

NAVAL POSTGRADUATE SCHOOL Monterey, California



THESIS

**THE EFFECT OF UNMANNED AERIAL VEHICLE
SYSTEMS ON PRECISION ENGAGEMENT**

by

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June 2002

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SYSTEMS ON PRECISION ENGAGEMENT**

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I. INTRODUCTION

The Chairman of the Joint Chiefs of Staff (CJCS) envisions the creation of a future joint force capable of demonstrating the operational concepts presented in *Joint Vision 2020: America's Military, Preparing for Tomorrow*. The goal of Joint Vision 2020 (JV2020) is to empower the joint force of tomorrow with the capabilities required to achieve full spectrum dominance, enabling the joint force to be persuasive in peace, decisive in war, and preeminent in any form of conflict. Achieving full spectrum dominance requires the integration of four operational concepts: dominant maneuver, precision engagement, focused logistics, and full dimensional protection. JV2020 explains full spectrum dominance as the ability to operate unilaterally or in combination with multinational and interagency partners, to defeat any adversary and control any situation across the full range of military operations ("Joint Vision", 2000, p. 6). The interdependent application of the four operational concepts mentioned above allows the future joint force to achieve full spectrum dominance.

A. JV2020 OPERATIONAL CONCEPTS

The operational concept of focused logistics means providing the joint force with the right personnel, equipment, and supplies in the right place, at the right time, and the right quantity. Dominant maneuver refers to the ability of the joint force to gain positional advantage with decisive speed and overwhelming operational tempo. Full dimensional protection defines the ability of a joint force to protect its personnel and other assets when decisively executing assigned tasks. The fourth operational concept, precision engagement, is the focal point of this research. Precision engagement is the ability of a joint force to locate, surveil, distinguish, and track objectives or targets; select, organize, and use the correct systems; generate desired effects; assess results; and reengage with decisive speed and overwhelming operational tempo as required, throughout the full range of military operations ("Joint Vision", 2000, p. 20-26). Of the four concepts supporting full spectrum dominance, precision engagement is the one increasing in importance due to its relevance to combating the current proliferation of asymmetric threats. The main characteristic of precision engagement is the linking of the

necessary sensors with the appropriate delivery systems to create a desired effect. Precision engagement's key enabler is the ability to analyze the enemy by achieving information superiority, which then permits us to identify and strike at the enemy's critical information nodes. Information superiority is the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same (p. 8). The difficulty in gaining information superiority over asymmetric threats lies in the ability to identify the critical information nodes, which are unlikely to be similar to our own. To gain an informational advantage over an asymmetric threat, we must identify the information needs of the enemy, and then attack those needs using our advanced information capabilities (Alberts, Garstka, Hayes, & Signori, 2001, p. 55). The element of surprise made possible through achieving information superiority will often be the prerequisite for success in combating asymmetric threats and the side capable of creating and maintaining an informational advantage will be most likely be capable of achieving surprise (p. 54).

1. Enabling Effects of Information Superiority

Technological advances in computers, electronics, and sensors are rapidly making precision engagement possible. These areas of technological advance support the collecting and processing of information that gives us information superiority. The commander utilizes information superiority to evaluate the situation, calculate the desired level of effect, select the appropriate forces and course of action (COA), accurately access the results of the actions taken, and then reengage the enemy as necessary ("Joint Vision", 2000, p. 22). Achieving information superiority implies a state or condition that provides an informational imbalance in one's favor. This imbalance can be used to prevent damage to our own forces through the age-old principle of achieving surprise, or by creating effective deception strategies. Current information systems supporting the battlespace are being networked together, creating a robust ability to support information superiority. Maintaining the information advantage is accomplished by effectively integrating the information systems supporting information operations. Information technology has increased the tools necessary to integrate information systems across a global network. Current advances with intelligence, surveillance, and reconnaissance (ISR) systems are connecting the information systems necessary to provide access to

precise and timely information across the battlespace. Unmanned aerial vehicles (UAVs) have slowly demonstrated an increasing ability to provide this precise and timely information. Increased use of precision-guided munitions is creating a proportional demand on the level of precise information required in the battlespace. Only 10 percent of weapons used in Operation Desert Storm were precision weapons. This rose dramatically to 90 percent with Operation Enduring Freedom (OEF) in Afghanistan (Israel, 2002, p. 1). Precise information enables precision-guided weapons to engage difficult targets, and the increasing ability to deliver this precise information in real-time has rapidly improved their effectiveness. Technological advances in UAV's are rapidly fulfilling the need for precise real-time information capabilities available through improved imagery, radar, and communications. This study examines the effects that advancing UAV technology is having on precision engagement.

B. THE EFFECTS OF ADVANCED UAV TECHNOLOGY

The current technological advances in UAVs have increased real-time ISR capabilities over the battlespace, and making tremendous changes in how we engage the enemy. Advanced UAV technology has steadily increased the quantity and quality of real-time ISR that directly benefits precision engagement. The improved real-time capabilities of UAVs are changing from what was once purely an ISR mission into supporting precision engagement with improved precision strike capabilities. Advanced UAV technology has expanded the real-time data links necessary to link information networks shared by command, control, communications, other ISR assets, and now directly with weapon systems. This expanding network has begun to provide us with heightened abilities that promote the information superiority necessary for precision engagement.

As a result of effectively increasing our access to information over the battlespace, advanced UAV real-time capabilities have sped up the flow of information along the sensor-to-shooter loop. The sensor-to-shooter loop is initiated by a sensor observing a target, then converting the data collected into precise targeting information as close to real-time as possible, communicating the information across a network of systems; and finally executing the desired effect. The increased real-time access to ISR information is providing enhancements in targeting data that has closed the gap between

the sensor and shooter. Precision engagement pursues this rapid decision capability by exploiting the real-time informational advantage representative of improved UAV technological advancements. UAV's have helped bring about this rapid decision capability by integrating the real-time ISR information necessary to exploit the information advantage and support precision engagement.

1. The Human Element on the Ground

The presence of friendly forces on the ground enhances the information advantage by providing the ground truth necessary to validate the situational awareness held by command elements. Ground truth is a common buzzword used to describe the actual situation on the ground compared to the situation perceived by rear echelon commanders. The additional situational awareness gained from integrating the human element on the ground into the sensor-to-shooter loop has a positive impact by validating and increasing the informational advantage. The presence of well-trained Special Operations Forces on the ground represents a critical link that can assist in the direction or execution of specific precision engagement goals. The increased situational awareness received by combining the ground truth relayed by a human sensor on the ground with the persistent ISR capabilities of UAVs makes dramatic improvements to precision engagement concepts.

C. UAV EVOLUTION FROM KOSOVO TO AFGHANISTAN

Two case studies will be analyzed for the operational trends and expanding missions of UAV systems. The first case study examines UAV operations in Kosovo (Operation Allied Force), and analyzes the numerous innovations that evolved with UAV employment in that conflict. The second case study will cover recent operations in Afghanistan (Operation Enduring Freedom) that uniquely demonstrated how UAVs promote precision engagement. Each case study will examine UAV vulnerabilities and limitations that still represent challenges to UAV integration. The case study of Operation Allied Force offers a comprehensive look at how the evolution of UAV technology has influenced the innovative use of ISR platforms, expanding them into areas of real-time ISR, time-critical targeting, and instantaneous battle damage assessments (BDA). The absence of ground forces during OAF provides an interesting contrast to Afghanistan, where the effective use of Special Forces on the ground enhanced the integration of UAV systems. Through a comparison of the two case

studies, we will see how UAVs have increased the ability of the U.S. military to achieve precision engagement.

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II. KOSOVO UAV EMPLOYMENT

Planners were aided by one of the most successful innovations of the air campaign. For the first time, we used the Predator UAV in a targeting role. Before Allied Force, the Predator could transmit targeting imagery to its operator on the ground as part of the intelligence collection network. During the air campaign, we reviewed Predator video in real-time and immediately provided pilots with the locations of mobile Serb targets. Toward the end of the war, we equipped the Predator with a laser so that it could place a beam on a target – this identified it so a loitering strike aircraft could destroy it. We were able to successfully employ the Predator with a laser only once before Allied Force ended, but in doing so, we developed a capability with great potential for rapid targeting. General John P. Jumper, U.S. Air Force Chief of Staff (Cordesman, 2001, p. 353)

A. BACKGROUND

When NATO forces publicly discounted the use of ground troops to repel Serb forces from Kosovo it resulted in the active pursuit of an air war strategy. A strategic air campaign was the NATO military response to the Kosovo crisis in the hopes of avoiding the casualties involved with an extensive ground campaign. The use of UAVs eliminated the risks of casualties associated with other modes of manned reconnaissance and surveillance or with the risks of placing Special Forces on the ground. By setting the surface ceiling for manned flight at 15,000 feet above ground level (AGL), NATO forces avoided threat engagements, and created a necessary use for UAVs. One of the first U.S. controlled UAV systems deployed was the Hunter RQ-5 tactical UAV, which has a service ceiling of 15,000 feet mean sea level (MSL) and therefore made the system uniquely qualified to operate within the airspace restrictions defined by the air campaign. Operation Allied Force (OAF) created many different missions for UAVs thereby establishing UAV's as a critical asset. As a result, NATO encountered many challenges for integrating UAV systems during the operation, such as air tasking order (ATO) integration, airspace deconfliction with manned aircraft, and integration with civilian traffic at forward operating bases. Allied UAV's deployed by other NATO countries included French, German, and British systems. This case study will show how for the

first time in combat UAVs were used to improve the decision superiority of NATO Allied forces and promoted innovative precision engagement strategies. Initial access to real-time ISR capabilities demonstrated the importance of pursuing capabilities that improved the information advantage of the commanders controlling the striking force.

This chapter will evaluate the mission of UAVs during Operation Allied Force (OAF) and the many lessons learned that resulted from their integration into combat operations. Exploring these lessons for potential future technological capabilities and or relevant limitations will contribute to our understanding of how to improve the effects of integrating UAV systems into precision engagement strategies. The survivability of UAVs in combat was one of the hardest lessons learned after the start of the war. Allied forces lost an estimated 21 UAV's to enemy actions, mechanical failures, or operator error. As many as 15 of these losses belonged to US forces and stirred a growing concern for the survivability of UAV's in future combat (Ripley, 1999, p. 6). In the next chapter, we will see how these lessons learned enhanced combat operations in Afghanistan, and further analyze how advances in technology are steadily improving UAV system integration.

B. UAV MISSION IS EXPANDED IN KOSOVO

The deployment of UAVs to support the Kosovo air campaign represented the largest deployment of UAV's since the Gulf War. The primary mission of UAV's during the Gulf War was to provide surveillance and reconnaissance, but the uses for UAVs expanded past surveillance during OAF to include target verification, battle damage assessments (BDA), time-critical targeting, signal intelligence (SIGINT) and imagery intelligence (IMINT) activities, as well as assisting in uncovering evidence of Serb atrocities (Ripley, 1999, pp. 1-3). Many NATO allied countries deployed UAV systems to support the war effort, but only a few US systems were capable of actively integrating real-time imagery into other systems.

US forces deployed the Army's Hunter tactical UAV, the Navy's Pioneer UAV, and the Air Force's Predator medium altitude endurance UAV to support OAF. British forces deployed the Phoenix UAV to support Harrier operations, and the French and German forces deployed CL-289 drones to support BDA and targeting operations. The

French also deployed the Crecerelle drone for surveillance purposes. The Hunter and the Predator UAV systems were the only UAVs initially capable of sending real-time or near real-time imagery to the Combined Air Operations Center (CAOC) located in Italy. The absence of NATO ground troops in Kosovo changed the role of the Hunter and Phoenix tactical UAVs to one of providing ISR capabilities to air assets versus supporting the ground forces that they were originally designed to support. These tactical UAVs helped provide the battlespace awareness sought after by NATO to strike targets deep within the battlespace. UAV importance increased due to the combination of persistent poor weather associated with the mountainous terrain that often hampered other means of ISR. The limitations on manned flights below 15,000' AGL also became a major factor in actively promoting the dull (surveillance and reconnaissance missions), or dangerous (high surface-to-air threat environments) missions, mitigating the risks to manned aircraft.

Through a performance analysis of the Hunter and Predator UAV during OAF, we can reveal some evidence of how the integration of UAVs into the battlespace have advanced the JV2020 concepts of precision engagement, along with improving our ability to achieve information superiority. NATO commanders slowly utilized the technological advances in UAV sensors, communications, along with new capabilities in targeting during OAF. The possibility for future improvements in UAV missions has expanded as a direct result of the lessons learned in Kosovo, and highlights the synergistic effects capable through UAV systems.

1. Hunter UAV Employment

The Hunter UAV serves the US Army as a tactical UAV supporting ground forces through targeting and reconnaissance missions. Task Force (TF) Hunter's mission in Kosovo evolved into supporting the strategic air campaign. As a result, TF Hunter had to adjust its tactics, techniques, and procedures (TTPs) to meet this tasking. The main mission of TF Hunter was to provide IMINT and target verification to support air strikes. The Hunter flew over 240 missions and over 1,300 flight hours in support of this effort (Nascimento, 2000, p. 1). TF Hunter deployed to Camp Able Sentry in Macedonia in March of 1999, and operated under an Army Corps Military Intelligence Brigade. The CAOC had operational control (OPCON) of TF Hunter in order to provide the imagery

on targets and direct air strikes. The secondary mission that TF Hunter accomplished was the support of the TF Hawk mission in Albania. TF Hawk consisted of the AH-64 Apache helicopters and the Multiple Launch Rocket System (MLRS) deployed for deep strikes into Kosovo. The development of the hunter-killer relationship between the two systems increased the survivability of the Apache and spurred the desire to hunt high payoff targets including tanks, APC's, artillery, and air defense facilities. UAV missions in Kosovo were the first to stimulate the need for weaponizing UAVs through the initial steps of placing laser target designators on Predator and Hunter UAVs.

a. Mission and Operations

TF Hunter had the primary responsibility of supporting Joint Task Force Noble Anvil (JTF-NA) with real-time imagery intelligence (IMINT) that soon became critical to the air campaign. The mission to support JTF-NA also represented a first time deployment of an Army UAV Company to support contingency operations. Connectivity between the CAOC and TF Hunter became a vital concern for providing direct support to the air campaign with real-time intelligence. The use of the Joint Broadcasting System (JBS) provided the CAOC with UAV imagery and helped immensely with integrating TF Hunter's mission into OAF actions. This innovation facilitated the integration of TF Hunter's ability to work closely with the CAOC and resolved the dissemination of real-time IMINT collection on targets used to direct air strikes. Operational control of TF Hunter went to TF Hawk when the AH-64 Apaches and the MLRS deployed to Albania. The support of the TF Hawk mission consisted of searching and validating enemy targets listed on a High Payoff Target List (HPTL). TF Hunter supported operations of the Apache within their engagement area. The main objective was to locate targets for the suppression of enemy air defenses (SEAD) along ingress and egress routes, and locate enemy defense positions, and border posts. (Nascimento, 2000, p. 3)

TF Hunter had to overcome many challenges to mission execution that included becoming proficient in dual UAV relay missions, disseminating intelligence to the users, and incorporating an increased awareness for risk management. The distances that TF Hunter had to extend UAV operations dictated that they fly two UAVs simultaneously to extend the communications range necessary to operate the UAV over mountainous terrain. Control of the UAV over great distances relies on a line-of-sight

system that often requires a relay by another UAV to complete the link. This requirement demanded increased training and proficiency by the air vehicle operators (AVOs) and doubled the flight time on UAVs to accomplish one mission. Personnel shortfalls perpetuated the problems of sustaining the UAV relay mission. Training missions in UAV relay operations prior to OAF were also very limited due to CONUS airspace constraints, creating the need for accelerated proficiency training at Camp Able Sentry. (Nascimento, 2000, pp. 9-10)

Disseminating intelligence information and imagery gathered by TF Hunter became a significant challenge upon initial deployment. The standard method of using the Remote Video Terminal designed to support tactical operations was limited to only 40 nautical miles and therefore was not sufficient to support the CAOC requirements. The alternative system recommended for this situation was the Trojan Spirit II system, but this system had limited access, and did not support the imagery resolution called upon to direct air strikes. To meet the requirement, TF Hunter gained access to the Joint Broadcasting System (JBS). The access was accomplished by providing live video feed via a Very Small Aperture Terminal (VSAT) up-link to the CAOC. JBS was capable of providing wide dissemination of real-time video to an extensive audience that promoted real-time battlespace awareness. The list of feeds included the CAOC in Italy, TF Hawk in Albania, the Allied Rapid Reaction Corps Headquarters in Macedonia, TF Sabre Headquarters in Macedonia, the Theater Military Intelligence in Germany, the intelligence analysis Center in England, and Pentagon officials (Nascimento, 2000, p. 10). Another benefit of the JBS was the secure encryption provided to the video feeds without degrading the required imagery resolution for the analysts. This capability to broadcast real-time imagery to a broad audience enabled TF Hunter to integrate their system into a process evolving around advanced capabilities in time critical targeting, instantaneous BDA, rapid target analysis, and target verification. These capabilities demonstrated in OAF were some of the first combat uses promoting precision engagement strategies.

Managing the risk to UAVs in the combat environment of Kosovo presented a specific challenge to all UAV support personnel. Even though designed with a tactical use in mind, the Hunter UAV could not incorporate needed aircraft survivability

equipment (ASE). Hunter UAV survivability relies on varying the ingress and egress flight paths, the relative size, and quietness of the UAV, and maximizing the standoff distance as much as possible to decrease detection. The Hunter UAV frequently loitered over and around targets for surveillance in Kosovo, thus providing the enemy more time to detect and engage the UAV. TF Hunter countered this threat by loitering over targets for only short durations and then later revisiting the target from another direction. The CAOC then provided TF Hunter with four entry points along the Macedonian-Kosovar border to hinder the detection by Serb forces (Nascimento, 2000, p. 11). This allowed for an ability to vary ingress and egress routes and helped to avoid predictability when flying over enemy positions. The remaining limitations and vulnerabilities of the Hunter were even more difficult to address and are discussed in the next section.

b. Limitations and Vulnerabilities

Design limitations of the Hunter UAV that affected operations during OAF were factors of endurance, range, and survivability. The tactical range of the Hunter UAV was optimized for the support of advancing ground forces, not strike aircraft. The use of the Hunter to support the air campaign via the CAOC exposed this limitation of the UAV. The expected endurance of the Hunter UAV is 8-10 hours at a normal cruise speed of 90 knots. Although this endurance is exceptional when compared to past tactical UAVs, it does not provide the lengthy coverage required for persistent ISR missions. The time available to accomplish tasks inside the Kosovo engagement area were reduced further by the lengthy ingress and egress flight times required from Camp Able Sentry in Macedonia. The mountainous terrain and line-of-sight communications requirements placed added limitations to the range of the UAV. Undesirable weather conditions created by the mountains increased the chances of experiencing turbulence, rain, and icing. Icing and hazardous wind conditions caused TF Hunter to develop tailored TTPs to reduce the risk. Operational flight altitudes that were often dictated to UAV operators required UAVs to pass through altitudes where icing conditions were common. The slow climb rates of the Hunter also increased the time spent in icing conditions.

The survivability of the Hunter UAV during the Kosovo conflict was a constant concern due to in-flight vulnerabilities of the system. Of the 21 UAV's

estimated lost during the war, eight of the losses were Hunter UAV's, and of the eight lost, five of the losses were attributed to enemy fire. The remaining two were lost to engine failure and operator error (Ripley, 1999, p. 5). The flight characteristics of the Hunter make it particularly vulnerable to enemy fire because of a 15,000 MSL service ceiling and a max cruise speed of 110 knots. The relatively low maximum takeoff gross weight of 1,600 pounds severely limits any ability to incorporate aircraft survivability equipment into the system. This limitation in survivability combined with the slow speed of the UAV left the system exposed to Serbian man portable surface to air missiles (MANPADS). Another favorite tactic of Serbian forces was using a Mi-8 HIP helicopter to fly up alongside the UAV and destroy it with machine gun fire. This tactic was effective for a time until the Allied air campaign made significant efforts to counter Serbian helicopter operations with NATO strike fighters. The allies eventually increased nighttime flying operations of UAVs in order to avoid further losses from Serb defenses. (p. 5)

c. Innovative Integrations

TF Hunter improved battlespace awareness and decision superiority by supplying real-time UAV imagery to the CAOC and integrating with TF Hawk to improve strike capabilities supporting the pursuit of precision engagement. The real-time IMINT link integrated with the CAOC and other airborne assets expanded TF Hunter's utilization in the war. TF Hunter adapted to the new missions by developing innovative TTPs necessary to operate integrated laser-targeting systems, and execute in-flight re-tasking that enhanced precision engagement concepts. Laser target designators outfitted to the Hunter UAV supported and enhanced the mission of Apache helicopters assigned to TF Hawk. This capability was refined during Kosovo, but never operationally executed before the war ended. The support and coordination with TF Hawk to accomplish this mission was prepared and validated for operations inside Kosovo. Previous testing of this hunter-killer integration proved to enhance the situational awareness of the low flying Apache. This integration allowed the Apache to increase its survivability by staying low in the terrain and still enabled the Apache to search for and acquire targets through UAV sensors. This enabled the Apache to engage targets rapidly with minimal exposure to enemy fire, thus increasing survivability. The Apache's greater

capacity to search larger areas for targets with this hunter-killer combination validated this tactic for use in future engagements. The only difficulty in accomplishing this TTP was providing the communication links required between the UAV operator and the Apache pilot. The communication channels deemed necessary to coordinate laser designations and target acquisitions were not established at this point. The quick fix in Kosovo for this problem was a relay through the EC-130E Airborne Battlefield Command, Control, and Communications (ABCCC) platform. Another option was to equip a second UAV to fly a relay mission with an FM radio retransmission package. (Nascimento, 2000, p. 13)

The hunter-killer concept was pursued further by an advanced concept technology demonstration (ACTD) called the Hunter standoff killer team (HSKT) and was used to refine TTPs and integrate the systems involved. The goal of the HSKT initiative is to enhance the supported commander's situational awareness and ability to command and control in the joint/coalition environment, enhance aircrew survivability and situational awareness, and greatly increase the lethality of the integration (Wright & Kuck, 2001, pp. 1-3). The HSKT has enhanced our ability to achieve decision superiority by providing a capability to react rapidly to enemy movements.

Another innovative development during TF Hunter was included in the concept of dynamic re-tasking used to check up on suspicious activity or update target areas. The new capability to disseminate real-time imagery among many different users made re-tasking the Hunter UAVs a highly sought after commodity by commanders. The obvious drawback to this newly discovered capability in attempting real-time battlespace awareness was that many times the re-tasking would yield insignificant results or increased loiter times over uncertain targets, and exposing the UAVs to increased opportunities for enemy fire (Nascimento, 2000, pp. 12-13). Dynamic re-tasking was a first attempt at time-critical targeting that revealed new challenges to utilizing UAVs in this manner. Growing acceptance for using UAVs to support this concept was an important lesson expanded upon and refined by other UAVs as demonstrated in the next case study.

2. Predator UAV Employment

Kosovo was the first combat operation for the USAF's RQ-1 Predator medium endurance UAV, deploying only 19 months after the program initiated in 1996. The speedy development and acquisition of the Predator is the result of the ACTD process that promotes advanced technology to meet immediate combat requirements. The initial mission of the Predator was to fill the reconnaissance and surveillance role during OAF. The Predator is able to stay airborne for up to 40 hours and has a maximum altitude of 25,000 feet. Tusla Air Base in Bosnia became home for Predator operations supporting OAF. The Predator had earlier deployments to Yugoslavia in 1995 before the Air Force accepted the system. A DoD detachment under US Army administrative control, using code-name Nomad Vigil, deployed the Predator during the summer of 1995 to support US forces over Bosnia. These operations supported JTF Provide Promise and came under the operational control of the CAOC in Vicenza, Italy. The Predator supported Operation Deliberate Force and Operation Joint Endeavor through 1996 before returning to the US. The USAF accepted the Predator in April 1996 and activated two squadrons, the 11th and 15th reconnaissance squadron (ets-news, 2002). However, when OAF started in March 1999, there were not any Predators deployed in theater. The Air Force quickly deployed the 11th RS to Tusla, AB to begin supporting air operations.

a. Mission and Operations

The surveillance and reconnaissance mission of the Predator UAV during OAF was very significant due to the real-time imagery capabilities of its sensors. The mission of the Predator was to assist in target acquisition and battle damage assessments (BDA) in theater. The sensors of the Predator also enhanced precision-guided munitions and increased the speed of time-critical strikes. Time-critical targeting was a major advancement in the employment of Predator operations and widely supported the advancement of precision engagement. Towards the end of the war, the USAF rushed to equip the Predator with laser designators used to engage laser-guided munitions on targets. This concept instigated suggested the plausibility of arming the Predator with Hellfire missiles. The opportunity to employ the Hellfire missile tactic ended abruptly with the end of the war. The next opportunity did not appear until its debut in Afghanistan. The results of this new capability will be reviewed in the next case study.

The imagery gathered by the Predator and relayed to the CAOC via Ku-Band satellite communications provided a high bandwidth transfer rate permitting a stream of real-time video. Predator imagery was disseminated across the JBS to a multitude of customers. Many senior officials viewed the role of the Predator during OAF as an innovative move opening up new opportunities in targeting. General John Jumper's comments at the beginning of this chapter reflect the innovative TTPs that resulted from the employment of the Predator during OAF. The Predator was the only UAV that remained solely under the control of Senior USAF leadership in the CAOC for the duration of the war. The new missions of Predator helped to advance the concepts of real-time battlespace awareness, and made clear some of the advantages to achieving decision superiority.

b. Limitations and Vulnerabilities

Serb forces knew of NATO's extensive use of UAVs during the 1994 Bosnia crisis and were prepared to counter UAV use in Kosovo. During OAF, the USAF lost two Predators to hostile actions and one that was non-combat related. The Predator had to fly lower at times to complete mission requirements due to the limitations of UAV imagery resolution and the nature of imagery requested. Following some targeting mistakes that led to civilian deaths (the inadvertent destruction of a bus and a tractor), NATO applied stringent rules of engagement (ROE) on target engagements (Ripley, 1999, p. 3). Target verification required at least two sources, and could include either the use of UAV real-time video or an Airborne Forward Air Controller (AFAC). This ROE slowed down the rate of destroying Serb equipment and frustrated many NATO pilots. A contributing factor to the slow target engagements was the 90-knot cruise speed of the Predator that limited how fast the UAV could travel to requested targets. This delayed target verification and frustrated the ability to strike time-critical targets (p. 4). Another limitation of the Predator UAV, as mentioned earlier, was the icing conditions that make Predator operations hazardous, leading to a reluctance to fly the Predator during the winter months.

c. Integration Possibilities

The Predator UAV improved the targeting process during OAF by providing persistence over the battlespace that increased our ability to engage targets with

precision-guided munitions. The need for precision targeting in the engagement of time-critical targets was a sought after capability during the air war. The Predator was able to assist in improving the accuracy of time-critical targeting through a process called “georeferencing tactical imagery.” The National Imaging and Mapping Agency (NIMA) maintains a database known as the Digital Point Position Database (DPPDB) and uses it to improve UAV tactical imagery through a georeferenced database called the Controlled Reference Image Base (CRIB). The CRIB is a database developed by the Naval Air Warfare Center Weapons Division. (Koch, 2000, p. 3) The CRIB converts raw tactical UAV imagery into extremely precise targeting information supplied to the tactical user, then used to deliver precision-guided munitions. Georeferencing synthesizes the resolution of satellite imagery, the timeliness of UAV tactical imagery, and the accuracy of the DPPDB to create extremely accurate location targeting information for time critical strikes (p. 3). Targeting accuracy was a prime concern during the Kosovo air campaign and made the Predator imagery from its electro-optical/infrared (EO/IR) cameras and synthetic aperture radar (SAR) extremely valuable. The process of georeferencing combined with the real-time sensor feeds of the Predator improved the identification of targets and the accuracy of precision engagements. Utilizing the CRIB in targeting analysis helped promote the integration of UAV imagery into the time-critical strike process. The Kosovo campaign developed the need to make better use of Predator imagery and prompted the National Reconnaissance Organization (NRO) to develop the Tactical Fusion Prototype (TFP) to facilitate the integration UAV imagery into the CRIB (p. 7). The TFP overlays the CRIB database with the UAV video to correlate exact targeting information for strike planners. This process occurs in a matter of minutes, and can be relayed to strike aircraft for use in improving the accuracy of hitting time-critical targets. The Joint Targeting Workstations (JTW) utilizes the CRIB data to produce target verification data through collaboration with other reconnaissance platforms such as the U-2, and then forward the product to the CAOC for immediate targeting. The CAOC exploited this process heavily in Kosovo by combining it with constantly running Target Package Generator Software, which allowed the CAOC to build strike packages on demand, and then transmit them to airborne fighters (p. 7). The Predator imagery enhanced the ability to strike time-critical targets by relaying real-time battlespace

awareness of moving targets that enhanced the ability to accelerate the sensor-to-shooter decision loop that is crucial to precision engagement strategies.

Initial actions for weaponizing UAV's took place towards the end of the Kosovo air campaign by incorporating laser guidance systems on the Predator to assist in rapid targeting. This created the capability to hit designated targets verified by the Predator with laser-guided munitions launched by manned strike aircraft (Lambeth, 2001, p. 95). The relevancy of pursuing concepts of UAV weaponization were also made clear with the hunter-killer integration of the Apache and the Hunter UAV during TF Hawk operations. These actions reflected the beginning of weaponizing UAV's, and as we will see in the next chapter lead to the first successful delivery of a Hellfire missile by a Predator UAV in combat.

C. CONCLUSION

The UAVs deployed during OAF expanded precision engagement by aiding in time-critical targeting, instantaneous battle damage assessments, and disseminating real-time imagery. New TTPs developed to perform dynamic re-tasking, operate in poor weather, and integrate hunter-killer packages between manned and unmanned platforms advanced the systematic integration of UAVs into the deep battlespace. The most relevant advancement for TF Hunter was the utilization of the JBS to proliferate UAV imagery to all the potential users of the product. The UAV imagery increased real-time ISR access and gave the CAOC the information advantage over Serbian troop movements. The Predator was able to increase the accuracy and effectiveness of rapid targeting through the real-time imagery integrated with satellite communications and other national assets. Access to the JBS allowed for the dissemination of Predator imagery to multiple users and promoted the integration of its resources. The accuracy of targeting that resulted from UAV imagery and georeferencing techniques significantly improved NATO's ability to reduce, but not eliminate, collateral damage. Limitations in the flight performance and payloads of the UAV's involved in Kosovo often caused some frustration in target analysis and some delays in time-critical strikes. The relatively slow flight of UAVs restricted immediate feedback of some target verification requests. The rules of engagement established by NATO precipitated many of the delays due to an over reliance on UAV imagery to confirm targets. This review of Kosovo UAV operations

highlights the acceleration of UAV technology that is certain to grow as the capabilities in speed, imaging resolution, and survivability increase in the coming years. The *Unmanned Aerial Vehicles Roadmap 2000-2025* produced by the Office of the Secretary of Defense establishes a strong case for the increased capabilities of UAVs of the future because of improvements in processing power, propulsion, communications, and payloads. The *UAV Roadmap* is reviewed briefly in the final chapter of this study.

Other integration issues addressed briefly for the first time in Kosovo was the integration of manned and unmanned flight within the same airspace or terminal airfield. The unique airspace restrictions within Kosovo enhanced UAVs' ability to operate in theater with minimal impact on manned flight operations. This will not always be the case in future conflicts and actions to further address the issue of UAVs operating near manned flight operations must be undertaken. One last issue strongly prevalent throughout OAF was the incompatibility between NATO allied UAVs and US systems that supplied real-time imagery. The British were continually frustrated with attempts to integrate Phoenix UAV imagery with the CAOC due to incompatibilities in data link communications that restricted any wide distribution. Methods for disseminating Phoenix imagery were solved towards the end of the war, but were not fully implemented in time. The future of coalition warfare makes allied interoperability a major concern. Only by addressing a standardized communication system will procedures for future integration of coalition forces be possible.

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III. AFGHANISTAN UAV EMPLOYMENT

There have been battles fought in Afghanistan for centuries, and I don't think any of them have seen the speed, results, and the speed of effect that we have here. Clearly something different is going on. Retired Navy Vice Admiral Arthur Cebrowski, DoD Director for Transformation (Bender, Burger, & Koch, 2001, p. 18)

One [lesson] is the value of unmanned aerial vehicles (UAV). Second I would [highlight] the connection between UAV's, combat aircraft and bombers, and the people on the ground and the value that is created by those connections and the use of smart munitions. That creates a powerful effect. Secretary of Defense, Donald Rumsfeld (Federal Department and Agency Documents, 2001)

A. BACKGROUND

This analysis of Operation Enduring Freedom (OEF) will highlight how rapidly evolving capabilities in UAV systems are enhancing precision engagement strategies and increasing our information advantage. Real-time UAV systems are changing the speed at which we can strike moving targets by reducing the decision time necessary to complete the sensor-to-shooter decision loop. Increased battlespace awareness capable with persistent ISR sensors on UAV systems has increased our real-time situational awareness of the enemy movements. The dynamics of precision engagement creates devastating effects on the enemy's ability to respond or effectively make decisions. This case study will concentrate on the integration of UAV system capabilities that increased our ability to maintain information superiority and exploit our real-time situational awareness.

Following the September 11, 2001 terrorist attack on the United States, the commitment to strike back at the Al Qaeda Network, and topple the Taliban leadership governing Afghanistan was extremely high. The US initiated military action on October 7, 2001 with air strikes on Taliban military targets and the country's sparse air defenses. The initial air strikes prepared the battlespace for the next phase and demonstrated the global reach of US strategic forces. The next phase was one of the most significant military developments during OEF by infiltrating little over 300 Special Operations Forces (SOF) and intelligence personnel on the ground. The first insertion of Special

Forces A-teams was on October 19, 2001 and just 49 days later, the Taliban government fell in the southern city of Kandahar on December 6, 2001.

The primary mission of the Special Forces on the ground in Afghanistan was threefold. First, they were to synchronize the unorganized forces of ethnic Uzbek and Tajik opposition groups in the north represented by the Northern Alliance. Second, they were to build small armies out of the Pushtun tribesmen in the south. Third, they were to create the critical linkage to provide targeting information to joint strike aircraft delivering precision guided weapons (Priest, 2002, p. 1A). This third mission of SOF proved to be very effective in rolling back the Taliban forces. The vital relationships forged between SOF forces and indigenous Afghan opposition to Taliban rule contributed to our ability to strike with certainty at the heart of Taliban front lines. A recently published interview with Air Force Chief of Staff, General John P. Jumper highlights the effectiveness of the relationships forged by Special Forces when integrated with precision engagement.

We witness transformation when we see airmen traveling by horseback with the tools of their trade (GPS and laser range finders) hanging from a saddle. With secure satellite and radio links, they pass target coordinates to bombers or fighters from the Air Force, Navy, or Marines flying miles overhead. We see the venerable 40-year old B-52 precisely place a JDAM just 800 meters from our friendly positions. No single piece of this equation is transformational but together it yields a transformational asymmetrical advantage over any enemy. General John P. Jumper, Chief of Staff, U.S. Air Force (“Force transformer”, 2002, 1, 2, p. 28)

The effective targeting skills provided by SOF improved the sensor-to-shooter decision loop immensely. SOF utilized techniques such as laser targeting designators, and the supply of accurate GPS coordinates to direct precision-guided munitions on Taliban positions. These techniques of targeting allowed US forces to shift their targeting from strategic fixed sites to mobile Taliban forces. The tremendous swing in momentum in favor of the Northern Alliance was immediately evident with the rapid advancement of forces around Mazar-e Sharif, and later into Northern Kabul. SOF teams on the ground became the supported force that enabled the on-call demand of precision-guided munitions.

The persistent coverage of real-time imagery provided through UAV sensors was effectively combined with the ground truth supplied by SOF and intelligence personnel to dramatically improve the information advantage over enemy forces in Afghanistan. US forces closely monitored the movement of Taliban and Al Qaida forces on the ground while the persistent use of sensors onboard the Predator RQ-1 and Global Hawk RQ-4 UAV monitored the enemy from the air. The movements of Taliban forces were easily traceable and countered swiftly through the common operating picture developed through integrated systems. Instantaneous battle damage assessments following an attack increased the certainty of achieving desired results on the enemy and validated the need for any necessary follow-on strikes. The synthetic aperture radar (SAR) and electro optical/infra-red (EO/IR) cameras aboard Predator and Global Hawk UAVs were capable of providing real-time imagery and precision coordinates over broadband data-links that streamed video imagery to a multitude of users. The remainder of this chapter reviews the integration of the Predator and Global Hawk into an improved sensor-to-shooter decision cycle that effectively increased our precision engagement capabilities. The analysis of each UAV system will cover the mission integration, operations, vulnerabilities, and limitations that confronted each system during combat operations.

B. PREDATOR UAV HUNTER/KILLER INTEGRATION

Predator use in Afghanistan expanded past the role of ISR to the next phase of military operations: the capability observe, track, and autonomously strike at targets with precision and deadly accuracy. In February 2001, the first test of a Hellfire missile from a Predator proved very successful. The tests succeeded in destroying targets 12 out of 16 times. Being able to wield this capability from a standoff distance, persistently monitor the target, precisely strike, and report instantaneous BDA closed the sensor-to-shooter loop to a matter of minutes. The CIA therefore embraced this capability during OEF by targeting Taliban convoys, SUVs, and tunnel complexes in the hopes of removing Al Qaeda or Taliban leadership. CIA Predators launched several attacks on 4-5 February 2002 in the Zhawar Killi region of eastern Afghanistan on suspected Al Qaeda tunnel complexes with this objective in mind (Samson, 2002, p. 1). This type of attack prior to UAV weaponization would have required extremely long flight hours of manned fighter aircraft, extensive space systems, and manned surveillance capabilities. The Predator

provides continuous coverage for these operations that would have been resource intensive for manned systems to accomplish. The long endurance hours of the Predator and the ability to operate sensors from a standoff distance allows for the persistent observation of targets until the appropriate moment to strike with the greatest effect presents itself. This capability provided an information advantage over the enemy that was virtually impossible for Taliban forces to counter. SOF ground forces and intelligence personnel trained to operate in the austere and remote environments provided the necessary ground truth to increase the certainty of our attacks and strike at mobile targets. The appropriate linkage in surveillance capabilities on the ground remains a critical contributor to properly identifying mobile targets. Kosovo demonstrated how difficult target verification could be without some reliance on ground forces to locate and distinguish certain types of mobile targets.

1. Mission and Operations

The Predator was prepared to execute targeting techniques developed at the close of OAF at the beginning of OEF. TTPs in laser targeting and target verification were established and ready for combat operations within the established USAF squadrons. The Predator guided strike aircraft to mobile targets, and then highlighted target with laser designators. The early shift in the UAV intelligence paradigm from purely ISR missions to include targeting was beginning to take hold. The director of the Pentagon's ISR systems, Kevin Meiners, commented about the changes resulting from OEF. "The big thing we're finding out in Afghanistan is that ISR is all about targeting." Intelligence once routed back to the analysts for targeting purposes can now be redirected to combat aircraft for immediate engagements (Fulgham, December 2001, p. 4). Predator operations in OEF pursued precision engagement by shortening the sensor-to-shooter decision cycle to a matter of minutes and provided the ability to strike time-critical targets that earlier would have been lost to the fog of war. The loitering capabilities of UAV systems over and around dangerous targets, deemed too risky for manned aircraft, provided the means to set up a surveillance capability well in advance of attacks, then observe the results and actions of the enemy immediately following the attack. This capability fully encompasses the desirable effects of precision engagement. These tactics used with great effect in Afghanistan capitalized on the Predator's ability to remain

airborne for up to 40 hours at distances of up to 500 nautical miles. The following vignette exemplifies this point.

The drone pinpointed the house where a group of senior al Qaeda officials, including Muhammad Atef, had gathered and relayed live video pictures of the scene to CIA and military officials, who called in strikes from a Navy F/A-18 fighter-bomber. As people fled the building, the Predator opened fire on them with Hellfire missiles. Finally, it circled over the area, assessing the damage. (Miller, & Schmitt, 2001, p. B1)

Afghanistan operations have catalyzed the discovery of innovative targeting techniques by utilizing Predator real-time video feeds and laser target designators. The most recent integration effecting precision engagement is the incorporation of Predator video feed directly to the AC-130U Spectre gunship. The AC-130 provides close air support and firepower to Special Forces via an extensive sensor package of its own that accurately directs the firepower of its three computer controlled guns; a 40mm gun, a 105-mm howitzer cannon, and a fully automatic 25mm Gatling gun (Goodman, 2001, p.2). The Predator establishes a direct data-link to the AC-130 thus providing surveillance video imagery and synthetic aperture radar data that can be used for target acquisition and real-time situational awareness. This data-link allows the gunship to monitor targets outside their general location and receive preliminary target acquisition data prior to arriving on scene. This capability expedites the active engagement of targets immediately upon arrival. General Jumper lauded this targeting enhancement as one of the most innovative targeting tactics developed over the course of the war. (Bender, Burger, & Koch, 2001, p. 20)

2. Limitations and Vulnerabilities

One of the major drawbacks of the Predator in Afghanistan was vulnerability to inclement weather, as was the case in Kosovo. The rugged mountains of Afghanistan can produce the same hazardous weather conditions experienced in the Kosovo region, such as icing and mountain wave turbulence. Prior to OEF, an estimated 19 Predators were lost to either poor performance in inclement weather or during critical phases of flight such as landings. This has resulted in nearly a third of the initial USAF fleet lost to non-combat related conditions (The active USAF inventory of Predators before the 9/11 attacks totaled 60 UAV's). As of February 2002, three Predators have been lost in

Afghanistan due to poor weather performance (Samson, 2002, p. 1). The relatively benign combat threat to Predators in Afghanistan has protected the UAV from hostile fire, but this has only highlighted the vulnerability of the Predator to weather conditions. Eventually, more responsive flight control surfaces and adequate deicing systems planned for next generation UAVs should help alleviate this vulnerability. The next generation Predator-B has already improved flight characteristics with increased propulsion in the form of a turboprop engine that allows it to fly higher, faster, and carry a larger payload than its baseline predecessor. The 45,000 feet cruise altitude of the Predator-B, compared to the previous 25,000 feet ceiling of the baseline Predator, will remove the Predator-B from the poor weather conditions often associated with altitudes below 25,000 feet. Although the higher altitudes will diminish the resolution of the current sensors on the baseline Predator, the improved propulsion and increased payload of the Predator-B will allow it to carry larger sensors that will change the capabilities over the baseline Predator significantly. In addition, the higher altitude capability of the Predator-B cannot replace the current mission of the baseline Predator firing the Hellfire missile due to necessary targeting parameters only met from lower altitudes. The baseline Predator normally deploys at altitudes between 15,000 and 25,000 feet that optimize real-time video feeds to command elements and other platforms. The increased performance of the Predator-B does not mean that it cannot be weaponized; only that it's not beneficial to arm it with the Hellfire missile. Other weapons under consideration include GPS-guided munitions such as the 250-pound Small Diameter Bomb currently being developed by the Air Force (Wall, 2002, January 2, p. 3).

3. Integration Possibilities

The opportunities to integrate the Predator are coming forward at a rapid pace. The use of Predator real-time video feeds by the AC-130 Gunship is an example of how the benefits of UAV systems, integrated with other weapon systems, produce effective capabilities congruent with precision engagement. The hunter-killer combination represented by Predator and the AC-130 fills a long-standing requirement for SOF to increase real-time access to intelligence gathering assets deemed necessary to support time-critical strikes often necessary to support special operations. Interest has already grown within SOCOM and the Pentagon to provide SOF with its own operational

Predator fleet. (Wall, 2002, April 29, p. 80). The ability of the Predator to carry communications packages is another viable mission for UAV systems, and would help overcome the tactical level limitations in coverage often experienced by SOF in the past. Another beneficial use of the Predator immensely benefiting precision engagement is using the system as a poor man's GPS satellite in areas of reduced satellite coverage (UAV roadmap, 2000, p. A-14).

C. GLOBAL HAWK ISR INTEGRATION

The strategic bombing campaign of Afghanistan initially required advanced ISR capabilities over the battlespace. Advanced space-based ISR systems and manned U-2 aircraft supported this initial requirement, but as the war progressed, time-critical targeting became an issue, and the need for additional ISR capabilities increased. The acceleration of Global Hawk to operational status through the increased efforts of the ACTD made Global Hawk available as an alternate ISR platform to integrate into the war as soon as possible. Out of the five Global Hawks that were operational at the start of the war, three deployed to the theater by early November (Fulghum & Wall, 2001, p. 3). The immediate mission of Global Hawk in Afghanistan was to extend the capabilities traditionally provided by the U-2 reconnaissance aircraft. A combination of the manned and unmanned systems assured nearly unbroken coverage for operations that provided persistent real-time coverage of the battlespace. The two ISR systems forward deployed together at Al Dhafra Air Base in the United Arab Emirates (Weinberger, 2002, p. 1).

1. Mission and Operations

The Global Hawk has a cruise altitude of 65,000 feet and is capable of 40-hour flights that go well beyond the human factors limiting manned flight. Global Hawk's sensors are capable of surveillance ranges out to 100 nautical miles that allow it to network targeting data among other systems such as E-8C Joint Surveillance Target Attack Radar System (JSTARS). The simultaneous deployment of Global Hawk and JSTARS reflects the synergistic targeting strategy supported by the two systems. The ground surveillance radar carried by JSTARS provides surveillance capabilities of enemy territory out to 200 nautical miles. This coverage allows JSTARS to direct Global Hawk operations within this umbrella manage the tracking of moving targets. Global Hawk sensors include electro-optical/infra-red cameras combined with synthetic aperture radar

capable of penetrating weather and performing nighttime operations. Other payloads include SIGINT and ELINT sensors such as the LR-100 electronic intelligence-gathering system (Fulghum & Wall, 2001, p. 3). The wide-angle coverage of Global Hawk and JSTARS combined provides a necessary ISR capability to direct strike aircraft. The Global Hawk sensors have integrated the “sensor to shooter” decision cycle among a network of other systems to increase the speed of engaging time-critical targets. The targeting data gathered by Global Hawk also coordinates information with Hellfire armed Predator UAVs, F-15E strike aircraft, and strategic bombers. Global Hawk target tracking data and ISR information is also networked with the RC-135 Rivet Joint, Joint-STARS, and AWACS aircraft to help provide a common operating picture (COP) of the battlespace (p. 4). This COP effectively enables decision superiority for the airborne commander when properly synthesized. UAV technological advancements made the combat debut of Global Hawk possible, and marked the beginning of an ability to provide continuous unbroken coverage. This increased persistence over the battlespace is what UAV systems provide as an enabler for increasing the information advantage.

2. Limitations and Vulnerabilities

Contrary to what Global Hawk advocates would have us believe, the payload and sensors of this system do not yet surpass the capabilities of the long-standing U-2 program. The higher resolution and processing power of the U-2 payloads and sensors currently more than double that of Global Hawk capabilities. This comparison is due to change in Global Hawk’s favor through advances in miniaturization of sensor components that will decrease payload requirements. Global Hawk has already incorporated the U-2 sensor processing software to improve imagery resolution. Due to the importance placed on Global Hawk, Raytheon, the company that designs the sensor suite for the UAV, has accelerated the full integration of all the sensors to include electro-optical/infra-red cameras, synthetic aperture radar, and electronic intelligence payloads.

The current successes of Global Hawk are reaping rewards in the budgeting process as well. FY03 Budget has nearly 630 million dollars slated for the production of three more Global Hawk aircraft, and is due to accelerate improvements in electronics and sensors. The Air Force is also projecting the purchase of up to six Global Hawks in 2004 (Wall, 2002, January 2, p. 4). The current limited inventory of Global Hawk’s

represents a problem if the UAV were to experience high combat losses. The limited number of Global Hawk UAV's is a temporary result of the accelerated operational deployment schedule so soon after USAF acquisition. Concerns mounted over this limitation when on December 30, 2001 a Global Hawk crashed while it was returning to UAE following a mission in Afghanistan. The accident investigation discovered that the cause of the crash was the failure of a rod that moved the control surface of the V-tail. The culprit was the improper installation of a bolt securing the rod during the manufacturing process. (Nordwall, 2002, p. 29) The USAF is also addressing the current limitation represented by Global Hawk's payload capacity. The current payload of 2,000 pounds is soon to increase to 3,000 pounds due to a recently awarded contract to Northrop-Grumman. (Morris, 2002, p. 2). The upgrade in payload will help Global Hawk carry an increased number of interchangeable sensor suites. The challenge set forth to Northrop-Grumman will be to increase the payload without decreasing the USAF requirement of 24 hours on station at 65,000 feet.

3. Integration Possibilities

The biggest future boost that Global Hawk will give to the time-critical targeting effort is through the Network-Centric Collaborative Targeting (NCCT) program, which is part of the newest round of ACTDs. The NCCT promotes the synergistic integration of intelligence platforms to improve the capability to detect, identify, and locate time-critical moving targets. Assistant Deputy Undersecretary of Defense for Precision Engagement, Judith Daly, stated the objective of the NCCT is to build networks linking platforms to meet the timeline requirements of air-launched weapons. The multitude of aircraft integrated into the NCCT include the RC-135 Rivet Joint, E-8 Joint STARS, E-3 AWACS, Global Hawk, Predator, U-2, Army Guardrail, Navy EP-3E and the Royal Air Force Nimrod and Astor. The NCCT will promote the linkage and overlay of numerous signals intelligence sources, producing a quick source of locating time-critical targets. The NCCT ACTD, which will reach completion in 2005, is sponsored by CENTCOM. (Fulghum & Wall, 2001, p. 6) The Pentagon and DARPA are pursuing programs to improve Global Hawk radar with foliage penetration synthetic aperture radar, and a multiplatform radar technology insertion program (MP-RTIP). The radar enhancement will permit the ability to track moving ground targets even when obscured by tree cover.

The MP-RTIP will improve Global Hawk radar ground tracking capabilities beyond the current limitation of Joint STARS radar by improving the accuracy and increasing the number of targets tracked simultaneously (Wall, 2002, April 29, p. 81). These investments in Global Hawk greatly enhance the network-centric integration of the UAVs and guarantee the viability of UAV's in the future.

D. CONCLUSION

The synergistic effect of new targeting techniques and advanced UAV capabilities has promoted the ability to exploit information superiority in a manner that questions many of the old paradigms set by conventional doctrine. Arming UAV's and extending the duration and capabilities of UAV sensors has forced the hand of stovepipe systems by rapidly integrating C4ISR processes that promote striking the enemy at the earliest detection. Achieving real-time situational awareness came closer to reality during OEF due to advanced capabilities of Global Hawk. A significant factor contributing to the success of Operation Enduring Freedom in comparison to Operation Allied Force was the employment of SOF ground forces in a manner that increased our precision engagement effectiveness. The human sensors represented by SOF were a necessity that enhanced our real-time situational awareness and improved our precision engagement strategies. The critical links attainable only through the presence of SOF on the ground produced measurable results with the effective targeting networks created. ISR platforms such as Global Hawk and Predator have allowed for time-critical targeting techniques that have contributed to closing the gap between the sensor and shooter in innovative ways. The contributions of real-time imagery enhancements provided to AC-130 aircrews, the hellfire engagements of Predator, and the strategic coverage of Global Hawk, have all greatly enhanced precision engagement.

IV. UAV PATHWAYS FOR PRECISION ENGAGEMENT

Integral to the effectiveness of any technology is our ability to harness the synergy of multiple systems. To that end, the Air Force is pursuing the seamless integration of manned, unmanned, and space assets. General John P. Jumper, Chief of Staff, U.S. Air Force (“Force transformer,” 2002, p. 26)

Afghanistan operations acted as a catalyst for accelerating a transformation in today’s joint force. Unmanned aerial vehicle (UAV) systems are quickly becoming a cornerstone for transformational change by networking advanced information technology. The information advantage created by real-time data links has developed a new paradigm for precision engagement. Networked information systems are achieving information superiority over the battlespace by providing access to real-time intelligence, surveillance, and reconnaissance (ISR) capabilities used to close the gap between the sensor and the shooter. This new persistence over the battlespace provided by today’s UAV systems is unprecedented compared to past combat ISR capabilities. The increased availability of real-time ISR to command and control (C2) nodes, weapon systems, and now ground forces has improved our situational awareness and access to precise information necessary to achieve the informational advantage that makes precision engagement possible.

Advances in UAV technology are filling the gaps necessary to integrate command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems. UAVs will continue to improve precision engagement through technological advances in propulsion, sensors, processing power, communications, and munitions. Real-time data links supplying imagery, signal, and electronic intelligence are providing the conduit for faster decision cycles in support of the time-critical targeting goals involved in precision engagement. Improved UAV imagery and radar continues to enhance the accuracy and speedy delivery of precise information from digital databases such as the Controlled Reference Image Base (CRIB) to precision-guided weapons.

Advancements in electronics and computers are steadily increasing the bandwidths and processing power of information systems that are greatly improving UAV capabilities. The importance of Advanced Concept Technology Demonstrations (ACTD) administered by the Department of Defense for Acquisition, Technology, and Logistics, has had a positive impact by accelerating the operational fielding of advanced technology. Improvements in Predator UAV capabilities, and the speedy acquisition of Global Hawk were only two of many ACTD contributions advancing UAV technology. Other ACTD programs such as Network-Centric Collaborative Targeting (NCCT) are promoting the integration of RC-135 Rivet Joint, E-8 Joint STARS, E-3 AWACS, RQ-4 Global Hawk, RQ-1 Predator, U-2, Army Guardrail, Navy EP-3E, and the Royal Air Force Nimrod and Astor, representing the necessary joint-combined and interoperable information networks required to execute precision engagement. The combined effects of UAV technological improvements in real-time capabilities continue to expand these networks by making large contributions to maintaining the information superiority that makes precision engagement possible.

A. THE FUTURE OF UAV TECHNOLOGY

Projected technological advancements over the next 25 years will steadily increase the contribution of UAVs to information superiority and precision engagement. Michael O'Hanlon (2000) reviewed several technological areas representing the best modernization opportunities to enhance future U.S. military capabilities discussed in JV2020. He recommends pursuing a strategy that encompasses the system-of-systems approach that capitalizes on projected advances in electronics and computers (O'Hanlon, 2000, p. 172). O'Hanlon concluded that the projected advancements in these areas would be pivotal in increasing the importance of two technologies critical to the system-of-systems approach: precision-guided munitions, and the information networks that control sensors and communications systems (p. 173). This thesis has just demonstrated through its case studies that these are the exact categories where UAV technology has contributed the most. Joint forces have just begun to realize the enabling effects of advanced UAV technology on precision engagement concepts, and how the missions of UAVs are expanding to exploit the information advantage gained through persistent real-time capabilities.

Another document that shows the importance of future UAV technology is the *Unmanned Aerial Vehicles Roadmap 2000-2025*. Prepared by the staffs of the Under Secretary of Defense for Acquisition, Technology, and Logistics, and the Assistant Secretary of Defense for C3I, this document reviews technological areas that will advance UAV missions and capabilities. It also estimates UAVs could meet forty per cent of the 146 shortfalls identified by the Unified Commands' 1999 Integrated Priority List (IPL) ("The UAV Roadmap", 2001, p. 13). The Roadmap categorized UAV related mission into 15 areas. The fifteen were command, control, and communications; weapons of mass destruction counterproliferation, combat search and rescue, time critical targeting; mine countermeasures; meteorology; psychological operations; signal intelligence; electronic intelligence; suppression of enemy air defenses; theater-air missile defense; force protection; and imagery intelligence. For the Unified Commanders to completely accept UAV systems to accomplish these missions, some improvements in survivability and processing power must occur. The survivability of UAV systems continues to grow with improvements in defensive systems, flight characteristics, and innovative tactics, techniques, and procedures (TTPs). Increasing processing power will increase the ability of UAVs to create targeting information. The effects of Moore's Law will be the deciding factor in this arena. Moore's Law predicts the doubling of the currently available processing power every 12 to 18 months. This would also aid in miniaturizing payloads, and allow the integration of increasingly capable processors to UAV sensors ("The UAV Roadmap", p. 17). The UAV roadmap does an excellent job combining the UAV missions identified by the Theater Commanders-in-Chief (CINCs) and forecasts of emerging technologies that maximize future technological possibilities of UAVs. A short summary of the significant capabilities projected over the next 25 years by the *UAV roadmap* highlights the many possible innovations affecting UAV precision engagement for the future.

Improvements in the area of digital data transfer hinge upon a continued increase of the data transfer rates currently available. Radiated Frequency (RF) systems are currently providing the needed improvements, but the demands for higher bandwidths will continue to rise. Currently, the RF system of the Joint Tactical Information Display System (JTIDS), also called Link 16, provides the best capabilities to transfer digital data

across the battlespace. The need to accommodate higher bandwidths continues to grow making optical systems such as laser communications very attractive. Laser communications are capable of increasing the bandwidth by an order of magnitude of three over the best RF systems the future has to offer (“The UAV Roadmap”, p. 32). Currently, problems associated with pointing, acquiring, and tracking data-link signals remain obstacles to fielding laser communications reliable enough for military use (p. 33). Increased data transfer rates will drastically improve the sharing of real-time information over the battlespace and greatly improve the real-time capabilities of UAVs.

Advances in propulsion translate directly to increased endurance for UAVs, and would offer dramatic increases to UAV persistence over the battlespace. Thrust-to-weight ratios are projected to increase up to 250% over next 15 years and will greatly improve the speed and agility of future UAVs (p. 18). Fuel consumption improvements show the promise of increasing the current range and endurance limits enjoyed by high endurance UAVs like Global Hawk. The incorporation of powerful fuel cells can also decrease audible noise levels, which significantly decrease the detectability of UAVs. This will enable future tactical UAVs to operate at lower altitudes, thus improving electronic and signal intelligence capabilities.

The continued improvements in sensor payload capacity of UAVs will improve the quality and quantity of information gathered over the battlespace. Improved communications systems, enhanced by advances in miniaturization, will expand the C2 mission of UAVs. Innovative munitions represented by the 250-pound small diameter bomb, high power microwaves, or incendiary devices are being explored to arm next generation tactical UAVs and unmanned combat aerial vehicles (UCAV). The effects of Moore’s law will advance the speed of sensor data processing related to imagery analysis and target acquisition that will directly affect the speed of shooter engagement decisions. Autonomous processing by UAVs will remove delays currently represented by the necessity to data link with ground-based systems or larger manned systems like JSTARS currently utilized to analyze the sensor imagery creating the targeting data. This will have real-time implications on the ability of UAVs to engage time-critical targets. Researchers expect the limits of silicon-based microprocessors to be reached by 2010-15. At that time, silicon will no longer be the standard medium for processors. Research

conducted to find an element to replace silicon-based microprocessors has resulted in alternative mediums such as gallium arsenide “microcube” technology that might possibly allow for enough processing power to provide an autonomous processing UAV capability (pp. 35-36).

In summary, the reduced acoustic signatures provided by improvements in propulsion systems, increased sensor and payload capabilities from improved processing power, and increased data-transfer rates will all improve the autonomous operations of UAVs, increasing their support for precision engagement strategies. Sensor improvements will reduce the need to fly in the threat envelopes of most surface-to-air missiles and therefore increase the survivability. The projected major breakthroughs in propulsion systems, sensor capabilities, and autonomous operations within the next 25 years, will correct the survivability issues raised in the two case studies. UAV importance to precision engagement will increase proportionally with increased survivability by decreasing the reluctance of commanders to use UAVs for fear of depleting their number.

B. UAV IMPLICATIONS FOR SOF

We are witness to the true potential of transformation. It can be seen in stories from current operations. Despite being out-numbered, outgunned, and deep within enemy territory, US Air Force Combat Controllers, serving as part of Special Operations Forces (SOF) insertion teams, are serving with distinction using transformational technologies, transformational tactics and joint processes. General John P. Jumper, Chief of Staff, U.S. Air Force (“Force transformer,” 2002, p. 28)

By providing real-time data links and persistent ISR capabilities, UAV systems would benefit SOF, particularly in the areas of extending situational awareness and increasing the information advantage. The integration of Predator UAV and AC-130U gunship operations is an excellent example of this. The combined effect of both has enhanced the survivability of the gunship while simultaneously increasing the speed of engagements, once again closing the gap between the sensor and shooter. This added situational awareness has increased our information advantage, thus increasing our ability to achieve surprise by rapidly engaging the enemy upon detection. USSOCOM is exploring ways in which UAVs might accelerate the full potential envisioned by

precision engagement concepts. SOFs historical reliance on technological superiority suggests that they should be a test bed for increasing UAV systems integration. Special Forces are traditionally the “first in and last out” in a conflict, which makes the rapid deployment and mission capabilities of UAV systems important to SOF. The C4ISR capabilities of UAV technology will only strengthen the situational awareness of Special Forces in the field while combining with the ground truth obtained through SOF, an operational concept that was proven in Afghanistan. The combination of SOF on the ground with real-time ISR capabilities of UAV systems enables an informational advantage, and increases our ability to engage the enemy with precision.

The advent of smaller precision munitions highly capable of engaging multiple targets will greatly enhance the operational capabilities possible with UAV systems integrated with SOF. Combined with projected increases in payload capacity and the extended endurance of UAVs, SOF will have a persistent capability over the battlespace that provides the necessary means to instantaneously respond when supporting direct action missions. Advances in time-critical targeting through network-centric warfare made clear throughout this thesis could enable SOF to coordinate direct action efforts with conventional forces using speed and accuracy never before possible. UAV systems stand at the synapse of this process and every effort must be made by SOF to improve joint interoperability with this rapidly evolving capability.

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