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GLOBAL UAS PROLIFERATION CHALLENGES

USAF AIR SUPERIORITY

by

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A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

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18 January 2016

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Biography

Lieutenant Colonel Mark Riselli is assigned to the Air War College, Air University, Maxwell Air Force Base, Alabama. He is an aircraft maintenance officer with multiple operational assignments generating F-15, F-16, MC-130, and B-2 sorties. Additional assignments include Weapon Systems Branch Chief (B-2, B-52, UH-1N) and Executive Officer, Headquarters Air Force Global Strike Command, Barksdale Air Force Base, Louisiana, CV-22 Site Activation Team Lead, V-22 Joint Program Office, Patuxent River Naval Air Station, Maryland and the Oklahoma City Air Logistics Center, Tinker Air Force Base, Oklahoma.

Abstract

Remotely piloted aircraft (RPA) have been under development with intent for use in a military environment for almost 100 years. For the majority of that time period, RPA complexity, size, cost, logistical and handling requirements have made them cumbersome and difficult to use dissuading most nations from pursuing them as a viable capability. However, dramatic improvements in technology over the last two decades have allowed for a decrease in size, cost, and complexity while increasing capability. As a result, proliferation of small inexpensive RPAs has occurred on a global scale making them available for nation states and non-state actors to procure. Lightweight RPAs present a threat to USAF contingency operations. To maintain air superiority the USAF must recognize inexpensive RPA proliferation is currently unchecked, the threats they present, and pursue material and non-material solutions to defeat these threats. This paper provides a short review of the history, development, and use of combat RPAs, highlights RPA proliferation and threat, explores emerging anti-RPA technologies and recommends material and non-material solutions to address the threat.

Introduction

The United States has retained air superiority in every conflict it has participated since the conclusion of the Vietnam War. No U.S. ground forces have been killed in combat by a foreign airpower since the Korean War.[1] The U.S. monopoly on airpower, however, is rapidly coming to a close with increasing global proliferation of inexpensive Remotely Piloted Aircraft (RPA). While the United States Air Force's (USAF) offensive Unmanned Aerial Systems (UAS) capability is unmatched, its defensive UAS capability is under developed, jeopardizing the USAF's ability to provide air superiority during contingency operations.[2]

The next evolution in aviation extends beyond the large multi-million dollar drone highlighted on the nightly news to the easily acquired RPA. Ease of access coupled with intent could lead to state and non-state actors using inexpensive RPAs against our nation. The USAF has little ability to defend against them as existing conventional radars and armaments are designed to detect and defeat large aircraft.[3] To maintain air superiority the USAF must recognize inexpensive UAS proliferation is unchecked, the threats they present, and pursue material and non-material technologies and capabilities to defeat these threats.

Low cost RPA technology has flooded the commercial market. Widespread Internet access provides means to purchase sub-components or a fully assembled, ready-to-fly unit. Small RPAs are defined as an asset with a wingspan or rotor-blade diameter less than six feet, can be concealed within the confines of a vehicle, suitcase or backpack, costs less than $25K, and can be operated by one person with no formal training.

Inexpensive RPA platforms can operate almost undetected and can create challenges for the USAF's ability to provide air superiority. While they might not possess the capability of larger RPAs, they do present a legitimate capability and threat. Lightweight RPAs provide state and non-state actors an inexpensive modern path to possessing this capability. Further, there is currently no fielded counter to this threat, which is the primary focus of this paper.

Rise of UAS Use

To understand unchecked proliferation of UAS and the emerging threats they present, it is valuable to review the origins, uses, limitations, and defenses of previous use and threats. UAS have a long history of military application dating back to World War I (WWI). Despite a recent increase in media coverage highlighting U.S. use of RPAs, the precedent for their operational use is not limited to the last decade. Furthermore, the appreciation for the current threat could be delayed because the United States has long led in development of this technology. An article published by Ian Shaw in 2013 explained the evolution of UAS can be understood as the passage of three overlapping phases: 1) the drone as a "target" (1910s-1950s), 2) the drone as a "sensor" (1960s-1990s), 3) the drone as a "weapon".[4] For more than 100 years UAS have been under development with intent to employ on the battlefield. Development complexities, cost, and logistics challenges have limited the ability of many nations to pursue RPA fielding.

WWI

United States history traces its first efforts to design, construct, and use an unmanned aerial system in military operations back to 1918 when Orville Wright and Charles Kettering supervised the project.[5] Kettering was an electrical engineer and founder of the Dayton Engineering Laboratories Company later bought out by General Motors (GM).[6] Following U.S. entry into WWI, GM entered the war effort and under Kettering's direction the government developed the world's first "self-flying aerial torpedo," later named the "Kettering Bug."[7] According to Jimmy Stamp from *Smithsonian Magazine*,

> The Bug was a simple, cheaply made 12-foot-long wooden biplane with a wingspan of nearly 15 feet that, according to the National Museum of the U.S. Air Force, weighed just 530 pounds, including a 180 pound bomb. It was powered by a four-cylinder, 40-horsepower engine manufactured by Ford. Kettering believed that his Bugs could be calibrated for precision attacks against fortified enemy defenses up to 75 miles away—a much greater distance than could be reached by any field artillery.[8]

The war ended before the project could be fielded in combat and it is unlikely it would have hit targets with the accuracy Kettering envisioned.[9] The Bug had many limitations--it was heavy, cumbersome, and required a significant amount of logistical support (assembly, fuel, and dolly system) to be launched. Additionally, it is likely the Bug would have been vulnerable to ground fire and attacking enemy aircraft once airborne. Despite its limitations and failure to make it to the battlefield, Kettering's Bug provided a foundation for later unmanned aerial systems.

WWII

Advancements in aviation technology during the Second World War ushered in the next generation of unmanned aerial systems. Efforts by Germany and the United States allowed for successes and failures in RPA warfare that furthered concepts and military application.

The Germans met with success in their development and fielding of the Vergeltungswaffe Eins or Vengeance Weapons One (V-1).[10] The V-1 was the world's first operational cruise missile and was given its name by the Nazi Propaganda Ministry, but the original Air Ministry nomenclature was Fi 103, after its airframe designer Gerhard Fieseler.[11] According to the U.S. National Air and Space Museum, the V-1 was a mid-wing monoplane primarily constructed of steel, although later long-range, lighter models utilized plywood wings on a tubular metal spar.[12] Mounted on top of the rear of the fuselage was an advanced for its time pulsejet engine.[13] The V-1 carried a 1,870-pound warhead at speeds up to 400 mph at altitudes ranging from 2,000 to 10,000 feet.[14] The first V-1s were launched against England 13 June 1944.[15] In total 8,892 V-1s were ground-launched with roughly 1,600 air-launched against Britain during the war.[16] Despite varying records, one estimate concludes V-1 operations led to 4,683 military and civilians killed and 10,075 being injured.[17] While the effects of the V-1 bombardments were heavy, the British developed countermeasures to reduce their impacts. The countermeasures included: anti-aircraft guns, aided by radar, searchlights, and ground spotters, as well as barrage balloons carrying cables which entangled the missiles.[18] Additionally, V-1s were shot down by Allied aircraft with some being flipped over before reaching targets by the wingtips of intercepting fighters flying dangerously close at high speed in flight.[19] Although the V-1 had size and logistical limitations (assembly, fuel requirements, dolly launching system, multiple personnel required) making operational fielding cumbersome, it proved to be deadly, destructive, and ushered in the use of UAS as a military weapon.

The United States' attempt to field a Remotely Piloted Aircraft during World War Two met with failure. Operation Aphrodite intended to use B-17 and B-24 aircraft loaded with explosives operated by manned crews who would pilot the aircraft until nearing the target area at which point they would depart via parachute.[20] Following departure a manned mothership would then take control, receiving live feed from an onboard television camera located in the cockpit.[21] Aphrodite's failure claimed the life of Joseph Kennedy Jr., when his B-17 exploded over the English countryside before he and his co-pilot were able to depart the aircraft.[22] Despite this failed attempt at RPA operations, the experience in the European theater coupled with technology acquired from Germany at the end of the war, proved critical and enabled further developments to UAS for later military operations, most notably Vietnam.

Vietnam

A growing interest coupled with tremendous leaps in technology allowed Vietnam to become a laboratory for testing advanced U.S. technology.[23] Among the many new technologies fielded by the U.S. during the Vietnam War, the RPA was arguably the most successful.

Two RPAs used extensively by the USAF during the Vietnam War were the Ryan Q-2 Firebee and the Ryan-147 Lightning Bug.[24] According to Andrew Tarantola,

> The first Firebee prototype delivered in 1951 was known as the XQ-2. The 22-foot-long pilotless drone was powered by a 1,060 pound-thrust Continental J69-T-19B turbojet engine capable of providing a top speed well in excess of 500 mph. These prototypes could either be launched from the under-wing of a modified Douglas A-26 Invader while in midair or from the ground using a solid fuel RATO booster.[25]

Later versions of the Q-2 Firebee could fly for 2 hours, up to 60,000 feet at 500 knots.[26] While Ryan RPAs performed many different applications, the USAF used them heavily in Vietnam as reconnaissance platforms. Remarkably, close to 85 percent of all bomb damage assessment reconnaissance photos in Vietnam can be attributed to pilotless aircraft.[27]

Despite approximately 3,000 UAS sorties, Ryan RPAs still experienced limitations, specifically navigation errors.[28] According to Thomas Ehrhard, navigation errors caused the Bug to hit less than half of all planned targets.[29] Additionally, Lightning Bugs were vulnerable to enemy aircraft, radar, missiles, and ground fire, as they had no onboard defensive capability beyond speed and altitude management. Despite the high cost of operations and technological limitations, the capabilities provided by RPAs in Vietnam cemented their role in future U.S. military operations. The next step in increasing UAS capability would be to integrate RPAs as real-time reconnaissance assets versus post-strike information providers.

Gulf War I

In the years following the Vietnam War, U.S. industry and military development of UAS capability led to significant advances. The fielding of the RQ-2A Pioneer brought real-time reconnaissance, surveillance, target acquisition, and battlefield damage assessment information for U.S. Navy targeting to the battlefield.[30] Updated technology allowed real-time capability to exist on a smaller and lighter airframe. As a result, launch, recovery, and logistical requirements became easier to manage than Vietnam era RPAs.[31] The Pioneer was propelled by a 26 horsepower two-cycle engine capable of keeping a 100-pound payload of optical gear airborne for 5.5 hours on only 12 gallons of fuel.[32] Additionally, a pilot operating remotely from the ground or on a ship was able to pilot Pioneer 115 miles away minimizing radar detection by flying at low altitude and utilizing its low signature materials.[33]

RPAs proved useful during the first Gulf War with 40 Pioneers flying 300 sorties and 993 flight hours for the U.S. Army, Navy, and Marine Corps.[34] However, due to its low speed and low flying tactics, Pioneer was vulnerable to ground fire and four Pioneers were lost or damaged during combat mission operations.[35] Pioneer's lightweight construction proved fragile, with another 25 Pioneers being damaged through routine operational use.[36]

As a result of Pioneer's operational success, U.S. adversaries and allies began to pursue development of indigenous UAS projects. However, cost and the lack of required technology proved central limitations for most nations seeking to field a comparable UAS capability. Each Pioneer cost $850,000 dollars, making development and large-scale acquisition cost prohibitive for many nations.[37] With the real-time capability realized by Pioneer's successes during Gulf War I, the U.S. would look to take the next step in UAS evolution by arming RPAs.

The first test of a U.S. RPA weapon launch occurred in February 2001 when a Hellfire-C laser-guided missile was successfully fired from a Predator air vehicle in flight tests at Nellis Air Force Base, Nevada.[38] This test ushered in the latest generation of UAS, once again giving the U.S. a capability exceeding the majority of its allies and enemies.

Proliferation and the Growing Threat

Following years of refinement in technology, logistics, and capability, U.S. allies and enemies alike have recognized RPAs provide a critical war fighting capability they cannot afford to operate without. As of June 2015 current analysis suggests 90 countries are developing and/or operating UAS and at least 10 have armed RPAs.[39] Many of these nations are moving rapidly through the acquisition and fielding phase. Additionally, the rise of independent terrorist actions underscores the growing danger of non-state sponsored UAS acquisition and use.

The USAF cannot overlook UAS as a growing asymmetric threat worldwide. In May 2014, North Korea launched multiple lightweight RPAs into South Korea.[40] In June 2015, Israeli RPAs crashed in Lebanon while conducting operations.[41] Additionally, China is working aggressively to integrate small and large UAS into military operations. According to Ian Bremmer, president of political risk consultancy Eurasia Group, "China has moved the most quickly to develop significant drone capabilities and will start deploying them to support their national security capabilities."[42] According to Bremmer, it is likely China's use of RPAs could range from aerial support over contested regions of the South China Sea to strikes against separatists and alleged terrorists in China's Xinjiang province.[43] Finally, the demonstrated use of small RPAs by the Islamic State in Iraq and al-Sham (ISIS) increases the urgency for development of defensive capabilities.[44] According to Caleb Weiss from *Threat Matrix*, in early 2015 ISIS released video showing their assault on the Baiji, Iraq oil refinery complex.[45] The video confirmed ISIS used small, unmanned aerial vehicles for reconnaissance, command and control, as well as act as spotters for artillery pieces.[46] Weiss reports additionally ISIS has used RPAs in similar fashion during operations in Raqqah, Syria and Fallujah and Zawbaa in Iraq's Anbar province.[47]

While demonstrated use of UAS by U.S. enemies is increasingly recognized, the ability to acquire and deploy inexpensive UAS must be acknowledged as a growing threat to which the USAF has no defense.

The UAS Threat

The widespread use of UAS creates three distinct challenges. Popular familiarity with RPAs undermines awareness of potential threats, creating a false sense of security. Limited regulation enables proliferation and uncontrolled use. Finally, the lack of a coherent USAF defense strategy allows for increased vulnerability at home station and forward operating locations.

Casual Internet research reveals the ability to purchase no less than 20 different lightweight, unmanned aerial vehicles with home delivery available. Research into this topic by David Morgan from *Reuters* reveals, "Consumer Electronics Association reports 120,000 small UAS sold in 2013, 430,000 in 2014 with 1 million drones of all kinds expected to be sold in U.S. this year (2015)."[48] Small RPAs are propelled by an electric battery powered motor(s) providing a capable flight time (15-20 minutes), small payload capacity, high definition camera, and precision navigation capability. Some are fixed-wing traditional aircraft designs, however, the majority are vertical lift rotorcraft-type RPAs. No training is required prior to purchase, and the sole logistics requirement for operation is charged batteries. Additionally, they can be launched, remotely piloted, and recovered by one person virtually anywhere. Low cost coupled with modern capability makes lightweight RPAs very popular with children, adults, aviation enthusiasts, and professionals who have adapted them for use in the work environment.

The introduction of small RPAs into the non-military working environment is happening at an exponential rate. They are now widely used by the media, highlighted recently by a major U.S. news agency, using one to provide live overhead video coverage of recovery efforts in Nepal following an earthquake.[49] Further non-military uses include overhead footage of professional sporting events, professional photography, agricultural, mapping uses, and advertising.[50]

Proliferation and use is occurring at a rate faster than aviation safety can regulate. For decades, U.S. remote control aircraft hobbyists enjoyed flying gas-powered aircraft and helicopters at designated locations governed by the rules and requirements of the local club's airfield. With the arrival of electric, quiet, easy to operate, and inexpensive RPAs capable of precision vertical/horizontal flight, they are now being operated from dense urban areas not dependent on an airfield. As a result, lightweight RPA technology has captured the global imagination of aviation enthusiasts, driving proliferation of these small, unmanned aircraft.

To date, there is limited and under developed regulation controlling proliferation and use of large and small RPAs.[51] Within the U.S., the Federal Aviation Administration has only recently developed guidelines for individual users of small RPAs.[52] This effort is underway in large part as a response to the growing number of reported near misses by airborne commercial and general aviation pilots concerned about the safety of their aircraft and passengers.[53]

The Missile Technology Cooperation Regime (MTCR) and Wassenaar Arrangements are currently the only two international agreements in-place to address UAS proliferation.[54] Both According to Michael Cali from the *Georgetown Journal of International Affairs*,

> [Both agreements] suffer from a club mentality and difficult barriers to entry excludes the states most prone to proliferation. Unlike other successful non-proliferation regimes—such as the Nuclear Non-Proliferation Treaty and the Chemical Weapons Convention, where the dynamic is based on mutual commitment to disarmament and non-proliferation—the MTCR and Wassenar Arrangement models are comprised of a relatively small number of states that control highly desirable material and means of preventing proliferation. This creates an in-group-out-group dynamic that alienates non-MCTR states…the 34-member MTCR is based around a U.S./E.U./Russian axis estranging the majority of Asia, the Middle East, and Africa. States that should cause the most concern for the U.S. regarding proliferation remain excluded from the MTCR. Some of these proliferators and potential rivals, like China, have applied for MTCR status, yet were denied admission. Considering the rapid rate of UAV proliferation, member states of the MTCR and Wassenaar Arrangements should marry transparent and inclusive amendments with language that deviates from the current Cold War era thinking—and embrace current issues and future proliferation trends, including the increasing use of micro UAVs, the emergence of the developing world in international politics, and the threat of terror-group UAV acquisition."[55]

In summary, proliferation of lightweight RPAs is underway on a global scale, is a real threat to U.S. military operations home station and abroad, and there are no effective international controls in place to restrict their proliferation.

Threats to domestic and overseas U.S. operations by UAS include: attacks on personnel/soft targets, disruption of flight ops, surveillance, psychological ops, and video footage collected via enemy for propaganda. In 2015, 18-year old Austin Haughwout of Connecticut successfully weaponized an inexpensive electric quad-copter for a school project by putting a handgun onboard and demonstrated it could fire the weapon while being controlled airborne.[56] This demonstration validates there is no training required and access to materials is easy allowing anyone to field a lightweight RPA threat.

To better understand the threat the capability must be explained. The reduction in size and cost of electronics coupled with the strength and reliability of plastics and composites as a weight saver has allowed for tremendous capability in endless applications. A leader in small RPA technology is Da-Jiang Innovations Science and Technology Co., LTD (DJI).[57] According to Ben Popper from *The Verge*, a media network dedicated to coving new science and technology, "over the last two years DJI has emerged as the world's most popular consumer drone maker, at least in revenue."[58] More specifically, "DJI reported around $500 million in revenue for 2014, roughly four times what it did in 2013, and is on pace to do about $1 billion in sales this year."[59] Two of DJIs popular products are the Phantom 3 Professional (retails for $1,250.00) and the Spreading Wings S1000 ($4550.00).[60] Both are quad-copter designs capable of stealth (quiet electric motors), precision navigation (hover, programmed waypoints, obstacle avoidance), useful flight duration (up to 20 minutes), and surveillance (high definition camera and/or live feed video in First Person View for precision real-time navigation and monitoring).[61] The Phantom 3 Professional is flightworthy out of the box once batteries are charged while the Spreading Wings S1000 requires assembly out of the box with some additional components requiring purchase above and beyond the baseline kit.[62] The Spreading Wings also provides the ability to fly with a payload of 2 plus pounds where the Phantom 3 Professional is limited to a payload the size and weight of a palm-sized GoPro camera.[63] All these capabilities together on a small airframe gives the user an ability to launch, fly, and recover from virtually anywhere with no prior training and minimal required logistics (batteries).

Specific Threats to Contingency Air Operations

Threats from RPAs on U.S. contingency air operations can manifest in a multitude of ways. Threats include surveillance of contingency airfields, lightweight RPA use as a delivery platform for weapons, explosives, or chemicals. A single or swarm of multiple small RPAs could be used to ram aircraft, equipment, and personnel on the ground or ram/harass aircraft taking off or landing. Additional threats include psychological operations in which they could be utilized to deliver leaflets. They can also be utilized as a propaganda tool by recording U.S. personnel at work then releasing the images publically. The video or still photos would insinuate personnel/installation/flight operations vulnerability regardless of the user's ability to inflict follow-on damage/harm.

One highly public example of small RPA use for propaganda/vulnerability exploitation occurred in Dresden, Germany in 2013.[64] While Chancellor Angela Merkel delivered a speech, an activist group (Germany's Pirate Party) successfully launched and landed an electric quad-copter on the stage before security services could stop the action.[65] Ironically, the activist group piloted the RPA to protest Chancellor Merkel's policy on surveillance yet her security apparatus was unable to keep the device from entering her personal security zone further validating the threat they present.

The Merkel example is just one of several news stories within the last year that feature the increased use of RPAs. Nearly every article underscores the absence of a fielded defense strategy against this growing threat. Further, the use of UAS in different circumstances highlights the need for both material and non-material technologies to counter the threat.

Material/Non-material Technologies, Capabilities, & Solutions to UAS Threat

Material

Although the USAF has yet to publish an open source UAS defense strategy, industry has begun to develop material technologies to counter the UAS threat.

Radar: two available systems could be tested by the USAF for use in detecting small RPA threats. First, the British company Plextex has developed a ground radar system called Blighter designed for battlefield use.[66] Blighter is a lightweight man-portable system that has successfully (in a test environment) identified a 1.5 meter wingspan composite RPA at two kilometer range.[67] A second already fielded capability that could be considered for use in detecting small UAS are Avian radars. Bird radars already in use at a limited number of USAF stateside installations (Offutt AFB and Whiteman AFB) could be used as test beds for determining if their current calibration and capability can detect lightweight RPAs.[68]

Optical/Infra-red: to provide 24 hour (day/night) optical coverage of key airfield sectors the USAF could consider testing/fielding a new capability provided by the Dedrone Company.[69] Dedrone was founded in 2014 by Jorg Lamprecht and Dr. Ingo Seebach in response to the RPA intrusion on Chancellor Merkel's public address.[70] Dedrone produces a multi-sensor drone warning system that can be mounted externally on any facility.[71] Dedrone uses a three system approach to detection by utilizing audio/ultrasonic, video (daylight), and near infrared (night) sensor arrays.[72] Combined, the Dedrone system can detect small UAS up to 100 meters away and transmit that information to a monitoring station alerting security forces to an intrusion.[73]

Signal Jamming: The concept of jamming has rapidly moved to the forefront as a means of deterring, disrupting, and/or defeating UAS threats. Several companies are developing anti-RPA signal jamming capabilities. Two emerging standouts the USAF should consider for use in countering threats are Battelle and the European Anti-UAV Defense System Team (AUDS Team) comprised of three companies: Blighter Surveillance Systems, Chess Dynamics, and Enterprise Control Systems Ltd.[74]

Battelle has built the Drone Defender (set to release in 2016) that provides hand-held radio jamming capability built on the frame of an assault rifle.[75] According to Russell Brandom from *The Verge*, the Drone Defender floods its target with overwhelming signals on all the frequencies used by commercial drones, including GPS, cutting it off from the pilot.[76] After being cut off from their signal point of origin most drones will hover stationary to the ground.[77] This technical approach to anti-RPA intervention was important to Alex Morrow, the project's technical director as he sought a solution that was safe, effective, and non-damaging that also allowed for forensics after an engagement.[78] Post engagement forensics might prove critical in determining point of origin, operator(s), and flight path.

The AUDS Team integrates a Ku band electronic scanning air security radar, stabilized electro-optic director, infra-red and daylight cameras, target tracking software, and a directional radio frequency (RF) inhibitor/jammer system to detect, track, classify, disrupt and neutralize RPAs at ranges of up to 8km.[79] These capabilities are combined on a manageable tripod system that can be moved, set-up, and operated by 2-3 individuals. This system could also likely be mounted to a vehicle for rapid movement and use in an airfield defense environment. The AUDS system offers a defense capability not yet available in contingency operations. However, the heavy regulation of signals in the U.S. would likely require a thorough examination of the legal and technical impacts on other signals operating in the same environment.

Laser: once identification of a small RPA takes place, neutralizing the threat becomes paramount. Boeing is working to field a technology that can provide this capability in their new Compact Laser Weapons System (CLWS).[80] CLWS can track down and fire on an RPA using a two-kilowatt laser that focuses directed energy at the target.[81] The CLWS uses a mid-wave infrared sensor to track targets up to 40 kilometers.[82] According to *Fox News'* Allison Barrie,

> The laser is controlled with an Xbox 360-like controller connected to a laptop equipped with targeting software. It takes just two warfighters to move the laser around the battle space and delivers focused firepower. The laser can be moved in a few boxes and set up within a few minutes.[83]

Using directed energy to down an enemy RPA minimizes the risk of collateral damage, potentially reducing such damage as caused by conventional weapons.

Non-material

Awareness Training & Policy: it is likely the majority of USAF personnel are familiar with the United States' unrivaled offensive RPA capability. Additionally, media and pop culture provide constant sources of RPA information via news reporting, commercials, movies, and video games. As a result, many U.S. service members have become desensitized to the threat of RPA operations. Airmen might think the airborne RPA they observe in a home station or contingency environment is a U.S. asset. Awareness training must be developed to alert all Airmen to the threat lightweight enemy RPAs present, as well as the critical requirement to report all RPAs when detected.

Additionally, policy must be expanded to include defensive UAS requirements. The Department of Defense Unmanned Systems Integrated Roadmap (FY2013-2038) released in 2013 provides zero mention of the importance and requirement for defensive UAS operations/systems.[84] Lt Gen Michael F. Spigelmire (ret.) and Col Timothy Baxter note the need to close this gap in capability. In their article, *Unmanned Aircraft Systems and the Next War* they argue, "because of wartime needs, the surge in UAS has not been matched with developing the user doctrine to support unified field operations—the full-spectrum fight. It is time to catch up."[85]

Military and Civilian Partnerships: the military activated the Joint UAS Center of Excellence at Creech AFB in 2005 only to deactivate it years later.[86] Reactivating this center and expanding its previous focus from offensive to defensive UAS operations will yield results. Additionally, if the U.S. military is interested in reducing costs for reactivating such a facility public-private partnerships with industry such as Google and Amazon could create cost sharing opportunities.[87] Both companies have indicated their intention to heavily utilize lightweight civilian RPAs to conduct business operations. A public-private partnership with industry would allow for shared resources as well as capitalizing on best practices. The added benefit for the USAF would be to leverage cutting edge technological advancements acquired by the private sector ahead of military budget and planning timelines.

Conclusion

Unchecked proliferation of small, unmanned aerial vehicles is a reality. Threats to U.S. civilian and military airborne operations are equally real. The ability of civilian aircraft to operate safely has already been challenged and must be resolved as well as regulated by the Federal Aviation Administration. While stateside efforts to get small RPA interference under control have begun, the USAF cannot expect to find similar controls in place during contingency operations. Consequently, the USAF must start planning immediately to identify and neutralize hostile RPAs within their airspace.

The best concept of operations would recognize the complexities of the threat and therefore include a combination of emerging anti-UAV technologies. For established airfields, the use of radar, optical/infra-red, signal jamming, and laser capabilities in fixed positions near the active runway, as well as mounted on vehicles would provide a persistent RPA detection and response capability. Additionally, static sensors similar to those provided by Dedrone could be utilized to protect personnel and high-value infrastructure. For remote, non-developed contingency airfields, utilizing a lightweight handheld signal jamming technology similar to the Battelle concept would provide an easy to handle and mobile point defense capability for designated response personnel.

While demonstrated use of UAS by U.S. enemies is increasingly recognized, the ability to acquire and deploy inexpensive UAS is a growing threat unaddressed by current USAF capability. Further, the widespread use of RPAs underscores the increasing likelihood that U.S. enemies will utilize these assets against U.S. interests. The false sense of security created by the popularity of RPAs must be countered by a coherent defense strategy and thoughtful regulation. The U.S. has maintained air superiority for more than 40 years by dominating all aspects of airspace. To continue as the global leader in air power, the USAF must be able to defend against the asymmetric threat presented by lightweight RPAs.

Notes

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