THE WRIGHT FLYER PAPERS

The Future of Remotely Piloted Aircraft in Special Operations

Methods to Improve AFSOC MQ-9 Effectiveness for Supporting Special Operations

Jordan Kowalski
Captain, USAF

Air Command and Staff College
Wright Flyer Paper No. 60

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Editor
The Wright Flyer Papers
Department of Research and Publications (ACSC/DER)
Air Command and Staff College
225 Chennault Circle, Bldg. 1402
Maxwell AFB AL 36112-6426
Tel: (334) 953-3558
Fax: (334) 953-2269
E-mail: acsc.der.researchorgmailbox@us.af.mil

AIR UNIVERSITY
AIR COMMAND AND STAFF COLLEGE

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Air University Press
Maxwell Air Force Base, Alabama

Project Editor
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AIR UNIVERSITY PRESS

Director and Publisher
Dr. Ernest Allan Rockwell

Air University Press
600 Chennault Circle, Building 1405
Maxwell AFB, AL 36112-6010
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AIR UNIVERSITY PRESS

Published by Air University Press in September 2017

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Foreword

It is my great pleasure to present another issue of *The Wright Flyer Papers.* Through this series, Air Command and Staff College presents a sampling of exemplary research produced by our residence and distance-learning students. This series has long showcased the kind of visionary thinking that drove the aspirations and activities of the earliest aviation pioneers. This year's selection of essays admirably extends that tradition. As the series title indicates, these papers aim to present cutting-edge, actionable knowledge—research that addresses some of the most complex security and defense challenges facing us today.

Recently, *The Wright Flyer Papers* transitioned to an exclusively electronic publication format. It is our hope that our migration from print editions to an electronic-only format will fire even greater intellectual debate among Airmen and fellow members of the profession of arms as the series reaches a growing global audience. By publishing these papers via the Air University Press website, ACSC hopes not only to reach more readers, but also to support Air Force–wide efforts to conserve resources. In this spirit, we invite you to peruse past and current issues of *The Wright Flyer Papers* at http://aupress.maxwell.af.mil/papers_all.asp?cat=wright.

Thank you for supporting *The Wright Flyer Papers* and our efforts to disseminate outstanding ACSC student research for the benefit of our Air Force and war fighters everywhere. We trust that what follows will stimulate thinking, invite debate, and further encourage today's air, space, and cyber war fighters in their continuing search for innovative and improved ways to defend our nation and way of life.

BRIAN HASTINGS
Colonel, USAF
Commandant

Preface

The research conducted to bring this paper to life was a labor of intensity and love for my aircraft and its often thankless mission. Many times I have felt that the mission failed due to faulty or inadequate equipment or by not having the correct weapons to accomplish the task at hand. Sometimes that led to the proverbial "bad guy" getting away, while other times it contributed to the loss of American lives. The problems of less than adequate equipment to accomplish the mission are exacerbated by a poor understanding of how to employ the aircraft once tasked to support a given unit, leading to frustration on both ends. Many of these frustrations could be avoided if there were better communication and understanding between the supported units and the crews flying the mission for them. With new threats popping up around the globe and our special forces' relentless mission of eliminating those threats before they can harm the homeland, I felt it prudent to provide a documented recommendation on how to improve remotely piloted aircraft (RPA) operations for current and future theaters without impeding on anyone's authority.

Abstract

Unmanned aerial vehicles' support to US special operations forces has grown throughout the conflicts in Afghanistan and Iraq to find, fix, and finish high-value targets in numerous terrorist networks. As conflicts continue to evolve across multiple new theaters in new environments and countries, several limitations with the MQ-9 and its support network generated the question "How might Air Force Special Operations Command (AFSOC) MQ-9s be improved to better support special operations teams around the world?" The report utilized a problem/solution framework, with examples presented in scenario vignettes to provide context to the current capabilities and limitations of the MQ-9. The resulting research identified solutions, including several hardware and software upgrades that improve communication, navigation, deconfliction, and weapons employment capabilities of the aircraft.

Specifically, adding a second airborne radio, a flight management system (FMS) with certified global positioning system (GPS) navigation and a traffic collision avoidance system (TCAS) or an equivalent system will provide safer and more effective flight into the US National Airspace System (NAS) as well as International Civil Aviation Organization (ICAO) airspace. Secondly, the requirement to quickly adapt new and more weapons to support ground teams would be solved by rapidly incorporating the Universal Armament Interface as well as weaponinzing the outer stations of the MQ-9's external stores. Finally, the research highlighted the need for the preemptive emplacement of subject matter experts, in addition to the liaison officers already in place, to train with special operations teams and units stateside before they are tasked with an operation. These changes will enhance current and future support to special operations and even conventional US military forces in every theater to come.

About the Author

Capt Jordan Kowalski received his commission and entered the Air Force in 2007 as a graduate of Norwich University. He attended undergraduate pilot training at Laughlin AFB, Texas, and was assigned to Air Force Special Operations Command (AFSOC) to fly MQ-1 Predators at Cannon AFB, New Mexico. He executed numerous missions supporting special operations for four years then moved to the mission qualification training schoolhouse to train future remotely piloted aircraft (RPA) crews on the AFSOC mission as an instructor and evaluator. After two years instructing new crews and maintaining the excellence of established crews through continuation training and evaluation, he converted to the MQ-9 Reaper and continued to fly in support of special operations forces (SOF) taskings. His time spent instructing tactics to work around technical problems and limitations led to a passion in helping develop new techniques, tactics, and procedures to better support SOF missions.

Capt Kowalski earned his masters of organizational leadership through Air Command and Staff College during his operational tenure at Cannon AFB. He completed a seven-year tour at Cannon and has moved to Hurlburt Field, Florida, to the Air Force Special Operations Air Warfare Center to lead changes to training as the chief of Flying Training.

Introduction

The scenarios described in this report do not detail specific operations but provide examples of plausible missions and issues for the Air Force Special Operations Command's (AFSOC) General Atomics MQ-9 Reaper remotely piloted aircraft (RPA).

Scenario

> A special operations forces (SOF) team is tasked to hunt for a high-ranking leader of al-Qaeda in the Islamic Maghreb (AQIM) in central Africa for Operation Threatening Viper. The US military presence in the region is scattered, and the air assets to assist the team in locating the high-value individual (HVI) are sparse. Many of the few information, surveillance, and reconnaissance (ISR) aircraft already in place do not have the sortie duration to develop adequate patterns of life (POL) models of the HVI for the team to plan operations. The decision is made to utilize Air Force Special Operations Command (AFSOC) RPAs to support the SOF team's mission. US Special Operations Command (USSOCOM) plans to establish a launch and recovery element (LRE) at an airfield within the MQ-9's sortie range, but the nations the Reaper would operate over will not allow a US "drone" to fly in their airspace. They do not understand how it operates, perceiving only that it does not work similarly to other aircraft. Ultimately, much effort is expended by the US Department of Defense (DOD) and the Department of State to ensure all host-nation approvals are met. The MQ-9 is allowed to fly over targets; however, missions are ineffective, as aircraft systems hamper effective communications and the supported SOF team has little practice working with RPAs.
>
> Many ISR hours are spent searching vast swathes of wilderness, and eventually, despite locating and attempting to strike the HVI before he can move against US interests, a lack of adequate weaponry and a poor understanding of MQ-9 employment allow the HVI to escape and complete his attack. How might this scenario change with improvements to the aircraft; the techniques, tactics, and procedures (TTP) used by the aircrew operating the RPA; and a greater understanding of capabilities by the SOF team prior to attempting to utilize the RPA for the task?

The preceding presents a possible scenario for future operations based on previous mission sets with numerous issues such as difficulty getting aircraft in country, communication problems, limited weapons capabilities, and little to no TTP development. The purpose of this research was to provide a series of solutions to the problems presented in the theoretical scenario. The overall issue regarding the current limitations affecting the effectiveness of MQ-9 systems, TTP development, and force interoperability must be addressed to improve support for SOF. Though the research was focused toward SOF support, the suggestions for improvement should prove beneficial to any end user of the RPA's ISR data streams. More specifically the problems presented deal with airspace over foreign countries, communications with SOF teams or any ground force component, the shared understanding of what a RPA can brings to the table and how, and finally the correct application of the RPA's ISR capabilities through joint training. This report's purpose was improving the US Air Force's MQ-9 Reaper aircraft and AFSOC joint operations.

The research method used was problem/solution with the scenario presented providing examples of operational limitations that have hampered mission effectiveness and which could be improved. When drafting the scenario, many of the issues have proven to be real-world problems when establishing MQ-9 combat air patrols in new theaters, though not during the same operation in the same area of responsibility (AOR). There has been friction and inefficiency in each instance of RPAs moving to a new theater with a new SOF end user, as the end user attempts to apply their knowledge and TTPs to what they know the RPA *should* be capable of to achieve the desired effects. Importing lessons learned from previous theater stand-ups overcomes some of the problems; however, not all SOF teams from each service branch can effectively communicate in the timelines needed to respond to rapid SOF operations overseas. To that end, the research has identified capability gaps and provided solutions from the viewpoint of the example scenario. With improvements to the communications structure, navigation equipment, weapons delivery capabilities, and systems education to develop TTPs with the supported units, SOF RPA will be more effective in shorter timelines.

Background

RPAs have proven over the course of Operation Enduring Freedom (OEF) and Operation Freedom's Sentinel (OFS) in Afghanistan, as well as Operation Iraqi Freedom (OIF) and Operation Inherent Resolve (OIR), their capability to provide high fidelity, real-time intelligence and armed reconnaissance to battlefield commanders.[1] The US Air Force Weapons School has written several research papers on how best to improve the tactical employment of the General Atomics MQ-1 Predator and MQ-9. The collective focus of many RPA-related papers has been to clearly define how to solve a tactical problem with a given toolset already established in the weapons system or on how to integrate a new piece of technology into existing TTPs. The papers, though designed to improve battlefield effectiveness, are limited to work with existing technology and equipment already in place on the aircraft or in the associated ground control station (GCS).

USAF RPAs

The current USAF inventory of RPAs consists mainly of the MQ-1, the MQ-9, and the Northrop Grumman RQ-4 Global Hawk. Ground parties generally interact with the MQ-1 and MQ-9 while executing their missions or from a forward operating base (FOB) receiving RPA full-motion video. Two main aircrew components of an RPA system—the LRE and mission control element (MCE)—are vital to the successful implementation of an RPA combat air patrol, the name designated to one continuous period of ISR coverage for a single RPA. The LRE is composed of a series of crews who reside in country with the aircraft they are launching. This is similar to manned platforms in that LRE crews ensure air worthiness before taking control of the aircraft via line-of-sight radio signals, taxi, takeoff, and landing. After the launch, a "handover" is performed with the MCE crew designated to control the RPA for the mission portion of the flight. MCE crews control the RPA via satellite signal from continental United States (CONUS) after establishing a positive handover from the LRE crew. The MCE crews, after taking control from the LRE, then fly to the target area and execute the mission task assigned by the supported unit, either a SOF ground team or traditional ground force.[2]

The mission tasks will vary depending on the supported unit's requirement to gather intelligence on a given target. For example, if a high-value target has been identified at a specific location, the crew might be tasked to watch a house associated with the individual while an intelligence video analyst carefully annotates who interacts with the target and how the targeted individual behaves. With the gathering of the HVI's POL, the supported unit can determine how best to exploit the individual. Sometimes the SOF team will elect to capture the individual in question as in Benghazi, Libya.[3] At other times, the RPA will employ weapons to eliminate the individual. These weapons vary from 500-pound (lb.) class bomb to Hellfire missiles.

The Air Force has traditionally utilized the find, fix, target, track, engage, assess (F2T2EA) targeting cycle, focused on localized engagements and the destruction of a given target that meets certain target criteria. USSOCOM and its SOF subordinate units utilize the find, fix, finish, exploit, and analyze (F3EA) targeting cycle, which emphasizes looking for the second- and third-order effects from a SOF action.[4] How this differs from the F2T2EA construct is the purpose behind the action. F3EA uses previously developed or discovered target information to determine the next target in the cycle (find), then uses RPA or other tracking sources to specify that target's location (fix). From there the decision to action, and how to action, the target is made (finish), which may be to capture the individual for questioning or to eliminate the individual. After the target has been actioned, all the target's information is assessed for viability, collected, and stored for later analysis (exploit). If the target is eliminated in a strike, the reactions of that individual's associates may also provide information that is exploited. Finally, based on any information or reactions generated, the next target in the chain is identified (assessment), and the chain starts over.

Communications and Navigation Issues

There are severe limitations to the current aircraft configuration as well as TTPs, despite the persistent presence of RPA across multiple theaters where SOF teams are operating. A poor understanding of what an RPA—specifically an MQ-9—is and what it can do to the local civilian air traffic compounds the difficulty in establishing an LRE in a new country. The current navigation and onboard communications systems are limited in scope and by bandwidth. There is currently one AN/ARC-210 radio to communicate via line-of-sight with other aircraft and ground parties.[5] The ARC-210 can transmit in both the very high-frequency and the ultrahigh-frequency ranges and can store up to 25 frequencies or presets.[6] There is also an antijam Have Quick capability as well as the ability to passively monitor the guard frequency.[7]

However, there is a limit on how many simultaneous channels may be received. The GCS has the option to monitor up to five channels nearly simultaneously in "scan" mode; however, when a signal is detected on one of the scanned channels, the radio will remain on that frequency until the transmission is finished. This blocks the other four channels, creating a serious hazard.[8] Additionally, guard monitoring is often overridden in the same way, making any passive guard monitoring ineffective. This can directly contribute to international flying incidents when controllers attempt to provide direction or clearance but are unable to contact the MQ-9 crew because the crew is limited to a single channel radio. This communications problem contributes to CONUS aviation restrictions as Federal Aviation Administration (FAA) regulations require aircrew to adhere to air traffic control direction and clearance unless there is an emergency or an immediate response required by a traffic alert and collision avoidance system (TCAS) directive.[9] These regulations are American derivatives of International Civil Aviation Organization (ICAO) procedures used to govern international flight rules, to which most nations with established international flight programs adhere.[10] Thus if an MQ-9 crew is unable to follow an air traffic controller's (ATC) direction, many governments are less willing to allow that aircraft into their airspace.

The MQ-9 lacks other navigation and flight safety items that are required for flight in certain airspace. The TCAS system aids pilots in avoiding aircraft collisions in heavily trafficked airspace. TCAS operates by passively sending and receiving signals with aircraft telemetry such as altitude, airspeed, and vertical velocity indications or climb and descent rates—to other TCAS equipped aircraft.[11] The latest versions of the system provide resolution advisories or directives to avoid colliding with another aircraft.[12]

Figure 1. TCAS RA display implemented on an instantaneous vertical speed indicator. (*Reprinted from* FAA, "Introduction to TCAS II," version 7.1, 28 February 2011, 15.)

However, the system only provides information and resolution advisories on aircraft also flying with an active TCAS installed. Future systems, such as the Airborne Digital Surveillance Broadcast (ADSB), will allow ground radar feeds to be projected into a display like TCAS but incorporating all aircraft, not just TCAS- or ADSB-equipped ones, to see who else is flying nearby.[13] These systems allow many aircraft to transit and approach busy airports with a higher safety margin than if the systems were not in use.

Another limiting factor that causes consternation among international ATCs and government agencies is the inability for MQ-9s to either navigate via global positioning system (GPS) database coordinates or fly approved ICAO or FAA procedures. The MQ-9 currently uses GPS receivers to navigate in conjunction with digital terrain elevation data (DTED) maps via a tracker display in the GCS pilot control station.[14]

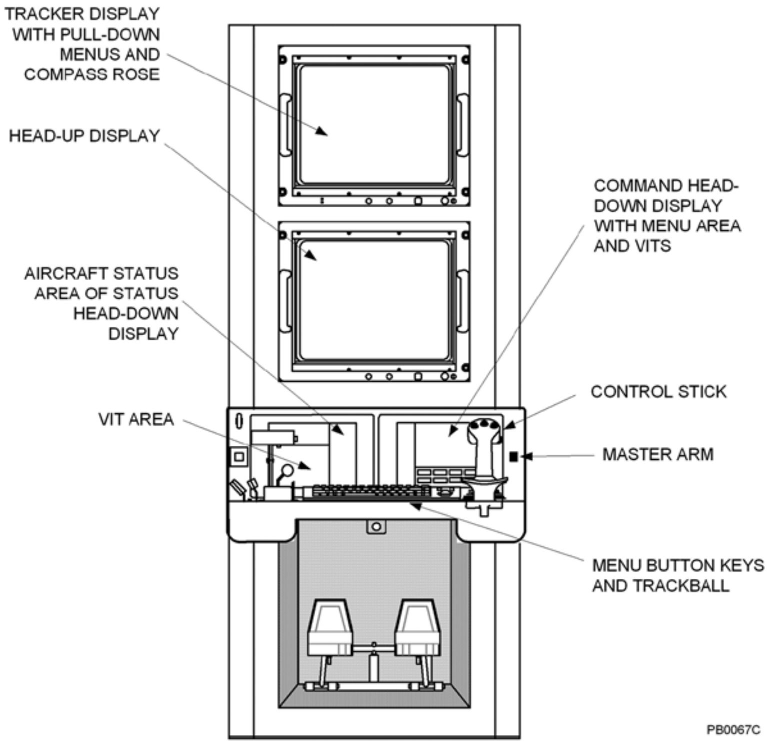

Figure 2. Pilot rack setup with heads-up display and tracker display. (*Reprinted from* Air Force Technical Order (TO) 1Q-9(M) A-1, *Flight Manual, USAF Series MQ-9 Aircraft*, change 1, 2 May 2014, 1-79.)

The aircraft matches its GPS position over the map, and pilots navigate to and from a location by inputting the coordinates of a given point into a "points of interest" file that is then displayed on the tracker maps.[15] The system is not approved for GPS navigation as the points are not loaded from an official and approved FAA or ICAO GPS database and the autopilot system has no way to navigate via the database points. Aircraft navigating solely via GPS must load all points along the intended route of flight with no addition or modification by the crew to ensure the points are accurate.[16]

Without the ability to verify where an MQ-9 will fly, nor the ability to execute GPS arrivals, departures, or approaches, members of the international community are skeptical of allowing MQ-9s free flight through their airspace. The FAA mirrors those sentiments and is actively attempting to provide direction to RPA manufacturers as well as the US Air Force about adding necessary equipment and procedures to ensure the safety of all aircraft.[17]

Weapons Systems

The current MQ-9 weapons system is controlled via a stores management system (SMS) interface controlled by the pilot in the GCS. The loadout of the weapons consists of air-to-ground (AGM) 114 missiles adapted for RPA use in the early stages of OEF, and 500 lb.-class laser-guided bombs.[18] These weapons are attached via either launch rails for the AGMs or bomb rails on one of seven hard-point stations on the underside of the aircraft.[19]

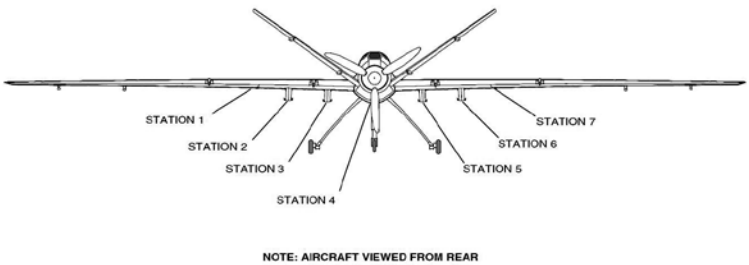

Figure 3. MQ-9 station depiction. (*Reprinted from* TO 1Q-9(M) A-34-1-1, *Technical Manual, USAF Series MQ-9 Aircraft Nonnuclear Munitions Delivery*, change 1, 1 March 2014, 1–3.)

Four hard points are currently utilized to carry weapons at any given time, but all were originally designed to be used as viable weapons launch points from the aircraft. The current weapons loads are also limited to the two weapons previously listed, which lack flexibility in their employment tactics due to fixed munition sizes and capabilities. The system software currently does not allow for other weapon types and their associated release mechanisms to be attached to any of the hard points and employed on a mission.

The AGM-114, known as a helicopter-fired (or Hellfire) missile, is a small payload missile originally designed as an antiarmor weapon to be launched from attack helicopters in a conventional land war.[20] The GBU-12 is a laser-guided, 500 lb.-class bomb designed for blast and fragmentation effects against nonreinforced targets.[21] These weapons, though effective in their primary roles, vary in regard to destructive power and accuracy. If a target is in an environment with large amounts of potential collateral damage, either weapon could misguide or malfunction and miss the intended aim point.

There are other weapons of varying explosive power currently in use that could provide a SOF ground force commander (GFC) options to engage a hostile target. The AGM-176 Griffin missile is smaller and weighs significantly less than a Hellfire—approximately 30 lbs. as compared to approximately 100 lbs. A given station could carry three Griffins instead of a single Hellfire with a different launching mechanism.[22] The GBU-39 is another viable alternative that weighs approximately 250 lbs. and has additional GPS navigation and targeting capabilities, allowing for precise targeting and a scaled down and more manageable blast radius as compared to a standard GBU-12.[23] These or other weapons which may be employed in the future currently have no active interface in the GCS software.

Techniques, Tactics, and Procedure Education and Development

RPA have been employed in Afghanistan since the beginning of the war. SOF have traditionally utilized ISR to learn about the battlespace and have relied on manned aircraft for support during the operation with little to no situational awareness gained just before moving to the objective area. With the addition of RPA to the field, SOF teams now rely on constant ISR in preparing and executing missions.[24] Despite the demand, many within the SOF community do not know how to employ MQ-9s or even what capabilities they possess. Often SOF teams are assigned an RPA for overwatch and target area monitoring prior to an operation and may assign scanning tasks that are not possible with the limited fields of view afforded by the Multi-Spectral Targeting System.

USSOCOM was created after the failure of Operation Eagle Claw in Iran in 1980, which aimed to extract the US hostages from the American embassy in Tehran.[25] The mission failed when, during a severe dust storm at the staging area, one of the helicopters assigned to the mission collided with one of the refueling C-130 transport aircraft nearby, killing eight US military personnel.[26] Many of the lessons learned from after action reports cited the lack of interservice planning prior to the start of the mission. In other words, each service branch's troops planned only their small portion of the mission without interaction from the other players. USSOCOM was charged with training and equipping elite special forces for operations and to understand what each player brought to the field to maximize efficiency and minimize risk. As such, integrated exercises and training rehearsals were required among each service branch's special forces contingent—Marine Corps Forces Special Operations Command, US Army Special Operations Command, AFSOC, and Naval Special Warfare Command—that would work together for an operation.[27]

In executing many of the preoperation training exercises and rehearsals, members of the units involved will send representatives to train with and educate the other unit about the capabilities and limitations offered by the other unit and its associated hardware. These liaison officers (LNO) often are the conduit between home station mission units and the partners executing mission. The LNO's tour may last for a specific operation's duration or for several months. During this time, the system LNO serves as the subject matter expert who provides solutions and ideas toward endstate objectives and actioned goals by the supported unit. However, the LNO is a temporary assignment, and with a constant flux of personnel and mission requirements, knowledge and trust between units can be easily lost.

Operational Considerations

SOF RPA in OEF and OIF

Each AOR generates different requirements for each type of aircraft to enter and operate within the given theater's airspace. Recent wartime examples of theaters RPA operate within include OFS (formerly OEF) in Afghanistan and OIR (formerly OIF) in Iraq.[28] In each theater, a primary enabler of MQ-9 flight has been a permissive environment with respect to antiaircraft systems due to systems limitations in combatting such threats. Afghanistan's poor integrated air defense system and lack of ability to counter US Air Force aircraft quickly dissolved their formal opposition to US efforts to track down and eliminate al-Qaeda leadership in the country. AFSOC aircraft and SOF teams were utilized to infiltrate the country and establish a series of bases from which to build US forces in the country as well. Venturing beyond the confines of a FOB often meant little to no support so many of the first few cycles of the F3EA cycle was permitted through the use of ISR aircraft, specifically MQ-1 Predators and MQ-9 Reapers.

Scenario: Communications

During the mission in central Africa, the MQ-9 MCE crew has switched frequencies from civilian ATC to their SOF team via the ARC-210. Though air traffic is scarce, light civilian aircraft occasionally transit through the target area. While the ground team moves toward their objective, the MQ-9 crew must switch rapidly between encrypted radio communications with the team and unencrypted radio communications with ATC to ensure air traffic deconfliction. During one of the ATC check-ins, the crew notices sentries in the target area. Due to the delay in sending commands to the aircraft via satellite signal and the transmission delay in the radio, the crew does not alert the ground team in time and the sentries begin firing on friendly positions. If another radio were present within the system, the crew could monitor ATC as well as speak to the ground team to warn of threats or activity at the target.

MQ-9 Communications

Within the confines of OFS and OIR, RPA are able to operate under procedural and radar control from ATC which utilizes "kill boxes" and "keypads" to define airspace boundaries at a specific altitude for an aircraft to operate.[29] Kill boxes are segments of airspace in 30 nautical mile by 30 nautical mile sections, effectively squares. Each kill box is further subdivided into keypads similar to the three-by-three numerical pad on most telephones. ATC can separate aircraft procedurally by tracking where each aircraft is assigned and direct separation by altitude or directing air traffic via routes using the Common Grid Reference System (CGRS) kill-box designations. ATC also separates and controls aircraft via radar, similar to how aircraft are controlled in the national air space (NAS). The radar tracking is enhanced by identifying aircraft via their on-board transponder, which is often "identify friend or foe" capable. RPA transponders are robust enough to be tracked by ATC and correlated to a radar track for precise control. ATC instruction to RPA is delivered by a tactical Internet relay chat (mIRC) due to the limited radio capabilities of RPA.

As discussed, the single ARC-210 radio employed by the MQ-1 and MQ-9 is limited in range and receiving capability as it can only track one audio channel's worth of transmission.[30] Should there be an audio signal on one of the passively monitored channels, such as "guard," there is a high likelihood of missing communications from ATC or another aircraft. As regulations require at least two forms of communication with a controlling agency for redundancy, mIRC is an acceptable alternative to poor radio communications. [31] Both Afghanistan and Iraq currently allow mIRC as the primary means MQ-9s use to communicate with ATC;

the US Air Force is uniquely equipped to utilize this form of technology to overcome the communications limitations of the MQ-9 and its single radio. However, such technological work-arounds will not always be possible.

Should an RPA deploy to a country unwilling to allow US military ATC primary control over both military and civilian aircraft, mIRC will no longer be an option. Other forms of communication, such as telephones, are authorized but not all civilian ATC agencies overseas have ready access to a phone that may be called from a DOD unclassified line.[32] So robust radios are needed to facilitate communication with ATC. Cases where the US military does not control the airspace for a given operation will become more prevalent as SOF RPA operations move to new theaters to hunt targets or gather intelligence. Operations such as the capture of a high-value terrorist in Libya, where the United States does not control the airspace, would have hindered an MQ-9's ability to aid the SOF team in their operation.[33]

Often when operating over a given target, there are more communications messages passed in mIRC than target updates and tactical information. Airspace notifications, movement directives, and traffic advisories all populate simultaneously while a crew scans for threats and passes those over-radio communications to the ground party. The current layout of the GCS does not allow for an efficient, nor all-encompassing scan that allows a pilot or special operator to quickly see a mIRC message and respond while talking to a ground team member.[34]

Figure 4. Typical GCS MCE configuration. (USAF photo by TSgt Ricky Best.)

The number of screens and information they contain at any given moment can quickly become overwhelming. It is also easy to miss scrolling messages from military ATC while conducting other tasks during a typical mission. The inability to quickly communicate with ATC and the ground party poses a safety risk to operators in terrestrial and airborne realms.

The same concern arises when speaking to multiple ATC agencies in civilian aviation. Many aircraft with two radios are able to monitor a primary ATC frequency but utilize a second radio to update airfield weather through the automated terminal information service, call other aircraft for pilot or in-flight reports regarding airway weather conditions, or call flight service stations to amend filed flight plans. When changing between ATC entities, there is a positive handover from one to the other initiated by having the aircraft "establish good two-way communications" (or "call good two-way") with the next agency before that aircraft is allowed to cease monitoring their current ATC frequency. A single radio hampers these efforts as any immediate and critical calls from ATC will be missed while checking in with the next ATC agency. The second radio facilitates vital safety and regulatory needs in nonmilitary ATC environments. Additionally, should an MQ-9 need to work on a tactical frequency to facilitate SOF team objectives during an operation, a second radio would provide the means to monitor ATC as well, negating the need for alternate forms of communication and enhancing flight safety.

Scenario: Navigation

The MQ-9 is vectored by civil ATC to several en route navigation points depicted only via GPS coordinates due to a lack of traditional navigational aid infrastructure. The MCE crew has the points loaded in their tracker display via their "points of interest" file, with the coordinates manually inputted by the crew. Due to task saturation from coordinating for the impending operation, they miss their navigation point by several miles, prompting ATC to begin directing them to vacate the airspace for failing to comply with directions. The crew is able to resolve the issue with help from support agencies at the AOR staff level and continue the mission, albeit delayed due to the coordination required.

MQ-9 Navigation

Both MQ-1 and MQ-9 navigation is structured DTED maps and inertial navigation system (INS) coupled with GPS navigation. The aircraft knows its INS/GPS position, which is overlaid on a map known as the GCS tracker display.[35]

The aircraft's actual position relative to the ground is based on the accuracy of the maps created. When operating in a given military-controlled airspace, locations are generally given in CGRS/Military Grid Reference System grids with kill-box/keypad references. Additional waypoints may be generated, but due to software rounding and accuracy limitations, the coordinates entered may not be accurate.

GPS navigational requirements dictate that all points to be navigated to or from along with GPS-only procedures must be loaded in their entirety and unaltered from an approved database.[36] An MQ-9 can load a series of points known as a "points of interest" (POI) file, but each point must be manually input to the system and saved, introducing the possibility of coordinate errors. Additionally, the MQ-9 is incapable of precisely navigating to those points during normal "autopilot" flying. A "preprogrammed" mission may be built by overlaying the waypoints onto the POI points, but each point of the mission's coordinates must be manually updated by the pilot—again introducing the possibility for input errors.

A flight management system (FMS) incorporated into the existing GCS architecture would eliminate the possibility of navigation input errors as well as increase the fidelity of navigation in a foreign civilian airspace. Foreign controllers currently cannot direct an MQ-9 to fly to a given navigation point, traditional or GPS, unless a crewmember previously built it into the system. In a new theater with controllers who are unfamiliar with the inaccuracies of operating an MQ-9, there is a high probability of MQ-9 crews violating flight directions. Worldwide GPS navigational databases eliminate crew-controller confusion as to where precisely an aircraft is expected to fly.

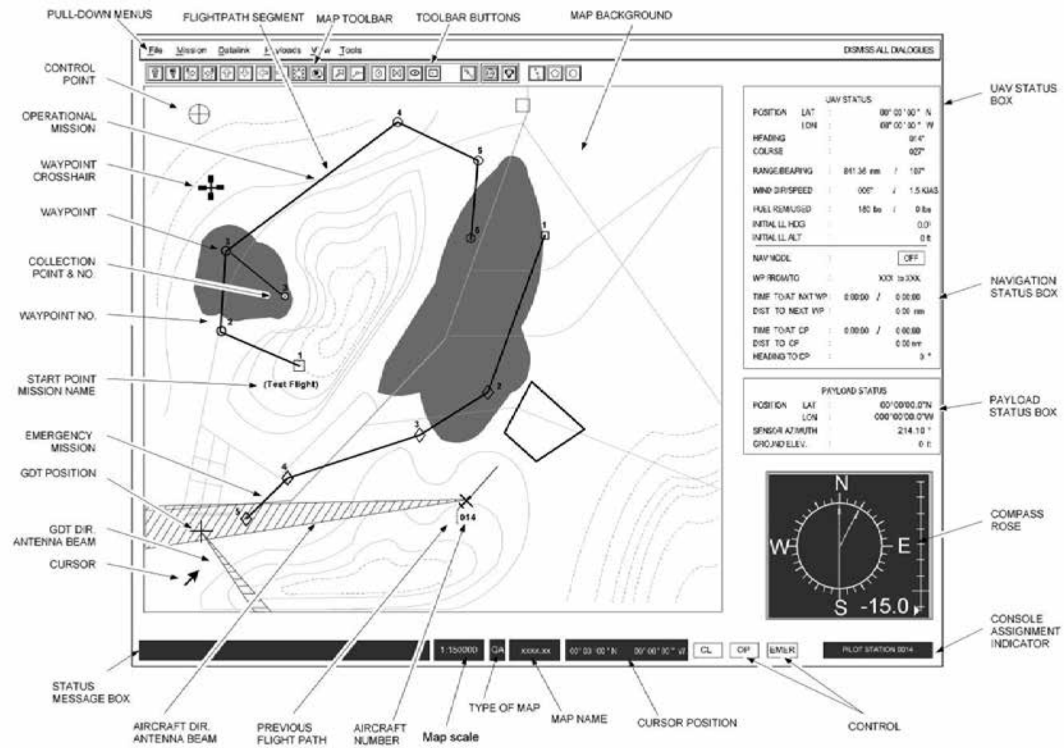

Figure 5. Tracker display used for navigation. (*Reprinted from* TO 1Q-9(M)A-1, *Flight Manual, USAF Series MQ-9 Aircraft*, change 1, 2 May 2014, 8–71.)

Furthermore, having an FMS capable of GPS-only navigation allows for the possibility of executing GPS approaches as well. The MQ-9's present software does not allow for the execution of precision arrivals, departures, or approaches associated with takeoff and landing at an airfield. The aircrew can build a facsimile approach in which the parameters of a given traditional approach—such as glide slope, descent points, and headings—are built into each GCS individually.[37] These approaches are able to be modified by the crew executing them, and as such, are not approved for instrument flight in instrument meteorological conditions (IMC). MQ-9s are thereby restricted to visual meteorological conditions (VMC) "straight-in" approaches. This affects the MQ-9's ability to safely fly given the limited airfields to launch from and recover to. Should an FMS GPS approach be fielded, MQ-9s could be cleared and treated the same as any host-nation aircraft with respect to airfield approaches, separation, and navigation. However, this would not address safe separation of aircraft requirements for flying in ICAO airspace generally handled TCAS.

Scenario: Traffic Awareness

Finally established on target and with positive communications with the ground team, the MQ-9 crew inadvertently flies within several thousand feet of a commercial airliner. The crew missed the radio alert from ATC due to the single ARC-210 on-board the MQ-9. ATC and the civilian airliner file a hazardous air traffic report to annotate the failure of the MQ-9 crew to adhere to safety regulations. As the report works its way through the system the issue in both the host nation and international community could result in the MQ-9 crew receiving disciplinary action in the form of downgrades in their aeronautical rating. Additionally, questions will be asked as to why a US military aircraft was operating without a means of safely deconflicting from other aircraft outside a declared warzone, bringing unwanted attention to the SOF mission.

MQ-9 Traffic Awareness

ATC is currently the only means of actively avoiding other traffic in a civilian controlled environment. As discussed, the lack of TCAS and TCAS II is prohibitive to safely navigating in civilian airspace. Although not perfect, TCAS does need to interact with the transponder or TCAS module of another aircraft to deliver timely resolution advisories, providing a greater safety margin for all aircraft in the vicinity. Future capabilities such as ADSB will further mitigate the MQ-9's inability to see and avoid other aircraft in a given piece of airspace.

The use of TCAS in a military-controlled theater is less restrictive due to the restrictions and separation requirements dictated to all military aircraft operating in that theater. Each aircraft under ATC control is separated by regulations in the airspace control plan (ACP) and vectored for safety accordingly. For operations requiring multiple aircraft in a localized restricted operating zone (ROZ), deconfliction and separation is handled by the ROZ controller or sometimes handed to an air warden to manage which aircraft are positioned where. The safe separation, both laterally and vertically, of aircraft in a ROZ is most important when conducting strikes. The aircraft in a ROZ may be positioned within altitude layers—"stacked"—preparing to support an operation. The need to quickly relocate to facilitate an air-to-ground strike is vital to that strike's success.

Delays in relocation due to the communications limitations via radios and mIRC take time in which ground members may be exposed to unnecessary risk. TCAS or ADSB would provide a picture for situational awareness of where the other aircraft in the stack are located relative to the MQ-9 and shorter, more direct communications could be delivered to move aircraft out of the way. For example, "F-16, MQ-9, I have you on TCAS, no factor for strike." This would also provide situational awareness in civilian airspace about other traffic in a given target area that may inadvertently fly through a US ROZ with only RPA inside. TCAS or ADSB could alert the MQ-9 pilot of a possible traffic conflict. This would allow either a conversation with ATC to divert the civilian traffic away from the target or the ability to safely adjust a flight or weapons path to continue the mission with the civilian traffic none the wiser.

Scenario: Weapons Limitations

The HVI at the target location is reported to drive a generic sedan with no armor plating or reinforcement. The Hellfire variants and 500-lb. bombs are ideally suited for destroying the vehicle should it flee the SOF team's raid on his headquarters. Upon arriving at the location, the sedan is located in a narrow street with several presumed civilian homes located close by. Four Hellfires with programmable effects and a single 500 lbs.-class bomb were loaded at the LRE location. Due to the location of the potential target relative to high collateral damage, the MQ-9 cannot ensure it can precisely strike the vehicle to prevent the target's escape and ensure no damage to the surrounding buildings or people. The four-hour transit to the LRE plus the re-arming with different Hellfire missiles and the removal of the existing bombs result in delays to arrive on station and developing the target before the operation can commence. The GFC asks for other options should the vehicle remain in the high collateral damage area, but the MQ-9 crew can offer no alternatives to the loads they had carried.

MQ-9 Weapons Systems Interface Update

As discussed, the MQ-9 weapons system is limited to AGM-114 Hellfire missiles as well as 500 lbs.-class bombs.[38] A number of variants of each kind of weapon caters to numerous desired kinetic effects and guidance programs that are effective against most types of enemy combatants in current theaters.[39] The SMS from the pilot's control station within a GCS controls each weapon.[40] Electrically controlled and powered munitions are able to change a number of settings to meet the target requirements based on the GFC's intent. Though the attack parameters for each weapon may be changed in flight, the current available weapons implemented are hard coded into the software for both the aircraft and the GCS, limiting stores to only Hellfires and 500 lbs.-class bombs.[41]

With the wide variety of targets in the current conflict—specifically in OFS against the Taliban and al-Qaeda and the Islamic State of Iraq and Syria (ISIS) in Iraq—Hellfires and 500lbs bombs may not have the correct parameters or precision to meet the GFC intent while also minimizing collateral damage. Numerous open-source reports and ISIS social media posts speak of seizing numerous military-grade weapons systems, including tanks and other heavily armored vehicles.[42] Specific Hellfires are designed to effectively neutralize such targets, but equipping an MQ-9 with antiarmor missiles reduces its capacity to employ for maximum lethality against other target types such as enemy personnel in the open or civilian structures.[43] Alternative weapons—such as the AGM-176, GBU-39, or other weapons that are compatible with the weight limitations for each station—coupled with 500 lbs.-class bombs and Hellfires, could meet the diverse requirements to combat the ever-changing threat in the latest and future conflicts.

Unfortunately, implementing new types of weapons means updating the SMS code to understand and interface with that weapon. The US Air Force has stated that it intends to implement a more versatile software line that essentially acts as a weapon plug-and-play system without having to ensure correct hard code is added to the current MQ-9 software load. The system is known as the Universal Armament Interface (UAI) and was originally designed for use with current and next generation fighter and bomber aircraft.[44] The system actively communicates with a given weapon to generate employment considerations and allows an on-demand new set of weapons to be loaded to the aircraft specifically tailored to the mission without having to wait for long-term code updates.[45]

Scenario: Number of Weapons

After the MQ-9 is established in orbit over the target area, the SOF team begins their raid via a helicopter drop off a few miles from the target and then completes the rest of the transit on foot. The HVI is known to keep to a small protection force formed from his AQIM members in the area; when the team nears the target, the greater part of the enemy force begins to move against the team's position. The team calls in air strikes to eliminate the threat while they assault the target building, and the MQ-9 crew employs all four of their Hellfires and their 500 lbs.-class bomb. This kills many of the first line of the enemy forces but not all. The team is still in danger and their only air support is out of weapons after only a short engagement. The team is forced to retreat early without the HVI.

Limited Weapons Capacity

The Air Force and all joint air components in a given theater are generally given the air tasking order (ATO), which is generated in a tasking cycle. The overall objectives passed from the theater commander drive the targeting decisions on what is targetable to the appropriate degree, which further generate the requirements for specific effects against those targets.[46] The desired effects are compared against the available strike platforms; the weapons they can carry are then allocated to a task list with target information within the ATO.[47] The aircraft are then outfitted with the weapons appropriate for the mission. MQ-9s are potentially only allotted a maximum of six weapons based on this type of weapon assignment and the available weapons able to integrate with the system.

Despite having the potential for a larger variety of weapons and weapon size changes with the UAI, the number of weapons carried still is a limiting factor. Four of the seven stations on the MQ-9 are capable of carrying weapons, with only two stations able to carry Hellfire variants.[48] The MQ-9 is capable of launching with stations two, three, five, and six loaded with the maximum weight weapons at takeoff at the cost of reduced fuel load to not exceed maximum ramp weight.[49] The approved configuration index shows a number of different combinations of Hellfires and 500 lbs.-class bombs but are severely limited in number.[50] An MQ-9 is therefore loaded with what munitions it may need for a given dynamic mission without the ability to add more or a different variety. The typical sortie duration of an MQ-9 is over 12 hours, far longer than the crew of a typical manned aircraft is able to remain airborne without aerial refueling. With this extended mission, all six weapons could be expended relatively early into the mission and no further support could be provided kinetically to any nearby friendly forces.

Combining the ability to load a number of new weapons with more weapons than previous SCLs creates the possibility for more varied weapon sets. Given the long sortie durations of the MQ-9, the aircraft's downtime between sorties is minimal compared to other airframes. The time it takes to switch out weapons racks—from a Hellfire launcher to a GBU for example—needs to be shorter than the time between sorties, otherwise it could impact launch times and mission prosecution. The weapons suspension systems to integrate new weaponry must be versatile enough to carry and employ the weapons while needing minimal maintenance effort to ensure continued effectiveness.

Scenario: SOF Team/MQ-9 Integration

In the time leading up to the operation against the HVI in central Africa, multiple experts in MQ-9 operations—including experienced pilots and sensor operators from the squadron tasked with supporting the team— briefed the SOF team. The SOF team ran many rehearsal missions, practicing how the personnel on the ground would execute the raid and accounting for many contingencies. The SOF unit had little to no practical experience with MQ-9 operations other than brief experiences receiving ISR video while deployed to OFS in Afghanistan. Their plan did not include detailed integration with the MQ-9 on station beyond standard overwatch callouts used by other SOF support aircraft. The MQ-9 crew is given the details of the raid, and despite knowing the SOF team has studied the MQ-9's capabilities, are unable to quickly provide the directed support to the team. The SOF team is very directive of the MQ-9's crew as to how to operate their system, rather than passing a desired effect. The resulting micromanagement drives the sensors away from the target building, during which time the HVI escapes.

AFSOC MQ-9 TTP Development

The responsibility to develop TTPs for effectively employing a given aircraft generally falls under the purview of a squadron's weapons officer. The weapons officer ensures that the TTPs are sound techniques based in repeatable processes to meet a given commander's intent, whether that is the air commander attempting to meet strategic objectives or the GFC managing a small, tactical scenario within the AOR.[51] When divorced from constant interaction with a ground party, a given aircrew may rely upon doctrinal publications, such as the Joint Publication (JP) 3 series, which cover all manner of joint mission sets.[52] The ability to reference and train to these common standards accounts for much of the mission-related training accomplished by aircrew.

SOF's specialized missions require an intensified training and planning schedule for executing operations, requiring its own publication in the JP 3 series.[53] Many of the tenets that mark a given force or operation designated as SOF include the special training and equipment employed to garner high success of the mission.[54] As such, the habitual and direct support provided by SOF MQ-9s requires intimate knowledge of a given SOF team's internal TTPs as well as their capabilities. In turn, the SOF teams in each service branch attempt to integrate with and learn the capabilities of each weapons system they plan to utilize during an operation.[55] The implementation of effective aircraft use is facilitated by the use of LNOs to coordinate and educate the SOF leadership and teams in theater and just prior to deployment.

In established operations, AFSOC MQ-9 LNOs work daily with teams to effectively work through the F3EA chain. However, the requirement to assign LNOs is usually reserved until the SOF team is preparing to execute operations in a given theater for a "just-in-time" sense of establishing partnered TTPs and operational standards. This, coupled with unclear lines of command and control at the strategic level, can contribute to frustrations and inefficiencies while employing MQ-9s in that new theater. There are several training opportunities throughout a given calendar year where a SOF team may train with and learn about AFSOC's unique MQ-9 capabilities, but given the limited resources of manpower and FAA NAS flight rules prohibiting free MQ-9 flight, the training is not as effective as it could be. LNO education at the SOF unit level, specifically at each of the major service component special operations organizations well prior to deployment times, has proven to improve MQ-9 support while simultaneously broadening the knowledge of how to effectively employ the weapons system in theater.[56]

Conclusion

RPA's support to SOF entities may be improved through the addition of existing flight technology, improving the communications scheme utilized by RPA systems, providing subject matter experts to the supported units around the globe, and training effectively prior to an operation commencing in accordance with the fourth SOF truth: "Competent special operations forces cannot be created after emergencies occur."[57]

The research within this report answered how best to improve MQ-9s with regard to entering and navigating in national or extranational airspace while also improving mission effectiveness. It is no longer solely AFSOC's prerogative to see MQ-9 support to SOF teams succeed, but the SOF team's prerogative as well. The knowledge gained from previous initiatives into new theaters shows that airspace controllers worldwide, including the FAA in the United States, do not know nor trust RPA capability to effectively communicate and navigate safely among human populated aircraft. Adding the standard navigation, communication, and deconfliction equipment common on most other military aircraft will limit doubts to MQ-9 safety, which will smooth entry of the aircraft into theater.

Additionally, the limited and slow-to-adapt weapons cycle of the MQ-9 does not account for the new and varied environments that the enemies of America will operate from in the future. USSOCOM and the US Air Force must work toward rapidly expanding the weapons capabilities of the MQ-9 to account for the numerous target sets that will be prosecuted in every conceivable environment. A plug-and-play weapons system in the form of the UAI will ensure the correct application of force, on-demand, with minimal collateral damage. The new weapons and environments will require the need to develop new TTPs with SOF teams who have not previously worked with RPA. Embedding LNOs with the SOF teams year round before they are required to deploy will increase the corporate knowledge of their SOF RPA brethren as well as their trust that the RPA crew will watch over them as they hunt the enemies of America.

Recommendations

To help solve the difficulty of establishing SOF RPA in a new theater with all of the necessary equipment and tools to be effective ISR platforms for any end user, this research proposes six recommendations. The recommendations will follow the order they have been presented in the preceding research.

Recommendation 1: Add Second Radio to MQ-9

A second radio with the necessary satellite bandwidth to allow the MCE crew to utilize them will greatly improve RPA on-scene communications. This provides many advantages concerning aircraft communication, not the least of which is interaction with air traffic control. The ability to have and use redundant communication systems is an FAA and Air Force flight requirement.[58] Additionally, a second radio affords the ability to speak to other military assets quickly and securely should secure military chat fail to be an option. RPAs with two radios will further be able to speak directly to ground parties while monitoring ATC. This configuration would eliminate delays in conveying critical information to those in harm's way, while also allowing the RPA to stay out of the way of other traffic operating under ATC control.

Factors that could hamper the effectiveness or implementation of a second airborne radio include the lack of a second aircraft ARC-210 interface in the GCS and limited satellite bandwidth for a second radio. Adding GCS interface functionality for a second radio in theory should not be difficult. It could be incorporated to the same upgrade cycle due out in the next several years. The window from the tracker display controlling ARC-210 functionality is simple, so adding a second radio interface to it could prove simple, but more research is needed from a program of record perspective to investigate actual difficulty. Bandwidth across the satellite control signal could also prove to be a challenge to upgrade. Each change in bandwidth affects the quality of the data streams from other systems, such as video quality or synthetic aperture radar (SAR) update rates.[59] A solution could be to limit or remove SAR functionality from dual radio-equipped aircraft. Neither of these factors should impede nor delay implementation of a second radio for both ATC awareness. The ability to communicate on multiple tactical frequencies will greatly enhance mission effectiveness.

Recommendation 2: Add GPS Navigation and Approach Capability to MQ-9

To act in accordance with flight regulations and deconfliction requirements for international flying, MQ-9s require the ability to navigate and execute GPS approaches from an approved database through an FMS. Many ICAO navigational and approach procedures have a GPS equivalent if an aircraft is unable to execute via traditional navigational aid. The current system employed by SOF RPA does not meet the USAF or ICAO GPS standards of maintaining an updated GPS database.[60] If an MQ-9 could navigate and execute GPS procedures from host-nation and ICAO standards, there would be little cause for concern as to where the RPA was flying and by what procedure. The effort to educate the host nation would be easier than attempting to explain "normal" RPA operations.

The use and implementation of FMS navigation would require training for MQ-9 pilots with no previous aircraft experience. Additionally, the maintenance of the systems and file updates would need to be incorporated into maintenance personnel contracts to ensure compliance with FAA regulation. Additionally, current GCS software and navigation techniques are not integrated with an FMS, requiring hardware upgrades for implementation, which will take time and money. None of these considerations should impede implementing true FAA compliant GPS navigation systems on MQ-9s.

Recommendation 3: Add TCAS or Equivalent to MQ-9

In addition to true GPS database navigation via FMS adding TCAS to the aircraft will also put host-nation and partner aircraft more at ease when flying near RPA. Though current TCAS systems give some advanced warning of traffic, and resolution advisories give several seconds to react, RPA's inherent control delay when operating under the MCE satellite configuration is not accounted for, leading to potential catastrophic delays. Adding TCAS or ADSB functionality will allow safer passage through host-nation and US NAS as well as make deconflicting strike assets in a target area easier. RPA would also be able to separate from other RPA easier without the need for additional software or attempting to coordinate and deconflict through the use of secure chat.

Including TCAS or a similar deconfliction system would require further bandwidth allocated to the new part of the system as well as additional changes to the GCS. A lengthy training process is required to incorporate an accurate and timely presentation to avoid collision with other aircraft into normal operating procedures for MQ-9 crews. Feasibility studies for current GCS configurations may be warranted, but implementation should be a priority to allow MQ-9 flight in US NAS as well as in ICAO compliant airspace.

Recommendation 4: Equip MQ-9 with UAI Weapons Interface

To correct the limited armament capability of the MQ-9, the UAI architecture should be incorporated as soon as possible into the MQ-9 software. As mentioned, the current weapons update cycle requires an overall system software update which includes hard-coded weapons files to allow the MQ-9 to interact with the weapons. Adding the UAI to current and future software upgrades to the system will allow for more weapons choices by both the crews and the supported unit to meet mission needs. With the addition of the UAI comes the need for an interchangeable rail system on the hard points. Changing mission needs and weapons requirements, coupled with 20-hour missions, necessitates the ability to quickly change out weapon types from under the wings of the MQ-9. Universal launch rail fittings that can accept a variety of missiles or bombs and could be changed during an aircraft's down time would revolutionize the concept of weapons-on-demand. The present systems development cycle does not allow for rapid adaptation of new weaponry without extensive, multiyear testing and procurement cycles. Despite the intentions listed in the RPA vision and vectoring document through 2038, current dynamic target sets and missions must be accounted for faster than typical development. The USAF headquarters has acknowledged it plans to implement the program. It is being developed concurrently for all major weapons systems, so there is no reason to delay implementing UAI on MQ-9s.

Recommendation 5: Add Ability to Weaponize All Seven Hard Points of MQ-9

Current SCLs only place weapons on four of the seven hard points depicted in the TO, but each has been rated to carry at least an equivalent payload as the Hellfire single-missile rail.[61] Plans to place an external fuel tank on one of the inboard stations notwithstanding, there are five remaining stations that could easily be converted to carry a number of different munitions capable of interacting with the universal launch interface. MQ-9s could truly be AFSOC's most versatile strike platforms with many precision weapons to ensure the safety of SOF teams and the disruption of enemy terrorist networks in multiple situations. Weaponizing the remaining stations—specifically one, four, and seven—will require a change in the procedures for exchanging weapons racks and missile rails. A new system of plug-and-play rails or racks would negate the need for heavy maintenance and limit aircraft down time between sorties should the mission require a different set of munitions quickly.

The addition of munitions pylons on stations one and seven could increase wing drag significantly. Flight profiles for airworthiness would determine the on-station loiter impacts of the additional weapons pylons. Given the weight limitations cited previously—150 lbs. on the outer stations—the size of the munitions should limit the performance reductions of the aircraft's loiter time, but further studies are required.

Recommendation 6: Place RPA LNOs with SOF Units prior to Commencing Operations

Each SOF team that deploys to an AOR understands what to expect from each aircraft that will support them, but treat RPA differently. Educating SOF teams and their parent commands before they deploy will increase in-theater effectiveness immensely, starting from the instant operations commence. To that end, RPA LNOs should be embedded with the SOF component of each service year round. These LNOs would facilitate training and form the habitual relationships that are crucial to SOF success. The LNOs would provide the most up-to-date capabilities and training RPA systems and crews have while developing TTPs for mission execution in whatever environment the SOF unit is operating in. The LNOs would be a permanent presence in the SOF ground communities, working hand-in-hand with other Air Force assets to ensure the SOF teams know how to use RPA effectively.

The current limitation to implementing LNOs with each SOF unit in all DOD branches is the current manning shortage faced by the RPA community. The Air Force chief of staff has outlined plans to improve RPA pilot retention and manning, but until the effectiveness of the initiatives is realized, there are limited personnel who are able to fill LNO billets.[62] The implementation of LNOs should be executed as manning increases as soon as able.

Scenario: Implemented Solutions

Prior to Operation Threatening Viper, the SOF MQ-9 LNO worked closely with the SOF unit command staff and team leaders throughout their training and operational spin-up. The team leaders and command staff became intimately familiar with established MQ-9 TTPs for target prosecution and communications prior to, during, and after a raid has been conducted as well as kinetic employment of the varied weapon sets available. The SOF teams were able to train multiple times with MQ-9 crews in different locations to simulate different environments and conditions around the US NAS. MQ-9s, having been equipped with multiple radios, were able to effectively communicate to ATC, other aircraft, and the ground teams efficiently while avoiding civilian and other military traffic through the use of TCAS.

When the order to execute Operation Threatening Viper was issued by USSOCOM headquarters, the SOF unit and their MQ-9 support were ready. The MQ-9 was quickly allowed into the country by demonstrating technical proficiency and ability to comply with ICAO and host-nation aviation procedures, allaying safety concerns. The SOF team was then able to analyze the target HVI's pattern of life, determine the best weapons to support the raid to capture the individual, and quickly modify the load-out of the MQ-9 assigned to match mission needs. The extra weapons on station one and seven proved vital to halting the advance of enemy fighters on the SOF team's position, providing enough time to capture the HVI or to vacate the hostile area. The MQ-9 still had enough weapons to employ kinetically on the HVI should the decision be made to kill rather than capture.

Notes

Notes will appear in full form only in their first iteration. Thereafter, they will appear in shortened form. For full details, see the appropriate entry in the bibliography.

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Abbreviations

ACP	airspace control plan
ADSB	Airborne Digital Surveillance Broadcast
AFI	Air Force instruction
AFSOC	Air Force Special Operations Command
AGM	air-to-ground missile
AOR	area of responsibility
AQIM	al-Qaeda in the Islamic Maghreb
ATO	air tasking order
CGRS	Common Grid Reference System
CONUS	continental United States
DOD	Department of Defense
DTED	digital terrain elevation data
F2T2EA	find, fix, target, track, engage, assess
F3EA	find, fix, finish, exploit, analyze
FAA	Federal Aviation Administration
FMS	flight management system
FOB	forward operating base
GCS	ground control station
GFC	ground force commander
GPS	global positioning system
HVI	high-value individual
ICAO	International Civil Aviation Organization
IMC	instrument meteorological conditions
INS	inertial navigation system
ISIS	Islamic State of Iraq and Syria
ISR	information, surveillance, and reconnaissance
JP	Joint Publication
lb.	pound
LNO	liaison officer
LRE	launch and recovery element
MCE	mission control element

mIRC	tactical Internet relay chat
NAS	national air space
OEF	Operation Enduring Freedom
OFS	Operation Freedom's Sentinel
OIF	Operation Iraqi Freedom
OIR	Operation Inherent Resolve
POI	points of interest
POL	patterns of life
ROZ	restricted operating zone
RPA	remotely piloted aircraft
SAR	synthetic aperture radar
SMS	stores management system
SOF	special operations forces
TCAS	traffic alert and collision avoidance system
TO	Technical Order
TTP	techniques, tactics, and procedures
UAI	Universal Armament Interface
USSOCOM	US Special Operations Command
VMC	visual meteorological conditions

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