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14. ABSTRACT
The evolution of unmanned aircraft systems (UAS) illustrate the reciprocal relationship between ideas and technology in military innovation. Medium altitude-long endurance (MALE) UAS, in particular, have the potential to be both a key enabler and a driver of future operating concepts. Based on this premise, the Marine Corps can develop two critical aspects of unmanned aircraft operations by immediately fielding an existing MALE UAS. First, existing MALE systems have the potential to meet short and mid-range operational shortfalls in the fires, intelligence, and command and control warfighting functions. Second, the Marine Corps can simultaneously gain the experience required to develop employment concepts, influence the advancement of future systems, and refine the support structure required to realize the manifest potential of UAS. The Marine Corps has an opportunity to meet current operational requirements, develop the manifest potential of unmanned systems to enable future operating concepts, and accelerate the development timeline by immediately fielding an existing MALE UAS.

15. SUBJECT TERMS
unmanned aircraft systems, UAS, medium altitude-long endurance, MALE, MQ-9 Reaper

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FUTURE WAR PAPER

The Future is Already Here: Medium Altitude-Long Endurance Unmanned Aircraft Systems in the Marine Air-Ground Task Force

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

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AY 2015-2016

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> The history of military revolutions suggests that the winner of the robotics revolution will not be who develops this technology first or even who has the best technology, but who figures out how best to use it.
>
> –Paul Scharre, Center for New American Security, 2014[1]

Technology and ideas have a reciprocal relationship. Ideas drive the development and employment of new technological means. Technological means, in turn, influence ideas by creating new possibilities. The evolution of unmanned aircraft systems (UAS) in recent decades illustrates these principles, just as the development of tanks and manned airplanes did in the twentieth century. Further, the pace of advancement makes it reasonable to conclude that unmanned aircraft will become primary platforms for many of the missions currently performed by manned aircraft in the near future. The competitor who develops new ideas to leverage the technology will gain decisive advantages on future battlefields.

Medium altitude-long endurance (MALE) UAS, in particular, have the potential to be a key enabler for current and future Marine Corps operating concepts. Existing MALE systems have the potential to meet short and mid-range shortfalls in the fires, intelligence, and command and control warfighting functions.[2] The service can simultaneously gain the experience required to develop new employment concepts, influence the advancement of future systems, and refine support structure requirements. The Marine Corps has an opportunity to meet current operational requirements, develop the manifest potential of unmanned systems to enable future operating concepts, and accelerate the development timeline by fielding an existing MALE UAS.

TERMINOLOGY AND PARAMETERS

Conversations about UAS can be confusing because the terminology varies in military and civilian circles. The term "unmanned aircraft system" is used here to describe a remotely piloted aircraft and the associated human operators, payload, control system, and support structure.[3] Joint doctrine divides UAS into five "groups" based on multiple factors, to include weight, operating altitude, and speed (see Appendix B). The label "medium altitude-long endurance" is used to describe multi-role aircraft capable of operating at long ranges for extended periods with heavy payloads. In the current US inventory, the MQ-9 Reaper most closely represents the type of long range, long endurance, weaponized UAS suitable for Marine Corps future operating concepts. Therefore, the performance metrics of the MQ-9 are used as a baseline for assessing the potential of MALE UAS.[4]

To be clear, no single manned or unmanned aircraft can provide all of the capabilities required for military operations. The Marine Corps will need a balanced family of UAS (FoUAS) for the future. With this in mind, three basic questions are addressed to examine the potential of MALE UAS to be a key component of Marine Corps aviation. First, what roles can MALE UAS play in meeting short and mid-range operational requirements? Second, why should the Marine Corps develop an organic MALE UAS capability? Finally, what are the implications of developing an organic MALE UAS capability? The answers to these questions illuminate the opportunities and risks unmanned aircraft present in the near future.

Characteristics	Platform Details
Tasks	ISR; CAS; AI; SCAR; PR; SA; SEAD; aviation operations in maritime surface warfare
Wingspan	66 feet
Length	36 feet
Cruise Speed	230 knots true airspeed
Loiter Speed	150–175 knots true airspeed
Maximum Speed	249 knots true airspeed
Endurance	17 hours (clean)/14 hours (armed)
Service Ceiling	Up to 40,000 feet
Maximum Range	Up to 1,400 nautical miles
Crew	2: pilot and sensor operator
Control Data link	Ku satellite communications, line of sight, direct line of sight
Tactical Data link	Link 16, situational awareness data link, blue force tracking
Aircraft Communications	1 x ultrahigh frequency/very high frequency (HAVEQUICK II, KY-100), Quickdraw II, remote video terminal (digital and analog)
Sensors	AN/DAS-1 multi-spectral targeting system: electro-optical, infrared, low-light level television, laser range detector, and infrared marker, Lynx synthetic aperture radar and ground moving target indicator, and signals intelligence
Armament	4 AGM-114 and 2 GBU-12 or GBU-38; 4 GBU-12 or GBU-38
Launch	Runway (aircrew controlled)
Recovery	Runway (aircrew controlled)

Figure 1: MQ-9 Reaper Summary Sheet

SHORT AND MID-TERM OPERATIONAL REQUIREMENTS

With these definitions in mind, it is possible to explore the first question presented above: what roles can existing MALE UAS play in meeting short and mid-range operational requirements? After-action reports and universal needs statements from the last five years have repeatedly identified the need for a multi-role MALE platform to provide lethal and non-lethal fires, conduct reconnaissance, surveillance and target acquisition (RSTA) activities, and enhance C2 functions.[5] These capabilities align with service-level and joint operating concepts that envision distributed or disaggregated units employing the full spectrum of joint resources to conduct forced entry and sustained operations in defended environments.[6] The reality of operating in anti-access/area-denial (A2/AD) environments with high-capability, but low-density ships and inadequate ship-to-shore connectors means that the Marine Corps will remain heavily reliant on aviation assets to project and support forces.

A number of capability shortfalls can be predicted against this background. The following section highlights capability gaps in the fires, command and control (C2), and intelligence warfighting functions. The potential of MALE UAS to mitigate these shortfalls is discussed in each case.

The Marine Corps has limited ability to provide lethal and non-lethal fires to widely distributed forces operating at extended ranges in A2/AD environments. Manned fixed and rotary-wing aircraft are limited by some combination of range, speed, time-on-station, payload options, or refueling requirements. Additionally, risk tolerance for manned aircraft becomes an increasingly important consideration in modern environments where anti-air threats can never be completely eliminated. Further, only the F-35 will have the ability to connect forward elements to the electronic warfare (EW) and cyber activities that future joint and service concepts prescribe. The Marine Corps' current FoUAS, including the recently fielded MQ-21, are more severely limited with operating radii less than 50 nautical miles and restricted payload options. Taken together, these shortfalls undercut the potential range and speed advantages created by the MV-22 Osprey.[7]

A MALE UAS could mitigate these fires shortfalls by providing lethal and non-lethal fire support options during long-range movements and persistent coverage in forward operating areas. With a 1400 nautical mile operating radius, air speeds up to 249 knots, and modular kinetic, EW, and ISR payloads, current MQ-9 Reaper models provide a better match for the MV-22 Osprey than any asset currently in the Marine Corps inventory.[8] More importantly, current MQ-9 Reaper models can provide far greater time-on-station at the objective, approximately 10-15 hours at a distance of 500-1,000 nautical miles.[9] This persistent presence would allow the Marine Corps to provide immediate targeting and fire support to forward units, in addition to connecting them to joint force resources.

The second warfighting function under discussion, command and control, is equally problematic. Distributed mini-MAGTFs will require access to voice and data systems to access resources and coordinate operations. Expeditionary Force-21 (EF-21) anticipates a minimum range of 65 nautical miles for terrestrial communications systems, and cites the need for amplification, retransmission, or relay over unlimited distances.[10] Operating in littoral mega-cities will exacerbate these C2 challenges. The service currently lacks organic airborne assets with the functionality, range, or loiter time to complement ground based voice and data systems.

MALE UAS can contribute to the C2 capabilities required to operate over extended distances by providing air-to-air and air-to-ground digital or voice communications. Extended on-station time creates new possibilities to support forces in urban environments by employing

UAS as "tactical satellites."[11] Access to digital networks creates opportunities for digital interoperability between ground and air elements using existing network systems, a capability that the Marine Corps has yet to develop on a wide scale.[12] The extended range, loiter time, and communications payload options of MALE UAS could significantly enhance the Marine Corps' ability to command and control deployed forces.

The Marine Corps also lacks the resources to conduct persistent intelligence, surveillance, and reconnaissance (ISR) activities to support distributed or disaggregated MAGTFs in expeditionary environments. The current FoUAS lack the range required to reach the objective area at the distances predicted for future operations. While the F-35 and modular pods on legacy aircraft do provide significant capabilities, they have limited time-on-station available after transiting to distant objective areas. These ISR shortfalls exacerbate the fire support and C2 issues previously noted.

MALE UAS can carry a virtually unlimited array of ISR payloads.[13] While these payload sets are partially available on smaller UAS platforms (Groups 1-3), only MALE aircraft have the range, time-on-station, and payload capacity to service forces operating in the distant expeditionary environments described by service literature. The communications suites currently available for MALE UAS also create opportunities to "flatten" the dissemination process by transmitting relevant information products simultaneously to the supported ground units for tactical awareness and higher-level organizations for intelligence processing.

Future operating concepts also raise concerns over the capacity of manned aircraft fleets. The US military has become reliant on air support and many future concepts are built on the idea of hyper-enabling small units with air assets. The proliferation of advanced anti-ship and anti-air weapons suggests the United States can no longer assume air supremacy in expeditionary environments. In short, the Marine Corps should prepare for the reality of losing aircraft, both manned and unmanned, in future conflicts. This reality creates the potential for a conflict between providing continuous support to forward deployed ground forces and risking a finite number of pilots and highly capable, but extremely expensive manned aircraft. The Marine Corps must find a way to generate the capacity for future operations.[14]

WHY DEVELOP ORGANIC MALE UAS

With the utility of MALE UAS for the Marine Corps established, the question remains, why should the Marine Corps develop an organic MALE UAS capability rather than relying on the joint community? There are two basic reasons.

First, the US Air Force (USAF) remotely piloted aircraft (RPA) fleet does not have the capacity to provide support during sustained regular force operations.[15] The national intelligence enterprise and special operations forces will remain the top priorities for the USAF's RPA fleet. Recent Special Purpose-MAGTF (SP-MAGTF) and Marine Expeditionary Unit (MEU) after-action reports and universal needs statements (UNS) testify to this reality.[16] The US Army's (USA) MQ-1C Gray Eagle program reinforces the Marine Corps' experience. The Gray Eagle is the latest in a succession of armed UAS platforms developed to compensate for shortfalls in USAF RPA coverage.[17] Although the USAF RPA fleet continues to expand, there are significant organizational and infrastructure challenges that will continue to limit the force.[18]

Second, each service's operational focus drives its employment concepts and the associated manpower, organizational, and C2 models. In other words, the same factors that influenced each service to develop unique employment concepts for manned aircraft apply to unmanned aircraft.[19] Additionally, proficiency in combat requires training. The current operational tempo and prioritization of USAF RPA assets preclude pre-deployment training. If the Marine Corps intends to leverage MALE UAS as a key enabler, it will require the development of organic assets attuned to the service's needs.

The Marine Corps has accepted this position, at least on paper. The 2015 Marine Aviation Plan calls for the development of the MQ-X, a multi-mission MALE platform that is shipboard compatible, to support Marine Expeditionary Forces (MEF), Marine Expeditionary Brigades (MEB), MEUs and SP-MAGTFs.[20] MQ-X development is linked to ongoing Defense Advanced Research Projects Agency (DARPA) and Office of Naval Research (ONR) projects to develop a shipboard compatible platform.[21] The initial operating capability for the MQ-X is planned for 2026, with full operational capability projected for 2029. The status of DARPA and ONR shipboard UAS projects, combined with the Marine Corps' lack of experience to base MALE UAS requirements documents on, make these projections unrealistic.[22]

The integration of a land-based MALE UAS into a naval service provides an interesting comparison to the MQ-X development plan. Current MALE UAS cannot launch or recover from naval shipping, but this does not mean the platforms are unsuitable for the Marine Corps. Organic Marine aviation operations rely on land-based KC-130J support for refueling and logistic requirements. MALE UAS are capable of utilizing the same air facilities. Further, existing modular ground control stations (GCS) have the potential for shipboard use. This "systems approach" to UAS blurs the meaning of naval-based aircraft.

Land based UAS could have the secondary benefit of mitigating the dearth of amphibious shipping by reducing the need for onboard cargo space. The US Navy (USN) has already embraced this concept; the Broad Area Maritime Surveillance (BAMS) UAS program employs a land-based Global Hawk UAS for worldwide operations.[23] Considering the fact that existing

UAS that *are* shipboard compatible do not have the range to reach forecasted objective areas, a land-based, ship-controlled UAS seems to be the most practical option for the foreseeable future.

IMPLICATIONS OF DEVELOPING ORGANIC MALE UAS

If the Marine Corps decides to develop an organic MALE UAS capability, what are the implications for the current force? As the name implies, unmanned aircraft systems require human operators, command and control systems, and supporting infrastructure to enable the actual platform. The answers to this question are organized around the subjects of doctrine, organization, training, personnel, and materiel.

Doctrine

A liberal definition of the term "doctrine" is used here to describe current institutional thinking on what aviation functions UAS can perform and the accepted tactics, techniques, and procedures (TTP) for UAS operations. Official aviation doctrine for UAS operations is inconsistent. MCWP 3-2 *Aviation Operations* describes a limited role for UAS, primarily in the air reconnaissance function. MCWP 3-42.1 *UAS Operations* and the 2015 USMC Aviation Plan recognize an expanded role for UAS in five of the six aviation functions.[24] The current FoUAS can only partially fulfill the expanding mission, however, because the platforms are not weaponized and lack sufficient range and loiter time. Fundamentally, the Marine Corps should begin to think of UAS as a **primary** platform for air reconnaissance (AR), OAS, EW, Antiair Warfare (AAW) and possibly Control of Aircraft and Missiles (CAM).[25]

At a more practical level, existing joint and service-level command and control doctrine is generally suitable for expanding the role of MALE UAS. The employment of MALE UAS in OAS, EW, and AR roles over the last two decades has validated the basic TTPs of UAS operations. Refinements will be required, however, to maximize the potential of UAS in the OAS, EW, CAM, and AAW functions.

The evolving concept of manned-unmanned-teaming (MUM-T) is integral to developing the potential of UAS to support these functions. While the details are beyond the scope of this work, the following MUM-T concepts highlight the potential of MALE UAS:

- Economy of Force: MALE UAS provide persistent fires, C2, and ISR support to dispersed forward units so that more capable manned aircraft can be conserved and employed where most needed. While UAS will not replace manned aircraft, gaining efficiency in "when" and "why" manned aircraft fly will preserve the fleet.

- Distributed STOVL Operations: MALE UAS could provide fires, intelligence, and C2 functions to support the enabling ground units operating in forward areas. Additionally, modular payloads could complement the capabilities of manned aircraft. UAS could self-deploy or use the same expeditionary air facilities as the FW assets they support.

- Tactical Satellite: The long endurance and modular communications payloads for MALE UAS could be used to provide radio and data links to ground, air, and command elements. Employing UAS in this way could decrease the requirement for land-based communications systems in forward areas, connect widely distributed ground forces, and provide digital interoperability between ground and aviation units.

- Counter-UAS: The commercial market has made small UAS almost universally available. Recent experiences in the Ukraine, Syria, and Iraq have demonstrated that these commercial platforms can be weaponized and used to great effect. To date, the US military has not developed TTPs to counter this growing threat. MALE UAS can be part of the solution to this challenge by providing the detection or weapons capabilities for defensive systems.

New thinking on "what" UAS can do necessitates refinements in "how" unmanned systems are tasked. Would MALE platforms be tasked as ISR assets with a secondary strike capability, or will they be tasked primarily as an EW, OAS, AAW, or communications platforms? The answer obviously lies somewhere in between, but the Marine Corps must learn how to merge unmanned and manned aircraft employment concepts to leverage the capabilities of MALE UAS. USAF, USA, and Special Operations Command (SOCOM) experiences can contribute to the conversation, but differences in service philosophies and employment concepts mean the Marine Corps will have to develop its own approach.

Increasing the scale and scope of UAS operations would also increase the amount of raw sensor data collected. All four elements of the MAGTF would have to work together to develop a methodology for information processing. The current USAF model is based on "reach-back" to Air Force and interagency personnel in the United States.[26] While appealing in a general sense, the resources required to make this model work on an expanded scale for conventional operations may be impracticable. The Marine Corps would have to refine methods to link the UAS fleet, the Marine Corps Intelligence, Surveillance, and Reconnaissance Enterprise (MCISRE), and tactical users.

Procedures for airspace control would also need to be refined to accommodate greater numbers of UAS flying at medium and high altitudes. Airspace control measures (ACMs) commonly used to control UAS, such as restricted operations zones (ROZs), may not be feasible if multiple UAS and manned aircraft are working in the same airspace. Additionally, existing procedures for "lost-link" and "see and avoid" scenarios will need to be enhanced. The experience gained by the joint and international aviation community in recent years can serve as a starting point.

Finally, the Marine Corps would need to refine TTPs for operating unmanned aircraft in environments where integrated air defense systems (IADS) exist. In future expeditionary environments it may not be possible or desirable to hold UAS outside an objective area until IADS have been defeated. UAS can contribute to defeating IADS and creating gaps for exploitation. One of the anticipated benefits of expanding unmanned operations is a reduction in the human and financial cost for lost aircraft. Still, TTPs to overcome jamming, electromagnetic, and kinetic anti-air weapons must be developed to make manned and unmanned aircraft teams survivable on modern battlefields.

Organization

The current Marine Corps organizational construct works for MALE UAS. The command and control, intelligence, and logistics backbone of the ACE would be essential for developing a MALE platform in the near term. Moving MALE UAS to the GCE, following the USA model for its organic MQ-1C Gray Eagle, would add unnecessary layers of C2 and redundancies in manpower. The co-location of the Marine Unmanned Aerial Vehicle Squadrons (VMU) with existing Marine Air Wing (MAW) infrastructure is the most practical option for expanding unmanned operations.

In the short term, the Marine Corps could field a MQ-9 Reaper detachment to Marine Operational Test and Evaluation Squadron 22 (VMX-22) to begin harvesting lessons from the joint community and experiment with service-specific employment and support concepts. Alternatively, an existing VMU could be converted into an experimental squadron. VMU-1, soon to relocate to Marine Corps Air Station Yuma, could fill this role. Regardless of the base unit, immediate research and experimentation is necessary to develop employment concepts and inform the MQ-X develop program.

Looking into the future, what should a MALE UAS unit look like and how many should there be? Leaders in the Marine Corps UAS community have already estimated the manpower and equipment requirements for MALE UAS based on current joint and international models.[27] Until the employment concepts have been developed and validated, however, the answer is unknowable. On the other hand, it is probable that the number of VMUs will increase to levels equivalent to manned aircraft squadrons in the future.

Training and Education

Educating and training the total force is a challenge whenever a new asset is fielded. This is certainly true for UAS. Although multi-role unmanned aircraft have been extensively employed by the joint community in recent decades, that experience has generally been limited to the intelligence, aviation, and special forces communities. Bringing MALE UAS into the Marine Corps main stream would require both education and training.

In the technical fields, enhanced EW and cyber operations training would be necessary. EW and cyber training pipelines already exist, but limited access to these programs has created niche communities. The expanded role of UAS and ground nodes in the evolving MAGTF-EW concept means that a broader audience will be capable of accessing EW capabilities. This "systems" approach will create both a challenge and an opportunity to educate and train the force to employ EW capabilities.[28]

Experimentation provides another method to train and educate the force. Fortunately, this initiative is already underway through the Futures Directorate (Warfighting Lab). MALE UAS could also be integrated into existing service-level exercises to increase exposure. Although contracted or joint aircraft may be required in the short term, exposing the platform to these communities will move the idea from the "slide show" to the real world where challenges and opportunities can be identified.[29]

Two additional steps within the aviation community could support the integration process. MALE UAS could support Joint Terminal Attack Controller (JTAC) courses. Supporting the JTAC training program would create the opportunity to simultaneously train UAS personnel, refine the C2 architecture, and educate the terminal controllers that provide a critical link to the ground forces. Potential secondary benefits include a reduction in the overall financial costs based on the operating costs for manned-versus-unmanned supporting aircraft and increases in course throughput because of the extended on-station-time UAS provide.[30]

The composition of the JTAC community could provide another opportunity for integration if 7315 UAS pilots were assigned to Forward Air Controllers (FAC) tours. In the same vein, the Marine Corps could explore the potential for 7314 enlisted UAS operators to serve as JTACs. Including UAS pilots in the FAC-JTAC programs could contribute to the rapid integration of UAS into the ground communities.[31]

Personnel

There are at least two general approaches to generate the manpower required to support the addition of MALE UAS. The first is to adjust the current manning model. In the short term, personnel for a MALE UAS unit could be generated by re-designating VMU-1 or augmenting VMX-22. In the mid-term, transition of the 7588 EA-6B Electronic Warfare Officer MOS to the UAS community will increase the size of the current 7315 population and provide significant EW experience.[32] In the long term, the Marine Corps should consider the more radical steps taken by the USA and Israeli Air Force to transition attack helicopter units to unmanned aircraft squadrons.

Adjusting the internal organization of the VMUs provides another option. One approach is to align the 7315 officer pilots with MALE platforms and the 7314 enlisted pilots with the current Group-3 platforms.[33] These suggestions do not include essential support personnel, but the VMUs are already staffed with intelligence and support Marines. Additional research and experimentation would be required to determine what modifications to the current VMU construct would be necessary.

The second approach is to replace the MQ-21 Blackjack with a MALE UAS. In the short term, this approach would be difficult because the Marine Corps has not even completed the initial fielding of MQ-21 systems. In the mid to long term, however, this may be necessary in light of end strength and budget limitations. If raising total force end strength or increasing the size of the ACE are not realistic options, the Marine Corps will have to decide which UAS platform delivers greater capabilities.

Materiel

Developing MALE UAS will obviously involve new aircraft and supporting equipment. Fortunately, the Marine Corps can leverage existing joint and international programs. This evolutionary approach would allow the Marine Corps to rapidly incorporate proven technologies while refining employment concepts. The materiel challenges can be grouped into three general categories: expeditionary command and control suites, communications architecture, and development costs.

First, MALE UAS will require expeditionary C2 suites. The 2015 Marine Aviation plan presents a concept for a Universal Mission Operations System (UMOS) that would provide a common control node for future unmanned aircraft.[34] Another approach is to experiment with existing MQ-9 equipment sets. The USAF has already developed container-based ground control stations (GCS) to support its remote split operations (RSO) concept.[35] The containers can be transported by C-130 and have potential for shipboard operations. Developing a common GCS that is compatible with USN specifications is an essential step towards fielding any new UAS.

The communications architecture required for long-range MALE operations is probably the most significant challenge for the Marine Corps and joint community. Individual UAS platforms are relatively inexpensive and easy to produce, but the satellite infrastructure used to control them is not. The USAF currently utilizes commercial satellites to control MQ-1 and

MQ-9 beyond the line of sight (BLOS). This creates issues for capacity, reliability, and coverage as the US and international UAS use continues to grow.

This problem creates two opportunities for the Marine Corps. First, the service should be involved in developing the DOD approach to solving the problem; if not, the Marine Corps risks being squeezed out by the dominant stakeholders. Programs, such as the US Navy's satellite-based Mobile User Objective System (MUOS), are already under development. Second, the Marine Corps can experiment with alternative methods to extend line of sight (LOS) control, such as mesh-networks, from both sea and shore bases. Developing these techniques is a critical step towards ensuring C2 capabilities on future battlefields where satellite access may not be available.

Finally, the most obvious challenge to developing MALE UAS in the near term is financial cost. A decision to accelerate the development of MALE UAS would affect other programs in the multi-year budget cycle. To this point, however, the Marine Corps has not completed a holistic analysis of the costs associated with developing, employing, and maintaining MALE UAS. The MQ-9 Reaper system is a known commodity with predictable baseline costs for procurement, maintenance, and operations.[36] The projected costs should be compared to the current manned and unmanned platforms to inform future decisions and budget priorities.

CONCLUSION

The inevitable move towards unmanned systems does not mean UAS will replace manned aircraft, but they will play a larger role in the future. MALE UAS will be part of that future. For the Marine Corps, the discussion is not about "ifs," it is about the "when" and "how." An existing MALE UAS, such as the MQ-9 Reaper, has the potential to meet short and mid-range operational requirements. Equally important, the knowledge gained from experimentation, training, and operational employment would shape the development of future platforms, employment concepts, and support requirements.

Revolutionary capabilities do not necessarily require revolutionary technology. The competitor that can harness the potential of existing technology will have an advantage on tomorrow's battlefield. Ten years is too long to wait, the competition is already underway. The future is here.

APPENDIX A: ELEMENTS OF AN UNMANNED AIRCRAFT SYSTEM

All UAS have several common components; the unmanned aircraft (UA), payload, control element, communications, and the support element. (See figure 1.)

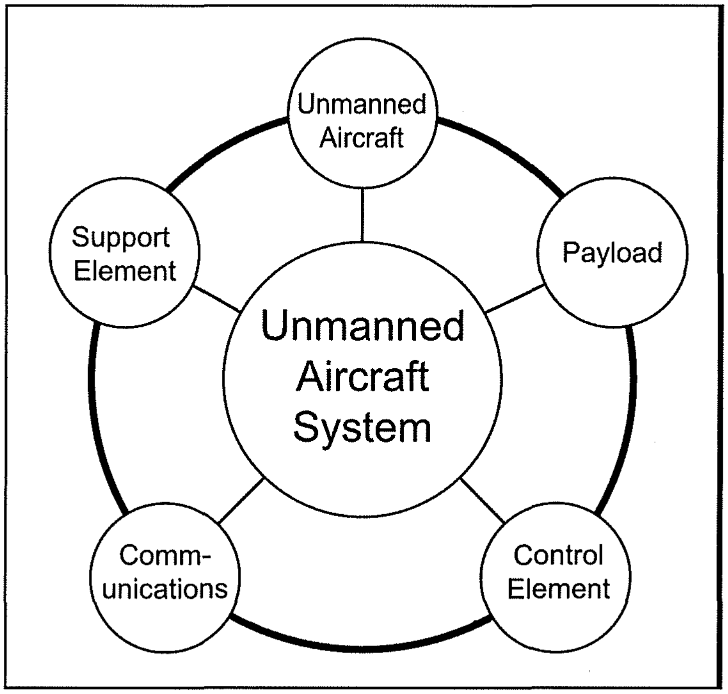

Figure 1: UAS Components

a. UA. UA are rotary- or fixed-wing aircraft or lighter-than-air vehicles capable of flight without an onboard crew. The UA includes the aircraft and integrated equipment (i.e., propulsion, avionics, fuel, navigation, and on-board communication systems).

b. Payload. Payloads may include sensors, communications relay, and weapons. The numbers and types of payloads present will affect the performance characteristics of most UASs. Refer to appendices A and B for platform specific payloads.

1. Sensors. The majority of today's payloads are imaging sensors, such as (1) electro-optical (EO), infrared (IR), synthetic aperture radar (SAR), inverse synthetic aperture radar (ISAR), and maritime search radar. In addition, there are ground, surface, and maritime moving target indicators; light detection and ranging (LIDAR); chemical, biological, radiological, and nuclear (CBRN) detection; Automatic Identification System (AIS), geospatial intelligence; and signals intelligence (SIGINT) sensors. Sensor packages may also include a laser range finder (LRF) and coded LRF/detector (LRF/D) capability. The use of multiple sensors (e.g., full motion video [FMV] and SAR) requires a large amount of dedicated bandwidth that may impact the ability to process and disseminate data.
2. Communications Relay. Communications relay payloads provide the (2) capability to extend voice and data transmissions via the UA.

3. Weapons. Payloads include lethal (e.g., missiles and bombs) and nonlethal (3) (laser designator) weapons. (For specific weapons carried by individual aircraft, see appendix B.)

c. Control Element. The control element (whether ground-based, sea-based, or airborne), may handle multiple mission aspects, such as mission planning and execution, payload control, and communications. The UA operator is physically located at the primary UAS control element referred to as the ground control station (GCS). The GCS can be a laptop computer, large control van, shipboard module, or fixed facility. It can be located onboard airborne platforms to enable control from manned aircraft. Some GCSs can allow one pilot or operator to control multiple UAs. For some larger UASs, the GCS may be geographically separated from the UA launch and recovery site (LRS) and may be located outside the area of operations. Additionally, sensor operators (SOs) control wide-area airborne surveillance and most SIGINT sensors at a location geographically separated from the primary UAS control element.

d. Communications. All communications among the UA, UAS control element, and supported unit occur via voice and data link. The UA may use line of sight (LOS) or beyond line of sight (BLOS) communications. UA data links can directly supply the warfighter with imagery and associated metadata via direct LOS downlink to a remote video terminal (RVT). Systems such as the distributed common ground/surface system (DCGS), Global Broadcast Service (GBS), or the UA directly (e.g., RVT) transmit the data products to the network. (See appendix A for platform specific RVT capabilities.)

e. Support Element. Like manned aircraft, UASs require logistic support. This support element includes the equipment to deploy, transport, maintain, launch and recover the UA, and enable its communications.

APPENDIX B: UAS GROUPS[37]

a. The UA group system establishes the foundation for joint UAS terminology. It provides a common reference to compare UA.

b. UA are grouped based on the physical and performance characteristics of weight, operating altitude, and airspeed. UA groups are determined without regard for payload, mission, command relationship, or Service. A UA possessing one attribute of the next higher group is placed in that group. All UA fall into one of five groups as outlined in table 1.

1. Group 1 UA are generally hand-launched and self-contained aircraft. Tactical (1) units (e.g., battalions, companies, and squadrons) typically employ Group 1 UA. They operate within LOS of the GCS at low altitudes and generally have limited endurance. Group 1 UA are typically man or vehicle portable and Group 1 UAS crews may operate from moving vehicles. Therefore, they can be hand launched in one area and recovered later in the route with little delay to normal ground maneuvers.
2. Group 2 UA are generally medium-sized, catapult-launched aircraft. These (2) systems have a small logistics footprint. They typically operate within LOS of the GCS and have short to medium endurance. Some Group 2 UA can operate from aboard ship or unimproved areas.
3. Group 3 UA are generally medium sized and normally operate at medium (3) altitudes. Range and endurance can vary significantly among platforms. Although they require a larger logistics footprint than Groups 1 and 2 UA, many Group 3 UA can operate from expeditionary or unimproved areas.
4. Group 4 UA are relatively large aircraft, operate at medium to high altitudes, (4) and have an extended range and endurance. Fixed-wing UA in this group generally require a runway for launch and recovery (LR); however, several UA can operate from unimproved locations (e.g., the Hunter can takeoff from unimproved roads). The logistics footprint for these aircraft may be similar to that of manned aircraft.
5. Group 5 UA are the largest aircraft, operate at medium to high altitudes, and (5) typically have the greatest range, endurance, and airspeed. Group 5 UA require runways and improved areas for LR. The logistics footprint may be similar to that of manned aircraft of similar size.

Table 1. UA Group Categories				
UA Category	Maximum Gross Takeoff Weight (lbs)	Normal Operating Altitude (ft)	Airspeed (KIAS)	Representative UA
Group 1	0–20	<1,200 AGL	<100	Raven Wasp Puma
Group 2	21–55	<3,500 AGL	<250	Scan Eagle
Group 3	56 < 1,320	<18,000 MSL		Shadow
Group 4	>1,320		Any airspeed	Hunter Predator Gray Eagle Fire Scout
Group 5		>18,000 MSL		Global Hawk Reaper Triton

Legend:

AGL—above ground level
ft—feet
KIAS—knots indicated airspeed
kts—knots
lbs—pounds
MSL—mean sea level
UA—unmanned aircraft

Note: Groups 1, 2, and 3 are sometimes referred to as low, slow, or small UASs

APPENDIX C: UAS CHARACTERISTICS[38]

Table 9. UA Performance Characteristics and Missions										
Group	Name	Mission Design Series	Service or Country	Mission	Maximum Airspeed (kts)	Cruise Airspeed (kts)	Maximum Altitude (ft MSL)	Normal Operating Altitude (ft MSL)	Endurance (hours)	Radius (nm)
1	Anubis		USAF	ISR	35	15	10k	500	1	1–2
	gMAV	RQ-16	USA	RSTA/ ISR	45	0–45	10k	500	0.8	5.3
	Puma	RQ-20A	USA USN USMC USAF USSOCOM	ISR	40	26	10.5k	1,000	2	12
	Raven	RQ-11B DDL	USA USMC USAF USSOCOM	RSTA/ ISR	44	26	10.5k	1,000	1.5	6
	Wasp	RQ-12A	USA USMC USAF USSOCOM	RSTA/ ISR	45	26	10.5k	500–1,000	0.8	3
2	Scan Eagle		USMC USAF USN USSOCOM	ISR	70–80	49	16.4k	1–5k	15–20	60
3	Blackjack	RQ-21A	USMC	ISR	90	55	15.0k	3,000	>12	50
	Shadow	RQ-7B	USA USMC	RSTA/ ISR	110	70	15k	6–8k	9	77
	Viking 400	Not applicable	USSOCOM	RSTA/ ISR	90	58–90	15k	3–8k	6–12	75

Table 9. UA Performance Characteristics and Missions (Cont'd.)										
Group	**Name**	**Mission Design Series**	**Service or Country**	**Mission**	**Maximum Airspeed (kts)**	**Cruise Airspeed (kts)**	**Maximum Altitude (ft MSL)**	**Normal Operating Altitude**	**Endurance (hours)**	**Radius (nm)**
4	Gray Eagle	MQ-1C	USA	Multi	150	75	25k	8–20k	36	648
	Fire Scout	MQ-8B	USN	ISR	120	60–120	12.5k	8–10k	4.5	150
	Hunter	MQ-5B	USA	ISR Multi	110	70	18k	3–15k	20.5	144
	K-Max		USA USMC	Cargo	100	80	20k	0–5k	3	130
	Predator	MQ-1B	USAF USSOCOM	Multi	120	75–85	25k	15k	24	1,100
	Warrior A	MQ-1	USA	Multi	120	70	25k	15k	24	500
5	Global Hawk	RQ-4B	USAF	Multi	340	310	60k	50–60k	28	5,400
	BAMS-D	RQ-4A	USN	ISR	340	340	60k	50–60k	31	5,300
	Triton	MQ-4C	USN	ISR	330	310	60k	50–60k	24	9,950
	Reaper	MQ-9	USAF UK	Attack Multi	249	230	40k	10–30k	14–17	1,400

Legend:
BAMS-D—Broad Area Maritime Surveillance-Demonstrator
ft—feet
ISR—intelligence, surveillance, and reconnaissance
k—kilometer
kt—knot
MSL—mean sea level
nm—nautical mile
RSTA—reconnaissance, surveillance, and target acquisition
UK—United Kingdom
USA—United States Army
USAF—United States Air Force
USMC—United States Marine Corps
USN—United States Navy
USSOCOM—United States Special Operations Command

APPENDIX D: UAS PAYLOADS[39]

Table 10. UA Payloads

Name	Mission Design Series	EO/IR	FMV	LRD/LRF	IR Pointer	SAR	GMTI	SIGINT	AIS	Communication Relay	Weapons and Cargo
Fire Scout	MQ-8B	X	X	X	X	X[1]			X	X	
Gray Eagle	MQ-1C	X	X	X	X	X	X	X		X	AGM-114
Global Hawk Block 20	RQ-4B									X	
Global Hawk Block 30i	RQ-4B	X				X					
Global Hawk Block 30m	RQ-4B	X				X		X			
Global Hawk Block 40	RQ-4B					X	X				
Triton	MQ-4C	X	X			X[1]		X	X	X	2,400 pounds external payload
BAMS-D	RQ-4A	X				X[1]	X		X		
gMAV	RQ-16	X	X								
Hunter	MQ-5B	X	X	X	X			X		X	
K-Max											Cargo sling load 6,500 pounds
Predator	MQ-1B	X	X	X	X			X			AGM-114
Puma	RQ-20A	X	X		X			X		X	

Table 10. UA Payloads (Cont'd.)

Name	Mission Design Series	EO/IR	FMV	LRD/LRF	IR Pointer	SAR	GMTI	SIGINT	AIS	Communication Relay	Weapons and Cargo
Raven	RQ-11B	X	X		X						
Reaper	MQ-9	X	X	X	X	X	X	X			AGM-114, GBU-12, GBU-38
Scan Eagle		X	X					X			
Blackjack	RQ-21A	X	X	X	X				X	X	
Shadow	RQ-7B	X	X	X	X					X	
Viking 400		X	X		X						
Warrior A	MQ-1	X	X	X	X	X[2]	X[2]			X	AGM-114
Wasp	RQ-12A	X	X		X						

Legend:
AGM—air-to-ground missile
AIS—Automatic Identification System
BAMS-D—Broad Area Maritime Surveillance-Demonstrator
EO—electro-optical
FMV—full motion video
GBU—guided bomb unit
GMTI—ground moving target indication
IR—infrared
LRD—laser range detector
LRF—laser range finder
SAR—synthetic aperture radar
SIGINT—signals intelligence

Notes:
1. This has inverse SAR.
2. Hellfire cannot be carried simultaneously with SAR and GMTI payloads.

APPENDIX E: UAS INVENTORY (as of 2012)[40]

SECTION 1 – ***Current UAS inventory levels and planned UAS inventory levels for each fiscal year through FY 2017:***

The following table describes the current UAS program of record inventory levels planned through FY 2017, net of attrition.

System Designation/Name		Current	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
			Air Force					
MQ-1B	Predator	163	152	141	130	121	115	110
MQ-9A	Reaper	70	96	135	167	199	229	256
RQ-4B *	Global Hawk	23	23	15	15	15	15	15
			Army					
RQ-11B	Raven	5394	6294	6528	6717	6921	7074	7074
RQ-7B	Shadow	408	408	408	408	408	408	408
MQ-5B	Hunter	45	45	45	45	45	45	45
MQ-1C	Gray Eagle	19	45	74	110	138	152	152
			Navy					
RQ-4A	Global Hawk	5	5	0	0	0	0	0
MQ-4C	BAMS	0	0	2	2	5	9	13
MQ-8B	Firescout/VTUAV	5	9	14	18	25	32	37
RQ-21A	STUAS	0	1	2	3	4	4	4
	Scan Eagle	122	122	122	122	122	122	122
X-47B	UCAS-D	2	2	2	2	0	0	0
	UCLASS	0	0	0	0	2	2	4
			Marine Corps					
RQ-7B	Shadow	52	52	52	52	52	52	52
RQ-21A	STUAS	8	8	8	23	48	73	100

Table 1: UAS Inventory Levels (FY12 budgeted inventory with noted exception)

* *Reflects RQ-4B Block 20/40 inventory remaining after FY 2012 (Block 30 cancelled in President's 2013 Budget submission).*

Endnotes

[1] Paul Scharre, *Robotics on the Battlefield Part I: Range, Persistence and Daring* (Washington, DC: Center for New American Security, May 2014), 9.

[2] The fires, intelligence, and command and control (C2) warfighting functions are representative of multiple specific capabilities shortfalls identified in the Marine Corps' Program Objective Memorandum (POM)-18 Marine Corps Gap List (MCGL).

[3] This definition is a combination of joint and service-level doctrine. It is intended to represent a holistic view of the unmanned aircraft system. JP 1-02, *Department of Defense Dictionary of Military and Associated Terms*, does not define the term "unmanned aircraft system." Joint Publication 3-30, *Command and Control of Joint Air Operations*, defines UAS as "that system whose components include the necessary equipment, network, and personnel to control an unmanned aircraft." MCRP 3-42.1A, *Multi-Service Tactics, Techniques, and Procedures For The Tactical Employment Of Unmanned Aircraft Systems,* notes that the "The United States (US) Air Force (USAF) refers to its Group 4 and 5 UA as remotely piloted aircraft (RPA) to emphasize that their operators are trained to the same standards as manned-aircraft pilots." The USAF *RPA Vision and Vector* further distinguishes that only Groups 4-5 are operated by rated pilots.

[4] Performance characteristics for the MQ-9 were drawn from Headquarters U.S. Marine Corps, Air, Land, Sea Application Center, *Multi-Service Tactics, Techniques, and Procedures for The Tactical Employment Of Unmanned Aircraft Systems,* MCRP 3-42.1A (Quantico, VA: Headquarters U.S. Marine Corps, Deputy Commandant, Combat Development and Integration, 22 January 2015), 3-4. This publication describes the MQ-9 Reaper as a medium- to high-altitude, long endurance, multi-mission platform.

[5] Headquarters U.S. Marine Corps, Combat Development Command, "Deliberate Universal Needs Statement (DUNS) for I MEF BLOS MALE UAS " (Camp Pendleton, CA: I Marine Expeditionary Force, November 20, 2015). This DUNS outlines capability requirements and references related UNS.

[6] US Department of Defense, Joint Chiefs of Staff, *Capstone Concept for Joint Operations: Joint Force 2020* (Washington, DC: Joint Chiefs of Staff, September 10, 2012), 4-7; US Department of Defense, Joint Chiefs of Staff, *Joint Operational Access Concept* (Washington, DC: Joint Chiefs of Staff, January 17, 2012), 17. The JOAC defines the military problem as follows: The future Joint Force must be able to enter onto foreign territory and immediately employ capabilities to accomplish assigned missions in the presence of armed opposition, including advanced area denial systems, while overcoming geographic challenges and degraded or austere infrastructure. Overcoming this challenge requires capabilities from across the entire Joint Force to conduct, support, and exploit entry operations.

[7] For a synopsis of the challenges associated with escorting the MV-22, see Tina Terry, "Arming the Osprey for Self-Escort," *Marine Corps Gazette* Volume 99, Issue 9 (September 2015): 23.

[8] MCRP 3-42.1A, 67-70. Post factory programs, such as Harvest Hawk, are useful but insufficient for the need. The Harvest Hawk mission kit is designed to re-configure the KC-130J aircraft into a platform capable of performing persistent targeting ISR and delivering precision fires using Hellfire, Griffin or Viper Strike munitions. This mission kit is designed as a complementary capability that takes advantage of the aircraft's extended endurance. MROC Decision 19-2012, however, reduced the total kit inventory objective from nine to six kits, with three each going to 2d MAW and 3d MAW. A total of 10 aircraft are modified to employ the Harvest Hawk kits with five modified aircraft in 2d MAW and five in 3d MAW. With limited KC-130 aircraft, the Marine Corps cannot dedicated scare resources against missions where they are only marginally effective. Harvest Hawk information paraphrased from the USMC 2015 Aviation Plan, 2.4.11.

[9] General Atomics Aeronautical Systems, "MQ-9E Capabilities Brief," PowerPoint presentation, September 8, 2015. Developmental models of the MQ-9 are projected to increase the range of the MQ-9. A fully armed MQ-9E Reaper is projected to be capable of 24hours time on station at a distance of 2,000nm.

[10] Headquarters U.S. Marine Corps, *Expeditionary Force 21* (Washington, DC: Headquarters U.S. Marine Corps, March 4, 2014): 34-35. Also see "Force Development Focus Areas: Command and Control," Marine Corps Combat Development Command, Combat Development and Integration, accessed October 23, 2015, http://www.mccdc.marines.mil/Resources/FocusAreas/CommandandControl.aspx.

[11] "Tactical satellite" is a non-doctrinal term used to describe a tactical concept in which a UAS remains over an objective area in order to perform radio wave and digital communications amplification, relay, and retransmissions.

[12] Examples of existing network systems include Link-16, Tactical Targeting Network Technology (TTNT), Adaptive Networking Wideband Waveform (ANW2). Additionally, fires planning and execution programs such as

Kinetic Integrated Low-cost SoftWare Integrated Tactical Combat Handheld (KILSWITCH) have been tested and operationally employed, but have not been integrated into the operating forces..

[13] See Appendix D for a partial list of payload options.

[14] For a summary of near and mid-range threat assessments see EF-21 or the *2015 Marine Corps Security Environment Forecast: Futures 2030-2045.*

[15] USAF *RPA Vision and Vector*, 11-13. This document summarizes the challenges the USAF faces in meeting current demand for RPA support.

[16] For a recent summary of operational forces requests, see Headquarters U.S. Marine Corps, Combat Development Command, "Deliberate Universal Needs Statement (DUNS) for I MEF BLOS MALE UAS" (Camp Pendleton, CA: I Marine Expeditionary Force, November 20, 2015).

[17] Headquarters U.S. Army, Unmanned Aircraft Systems Center of Excellence, *Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army* (Fort Rucker, AL: Headquarters US Army, Unmanned Aircraft Systems Center of Excellence, April 2010), 46, 78-79.
http://www.rucker.army.mil/usaace/uas/US%20Army%20UAS%20RoadMap%202010%202035.pdf.

[18] USAF *RPA Vision and Vector*, 16-27.

[19] For a discussion of the ongoing debate between the USAF and USA over existing UAS programs see, David B Hume, *Integration of Weaponized Unmanned Aircraft into the Air-to-Ground System,* Maxwell Paper No. 41, USAF Air War College, 2007, http://dtic.mil.

[20] The official nomenclature for the MQ-X is the MAGTF Unmanned Aircraft Systems (UAS) Expeditionary (MUX). The term MQ-X is used here to align with the 2015 Marine Aviation Plan.

[21] Headquarters U.S. Marine Corps, *2015 Marine Aviation Plan* (Washington, DC: Headquarters U.S. Marine Corps, Last Revised November 18, 2014), 2.7.3 and 2.7.8. Also see Defense Advanced Research Projects Agency, Tactically Exploited Reconnaissance Node (TERN), http://www.darpa.mil/program/tactically-exploited-reconnaissance-node.

[22] DARPA, "Tactically Exploited Reconnaissance Node (TERN)."

[23] Naval Air Systems Command, "Broad Area Maritime Surveillance—Demonstrator (BAMS-D)." Accessed December 20, 2015. http://www.navair.navy.mil/index.cfm?fuseaction=home.displayPlatform&key=624BC6D7-45CE-446C-BA1E-5818E57F9914.

[24] *2015 Marine Aviation Plan,* 2.7.2 and Headquarters U.S. Marine Corps, *Unmanned Aircraft Systems Operations,* MCWP 3-42.1 (Washington, DC: Headquarters U.S. Marine Corps, December 9, 2015).

[25] See Headquarters U.S. Marine Corps, *Control of Aircraft and Missiles*, MCWP 3-25 (Washington, DC: Headquarters U.S. Marine Corps, July 30, 2012) and Headquarters U.S. Marine Corps, *Aviation Operations,* MCWP 3-2 (Washington, DC: Headquarters U.S. Marine Corps, May 9, 2000).

[26] USAF *RPA Vision and Vector*, 16-24.

[27] Headquarters U.S. Marine Corps, UAS OPT April-May 2013, "Improving Unmanned Aviation Support to the MAGTF," PowerPoint presentation, May 2013.

[28] 2015 Marine Aviation Plan, 2.1.4. The Marine Corps' comprehensive plan to address post-EA-6B Prowler Electronic Warfare (EW) requirements is Marine Air Ground Task Force (MAGTF) EW. MAGTF EW leverages emerging technologies and integrates multiple aviation platforms (unmanned, fixed wing, and rotary wing assets); payloads; ground-based EW nodes; and cyber effects to provide commanders with an organic and persistent EW capability. MAGTF EW transitions the Marine Corps from a focus on low-density/high-demand (LD/HD) EW capability, to a distributed, platform-agnostic approach (quoted from source).

[29] During March 2016, the California Air National Guard 163d Operation Group supported exercise TALON REACH IV. See Cory Radcliffe, "AAR from the USMC LNO to the MQ-9 det. supporting MAGTF operations during TALON REACH IV" (unofficial after action report). Additionally, contracted MQ-9 support is planned for the MAGTF Integrated Experiment (MIX) during RIMPAC 2016.

[30] Steven Djunaedi, Peter J. Guerrant, and Richard Stafford, "Cost Benefit Analysis of EWTGLANT Forward Air Controller / Joint Terminal Attack Controller Training Options" (EMBA Project Report, Naval Postgraduate School, March 13, 2013), and Kevin Murray and Anthony C. Bolden, "GROUP V UAS Support to TACP & MAGTF Training and Readiness," PowerPoint presentation, last modified October 5, 2015.

[31] This idea was put forward in the 2011 article by Ryan J. 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, " *Marine Corps Gazette*, Volume 95, Issue 7 (July 2011): 60. Experimentation for 7315 integration is scheduled for 2016.
http://www.mca-marines.org/gazette/article/it%E2%80%99s-mug-time (accessed December 29, 2015).

[32] 2015 Marine Aviation Plan, 2.7.5. In FY16, structure and personnel from the 7588 Naval Flight Officer EA-6B Electronic Warfare Officer MOS will begin to migrate to the UAS community.

[33] Realigning the 7314 MOS could be an intermediate step to developing JTACs or small UAS operators to support operational units.

We see the explosion of Group I as the future of the battalion level UAS. COTS, converted to military use is what we need to do. Moving the 7314's to the Battalions will also provide room for other RAS, such as UGV's and the 7315's can drive those too....

[34] 2015 Marine Aviation Plan, 2.7.6. The Universal Mission Operations System (UMOS) is the cockpit for the Unmanned Aircraft Commander and will be digitally interoperable with all UAS. Currently in development, UMOS will fuse information collected from the Air Vehicle (AV) with information from other Tactical Data Systems. Beginning with Link 16, and quickly growing to encompass Variable Message Format (VMF), Advanced Field Artillery Tactical Data System (AFATDS), Theater Battle Management Core System (TBMCS) and Blue Force Tracker (BFT) 2, the UMOS will provide the Unmanned Aircraft Commander (UAC), and the supported unit, with an integrated picture of the battlefield. This will enhance the ability of the MAGTF to integrate intelligence and fires with maneuver, and streamline the kill chain. Additionally, the UMOS will significantly augment the ability of the VMU to efficiently execute the task, collect, process, exploit, and disseminate (TCPED) cycle. As the number and capability of airborne sensors on the battlefield increases, so will the amount of data that is collected. The UMOS will act as a digitally interoperable hub for the collection, cataloguing and storage of full motion video, multi-intelligence sensor data, topological data, and targeting information. Initially, the majority of the processing, exploitation, and dissemination will be done manually. The UMOS will be able to measure the available bandwidth and determine the optimal means to disseminate intelligence products. Future iterations of UMOS will use algorithms to analyze the vast amount of data as it is collected, and automatically cue operators and analysts to events of interest. The UMOS enables the full capability of the digitally interoperable VMU. Incorporating the UMOS into a program of record is imperative for the UAS community. (quoted from source)

[35] USAF *RPA Vision and Vector*, 20-22.

[36] Costs estimates for the MQ-9 Reaper vary widely based on what factors are included in the calculation. The author has seen variations in the estimates as much as $50,000,000 per aircraft. To achieve a reasonable estimate for planning, the Marine Corps would have to define specific parameters to estimate and compare the costs of manned and unmanned aircraft. For an example of the variations in cost calculations see the following two articles: Winslow Wheeler, "MQ-9 Reaper: Not the "Revolution in Warfare" You've Been Told," *Common Defense Quarterly* (Summer 2012): 27-29, http://www.commondefensequarterly.com/CDQ13/CDQ13.pdf and "Affordably Unmanned: A Cost Comparison of the MQ-9 to the F-16 and A-10, and a Response to Winslow Wheeler's Criticisms of the Drone," James Hasik, *Industrial Analysis for Global* Security, accessed February 10, 2016, http://www.jameshasik.com/weblog/2012/06/affordably-unmanned-a-cost-comparison-of-the-mq-9-to-the-f-16-and-a-10-and-a-response-to-winslow-whe.html.

[37] MCRP 3-42.1A, 3-4.

[38] MCRP 3-42.1A, 67-68.

[39] MCRP 3-42.1A, 69-70.

[40] US Department of Defense, Under Secretary of Defense for Acquisition, Technology and Logistics, *Report to Congress on Future Unmanned Aircraft Systems Training, Operations, and Sustainability* (Washington, DC: Department of Defense, April 2012), 2.

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