ⁴³ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ⁴⁴ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ⁴⁵ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ⁴⁶ Alan Murray, “How to Change Your Organization’s Culture.” <http://guides.wsj.com/management/innovation/how-to-change-your-organizations-culture/> (accessed November 21, 2011).
- ⁴⁷ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ⁴⁸ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ⁴⁹ Maj Hendricks, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ⁵⁰ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ⁵¹ Maj Lawrence B. Green, telephone conversations and emails with author, October 2011 – March 2012.

-
- ⁵² Maj Hendricks, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ⁵³ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ⁵⁴ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ⁵⁵ Lt Col George Beach, USMC, and Maj Lawrence B. Green, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ⁵⁶ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ⁵⁷ Unmanned Aerial Vehicle Operator's (Mos 7314) Enlisted Unmanned Aircraft Commander (E-UAC) Military On-The-Job Training (MOJT) Syllabus.
- ⁵⁸ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ⁵⁹ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ⁶⁰ VMU-3 Fiscal Year 2012 Table of Organization (T/O).
- ⁶¹ Lt Col George Beach, USMC, telephone conversations and emails with author, October 2011 – March 2012.
- ⁶² <http://www.marines.mil/unit/aviation/madpax/Documents/NEWSLETTER/20090429%20MADNewsletterFINAL.pdf>
- ⁶³ LtCol Mikel Huber, USMC, interview and emails with author, October 2011 – March 2012.
- ⁶⁴ VMU-3 Fiscal Year 2012 Table of Organization (T/O).
- ⁶⁵ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ⁶⁶ Capt Dale Fenton, USMC, interview and emails with author, October 2011 – March 2012.
- ⁶⁷ UAV Forum, "UA Timeline" http://www.uavforum.org/ua_timeline.asp (accessed March 13, 2012).
- ⁶⁸ NOVA, "Time Line of UAVs" <http://www.pbs.org/wgbh/nova/spiesfly/uavs.html> (accessed 05 March 2012).
- ⁶⁹ NTTP 3-22.3 VMU pg A-1.
- ⁷⁰ VMU-2 SOP.
- ⁷¹ VMU-2 SOP.
- ⁷² AAi Corporation, <http://www.aaicorp.com/pdfs/Shadow%20TriFold.pdf> (accessed March 12, 2012)
- ⁷³ k-max picture: <http://shamazkhan.files.wordpress.com/2010/12/kmax.jpg> (accessed January 03, 2012).
- ScanEagle: <http://www.defence.pk/forums/military-aviation/47585-us-supply-scanegle-pakistan.html> (accessed January 03, 2012).
- Shadow: http://bemil.chosun.com/nbrd/bbs/view.html?b_bbs_id=10066&pn=0&num=221 (accessed January 03, 2012).
- ⁷⁴ Predator: <http://deepbluehorizon.blogspot.com/2010/07/predator-mq-1b-crashes-at-cannon-afb.html> (accessed January 03, 2012).
- Reaper: <http://air-attack.com/images/single/618/A-fully-armed-MQ-9-Reaper-taxis-down-an-Afghanistan-runway.html> (accessed January 03, 2012).
- ⁷⁵ MACG-28 VMU-2 PME Brief.
- ⁷⁶ VMU-2 SOP.