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Unnamed Aircraft Systems: Challenges to Air Defense

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Abstract

The 2019 attacks on the oil processing facilities in Saudi Arabia and the effectiveness of combating Armenian long-range anti-aircraft systems have highlighted the nature and scale of the challenges for air defense posed by unmanned aircraft systems. The aim of this article is to summarize the lessons learned from the use of unmanned systems in recent conflicts, to assess the development of trends in such systems, and to discuss the implications of those developments for air defense. This article discusses the impact of the development of unmanned aircraft systems on air defense concepts, their organization, and the effectiveness of this defense for the defended assets. It also tries to highlight how unmanned aircraft systems may reduce the survivability of air defense systems. This research is based on publicly available documents related to air defense and unmanned aircraft systems as well as selected analytical studies on the implications of the development and use of unmanned aircraft systems for air defense. As such, this research identifies the possible challenges related to ensuring effective air defense against attacks by unmanned aircraft systems, resulting from the costs of defense despite the availability of technological solutions. It also raises the issue of survivability of air defense systems if attacked by unmanned aircraft systems.

Keywords

air defense, challenges, threats, unmanned aircraft systems

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1. Introduction

Although unmanned aircraft systems have been used in combat operations for a long period of time, the last two decades have witnessed their widespread deployment in a wide range of reconnaissance, surveillance, and strike tasks. The dynamic development and proliferation of technologies that enable the development and use of unmanned aircraft systems has increased their availability not only to major military powers but also to smaller countries and non-state actors. Currently, unmanned aerial vehicles provide a wide spectrum of platforms, having different endurance, altitude and flight speed, or being multi-role or optimized for specific tasks. A significant part of them – especially those smaller and cheaper unmanned aircraft systems – became available to a wide group of countries, substituting manned aviation. The weaponization of small, unmanned aircraft systems increased the combat capabilities of light infantry in several countries but also provided non-state actors with a new offensive weapon. The employment of unmanned aircraft systems in Syria by ISIS and anti-government forces as well as attacks on oil processing facilities in Saudi Arabia have proved the potential of unmanned aircraft systems to conduct not only tactical but strategic attacks. The unmanned swarm attack against the terminal highlighted the potential challenges for air defense resulting from the skillful use of unmanned swarms as part of an air and missile attack by a state opponent or an attack on critical infrastructure elements by non-state actors. The unmanned aircraft systems proved effective in the destruction of ground-based air defenses in Syria, Libya, and the Nagorno-Karabakh conflict between Armenia and Azerbaijan. Therefore, recent conflicts have highlighted the direct threat to air defenses posed by unmanned systems. Both of these trends observed in recent years can be considered a harbinger of challenges for air defense in the coming decade.

The aim of this article is to make a preliminary assessment of the challenges and threats to air defense posed by unmanned aircraft systems. Based on the analysis of selected attacks with the use of unmanned aircraft systems in recent years, the possible consequences for air defense were assessed in two aspects. First, this article explores how the development of unmanned aircraft systems affects the effectiveness of air defense. Then, the article addresses the issue of how unmanned aircraft systems influence the survivability of the components of the air defense system.

This research uses publicly available documents related to air defense and unmanned aircraft systems as well as selected analytical studies on the implications of the development and use of unmanned aircraft systems for air defense. While quantitative analysis of the subject has been hard to conduct due to a lack of verifiable information, this article focuses on the qualitative aspects of the challenges that unmanned aircraft systems pose to air defense. Therefore, new concepts for employment, tactics and impact on warfare and air defense are researched in more detail.

The introductory part of this article discusses the main trends in the development of unmanned aircraft systems in the context of the challenges and threats they may pose to air defense. Then, the article presents a preliminary assessment of unmanned aircraft systems' attacks in the context of the requirements for air defense related to the protection of defended assets. The next part of the article focuses on the assessment of the impact of the use of unmanned aircraft systems on the survivability of the air defense system and its individual components. The final part of the article addresses future trends related to the use of unmanned aircraft systems and analyzes the possible impact on air defense.

2. The evolving threat of unmanned aircraft systems

The threat posed by unmanned aircraft systems is broad and comprehensive, which results, inter alia, from the existing diversity of their design, purpose, and availability. For air defense, the tactical and technical parameters of unmanned aircraft systems are more important than their military or civilian affiliation. Therefore, in assessing the trends related to the proliferation of such systems, military, civil, and commercial off the shelf systems should be considered. The upper tier of military unmanned aircraft systems, such as High-Altitude Long Endurance (HALE) systems and dedicated Unmanned Combat Aircraft Systems (UCAS), will most likely remain available to a relatively small group of states with an advanced technological base. At the same time, Medium Altitude Long Endurance (MALE) unmanned aircraft systems will proliferate around the world at modest pace either produced by growing number of states or procured. The most disruptive proliferation will be witnessed for smaller unmanned aircraft systems, as they are becoming available virtually to any state or non-state actor. According to available Joint Air Power Competence Centre (JAPCC) estimates, at least ninety-five countries in the world maintain active unmanned aircraft systems programs, and armed forces have used at least twenty-one thousand drones (JAPCC, 2020). The US Department of Defense itself has operated more than eleven thousand unmanned aircraft systems of different classes. At least twenty countries have produced military-grade unmanned aircraft systems, which creates favorable conditions for the proliferation of this type of weapon system. The number of non-state actors with drone capability is increasing. Such actors tend to weaponize commercially available drones or are provided with military grade systems by sponsoring states (Patterson, 2017).

Commercially available unmanned aircraft systems weighing from 100 grams to 150 kilograms dominate in civil applications. The scale of unmanned aircraft system proliferation can be assessed through the prism of data available for several countries. In 2019, 1.3 million recreational unmanned aircraft systems were registered in the United States. However, it is estimated that several hundred thousand more remain unregistered. In Germany, the number of unmanned aircraft systems increased from 162,000 in 2015 to over 600,000 in 2020 (JAPCC, 2020). Such trends may be probably observed for several other states around the world.

Unlike the conventional air threats of manned aircraft and missiles, which are predominantly used in times of war, the unmanned aircraft systems must be considered a threat in times of peace, crisis, and war. To some extent, HALE and MALE unmanned systems may be considered conventional air threats, as they are easily attributable to their state operators. This does not hold true for a range of smaller aircraft systems, which may be hardly attributable to specific state actors. Therefore, in peacetime, small, unmanned aircraft systems that may be used as a means of air attacks will most likely be commercial civil systems used by non-state or state actors willing to conceal the origin of the attack. The threat in peacetime cannot be considered through the lens of possible kinetic attacks as unmanned aircraft systems may be employed for obtaining the information necessary for further terrorist or criminal activities. There is no doubt that the ad hoc weaponization of the civilian unmanned aircraft systems may allow their use in kinetic attacks as well. Due to the limited payload offered by most of commercial unmanned aircraft systems, they might be used primarily for attacks on soft targets, such as civilian or military infrastructure facilities and mass events (Zieliński, 2018a).

The use of dedicated military unmanned aircraft systems will dominate during major combat and crisis response operations. The threat posed by unmanned aircraft systems during such operations will be a consequence of their employment for both information acquisition and as a means for strike missions (Cieślak, 2018). Unmanned aircraft systems have

traditionally provided target acquisition data for land, air, and sea fire support systems. The conflict in Eastern Ukraine saw three Ukrainian mechanized battalions destroyed by rocked artillery fire in several minutes due to surveillance and target acquisition provided by drones (IISS, 2019). Armed unmanned aircraft systems can pose a threat to point targets and soft area targets. Unmanned aircraft systems platforms employed in electronic warfare may disrupt the enemy's command, control, and communications systems, preventing the enemy from achieving and maintaining information superiority.

The relatively low costs of acquiring small, unmanned aircraft systems mean that they are specifically designed for expandability. Although there are dedicated loitering munitions or 'kamikaze' drones, low costs facilitate decisions to turn regular small, unmanned aircraft systems into munitions. Low costs and advances in the field of system automation and autonomy will change the tactics of unmanned aircraft systems. One may expect more frequent use of swarming tactics by the drones in the execution of their attacks on both defended assets and air defenses. For unmanned aircraft systems optimized for Suppression of Enemy Air Defenses (SEAD), one should consider that the unmanned aircraft systems will be able to perform increased tasks in autonomous mode. Unmanned aircraft systems provide clear advantage over manned aircraft in regard to operational threshold, and therefore they constitute new challenges for air defense. The JAPCC report on comprehensive approach to countering unmanned aircraft systems lists three principal advantages related to reduced risk, expendability and less potential for escalation (JAPCC, 2020). This may mean that, unlike manned unmanned aircraft systems, unmanned aircraft can be widely used already during a developing crisis.

Another factor that changes traditional air defense calculus relates to space and time considerations. Traditionally, effective air defense benefited from early warning that allowed multiple engagement of fighters and ground-based air defenses against air threats. That may not be the case for attacks by small, unmanned aircraft systems. Such attacks may be executed from the proximity of intended targets, and the means of attack may be assembled from commercially available components in the last minutes prior to the attack. Such a scenario limits the warning period for traditional air defense air surveillance and control systems and limits kinetic defense to the terminal phase of attack. The possibility of conducting an attack from within the enemy air defense system also offers several other advantages. It may increase chances for plausible deniability. This may encourage possible attacker and increase the risk of false flag attacks. Availability of small, unmanned aircraft systems may also enable lone wolf attacks.

3. Defending against unmanned aircraft systems

The last two decades have been a period of unmanned aircraft systems proliferation in military applications. The most common trend has been the use of unmanned aircraft systems for reconnaissance and observation, but a growing number of strike missions have been performed as well. Unmanned aircraft systems have started to be used for transport missions. As the post 11 September 2001 period has seen the so-called 'Global War on Terrorism,' the drone attacks during last two decades focused on key leaders of terrorist organizations. The use of Medium Altitude Long Endurance (MALE) unmanned aircraft systems in Afghanistan, Iraq, Syria, and North Africa was part of military operations, and these systems were used by various types of armed forces and government institutions. The use of unmanned aircraft systems by non-state actors in the first decade of the 21st century was

incidental. Attempts to use unmanned aerial vehicles were made by Hezbollah in 2004 but were mostly unsuccessful (IISS, 2019).

The situation began to change after 2011, when unmanned aircraft systems began to be used more often by non-state actors. The first successful use of an UAS for a strike mission by a non-state actor took place in 2013, when Hezbollah attacked a camp of anti-government forces in Syria (Uracosta, 2020). The most prolific user of unmanned aircraft systems turned out to be the so-called Islamic State of Iraq and the Levant. It proved competent in using such systems against Iraqi and Coalition forces in Iraq between 2013 and 2017. This terrorist organization developed its own "Jihadi drone air arm" and was able to conduct large number of attacks against battlefield targets (Urcosta, 2020). As Gen. Raymond Thomas observed jihadi drones were most daunting threat to U.S. and coalition forces fighting in Mosul in 2016. The adaptive use of drones allowed Islamic State group militants to enjoy tactical superiority under coalition forces' conventional air superiority. And the only available response at that time was small arms fire (Larter, 2017).

The attacks by unmanned aircraft systems that have influenced the perception of threats from such systems in recent years include the attack on oil installations in Saudi Arabia in September 2019. A swarm of twenty-five drones and cruise missiles hit oil-processing facilities at Abqaiq and Khurais, cutting Saudi daily production of oil by 50 percent and global supply by 5 percent. The Houthi movement of Yemen claimed responsibility for the attacks while the United States and Saudi Arabia believed that Iran was behind them. Iranian involvement was however not proven despite a three-years long investigation conducted by the United Nations. The economic consequences of the attack and the defenselessness of the Saudi air defense system highlighted the possibility of using unmanned aircraft systems to carry out strategic air attacks (Frantzman, 2019). Difficulty in attributing this aggressive act to any state or non-state actor may be considered another worrying factor describing unmanned aircraft systems attacks against Saudi Arabia in 2019. This might in turn be seen as a possible incentive for future use of unmanned aircraft systems by rouge states. Anthony H. Cordesman of the Center for Strategic and International Studies observed (2019), the use of unmanned aircraft systems against Saudi Arabia oil installations provided a clear strategic warning that the era of air supremacy of the United States and the near US monopoly on precision strike capability is rapidly fading. This lesson will be learnt by other global and regional powers, as unmanned aircraft systems are becoming one of the most prominent weapons of choice in hybrid and gray area warfare.

The unmanned aircraft systems attack on Russian air and naval bases in Syria, most likely carried out by Syrian opposition forces, should also be noted. While the attack of thirteen drones on 6 January 2018 has been most publicized, there were many more such attacks in recent years. The Khmeimim air base alone was attacked by hundreds of drones between 2018 and 2020 along with separate mortar and rocket attacks. In 2019, there were around sixty drone attacks against this base alone (Urcosta, 2020). The drone threat was persistent and affected air base operations for extended periods of time. The military significance of these drone attacks against Russian bases in Syria goes beyond the arithmetic of losses inflicted to equipment and manpower. Rather, they have shown the new opportunities of attacking military infrastructure by an enemy without advanced weapon systems and traditional airpower. Attacks against Russian air bases in Syria have also demonstrated the necessity to consider defense against unmanned aircraft systems as a vital part of the force protection measures. Based on Russian experience in Syria, one may argue that in the future, other leading militaries may be subjected to similar attacks. What is more, the threat of drone attacks against air bases may be present not only during expeditionary operations but extend also to air bases in home countries (Vick et al., 2020).

The use of unmanned aircraft systems by Turkish forces in Syria in spring 2020 is a good example of the effective use of these systems in conventional warfare. Turkey proved to be

competent in using a domestically produced medium altitude long endurance unmanned aircraft systems fleet, marking the integration of unmanned systems in combined arms operations. The Turkish military was able to mount hundreds of unmanned aircraft system attacks against Syrian ground troops, allegedly destroying more than a hundred targets and effectively halting their offensive. Both direct drone strikes and unmanned aircraft systems' support to indirect fires were integrated with combined arms operations (Urcosta, 2020). On the contrary, despite the short duration of military confrontation, notable losses to Turkish unmanned aircraft systems force could have been observed, which puts into question the sustainability of their tactics in future scenarios, especially in a contested air environment and against an integrated air defense system typical for a conflict with a peer adversary (Parahini, 2020).

Some experts have touted the Libyan Civil War as the largest drone war in the world (Defenceworld.net, 2020). The conflict has seen more than one thousand strikes by unmanned aircraft systems since its beginning of conflict, with the Libyan National Army forces alone conducting around 850 drone strikes before the beginning of 2020 (United Nations Support Mission in Libya, 2020). All parties to the conflict in Libya have been using low-endurance commercial drones for intelligence, surveillance, and reconnaissance tasks at the tactical level (Panel of Experts, 2019). In 2016, external support by the United Arab Emirates to the Libyan National Army (LNA) allowed it employing Chinese medium altitude long endurance systems and gain advantage over the UN-recognized Government of National Accord (GNA). Since mid-2019, Turkey buttressed its support to the GNA forces with medium altitude long endurance unmanned aircraft systems, and the balance of power shifted again. Turkish armed drones attacked LNA's ground targets, conducted air interdiction against its supply lines, and were able to conduct effective strikes against its forward airbases, destroying several aircraft and surface to air missile systems there. Skillful use of ground-based air defenses along with jamming systems by the Turkish forces increased the survivability of the GNA drone force and disrupted drone operations by the LNA, thus depriving it from achieving initial air supremacy. High intensity drone operations resulted in a significant rate of attrition. During the first half of 2020 alone, seven-teen Turkish and eight Chinese-made medium altitude long endurance unmanned aircraft systems belonging to the two warring parties were destroyed (Defence-world.net, 2020). It testifies that there are notable costs of drone warfare, even if they are lower than those of conventional war.

The conflict for Nagorno-Karabakh in autumn 2020 has sparked an intense discussion on emerging importance of unmanned aircraft systems in future warfare. The widely discussed effectiveness of Azerbaijani UAS deployment in the conflict with Armenia sparked several comments related to the decline of tanks and advent of drone warfare. Such claims seem premature. While air defense systems are only partly effective against emerging threat of unmanned aircraft systems, several other factors might have contributed to the Armenian defeat. The Armenian military was not prepared for a limited conflict both in terms of its hardware and in terms of tactics. On the other hand, the Azerbaijani military heavily invested in advanced weapon systems in recent decade and prepared for using those (Flannelly, 2020). The Armenian military failed to meet the basic requirements of combined arms operations, which ultimately allowed freedom of deployment for Azerbaijani unmanned aircraft systems and contributed to their effectiveness (Clancy, 2020). Live video footage from unmanned aircraft systems and loitering munitions heavily influenced the public perception of the conflict. Azerbaijan was able to use live footage to reinforce its propaganda and shape perceptions of not only the Armenian population and military, but also that of the international community as well.

When assessing the threat posed by unmanned aircraft systems, attention should be paid to their use by criminal groups, including terrorist organizations, and to the risks related to

commercial and hobby activities. Unmanned aircraft systems are used for criminal surveillance purposes, including tracking police activities, transporting drugs and other goods, delivering weapons, and prison contraband drops. Attacks on rival groups as well as intimidating police have been observed in recent years. Attacks against high-level politicians and military have also been conducted, but it has been difficult to attribute them immediately to specific actors (IISS, 2019). Unidentified unmanned aircraft systems have been recently observed around critical infrastructure, such as nuclear plants, which raises concerns related to their vulnerability to drone attacks (Solodov et al., 2018). A growing number of civilian airports have suffered disruption of air operations because of unmanned aircraft systems in their vicinity. Pyrgies (2019) identified 139 serious UAV incidents in the vicinity of worldwide airports between 2014 and May 2018 alone. Stray unmanned aircraft systems have ended up near governmental buildings such as the White House or the Japanese Prime minister's office, just to name a few examples. The limited scope of the criminal use of unmanned aircraft systems so far results in a situation in which they remain in the focus of police and civilian investigative services but do not raise public interest or concerns. However, with the growing potential of unmanned aircraft systems, the military air defense community cannot neglect it.

4. Surviving Unmanned Aircraft Systems attacks

The challenge of unmanned aircraft systems to air defense is twofold. With challenges related to the effective protection of defended assets discussed in the previous part of the article, more attention should be given to the threat that unmanned aircraft systems pose to air defense systems themselves. The development of advanced ground-based surface to air missile systems, termed sometimes as "double digit SAMs," pushed for a more effective means of suppression of enemy air defenses (SEAD). As a single combat air defense vehicle was able to pose a threat to air operations, there was a growing requirement for means capable to hunt for such targets. Anti-radar missiles that revolutionized SEAD operations after the Vietnam War lacked the capability to remain over battlefield for an extended time. It meant that to provide effective suppression for longer time, one needed to fire preemptive salvos of expensive missiles.

Unmanned aircraft systems have changed this calculus. Traditionally, unmanned aircraft systems were used as decoys to deceive enemy air defenses, to saturate them or bait so that they would become easier targets for anti-radiation missiles. Since the end of 1990s, 'kamikaze' drones entered the service, with IAI Harpy as the most prominent example and unmanned aircraft systems started to be used more frequently for assisting SEAD attacks by other weapon systems.

The last few years saw highly publicized cases of effective attacks by unmanned aircraft systems against ground-based air defenses. In Syria, Turkish unmanned aircraft systems were able to destroy several advanced Russian SA-22 systems in early 2020 and that was also the case in Libya (United Nations Support Mission in Libya, 2020). The Armenian-Azerbaijani conflict later in autumn 2020 saw successful unmanned aircraft systems attacks against S-300 launcher vehicles. Live footage of attacks supported Turkish and Azerbaijani claims about the effectiveness of unmanned aircraft systems attacks and grabbed the attention of international community, which started heralding a new era of drone wars (Clancy, 2020). SA-22 performance against unmanned aircraft systems seems disappointing, although they were able to shoot down several medium altitude long endurance unmanned aircraft systems both in Syria and in Libya. The anti-government forces of General Haftar,

which operated the SA-22 systems in Libya, may have lacked proper training with this specific weapon system. It is hard to accept such an explanation for the actions of the Syrian armed forces. The disparity of the quality of weapon systems and deficient training may have also contributed to the defeat of Armenian air defenses in the Nagorno-Karabakh conflict. Predominantly Soviet-era surface-to-air missile systems failed to stand up to the coordinated use of strike and 'kamikaze' drones supported by surveillance and command and control unmanned aircraft systems and indirect fires (Shaikh & Rumbaugh, 2020).

What recent analyses miss is the fact that successful unmanned aircraft systems attack in Libya, Syria, and Armenia were not conducted against integrated air defense systems combining ground-based air defenses with fighters, early warning systems, and electronic warfare systems. To simplify this description to some extent, unmanned aircraft systems proved effective against stand-alone SAMs fighting in the open. It is hard to believe that this is going to be the most likely scenario in the future.

While there is no publicly available data regarding unmanned aircraft systems strikes against air defense's fighter force, the attacks against Khmeimim in Syria may offer some lessons about vulnerabilities of air defense fighters while on the ground. A non-state opponent without conventional manned air assets was able to disrupt airfield operations and cast doubt on the survivability of air assets outside reinforced shelters. With potential for follow-on strikes, such use of unmanned aircraft systems would effectively deny air defense to employ its fighters for at least a limited time. This in turn may be sufficient to create conditions for successful air and missile attacks against other targets. In a broader sense, unmanned aircraft systems attack against Russian airbases in Syria have emphasized the urgent need for improvements in the survivability of air defense systems in relation to both active and passive air defense.

5. Future challenges related to unmanned aircraft systems

The discussion on future challenges for air defense posed by unmanned aircraft systems needs to be seen within a broader context and not merely concentrate on its tools. Such unmanned aircraft systems will proliferate and become available to a growing number of both state and non-state actors. While unmanned combat aircraft systems and high altitude long endurance and medium altitude long endurance systems will most likely remain in state arsenals, smaller unmanned aircraft systems may be used increasingly frequently by both state and non-state actors. Such smaller systems offer the capability to attack beneath adversary air supremacy and allow for plausible deniability, which both are worrying trends for international peace and security. Small, unmanned aircraft systems may become a weapon of choice in proxy wars but may be more often used in local and regional interstate conflicts. Due to relatively low costs small, unmanned aircraft systems may facilitate the "democratization of technology," which means that leading militaries will not only take advantage of having them as a new capability but will have to see them as a ubiquitous threat to themselves.

Unmanned aircraft systems will pose a challenge to air defense as both strike and surveillance assets. They will provide precision strike capability in lieu of close air support, but at the same time, they may contribute to counter air operations and strategic air attack. Persistent surveillance capability offered by unmanned aircraft systems may shorten the so-called "kill-chain" and increase effectiveness of missile and artillery strikes (Cieślak, 2020). Limited unmanned aircraft systems strike may originate from inside of the adversary territory and even from vicinity of their intended targets, diminishing warning time, and denying

traditional layered air defense concepts. Unmanned aircraft systems may conduct standalone attacks, but most likely they will be used by state actors as a part of saturation attacks, supporting more complex air and missile strikes. The number of possible targets that may be attacked with unmanned aircraft systems precludes the viability of permanent air defense of all protected assets in peacetime, crisis, and war. It will have to be decided which assets need dedicated drone defense, and which may be left without it.

The affordability of small unmanned aircraft systems and advances in information technologies will increase the probability of swarming tactics combining kamikaze drones with traditional unmanned aircraft systems. Swarms of 'kamikaze' drones will increase the demands for the point or terminal air defense of protected assets. Recent developments suggest that one may see swarms of hundreds drones in near future in comparison with the current coordinated attacks of swarms of tens. The largest difference will lie in the emerging capability of swarms to conduct autonomous attacks and last-minute coordination (Zieliński, 2018a, b). As a result, future swarm attacks will pose a much greater challenge to air defenses compared to those mostly deconflicted ones as of now (Sprenger, 2019). The lessons learned in recent years suggest an increasing need for both hard and soft defenses, combining affordable kinetic defense with electronic warfare.

The future drone threat demands reactive and proactive developments in air defense systems. Although one may argue that drones caught air defense by surprise, this period has now ended. Air defense systems will remain largely relevant in countering the threat posed by high altitude long endurance and medium altitude long endurance unmanned aircraft systems. The most problematic threat will be posed by those smaller unmanned aircraft systems that are becoming ubiquitous and have become cheaper than most of air defense effectors. There is a widely recognized need for low-cost anti-drone systems, and they are starting to be fielded by several states and their militaries (Patterson, 2017). Most of those systems combine several surveillance techniques with electronic interference and kinetic defenses. So far, the available anti-drone systems are short and very short-range systems that may be exclusively used for point defense. Due to the drone threat, several militaries are rethinking the role of anti-aircraft artillery while some leading militaries opt for anti-drone lasers (IISS, 2019). There is no doubt that air defenses are getting more vulnerable to attacks by unmanned aircraft systems. Therefore, currently deployed air defense assets need better protection against drone attacks. For long and medium range surface to air missile systems, the static elements of air surveillance, control assets and airbases, and additional layers of terminal kinetic and electronic effectors are needed.

6. Conclusions

While recent years have witnessed spectacular examples of the effectiveness of attacks by unmanned aircraft systems, it may be argued that it is only a preview of what will occur in the nearest future. The proliferation of unmanned aircraft systems and the democratization of access to this capability means that drones may become a weapon of choice for a wide range of state and non-state actors. Defending against drone attacks has proved problematic as current air defenses are optimized for conventional manned air threats. Unmanned aircraft systems have been successfully employed in attacks against strategic targets, displaying their potential in suppression of enemy air defenses and in the handling battlefield targets. Swarming has started to become standard tactics of drone employment, which adds another layer of complexity to the process of defense against them. Unmanned aircraft systems have revealed the vulnerabilities of existing air defenses against drone attacks. Although recent

conflicts have provided most of the examples of successful attacks against ground-based air defenses, unmanned aircraft systems may also attack airbases and air surveillance and control systems. This underpins the importance of the survivability of air defense systems against this emerging threat and the potential role of unmanned aircraft systems in the counter air operations.

A large portion of current air defenses will remain relevant if the conventional threat of manned aircraft and missile attacks continue to exist in their current form. However, air defense systems will need additional surveillance assets and effectors dedicated to counter the threat of unmanned aircraft systems in nearest future. The affordability of anti-drone defense will be crucial as the costs of prospective small, unmanned aircraft systems will be quite low. With the growing potential to launch drone attacks from within a territory protected by air defense system, there is a need to reinforce point and terminal air defenses, which combine both hard and soft techniques to address the drone threat. The opening of the confrontation between unmanned aircraft systems and air defenses has seemed to favor the attacking side in recent decades. However, there is no doubt that air defenses will adapt to the situation, shifting the balance back to an equilibrium, getting more effective against drone attacks, and becoming less vulnerable to their attacks.

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