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14. ABSTRACT
Advancing technologies and equipment give smaller Group I type unmanned aerial system aircraft such as the RQ-11 Raven B, Wasp, and other miniature sized vehicles the capability for a single Marine to carry and employ a Group I UAS to provide over the hill intelligence and surveillance for a prolonged period of time at the tactical level. Because the Wasp and Raven B both have the capability to locate targets and provide a 10-digit grid, a forward observer or fire support team can utilize the airborne capability of adjusting fire for indirect weapons as well identifying targets and surveying damage induced by indirect fire when larger assets are not available or timely because of deliberate planning and higher level requirements for larger Group II type UASs support. As Group I UASs become more prevalent at the tactical level, especially within the fire support community, it is imperative that FOs, FiSTs, and even squad members fully embrace this capability and train to harness the information it can provide. Group I Type UASs are the force multiplier to the fire support team.

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MASTER OF MILITARY STUDIES

GROUP I TYPE UNMANNED AERIAL SYSTEMS (UAS) AS A FORCE MULTIPLIER TO THE FIRE SUPPORT TEAM

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Illustrations

Page

Tables

Acronyms

AFATDS	advance field artillery tactical data system
BDA	battle damage assessment
CAS	close air support
CFF	call for fire
FAC	forward air controller
FDC	fire direction center
FiST	fire support team
FO	forward observer
GCS	ground control station
GPS	global positioning system
HMMWV	high mobility multipurpose wheeled vehicle
ISR	intelligence, surveillance, and reconnaissance
LOS	line of sight
NSFS	naval surface fire support
OEF	OPERATION ENDURING FREEDOM
OIF	OPERATION IRAQI FREEDOM
PID	positive identification
RSTA	reconnaissance, surveillance, and target acquisition
UAS	unmanned aerial system
UAV	unmanned aerial vehicle

Preface

The purpose of this paper is to validate the use of small, unmanned aerial vehicles, specifically Group I type and micro, to reinforce the capabilities of the forward observer or fire support team in conducting calls for fire that put rounds on target in an environment that prevents line-of-sight to the target. My interest is peaked on this topic because of my personal hobby experience with first person view cameras on remote control aircraft that I have flown since I was a child. Combine my long time interest for remote control devices with my artillery experience as a fire supporter, I believe a small Group I type UAS is an effective and economical tool for the FO team to utilize in the execution of its mission. While larger Group II and III type UASs in the military inventory easily provide this capability, they are usually reserved for battalion or larger operations. I want to explore a capability that resides at the tactical level for the FO or FiST in providing an aerial view that allows an alternate and effective method of employing indirect fire support for the warfighter. With current technology and with the size of UAS technology coming in smaller and more robust packages over time, I see a man-packed portable UAS capable of using a camera to identify a target, unseen from the ground by the observer, utilizing its laser range finder to providing an immediate 10-digit grid back to the FO without him ever raising his head out of his fighting position. Carrying this ideal even farther is having a laser designator that can direct precision laser guided munitions to a target just as the larger UAS platforms are capable of doing today.

I want to thank Dr. Erickson for helping me take on this endeavor as my mentor. As a former field artilleryman, he understands my passion for remote controlled vehicles and the art of fire support to the warfighter. I appreciate his guidance, advice, and expertise concerning this topic.

I would like to thank Ms. Irma Alexander for putting me in contact with the personnel that have provided valuable information on what is currently taught to the UAS users in today's military forces. She has been unrelenting in her contact to ensure I was finding the information I needed for this paper.

Thank you to Derrick DeVeau for his insightful knowledge and first hand combat experience in utilizing Group I type UASs. You have provided tremendous information to me that would have otherwise made this paper impossible. Keep conducting the great training you are providing to the men and women of our Armed Services.

To Mr. Jon "Blade" Hackett, thank you for also providing a wealth of knowledge concerning the use of UASs in the MARSOC community. I look forward to hearing the results of your UAS testing in conducting mortar calls for fire.

I want to thank my family. To my wonderful wife Samantha for her love and devotion during my Marine Corps career. Thank you for your perseverance and dedication to our marriage. You have always been encouraging and supportive through all my endeavors and this project has been no exception. I would not be as successful as I am without you. To my children, Blake, Brandon, Johnathon, Alexys, and Ayden. Thanks for being patient and understanding during my busy moments but making the times we spend together worth every minute. You guys make me smile and laugh everyday no matter what the situation might bring.

Table of Contents

Page

Executive Summary

Title: Group I Type Unmanned Aerial Systems (UAS) as a Force Multiplier to the Fire Support Team

Author: Major James T. Kay, United States Marine Corps

Thesis: Reinforcing forward observer or fire support teams with Group I type unmanned aerial systems at the tactical level increases their capability to provide a timely and readily available airborne method of locating, identifying, and engaging targets by fire support assets.

Discussion: Larger Group II and III type unmanned aerial systems like the Global Hawk, Predator, and Shadow are currently utilized by today's military forces with the mission of intelligence gathering, reconnaissance, surveillance, and execution of identified targets. The problem with these assets are the level at which they can be deployed, the deliberate planning required to employ these UAS, and the logistic trains required to support such capabilities. While these larger group UASs have their place in today's missions, they don't always meet the needs of the maneuver elements at the tactical level. With rapidly advancing technologies and equipment, smaller UAS aircraft such as the RQ-11 Raven B, Wasp, and other miniature or micro sized vehicles have allowed a single Marine to carry and employ a very capable UAS that can provide over the hill intelligence and surveillance for a prolonged period of time. Because the Wasp and Raven B both have the capability to locate targets and provide a 10-digit grid, a forward observer or fire support team can utilize the airborne capability of adjusting fire for indirect weapons as well identifying targets and surveying damage induced by indirect fire when larger assets are not available or timely. As Group I UASs become more prevalent at the tactical level, especially within the fire support community, it is imperative that FOs and FiSTs fully embrace this capability and train to harness the information it can provide.

Conclusion: The battlefield is ever evolving with advancements in technology. Employing Group I type UASs by the artillery forward observer teams or fire support teams can greatly enhance their capabilities making them a force multiplier for the maneuver forces. Simple, inexpensive, and continuous equipment changes to the available and proven Group I UAS platforms makes the task even more achievable. With limited training, an artillery forward observer team will effectively put rounds on target with fewer adjustments and better accuracy for first round fire for effect in situations where the observer line of sight to the target from the ground is unattainable.

Introduction

For the warfighter on the ground at the tactical level, having a piloted combat aircraft or a Group II or higher type armed unmanned aerial system (UAS) circling overhead, provides the ideal weapon for identifying a target and executing that target with its organic weapons or providing target information to indirect fire systems in support of the warfighter. However, there are several problems that can arise with these airborne assets making this option unpractical for the combat Marine on the ground. The difficulty is the level at which they are employed and the deliberate planning required to utilize the robust capabilities these systems have to offer. Other problems include a lack of trained forward air controllers (FAC), adverse weather, possible communications challenges, and delays in receiving imagery from these assets. Table 1 provides an overview of the different groups and characteristics of UASs as defined by the Marine Corps.

Type	Operating Altitude	Range	Example	Deployment Level
Group I	100 - 500 Meters	10km +	RQ-11 Raven	Battalion
Group II	5000 - 15000 Meters	80km +	Shadow	Regimental
Group III	15000+	100km +	Pioneer	Regimental/MEF

Table 1 Examples of Marine Corps Group Types and Platforms[1]

The United States Marine Corps as well as other military and naval services have made great strides in the realm of unmanned aerial systems (UAS). They are used in many military and civilian roles including combat, border patrolling, search and rescue, and counter drug operations. Today's UASs range in a variety of sizes and designs with some of the largest being the size of corporate jets and weighing tens of thousands of pounds and able to carry payloads in the thousands of pounds. There is even speculation, reported sightings in Afghanistan, and portrayal of a stealth UAS that has the characteristics of the B2 bomber.[2] Because these larger group type aircraft do not always meet the spontaneous needs of the tactical warfighter on the

ground, he may need to rely on organic UASs to provide immediate intelligence, surveillance, reconnaissance (ISR), or target acquisition over the next hill, around a building, or through obscurations on the battle field. This requirement is met by Group I type UAS such as the RQ-11 Raven used at the tactical level which can be employed in a matter of a few minutes. Group I type UASs have provided valuable information to the warfighter on the ground in past and current ongoing operations; however, unlike the larger Group UASs that can actually designate for laser guided munitions, the Group I UASs have only been used to see what is around the corner of a building, down the road from a convoy but still providing a 10-digit grid to a target. While the feasibility of hanging a Hellfire missile on the wing of a hand launched RQ-11 Raven B is not feasible, there are other technologies that are being tested to meet this capability on a smaller scale.

As technology continues to develop, the capabilities of larger UASs is shrinking to a point where they can fit into a smaller package as part of the already available, man portable, smaller Group type UAS. It does not have a large logistical requirement or footprint like the larger operational or strategic UASs. A forward observer team or fire support team supporting a maneuver company or smaller can employ a currently available Group I type UAS from behind protected cover after removing it from a backpack. These UASs have already proven themselves over and over again in combat to provide reconnaissance, surveillance and target acquisition. As stated in the Marine Corps Vision and Strategy 2025 publication,[3]

> We will pursue developments with unmanned aircraft systems (UASs) to widen the force size multiplying capabilities that these enhanced, multispectral systems bring to the fight. Newly emergent concepts for UAS employment will continue to enhance and extend the lethal and nonlethal capability of the MAGTF and joint force commander to new levels, fostering transformational advancements in battlespace command and situational awareness.[4]

The forward focus of this paper is to provide some history on UASs and then identify how Group I UAS capabilities can be expanded to better aid in the conduct of fire support techniques, tactics, and procedures currently utilized by the artillery fire supporters and warfighters on the ground. The last part of the paper will focus on future capabilities and recommendations for the future of Group I UASs. Reinforcing forward observer (FO) or fire support teams (FiST) with Group I type unmanned aerial systems at the tactical level increases their capability to provide a timely and readily available airborne method of locating, identifying, and engaging targets by fire support assets.

History

The use of UASs began back in the American Civil War when the Union and Confederate Armies used balloons to deliver packaged explosives. This method of weapon delivery did not prove very effective. In World War II, Japan devised a plan with the same theory of floating explosive laden balloons to the United States hoping to start mass hysteria via forest fires. Again, attempting to direct the balloons on a path that would guide themselves to a targeted area in the U.S. proved to be impossible so the Japanese considered the idea a failed project.[5]

At the same time that Japan was developing their balloon bombing plan, the United States was developing its drone type UAS by turning a normally piloted aircraft into an armed unmanned drone. The limitation in this project was the lack of technology to successfully employ such a pilot absent vehicle. The aircraft had to be taken off using a manned pilot aboard who would then abandon the aircraft to start the unmanned aerial mission. This testing is attributed to the death of Joseph P. Kennedy whose life was lost during the take off of a bomb laden B-24 that exploded before he could parachute from the aircraft. It was not until the

Vietnam conflict that technology finally allowed for the use of unmanned aircraft to transport camera's that could record day and night imagery. The Ryan Firebee flew over 3400 missions in Vietnam.[6]

By the mid-1980's, the development of more advanced UASs is accredited to the Israelis. From their advancements in the UAS area, the United States developed the Pioneer, which was the mainstay UAS for the Marine Corps during OPERATION DESERT STORM. This is the first case recorded where a UAS was used by U.S. battleships to view and adjust fires for their 16-inch guns. It was noted during the war, Iraqi soldiers were surrendering to the sounds of the Pioneer UASs knowing they were being targeted for naval gunfire bombardment.[7]

Moving forward ten years, the Air Force's RQ-1 Predator along with smaller UASs like the Marine Corps Dragon Eye began their debut in the combat scene during OPERATION IRAQI FREEDOM and OPERATION ENDURING FREEDOM. The Predator demonstrates the capability in combat to attack a target by using its own laser designator and then launching a Hellfire missile from a pod mounted under the wing with pinpoint accuracy.[8] In Fallujah, "Working with UAS squadrons proved successful. Initially used as an observer platform, they could send fire missions, with its own AFATDS data, directly to the firing unit. The missions went well, often requiring only one adjusting round."[9] Keep in mind that the UAS referred to is a Group Type II or larger. The article went on to describe how the Raven lacked the ability to acquire a 10-digit grid. The Raven B discussed later resolves this lacking capability.

The Forward Observer and the Mission

Before dissecting the use of Group 1 Type UASs as a force multiplier to the forward observer or fires support team, it is important to understand the role these combat elements play when attacking a target with indirect fires such as artillery, mortars, or naval surface fire support

(NSFS). "The mission of artillery is to furnish close and continuous fire support by neutralizing, destroying or suppressing targets that threaten the success of the supported unit."[10] While this mission statement is artillery specific, the principle applies to all indirect fires support systems and even direct weapons systems such as those employed by aerial vehicles whether piloted or unmanned.

An indirect fire support system is comprised of three major elements working in unison to provide accurate effects on a target. Broken down into simplistic terms, the artillery unit has the "eyes" or forward observers that are locating targets. This target location information or calls for fire (CFF) are sent to the "brains" or fire direction center (FDC) where a firing solution to execute the target is calculated. This solution is sent down to the "muscle" or the gun line as a measurement in mils[11] elevation (up and down) and deflection (direction left or right) which then delivers the approved munitions to the intended target. The fire support team is a collection of forward observer experts and is usually comprised of an artillery forward observer, a mortar observer, a naval gunfire spotter, and a forward air controller (FAC) along with necessary equipment and communicators to support each of these fire support assets. Each observer in the FiST brings its own expertise for each weapon system but cross training between FiST members helps provide a skill set capable of employing more than just the system they represent. Per the FM 6-30, the primary mission of the artillery forward observer is to support the maneuver commander. The FO or FiST is there to advise the commander on the best way to employ his indirect fire assets.[12]

Target Acquisition and Execution

There are a few factors that, when combined together, help determine the accuracy of indirect fires. Some of those include accurate gun location, powder temperature, upper level

winds, distance to the target, small differentiation in ammunition weights, ammunition type, the Earth's Coriolis effect, and location of the target.[13] Target location is the relevant key when discussing the use of Group I UASs in support of the forward observer. According to an after action report from the 3rd Battalion, 10th Marines in Afghanistan to Marine Corps Lessons Learned, "An accurate target location is vital. The battalion felt that the artillery community had done a poor job of educating and working with the infantry regarding fire support coordination."[14]

Utilizing Group I type UASs for target acquisition can replace or enhance the current methods outline below and employed by FO and FiST. Ideally, the best method of target acquisition is having a confirmed 10-digit grid coordinate to a known target. This is achieved through several methods. First is simply a target that has been confirmed by someone logging the coordinates from a global position system (GPS) while standing at the location of the target. Accuracy is dependent on the accuracy of the GPS and number of satellite signals received. This method does not present itself very often in offensive operations where the battlefield is dynamic and fluid. It does work well in defensive operations. Another solution uses the combination of GPS and a laser range finder such as the AN/GVS-5, which provides a 10-digit grid coordinate to the target based on the users position and the distance to the target. Artillery registration is another method that uses a series of fired rounds at a proposed target with the objective of landing 2 rounds over the target and 2 rounds short of the target consecutively using the same firing data.[15] While this provides very accurate gun data, this can use an abundance of ammunition, eliminates any element of surprise if the enemy is nearby, and can rarely be used in an offensive type operation. Counter-battery target acquisition radar can provide extremely fast and accurate first round fire for effect on a target. Unfortunately this is a reactive type of target

acquisition in which an enemy is located when a radar system picks up on the trajectory of an enemy fired munitions. The radar system provides both the point of origin from which the weapon was fired and the point of impact the weapon will land. This information can be relayed to the fire direction center before the enemy round ever lands on the ground so that a firing solution can be provided to the gun line and the target is executed in a matter of seconds depending on the speed of gun crews and clearing agency requirements. The availability of this system is very limited, especially in a distributed operations environment where a single unit is spread over a larger area. The final method is the observer using his map, compass, and a set of binoculars to determine target location and adjusting rounds until he has effects on target. While a well-trained observer can still put first round fire for effects with this method, an observer can experience large probable errors in range due to the distance a target is from the observer's location.

To add another level of complication to the situation, imagine if the observer cannot see the target with the naked eye due to mountainous terrain or buildings blocking his view in an urban environment. This is where putting an observer's view in an aerial platform looking down to a target is ideal. It is even more effective if the aerial observer has laser capabilities, which as described previously, can be used to provide a 10-digit grid to a target. If the laser has designation capabilities, it can provide targeting capabilities for precision laser munitions like the Hellfire II missile. Before UASs, an observer desiring an aerial view relied on a manned aerial observer, an AH-1W Cobra for example, that can use his laser equipment to adjust indirect fire by spot lasing the impacts of adjusting rounds. Coordinates provided to the FDC can calculate new data for the gun line that will automatically move the placement of the next adjustment round based on the calculated difference between initial coordinates provided and adjustment

round impacts to provide a second round fire for effect. This is only if the first round even requires adjustment. While the notion of every maneuver company or even battalion having this type aerial support for this purpose would be desirable, it is a far stretch from reality due to asset shortages. As mentioned previously, this type of aerial support requires advanced planning and coordination, and it is usually held at a maneuver element level above the battalion.

Even if planned and available, other elements on the battlefield can thwart the use of manned aircraft or larger Group II UASs like mechanical problems, low cloud decks, or areas saturated with enemy air defense systems. For spontaneous aerial support, the smaller maneuver unit such as the platoon or company should look to its own organic aerial assets available to him whenever he requires the support. Group 1 type unmanned aerial systems and smaller UASs fits this need.

Employment of Group I UAS by the Forward Observer

In an interview with LtGen John F. Sattler, Commanding Officer of 1st Marine Expeditionary Force during the second battle of Fallujah, he was asked, "How did you employ fire support in urban operations in Fallujah, and how effective was it? How important were your forward observers to the process?" Part of his response was:

> We fired more than 6,000 artillery rounds during the battle. Every round was in response to enemy action--there were no prep fires before the attack, no harassing and interdicting fires. Every round fired was controlled by a forward observer [FO] or, in some cases, an unmanned aerial vehicle [UAV]. Our UAVs gave us the grid coordinates of an enemy position and allowed us to clear the area for forces and estimate collateral damage. Our FOs were critical. To minimize damage and injuries to noncombatants, every round was on a specific target often one tube firing at a time, and was observed. Based on the way we had laid out Fallujah's imagery with the buildings numbered, all FOs had the same imagery the pilots and personnel back at the combat operations center [COC] had.[16]

The above is a perfect example of how Group II type UASs aided forward observers in an urban environment making dumb bombs a little smarter and a little more accurate. With the emergence of smaller and newer technology, this capability now resides in the compact Group I UASs such as the RQ-11 Raven B and the Wasp made by AeroVironment. While it still lacks a capability to designate targets for laser guided munitions, it can be expected that the technology is very close to becoming a reality.

Assigned to the 82nd Airborne Division during both OIF and OEF, former Army Staff Sergeant Derrick DeVeau employed the Raven B not only to identify targets for close air support but also utilized the laser range finder and integrated software to execute calls for fire on targets in both Iraq and Afghanistan. Mr. DeVeau is now a Raven B training instructor working for Etchey Training Group, a company contracted to train military personnel on the Raven B UAS. Mr. DeVeau explained that the Raven B provides valuable information to the operator.

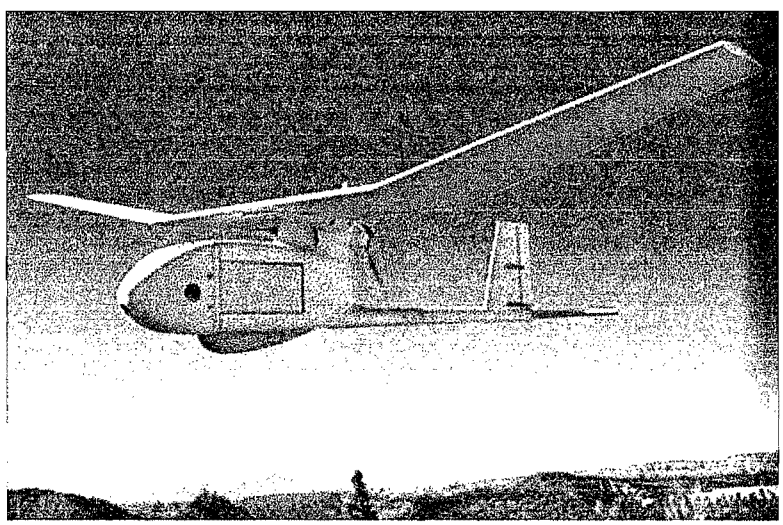

Figure 1 RQ-11 Raven B[17]

In a phone interview with DeVeau he explained how he personally employed the Raven B during several combat scenarios in which both CAS and indirect calls for fire were involved.[18]

In the first scenario, the Raven B was flown to a suspected target area. Once positive identification (PID) of the target was confirmed via video feed into the GCS, the operator centered the crosshair available in the UAS viewfinder on the target and took a snap shot of the target. He explained that once this snapshot was taken, the software in the GCS took the position of the Raven B at the time the image was taken and using the laser range finder calculates the distance from the Raven to the target based on where the crosshairs were centered when the snapshot was taken. The slant range or slope from the UAS to the target was calculated. The calculation provided a 10-digit grid to the target itself or where the crosshairs were centered when the snapshot image was taken. The target location and a description of the target were then sent to the CAS platform via voice communications. Due to airspace collision potential between the manned and unmanned aircraft, the UAS was flown out of the CAS attack area. Once the target was attacked by the manned CAS platform, the UAS was then flown back over the target area for battle damage assessment (BDA).

The second scenario involved the identification of the target by the Raven B and like in the first scenario, a 10-digit grid was provided after a snapshot was taken of the target. This10-digit grid was then sent to the fire direction center (FDC) at the artillery unit. The artillery unit sent one adjusting round. There is no area de-confliction required during artillery fire when utilizing the a Group I UAS according to DeVeau; therefore, when the forward observer or unit controlling fires receives "splash"[19] from the artillery FDC, the operator of the UAS starts looking for the impact of the adjustment round. When the impact becomes visible, another snapshot is taken with the crosshairs placed over the center of the impact. There are two options from this point. In the first option, the UAS operator passes the grid of the round impact to the FDC as a laser adjustment mission and lets the Advance Field Artillery Tactical Data System

(AFATDS)[20] do the calculating to provide the new data for the next round to the gun-line. This is how full size manned aircraft would conduct the call for fire if they were doing laser spotting from the air. The second option is for the UAS operator to acquire the 10-digit grid provided by the UAS for the adjustment round and let the software in the GCS make the calculations to provide the appropriate left, right, add, or drop corrections to be passed back to the fire direction center as a normal adjustment mission correction. Either way, DeVeau states that a second round fire for effect was the norm. When asked if all students taught by the Etchey Training Group received this training concerning the conduct of CAS and calls for fire, he replied, "It is a part of the training syllabus!"[21]

In the case where an older Group I type UAS without a laser range finder is utilized by the FO, a different method might still be used and while only theoretical and unproven, the method is basically used by FO in a typical polar type mission.

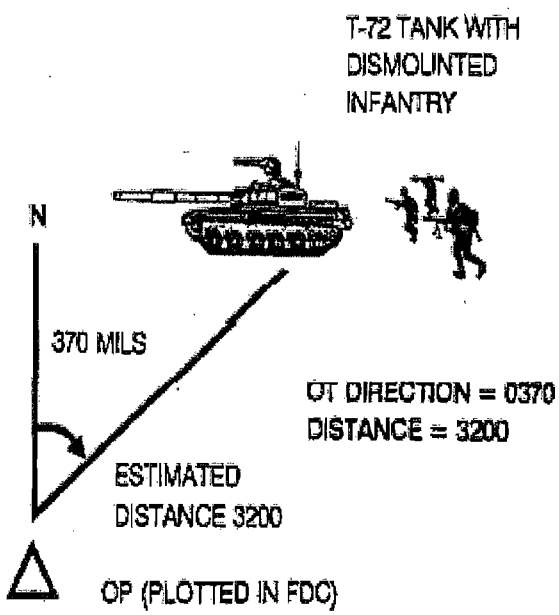

Figure 2 Visual Example of Polar Mission Elements

DeVeau explains that the GPS on the UAS always provides a distance and direction of the UAS from the GCS. Since this is the case, instead of acquiring the target via a 10-digit grid using the

laser range finder, the UAS operator centers the UAS over the target and captures the direction and distance from the GCS to the UAS. The forward observer then simply sends a polar fire mission to the FDC for fire mission calculating. The key element for the FO to remember is to send the location of the GCS to the FDC and not his own position in the event they are not co-located. The GCS would be OP (observation point) as depicted in Figure 2 shown above.

If the initial round requires adjustment, then the observer looking through the UAS camera can provide the FDC with proper adjustments, moving the strike of the round to the target via add, drop, left, and right commands using the cardinal direction of north as a direction for the FDC as seen through the camera. This method of adjustment was successful using Group II Type UASs in Fallujah.[22]

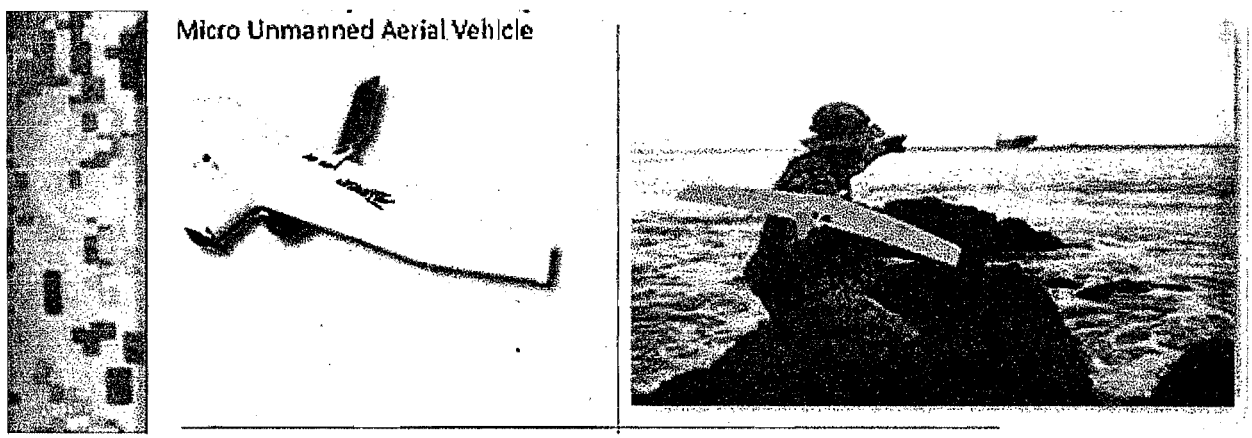

Figure 3 Wasp[23]

Marine Special Operations Capability (MARSOC) currently employs both the Raven B and Wasp UASs. While these vehicles are used mainly for ISR and over watch missions, the UAS section is looking into the possible capabilities of utilizing the Group I UASs in a target acquisition and execution role. Mr. Jon "Blade" Hackett, a former AH-1W Cobra pilot and now the program manager at MARSOC for the UAS, discussed future testing of the Raven B and Wasp in a fire support role. A scheduled test using mortars as the fire support asset will be

completed just after the publishing of this paper but will prove whether or not the systems are a viable option in performing the fire support role for the Marine Corps special operators in a combat situation.[24]

The Group Type I can also assist the FO in performing an artillery registration (described previous) on a target. Because the Raven B and Wasp can provide a 10-digit grid, an observer can spot the rounds and make adjustments back to the FDC. Once the UAS is utilized to spot two rounds over the target area and two rounds short of the target area with the same firing data, the target area can be considered registered. Because of the precision required to perform such a task, the UAS becomes a force multiplier by giving a much better view from the air looking down onto the target being registered.

The new XM982 Excalibur is a GPS guided munitions with a capability of hitting a target from 40 kilometers with an accuracy of less than ten meters. Most rounds have been hitting closer to 5 meters of the target. Most units that have utilized the round in combat are very happy with its performance. The accuracy of the round is dependent on the accuracy of the 10-digit grid supplied to the munitions before firing.[25] This is another case where a Group I UAS can locate a target and provide a 10-digit grid and minimize collateral damage by using these precision munitions.

Group I type UASs provide one other capability that reinforces the FiST. Eyes on the target are only good if the information can be relayed back to the FDC. On occasion, the FiST may outrun its communications capability unless it has satellite capabilities or a relay of some type. The UASs extend the eyes of the FiST, thereby extending the range of the communications. Typical frequency hopping radios have a range of about five to ten kilometers in a good environment. The Group I UAS has a reliable 10-kilometer range which doubles the

FiST range from the FDC. This range will extend even further once the digital data link (DDL) becomes available.[26]

Wasp and Raven B Comparison

Small unit operators prefer the Wasp to the Raven B due to its portability and realistic single person employment capability. The Wasp is truly man-packed capable. While the Raven B is man portable, it takes at least two people to operate this UAS and this does not include other required FO gear and communications. With that in mind, employing the Raven B requires some mobility assets such as an additional man in the team, or a vehicle of some sort. The Raven B still maintains longer endurance and loitering times but has a very recognizable silhouette in the sky and can be heard from several hundred meters away. While MARSOC operators have developed methods to reduce the sound detection, like shutting down the electric motor and gliding into the target area, it may ruin the element of surprise, sending a potential target into hiding. The Wasp on the other hand can fly to within meters of a target area without detection, and it is just a speck in the sky at its operating height. With its delta wing form, it gives the silhouette of a bird at lower altitudes. Besides a much shorter endurance time than the Raven B, the Wasp also requires a larger launch and recovery space whereas the Raven B can be launched vertically and induces a high stall landing for small area recovery. One upgrade to the Raven B will be from the analog link system currently employed to a digital data link. This will provide a more stabilized camera with greater zoom capabilities than the previous analog system. Mr. Hackett believes this will shift the desirability of platforms from the Wasp to the Raven. Mr. Hackett says there is also discussion of future upgrades that will allow the Wasp to systematically create a 9-line CAS mission after target identification and have it transmitted directly to an armed manned platform for execution of a target[27]

The cost for a Raven system is approximately $250,000, which includes four UASs, two GCSs, and one Reconnaissance, Surveillance, and Target Acquisition (RSTA) kit. The Wasp system is approximately $200,000, which includes three UASs, two GCSs, and one RSTA kit. When compared to the predator at an estimated $4.5 million per system, the smaller UASs are an economical tool for target acquisition and execution.

Limitations of Group I UASs

There are a few drawbacks to Group I type UASs. Because they are small in nature, they are limited to the amount of equipment or payload they can carry. This puts a limitation on the abilities a Group I UASs can provide compared to that of a larger Group UAS.

Weather can also play havoc on the size of the UASs. Degradation of the Raven starts when it encounters over eighteen knots of wind. At twenty-five knots it becomes ineffective.[28] This poses a huge issue in mountainous areas like Afghanistan where winds and updrafts are prevalent. Icing can become an issue where there is moisture and a low freezing level. The Raven can only handle trace amounts of icing because it adds to the weight of the aircraft. Small UASs are susceptible to ground fire. Although the size of the UAS at five hundred feet makes for a very small target, it is not impervious to small arms fire.

The communications required to transmit control signals and view camera feeds is line of sight (LOS) which limits its range to approximately ten kilometers. For most scenarios, this distance should prove acceptable and as previously mentioned, still provides a longer communication line from the target back to the FDC. The communications limitation will most likely be improved with time. Lastly, against a formidable enemy with jamming capabilities, UASs of all sizes may become ineffective and uncontrollable if the signal that controls the UAS is disrupted especially the signal received from the satellites to provide GPS location. This was

experienced when U.S. military forces employed its own electronic counter measures in the vicinity of an operating UAS.[29]

The endurance of the smaller UASs is very reduced when compared to larger UASs that can loiter for more than thirty hours at a time. Improving this capability may improve with time as lighter materials for construction including the batteries, higher capacity batteries or energy sources, and more efficient electric motors. Harnessing the sun's energy via solar cells on the aircraft may also increase flight time. As it stands now, there is a weight to efficiency tradeoff that does not prove this to be a more efficient source of energy for extended flight time. There has been recent testing on a fuel cell that has provided up to thirty hours of flight time on a Group I UAS while still powering onboard systems. Unfortunately it does not meet the stability requirements of the military at this time. This issue is being resolved.[30]

A lack of procured systems is also a current issue. While the Marine Corps has acquired and starting to deploy more Group 1 UASs to the different battalions, it will still require time before there are sufficient numbers, especially in the artillery battalion, to prove it an effective tool for forward observer.

The laser accuracy is also questionable on the Group I UASs. They can be off as much as fifty meters at times[31]. This error still brings a target under the effective range of a 155 millimeter high explosive artillery round especially when a battery is fired at the target which means a total of at least six rounds would hit the ground. In a linear dispersion, a six gun 155mm battery will cover a three hundred meter by fifty meter target area. This occasional inaccuracy also requires both the FO and the FDC to double check target areas on a map before firing munitions.

Constant training in any skill is required in order to maintain proficiency in that skill. The lack of UAS availability at this time precludes the use of UASs during typical live fire artillery training. This problem is compounded by the requirement for air and space de-confliction in a training area or from just a lack of a training area from which to launch and recover UASs.[32] It is expected that this issue will be resolved with time as Group I UASs become more prevalent and proved as a viable force multiplier for the FO team.

The Future of Group 1 UASs

The future presents new possibilities for the FO or FiST. The AeroViroment Company, the manufacturer of the Raven B and Wasp, are working on another man-portable that answers the need for UASs as a precision guided munitions. This five-pound expendable UAS is being called the Switchblade. From the AeroViroment website:

> The Switchblade is designed to provide the warfighter with a "magic bullet". It can rapidly provide a powerful, but expendable miniature flying Intelligence, Surveillance and Reconnaissance (ISR) package on a Beyond Line-of-Sight (BLOS) target within minutes. This miniature, remotely-piloted or autonomous platform can either glide or propel itself via quiet electric propulsion, providing real-time GPS coordinates and video for information gathering, targeting, or feature/object recognition. The vehicle's small size and quiet motor make it difficult to detect, recognize, and track even at very close range. The Switchblade is fully scalable and can be launched from a variety of air and ground platforms.[33]

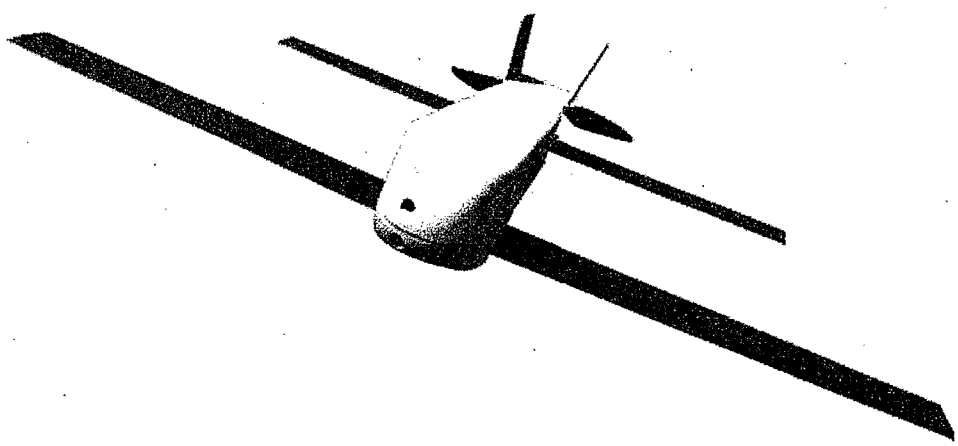

Figure 4 Picture of the Switchblade[34]

Inevitably you have a dual role UAS that can perform the same missions as the Raven B and Wasp, but if the target is about to escape in a car after planting an improved explosive device, his movement can be immediately deterred by the operator flying the explosive laden UAS into the vehicle.

Students at the Naval Postgraduate School are conducting research concerning UASs that can fly out to a target and provide ISR and target acquisition as already discussed except that at some point the UAS can land and convert itself into a land based unmanned vehicle. It has the capability to then crawl up the target site where it can perform a number of tasks such as continued ISR, better target location, or even a suicide mission. The thought is that the UAS can perceivably go where no other UASs can fly, such as a cave or open window. The UAS could then convert back to its flying configuration and return home to be used another day.[35]

The gMAV or gas micro air vehicle was developed by Honeywell Corporation and currently being test in Afghanistan and Iraq. This ducted fan UAS provides a vertical lift take off that can then move around the battlefield conducting ISR and target acquisition. "The gMAVs are primarily used for counter-IED (improvised explosive device) missions, explosive ordnance disposal, route clearance operations and the security of convoys, especially topical since the Iraqi government now requires all coalition convoy operations to be conducted at night."[36] This UAS platform does have lateral as well as vertical capabilities which gives it the capability to provide the FiST a call for fire system that can look over the hill or building obscuring the teams view from a target.

Conclusion

Larger Group II type UASs and manned aircraft provide the warfighter on the ground at the tactical level the ideal support for target acquisition and execution; however, due to a number

of restricting factors such as deliberate planning, coordinating, maintenance, shortage of assets, lack of spontaneous actions, air space coordination issues, and natural phenomenon, these larger support assets are not always available at the squad or company level. With the speed of Group I UAS procurement to the common operating forces, it is feasible in the foreseeable future to utilize the already available Group 1 type UASs to meet the needs of the fire supporter on the ground. The availability of lasers for grid acquisition in these miniature and micro aerial systems means the Group 1 type UASs can be a force multiplier to the FiST team by providing a 10-digit grid and then providing subsequent adjustments to compensate for effects of weather and temperature on the accuracy of fire support munitions. After execution of the target the UAS can then be used to provide BDA on the target. The employment of Group I UAS will require training for the FO and FiST but because of the simple and easy to use GCS software, this should not be a huge task.

Rapidly advancing technologies will only continue to improve the capabilities of these smaller UASs. It is foreseeable in the future to have smaller UASs with longer endurance times, better digital imagery, and automatic CFF relay systems available to each and every maneuver squad and at an affordable cost to the government. Units at the lower levels will no longer have to wait for larger UASs or piloted aircraft in order to get eyes on the battlefield.

Group I type UASs are the future for today's warfighter. They are a force enhancement that can extend the FO or FiST's abilities to conduct ISR, locate targets, and execute those targets using all fire support assets. Harnessing its capabilities will give today's military, especially at the tactical level, the fighting edge while saving lives and providing a deterrent to those forces that oppose the United States of America.

Endnotes

[1] Data for Table 1 gathered from http://www.navair.navy.mil/pma263. Accessed Jan 2, 2011.

[2] Joe Pappalardo, "Air Force Acknowledges Secret Stealth UAV." http://www.popularmechanics.com/technology/aviation/military/4339138. Dec 7, 2009. Accessed Dec 15, 2010.

[3] Headquarters Marine Corps. Marine Corps Vision and Strategy 2025 publication.

[4] Marine Corps Vision and Strategy 2025 publication. pg. 41.

[5] Jim Garamone. "From U.S. Civil War to Afghanistan: Flyers Sent Into Battle." American Forces Press Service, 2002.

[6] Jim Garamone.

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[8] Air Force Website. "Oct. 12 airpower summary: Predator fires Hellfire Missile". 10/13/2008. http://www.af.mil/news/story.asp?id=123119371. Accessed Dec 15, 2010.

[9] United States Marine Corps Lessons Learned. Artillery Battalion Lessons Learned. Lessons and Observations from 3rd Battalion 10th Marines, November 2009 – May 2010. November 5 2010.Pg 12.

[10] United States Marine Corps. "Artillery Operations". Marine Corps Warfighting Publication 3-16.1. May 2002. pg 1-1.

[11] Mil is an angular measurement used in artillery. 6400 mils describe a complete revolution or 360 degrees angle. Mils are used instead of degrees in artillery because they provide a more precise measurement. 1 degree is equal to a rounded 17.8 mils.

[12] Headquarters, Department of the Army. "Techniques, Tactics, and Procedures for Observed Fire". Field Manual 6-30. Washington, DC, 1991. pgs 2-1 to 2-2.

[13] Headquarters, Department of the Army, United States Marine Corps. "Tactics, Techniques, and Procedures for Field Artillery Manual Cannon Gunnery". Field Manual 6-40/MCWP 3-16.4. Washington, DC, 1996. Chapt 10.

[14] United States Marine Corps Lessons Learned. Artillery Battalion Lessons Learned. Lessons and Observations from 3rd Battalion 10th Marines, November 2009 – May 2010. November 5 2010.Pg 11.

[15] FM 6-40.pg 10-3.

[16] Patrecia Slayden Hollis. "Second Battle of Fallujah – Urban Operations in a New Kind of War." Interview with LtGen Sattler. Field Artillery March-April 2006.

[17] "AeroVironment, Inc.: UAS Advanced Development Center: Raven B Detail." *AeroVironment, Inc. : Unmanned Aircraft Systems, Electric Vehicle Charging Systems, Power Cycling & Test Systems*. Web. 25 Jan. 2011. http://www.avinc.com/uas.

[18] Derrick DeVeau. Telephone interview by James T. Kay. January 25, 2011.

[19] "Splash" is the word sent from the fire direction center of an artillery round 5 seconds prior to an artillery round hitting the ground. This is gives the observer an advanced warning to start looking for the impact of the round.

[20] AFATDS provides fully automated support for planning, coordinating, controlling, and executing fires and effects. It supports weapon systems such as mortars, field artillery cannons, rockets, close air support, attack helicopters, and Naval Surface Fire Support (NSFS) systems. Accessed from the Raytheon Company Website. Accessed January 21, 2011.

[21] The author conducted a phone interview on January 25, 2011, with Derrick Deveau and have written the information in this paper with permission from him and the Etchey Training Group

[22] James T. Cobb, Christopher A. LaCour, and William H. Hight. "TF 2-2 IN FSE AAR: Indirect Fires in the Battle of Fallujah" *Field Artillery.* March – April 2005.

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[25] Durant, Riley. "Excalibur Unitary PGM down range in Iraq." *FA Journal.* July – August 2005.

[26] Jon Hackett. Telephone interview.

[27] Jon Hackett. Telephone interview.

[28] Army, Marine Corps, Navy, Air Force. "UAS – Multi-service Tactics, Techniques, and Procedures for the Tactical Employment of Unmanned Aircraft System." FM 3-04.15, NTTP 3-55.14, AFTTP(I) 3-2.64. August 2006.

[29] Capt Michael Mishoe. Wasp and Raven Trainer for the Marine Corps. Personal interview by James T. Kay. February 2, 2011.

[30] Major Daniel Griffiths. Warfighting Lab. UAS Program Manager. Personal interview February 1, 2011.

[31] John Hackett. Telephone interview.

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[36] Andrew White. "Upgrades for gMAV in light of Iraq ops." UVNews. April 22, 2010. http://www.shephard.co.uk/news/uvonline/upgrades-for-gmav-in-light-of-iraq-ops/6185/

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