Defeating the Threat of Small Unmanned Aerial Systems

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Unmanned aerial systems (UAS) offer new or improved military capability in many airpower applications. Contemporary UASs range in size from aircraft with wingspans exceeding 150 feet to vehicles that fit into the palm of an operator's hand. Medium-sized unmanned aircraft such as the MQ-1B Predator have become icons of American counterterrorism warfare, but small unmanned aerial systems (SUAS) have performed significant roles in militaries around the globe as well. SUASs provide game-changing potential for small militaries and nonstate actors by enabling airpower capability that may have been previously out of reach. More advanced militaries can also leverage SUAS capability to enhance existing combat systems.

Innovative applications of SUASs by adversaries create new threats to US joint forces. Defeating the threat posed by SUASs will require commanders to combine new technology and doctrine along with appropriate planning and policy to protect the joint force. Examining the proliferation, arming, and unique tactical advantages of SUASs is necessary to demonstrate the threat against a joint force. With the threat to the force understood, methods for countering it can be identified and conclusions drawn to ensure joint force mission success.

Proliferation of Small Unmanned Aerial Systems

UASs have historically been the privilege of few nations as technology limited to large aerospace companies was required to conduct remote or autonomous flight. Recent engineering achievement has led to commercially available unmanned flight control systems enabling the development or acquisition of UASs by much smaller entities, including individuals. Oxford University doctoral candidate Ulrike Esther Franke focused much of her research on the implications of increased military use of unmanned systems. Ms. Franke reported that in 2000 only 17 countries possessed UASs for military application; by 2015 that number had risen to more than 75.[1]

The spectrum of UAS military users spans the globe and has not been limited to sovereign countries. Nonstate actors are operating UASs for military purposes, such as the terrorist group Hezbollah that has flown unarmed Iranian-built UASs over Lebanon and Syria.[2] As the development and export of UASs expand, the number of UAS users will no doubt increase to include more unstable or hostile governments as well as violent extremist organizations.

Smaller UASs present a substantial potential for armed groups that cannot afford or gain access to larger, more complex systems. For advanced militaries, SUASs provide a new opportunity to increase the quantity of military assets and introduce a new capability at significantly reduced cost compared to that of larger systems. The number of countries currently employing SUASs far exceeds those with medium and large systems. Ms. Franke's research notes that a multitude of European militaries have domestically developed SUAS programs. Additionally, many non-European countries are creating their SUAS systems.[3] It is hard to imagine a potential adversary, whether a state or nonstate actor, that will not employ a form of SUASs during future armed conflict.

State-funded defense programs are not the only source of unmanned aircraft. Commercial production has exploded in recent years with low-cost aircraft offering advanced autonomy and sensor features. Dà–Jiāng Innovation (DJI) Technology Company's Phantom 4 is an example of a SUAS available for purchase over the Internet. The Chinese-manufactured aircraft are capable of flight for almost 30 minutes, can reach altitudes over 18,000 feet, and come equipped with data-linked, high-definition cameras. The cost for this capability is a meager $1,400.[4]

In addition to cost savings and sensor capability, SUASs permit flexibility in employment. The systems are portable and do not require airfields or other support networks. Many small air vehicles are hand-launched or use some type of catapult for takeoff. Recovery is also relatively simple since most vehicles either land on short surfaces or employ a capture device to retrieve the aircraft in flight. Transportability allows SUASs to be used during maneuver warfare when operating in remote areas or where air cover and intelligence assets are otherwise unattainable. As identified in Ms. Franke's research, the proliferation of SUASs is proceeding at an alarming rate and will likely continue in the quantity of assets available and the armed groups that employ them. Combat capabilities will also expand through advancements in flight duration and autonomy, further enabling intelligence collection, communications, and strike missions.

Arming Small Unarmed Aerial Systems

Although many nations are rapidly acquiring UASs for military application, the ability to arm these aircraft has remained limited until recently. As of 2013, only the United States, United Kingdom, and Israel operated armed UASs; by 2015 both China and Iran possessed domestically developed armed UAS programs.[5] It is expected that armed UAS exports will grow swiftly to meet international market demand.

Evidence of armed UAS proliferation was provided in a January 2016 news story about Iraq operating armed unmanned aircraft manufactured in China. A deeper examination of Chinese exports showed that Saudi Arabia, the United Arab Emirates, and Egypt have also procured armed UASs from China. With more than 75 corporate and state organizations developing products for the UAS industry, China is postured to become a major supplier.[6] The appeal of China as an armed UAS supplier comes from its export policy founded on "price, privacy, and product."[7] China provides products at prices small governments can afford. Further, China's approach to privacy is highly attractive to many consumers who desire limited attention when procuring advanced weapons.[8]

Regardless of availability, the cost of medium to large aircraft can prohibit organizations from attaining armed UAS capability. The significantly lower cost of procurement and operation of SUASs has generated a new armed aircraft market. Although the current supply of armed SUASs is limited, the field is fast expanding. US-based Textron Systems, which produces the RQ-7 Shadow that is fielded by the US Army for intelligence collection, is one example of a new armed SUAS project. Bill Irby, senior vice president and general manager for Textron's unmanned systems, stated that Textron has successfully tested the RQ-7 with its lightweight, precision-guided weapons. Another example is the Chinese CH-3A.[9]

One challenge to armed SUAS development has been attaining weapons small enough to be employed from the air vehicles. Weapons like the AGM-114 Hellfire, carried on the MQ-1, weigh about 100 pounds. Newer designs such as the AGM-176 Griffin missile are significantly smaller yet still too heavy for many air vehicles in development. To solve this problem, in 2010 the US military released a request for proposals to develop precision weapons that weigh less than 11.3 kilograms (kg) (25 pounds).[10]

The industry responded to this request by designing a multitude of lightweight precision weapons. The Raytheon Pyros glide bomb weighs only 6 kg (13.2 pounds), while Lockheed-Martin's Shadow Hawk weapon weighs only 5 kg (11 pounds).[11] Although attaining information on China's developments in small precision weapons is difficult, it is not a stretch to imagine that its corporations are steadfastly working on SUASs and their accompanying weapons for the Chinese military and the international marketplace.

Along with arming SUASs to provide strike capability, expendable miniature aircraft designed to be munitions in themselves are available. Small aircraft that have integrated sensor-warhead payloads offer an even lower cost and a highly flexible option to militaries of all sizes. AeroVironment's Switchblade SUAS is an example of a single-use vehicle with integrated warhead and sensors. Switchblade comes in a portable package weighing just 2.5 kg (5.5 pounds), including the weight of the vehicle and launcher. With a 10-minute flight time and a top speed of more than 85 miles per hour (mph), Switchblade offers individual warriors a weapon that can fly up to altitude, spot an enemy, and rapidly engage with precision, yielding lethal effects with limited collateral damage.[12]

Armed SUAS acquisition is not limited to organizations with access to defense contractors that might be subject to some degree of government oversight. For groups without a benefactor with access to military hardware, weapons may be attained through another method. Advanced SUASs for commercial purposes can be readily adapted for armed missions. By removing cameras or other commercial payloads on small air vehicles purchased through the Internet, small improvised explosive devices (IED) can be added, creating makeshift guided missiles. As an example, the DJI S1000 aircraft features a payload dock on the bottom of the vehicle. The system was designed to allow users to attach different camera equipment based on the mission. In the hands of an innovative user, the S1000 is a highly capable SUAS that can fly a 9.5 kg (20 pound) payload for 15 minutes. This capability can enable a lone-wolf actor to perform precise kinetic strikes against targets in protected areas for less than $5,000.[13]

Whether purchasing SUASs that can carry precision-guided weapons, using aircraft that are weapons in themselves, or adapting drones ordered online to carry IEDs, the options for armed groups are rapidly expanding. The cost ranges from well above $500,000 to only a few thousand dollars, providing air-attack capability and quantity options never previously available.

Tactical Advantages of Small Unmanned Aerial Systems

The tactical applications of SUASs are numerous. Attempting to identify every potential military option would be virtually impossible, so it is perhaps more beneficial to focus on the tactical advantages unique to SUASs. These advantages can be understood by examining three properties of SUASs: size, speed, and swarm. Each of these properties provides a benefit in armed conflict. Combined, the properties generate combat potential that presents a significant threat to US military forces.

The small size and relative speeds of the air vehicles create substantial defensive difficulties. Joint Publication (JP) 3-0, *Joint Operations*, states: "Unmanned aircraft are a new challenge to US air defenses, as many systems have smaller radar cross sections and fly at much slower speeds than manned aircraft making them much harder to detect."[14] This doctrinally stated weakness was demonstrated in January 2015 when a DJI Phantom—flown by an amateur operator in the Washington, DC, area—crashed on the lawn of the White House. While the event was an accident and had no apparent malicious intent, it highlighted how small, slow air vehicles could exploit a seam between robust air and ground defenses.[15] A few months later on 22 April 2015, security personnel discovered another DJI Phantom on the roof of Japanese prime minister Shinzo Abe's office. Security personnel did not know when the aircraft landed on the building since the roof had not been accessed for a month and the approach and landing were not detected.[16]

SUASs have additional advantages beyond electronic and visual detection avoidance. Their small size make them easily transportable; they can be moved with small vehicles and, in some instances, carried in a backpack. An adversary can move equipment and operators near joint force basing areas before deploying the air vehicle. Instead of trying to penetrate US air defenses with fighter aircraft, adversaries could use passive detection measures to conceal the presence of armed SUASs and then launch them from a position inside US fortifications.

Although slow moving compared to most aircraft, their mere ability to fly generates a speed advantage in bypassing obstacles from launch to engagement. With an operating speed of up to 100 mph in some systems, small air vehicles can close employment range very quickly. When combined with small size, the speed of SUASs can create attack options where the first sign of an enemy presence would be weapon detonation. A profound benefit of speed and size is also the ability to operate inside the commander's decision loop. With the potential to attack repeatedly and to do so undetected, SUASs present a potentially devastating threat by creating a confusing environment for the unprepared operational commander.

One's aircraft fleet size must be considered when analyzing the impact of SUASs. The rapid growth of SUAS capability has led to a new reality in the application of airpower. Former secretary of defense Chuck Hagel alluded to this reality in a keynote speech to the Southeastern New England Defense Industry Alliance in September 2014 when he stated, "Disruptive technologies and destructive weapons, once solely possessed by only advanced nations, have proliferated widely and are being sought or acquired by unsophisticated militaries and terrorist groups."[17] SUAS proliferation is adjusting the balance of airpower, which has for decades been dominated by a select few nations.

With the advent of armed SUASs, US forces must change the way they have historically defended against enemy airpower. JP 3-0 identifies air and missile defense (AMD) as a key task of joint forces.[18] Historical assumptions in planning for AMD may no longer be valid due to the SUAS threat. A joint base in a theater without a significant enemy air force may have few assets allocated for AMD. Through the employment of SUASs, an enemy could exploit this US defense weakness or at least force operational commanders to allocate resources to air defense against the SUAS threat, removing offensive potential.

Defense analyst Paul Scharre calls attention to the change in relative airpower capability created by SUASs. In a 2014 report, Scharre notes, "Overwhelming adversaries through greater numbers is a viable strategy for technology competition, and was used successfully by the United States in World War II. One of the chief advantages of this strategy is that it can be used to *impose costs* on adversaries because it forces one's adversary to counter large numbers of systems (emphasis in original)."[19]

SUASs can impose air defense costs where none were previously necessary or drastically increase AMD costs against enemies with marginal air attack capabilities.

The ability to acquire large quantities of SUASs further affects relative airpower by allowing an enemy the opportunity to mass tens or even hundreds of air assets in a coordinated attack instead of employing a few legacy aircraft. By attacking with overwhelming numbers, SUASs could require US joint forces to engage numerous targets, imposing a significantly higher cost of defense compared to legacy airpower means. Although US joint forces may enjoy a significant technology advantage, their defenses may not be sufficient against a swarm of small air vehicles.

In a separate 2014 report, Scharre evaluates superior quality against large quantities in military engagements using a principal called Lanchester's Law. Scharre concludes, "A numerically inferior force can compensate with greater qualitative superiority, but a force that is outnumbered by its opponent 2-to-1 must, therefore, be *four times better* in quality in order to simply match its opponent. There is, in essence, a limit to how much qualitative superiority can compensate for smaller numbers" (emphasis in original).[20] The low cost of SUASs creates a possibility for a savvy adversary to simply overwhelm joint air defenses, adjusting the relative airpower for the attacker.

Combining the advantages of size and speed of SUASs with the quantities available due to low cost magnifies the change in the balance of airpower. Armed groups that previously had no option for successfully employing airpower can now challenge US joint forces. By employing SUASs in swarms, an adversary can further tip the scale in their favor.

As defined by Scharre, "a swarm consists of disparate elements that coordinate and adapt their movements in order to give rise to an emergent, coherent whole."[21] Swarming is much more than just coordinating an action with large masses. In a massed attack, the individual members use coordinated fire and maneuver to achieve a coherent objective. In swarming, coherency is within the mass itself. Scharre clarifies this distinction in noting that "a wolf pack is something quite different from a group of wolves."[22]

The ability to swarm SUASs is restricted with current technology. Operators have limited capabilities to link SUASs together or, by using autonomy, to react in harmony to changes in the battle situation and within the swarm itself. However, with proper planning and coordination, an adversary can take advantage of some SUAS swarm capabilities. "Centralized coordination" is a basic model of swarm command and control that uses a designated leader to orchestrate mission plans and maneuvers and to assign tasks during the mission.[23] A team operating SUASs under a centralized coordination construct can impose greater levels of damage than can masses of SUASs operating alone. The combination of speed, size, scale, and swarming allows SUAS tactical actions to extract operational gains. SUASs open a door for adversaries to counter joint force strengths through enabling their attack of critical vulnerabilities previously out of their reach.

An example of an opportunity afforded through swarming is demonstrated by the role of mining in warfare. Dr. Milan Vego, a US Naval War College professor of operations, suggests that mining is "in some cases almost the only means available to a weaker opponent at sea to challenge the control of a stronger navy." Dr. Vego adds that mines could be used to shape the battlespace by denying the free use of space and by forcing vessels out of protected waters where they may be vulnerable to attack by other means.[24] Similar to mines at sea or IEDs on land, large quantities of low-cost SUASs can be employed in a manner to mine airspace in locations of high-density air traffic.[25]

Airspace mining is just one illustration of how the unique advantages of SUASs can be used to challenge maneuver, sustainment, or protection measures. The threat posed by SUASs extends far beyond simple tactics. Adversary forces can use SUASs to impose costs on operational commanders by attacking personnel, infrastructure, and support systems. Delaying preparations to defend against the threat could end in disaster.

Defeating the Threat Created by Small Unmanned Aerial Systems

Averting disaster in joint operations will require commanders to address the SUAS threat. To be successful, commanders cannot wait and react to their enemy; rather, they must proactively work to achieve victory. Defeating the threat created by SUASs will require a combination of new technical solutions, updates to doctrine, incorporation of counter-SUAS efforts in planning for operations, and a new policy for fighting a new kind of enemy.

Technical solutions are intended to solve the problem of SUAS detection and provide an ability to destroy, disable, or neutralize the enemy aircraft. Leading the effort toward SUAS detection and defeat is the Joint Integrated Air and Missile Defense Organization (JIAMDO). JIAMDO is charged to plan, coordinate, and oversee AMD and associated joint concepts, according to a defense budget justification report.[26] One of JIAMDO's efforts at technical solutions to counter the SUAS threat is the annual Black Dart exercise.

In 2015 JIAMDO executed a $4.2 million budget for Black Dart. The event comprised a multiday series of experiments aimed at testing the detection and defeat of SUASs. Results from experiments at Black Dart revealed that a "system of systems" is necessary to identify and defend against SUASs. Detection involves a combination of radar, electro-optical, infrared, and acoustic technologies. Destruction or neutralization of the air vehicle requires a combination of kinetic and electronic solutions.[27]

Attempting to counter the threat of SUAS by defending with technical solutions alone will not suffice. A solely technical effort applied to current force protection constructs may lead to unacceptable costs of defense at the expense of mission capability. Doctrine must be updated to consider the capabilities unique to SUASs. Although many sources of doctrine can be considered, *Countering Air and Missile Threats* (JP 3-01) offers a logically sound point of origin to assess current doctrinal suitability for defeating this new threat.

Counter-AMD is typically led by the joint force air component commander. The counter-AMD construct is broken into two primary areas: offensive counterair (OCA) and defensive counterair (DCA). Each area must address the unique capabilities of SUASs.[28]

OCA is defined as "offensive operations to destroy, disrupt, or neutralize enemy aircraft, missiles, launch platforms, and their supporting structures and systems both before and after launch, and as close to their source as possible."[29] Attack operations, as part of OCA, are aimed at striking these components of enemy airpower before they can be employed against friendly forces. Airpower enablers, such as fuel storage and repair facilities, can also be targeted.[30]

The size and available quantity of SUASs make OCA missions against this threat difficult at best. Targeting the aircraft themselves can be an expensive and futile effort. Likewise, launch and support systems are easily concealable, transportable, and numerous. Because some SUASs use conventional fuel types, attacking fuel storage may yield some positive results. However, the low fuel volumes required enable adversaries to store sufficient quantities of fuel in small containers that are mobile and concealable. Also, many SUASs are electrically powered and can be charged from civil infrastructure that may be off limits to attack. The unique characteristics of these systems reveal that current OCA doctrine is insufficient to provide an effective plan to counter enemy SUAS employment potential.

Deficiencies also exist in current DCA literature. The DCA mission is defined by JP 3-01 as "all defensive measures designed to detect, identify, intercept, and neutralize or destroy enemy forces attempting to penetrate or attack through friendly airspace."[31] Executing this role requires utilizing a wide range of sensors and weapons based on land, sea, and air. The goal for DCA is to generate "defense in depth," allowing defensive systems an opportunity for multiple engagements against incoming air threats.[32]

The unique attributes of SUASs allow for evasion of detection with current air defense technology, while developing adequate sensors to detect the full range of SUASs can be prohibitively expensive. The transportability of SUASs allows for penetration of outer defense layers on land and sea, so employment can be initiated from close-in ranges that prohibit multiple engagements. When properly massed, swarms of SUASs can overwhelm inner defenses and create gaps for follow-on attacks to exploit.

Both OCA and DCA missions require significant study to generate doctrinal guidance to defeat the SUAS threat. However, a vector for solving this problem may come from the current doctrine itself: JP 3-01 identifies special operations forces (SOF) as a method of aiding the counterair mission. SOF units can be used to locate and eliminate air and missile facilities, support systems, and command nodes.[33]

Hunting enemy air systems that are mobile can be difficult. The size of SUASs makes this mission more difficult than for legacy missile systems by orders of magnitude because systems can be hidden virtually anywhere with ease. Although employing SOF units per current doctrine will likely yield insufficient results to counter the SUAS threat, it does illuminate a potential counter-SUAS technique.

The attributes of the SUAS that afford an advantage in attack can also be used against it. Installation commanders may seek to clear larger perimeters around joint force facilities than are historically maintained. Eliminating havens from which to launch SUASs close-in against friendly operating areas could force enemy attacks from distances that enable detection and elimination and challenge the range of systems too small to detect. Using ground forces to clear and hold a perimeter can be viewed as a new means of OCA.

JP 3-01 states that ballistic missile defense is a different mission, unique from defense against aircraft and cruise missiles.[34] Countering the SUAS threat will also require a different emphasis from current air and missile defense literature. By providing adequate doctrine, commanders will be able to incorporate technical solutions within joint forces during the planning process to help defeat the SUAS threat.

Planning for this threat is essential in the current battlespace. The low cost of SUASs enables adversaries to increase their relative airpower in their favor. Intelligence assessments on the ability of an adversary to obtain and operate large masses of SUASs must be accounted for in a planner's time-space-force estimation. SUAS analysis must consider an adversary's increased force size, space covered by the air assets, and the short reaction times commanders may have when SUASs are discovered. In examining the force-time factor, planners must also determine how to replace their systems rapidly.

When assessing how to protect one's center of gravity, a planner must weigh SUAS capabilities. In developing an operation idea, a planner must consider the SUAS's potential to disrupt, disable, or neutralize critical capabilities. The ability to collect intelligence and attack speedily against joint critical vulnerabilities must be evaluated.

Plans for sustaining forces and maintaining lines of communication (LOC) need to be developed with the SUAS threat in mind. Long unprotected LOCs make ideal targets for highly mobile SUAS operations aimed at degrading resupply to forces in the field. As an operational axis is determined and operations are phased, planning for sustainment can be difficult against a capable adversary with masses of SUASs.

In addition to having a well-constructed plan that incorporates effective technological solutions and doctrinal practices, operational commanders must also enact appropriate policy. The most highly trained force operating under a perfect structure cannot be successful without adequate guidance, such as clearly delineated rules of engagement (ROE). Applying a sound policy to the operating environment is a must if victory is to be achieved.

Since many operational bases, both land and maritime, exist in areas with significant populations, the use of SUASs for civil purposes can add a degree of complexity to the commander's mission. Maj Scott Gregg, USAF, director of Black Dart, noticed this difficulty at the 2015 exercise. During an interview regarding the difficulty of detecting SUASs, Major Gregg questioned, "How do you differentiate between a 10-year-old kid who just doesn't know any better and is flying something from a hobby shop and somebody who's flying that identical something from a hobby shop but has nefarious intent? You can't tell that with a radar or an infrared sensor."[35] As technology and doctrine are developed to parry the threat generated by SUASs, a necessary policy such as ROEs must be identified during operational planning and enacted.

Policy updates are needed not only in the operational sphere but also in the acquisition arena. SUAS advancements are largely driven by computer technology gains, so capabilities will likely continue to increase. The US defense acquisition process is unfortunately at odds with this reality. New defense equipment takes years to design, test, and field. Under this framework, necessary hardware identified through Black Dart or other methods may be irrelevant by the time it is fielded if adversaries simply outpace US technical solutions. A revised acquisition policy will facilitate timely technical solutions, allowing commanders to respond to the SUAS threat.

Conclusion

SUASs furnish an innovative adversary with new weapons that have substantial potential. The unique capabilities of small unarmed aerial systems—combined with their potentially large quantities—create the possibility of a completely new battlespace. Defense analyst Robert Martinage has studied the impending changes to battle brought on by advancements in technology. In *Toward a New Offset Strategy: Exploiting US Long-Term Advantages to Restore US Global Power Projection Capability*, Martinage observes that "the United States cannot afford to simply scale up the mix of joint power projection capabilities."[36] New systems with advanced technology are proliferating to enemies of the United States at an astounding pace. SUASs represent just one piece of the shift; the problem is a current and not solely a future threat.

Scharre argues that "the history of revolutions in warfare has shown they are won by those who uncover the most effective ways of using new technologies, not necessarily those who invent the technology first or even have the best technology."[37] The views of Martinage and Scharre reveal the need to act on the threat of SUASs now. The technological advantage in unmanned systems, once wielded by an elite few, is disappearing rapidly. The gap is being filled in a manner that gives US adversaries high-tech, effective means to attack joint forces worldwide. Successfully defeating groups armed with SUASs will require innovative solutions in technology, doctrine, planning, and policy. ✪

Notes

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