The Imperative for the U.S. Military to Develop a CounterUAS Strategy

美國軍方發展反無人機策略的重要性分析

譯者簡介

鄧炘傑備役少校，管院專9期、國防大學政治作戰學院英文正規班、中原大學企管研究所碩士；曾任排長、連長、地區補給庫分庫長、教準部編譯官，現任特約翻譯、華語／英語專業領隊／導遊。

作者簡介：美國陸軍少校Edward A. Guelfi，任職於第11野戰砲兵團第2營。
Buddhika Jayamaha博士，任教於美國空軍官校。
美國陸軍中校Travis Robison，第11野戰砲兵團第2營營長。
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Military power often emerges at the nexus of technology, organizational processes of force employment, and training.[1] However, rapid technological change, the constantly evolving character of warfare, and the lingering effects of sustained combat on military readiness constrain the U.S. military's ability to respond to emerging global security challenges. The proliferation of unmanned aerial systems (UAS), more commonly referred to as drones, represents one of the largest emerging challenges to the joint community since the rise of improvised explosive devices during the onset of Operation Iraqi Freedom. Recent conflicts

1 Stephen Biddle, Military Power: Explaining Victory and Defeat in Modern Battle (Princeton: Princeton University Press, 2006).

involving state and non-state actors and the acquisition priorities of U.S. rivals like Russia and China demonstrate that Soldiers on future battlefields will see the widespread use of drones. For example, Russia and Russian-backed separatists have used various types of drones to achieve devastating effects during their ongoing conflict with Ukraine.[2] U.S. forces in Syria could not retain operational control of the airspace below 3,500 feet for an extended period of time where the so-called Islamic State (IS) conducted lethal and nonlethal drone operations.[3] Looking ahead, theDepartment of Defense (DOD) anticipates that China will soon outspend the United States in drone investment, with more than $10 billion dedicated solely to research and development, and may become the world leader in this area by 2023.[4]

軍事武力經常會出現一系列新技術、軍力運用和組織訓練的關聯性。[1] 然而，飛快的技術變革、作戰特性的持續演進，以及軍事戰備的不斷砥礪，正持續逼迫美軍對全球陸續出現的安全挑戰，作出回應。無人飛行系統(Unmanned Aerial Systems, UAS)，或是說一般人更為熟知的無人飛機的擴散，則是從伊拉克自由行動之後開始出現的，對聯合作戰部隊形成最大挑戰的拼裝式爆破裝置。最近在國家與非國家行動者之間發生的衝突，以及與美國敵手俄羅斯、中國較勁中，都顯示戰士們在未來戰場上，一定會目睹無人飛機的大量使用。舉例來說，俄羅斯與其援助的分離份子，已經在與烏克蘭的衝突中，使用過好幾種不同型號的無人機，並造成毀滅性的傷害。[2] 駐敘利亞美軍在很長一段時間，無法在3,500呎以下空域維持有效的作戰管制，也是因為伊斯蘭國(IS)採用了致命與非致命的無人機作戰。[3] 往前看，美國國防部預測中國在無人機這方面的投資，很快就要超越美國，僅僅在研究和發展部門，就花掉超過百億美金；預計到2023年，中國在無人機這個領域的發展，可能執世界之牛耳。[4]

For the first time in more than six decades, U.S. ground forces have found themselves under aerial attack and are generally unable to counter the threat. Existing air defense systems have proved tragically unable to detect or engage slow, low-flying UAS.[5] Failure to mitigate

2 Phillip A. Karber, "'Lessons Learned' from the Russo-Ukrainian War: Personal Observations," draft, Johns Hopkins Applied Physics Laboratory and U.S. Army Capabilities Center, July 2015, 12, available at .

3 Mark Pomerleau, "How $650 Drones Are Creating Problems in Iraq and Syria," C4ISRNET, January 2018, available at .

4 Ian McPhedran, "U.S. Predicts 42,000 Unmanned Chinese Military Planes by 2023," News Corp Australia Network, July 8, 2015, available at .

5 Pomerleau, "How $650 Drones Are Creating Problems in Iraq and Syria."

this operational risk across the full spectrum of conflict will leave the U.S. Army vulnerable to the use of drones by state and non-state adversaries. This risk results in an imperative for the Army to develop and implement a more comprehensive counter-UAS strategy than currently exists and that must include material, organizational, and Soldier solutions. Drones present a multi-domain challenge, so improving the Army's counter-UAS strategy will provide a framework for developing and integrating counter-UAS capabilities into emerging war-fighting concepts. This article explains the UAS threat in terms of technological diffusion and patterns of use and provides counter-UAS recommendations for consideration by senior military leaders.

六十幾年來，美軍地面部隊第一次發現自己處於空中攻擊威脅之下，還經常無計可施。現有防空系統已經證實，無法針對低空慢速飛行的無人機進行防禦及反制。[5] 面對敵人採取的無人機戰術，如果美軍無法有效降低作戰風險，在全面性衝突中，勢必讓美軍吃足苦頭。這種風險讓軍方不得不設法在現有方式之外，從物資、組織和士兵各方面著手，更全面的發展反制無人飛機的策略。無人機的出現，代表的是一種多領域的挑戰，所以軍方若要強化反制無人機的策略，必須發展並整合出一套架構，才足以應付諸般新興的作戰概念。這篇文章從技術擴散到模式運用各方面，提供給軍方高層領導者，許多反制無人飛機的建議和思考方向。

The Threat
威脅

Technological Diffusion. The Cold War demand for persistent surveillance of the Soviet Union led the Air Force and U.S. intelligence agencies to pursue UAS development by the late 1950s, and these drone technologies materialized in the early 1960s.[6] During the latter part of the 1960s, the United States employed these new technologies to monitor China's development of nuclear and air defense capabilities, as well as to conduct battle damage assessments during the Vietnam War.[7] Following that conflict, the United States struggled to integrate UAS into its European operations against the Soviet Union due to technological and airspace restrictions.[8] Regardless, the United States continued to improve drone technologies and by the 1990s had

6 Thomas P. Ehrhard, Air Force UAVs: The Secret History (Arlington, VA: Air Force Association, July 2010).

7 Drones conducted 93 percent of damage assessments following Operation Linebacker II. See also Ehrhard, Air Force UAVs, 9, 28.

8 Ehrhard, Air Force UAVs, 32-33.

successfully developed the Predator, which provided operationally viable persistent surveillance capabilities.[9]

技術擴散。1950年代冷戰時期，為了長期監控蘇聯的作戰需求，空軍和美國情報單位開始了無人機的發展，相關技術在1960年代具體化。[6] 1960年代後期，美國將這種技術用於監視中國核子武器與空防能力發展，以及在越戰中，用於評估作戰損失。[7] 之後為了因應各種衝突，以及技術與空域各方面的限制，美國將無人機技術整合，以利於在歐洲戰場上牽制蘇聯。[8] 美國持續在這方面鑽研，終於在1990年代成功發展出掠食者無人機，在對蘇聯的作戰能力持續監控方面，獲致很大進展。[9]

The first operational deployment of a Predator squadron occurred in Bosnia in 1995, where it provided targeting information, monitored refugee flows, and provided battle damage assessments.[10] After seeing the operational benefits of 24-hour persistent surveillance in rough terrain and adverse weather conditions, Congress more than doubled the Predator budget and accelerated additional UAS programs, which subsequently became the foundation of current global drone fleets and tactics.[11] While the United States initiated the use of UAS, over the past two decades drones have proliferated throughout the world. Today, more than 90 state and non-state actors possess drone capabilities ranging from small, commercial drones to more sophisticated military variants. Moreover, at least 16 countries have armed drone programs with another 20 countries attempting to develop them.[12] The evolution of electronics and software technologies and the changing character of warfare converged to influence the rapid and widespread proliferation of civilian and military drones. Today, there are more than 600 types of armed and unarmed drones used or being developed around the world.[13]

9 Frank Strickland, "An Insider's Perspective on Innovation During Fiscal Austerity: The Early Evolution of the Predator Drone," Strategies in Intelligence 57, no. 1 (March 2013), 6; Richard Whittle, Predator: The Secret Origins of the Drone Revolution (New York: Henry Holt & Co., 2014).

10 Arthur Holland Michel, "Drones in Bosnia," Center for the Study of the Drone, Bard College, New York, June 7, 2013, available at ; Elizabeth Becker, "Crisis in the Balkans: The Drones; They're Unmanned, They Fly Low, and They Get the Picture," New York Times, June 3, 1999, available at .

11 Michel, "Drones in Bosnia"; Strickland, "An Insider's Perspective on Innovation During Fiscal Austerity," 3.

12 Matt Fuhrmann and Michael C. Horowitz, "Droning On: Explaining the Proliferation of Unmanned Aerial Vehicles," International Organization 71, no. 2 (Spring 2017), 397-418.

13 於下頁。

掠食者無人機中隊第一次作戰部署是1995年在波士尼亞，負責提供目標資訊、監視難民流向，以及評估戰鬥損失。[10] 因為看到掠食者無人機在複雜地形、惡劣天氣中全天候執行偵查任務的能耐，美國國會將掠食者的預算增加了一倍多，並額外加速推進其他無人飛行系統的計畫。這些計畫後來也成為現今全球無人機隊編制和戰術的基礎。[11] 自從美國開啟了相關計畫，過去20幾年無人機在世界各地陸續出現。今天，超過90個國家及非國家行為者擁有製造無人機的技術，從小型商業用，到複雜精密的軍用無人機，品項繁多。此外，至少有16個國家有武裝無人機計畫，還有其他20個國家試圖發展。[12] 電子和軟體科技的演進，以及作戰特性的改變，這兩者相互結合，造成民用和軍用無人機快速且大範圍的擴散。目前，全世界有超過600型武裝或非武裝無人機正在使用，或正在發展中。[13]

The accessibility, affordability, and capabilities of available UAS influence their proliferation. Small, affordable, and commercially available hobbyist drones are less capable overall, but they provide groups with an accessible intelligence, surveillance, and reconnaissance (ISR) capability that often rivals more sophisticated military variants. For example, the Chinese-made DJI Mavic is a commercially available quad-copter that costs less than $100 and is capable of autonomous takeoffs and landings, flying GPS-programmed routes, tracking and following moving objects, and sensing and avoiding obstacles.[14] The Mavic's degree of autonomous flight currently exceeds that of the U.S. Air Force's approximately $17 million MQ-9 Reaper UAS.[15]

發展門檻不高、成本低，以及運用方式多元，是無人機在世界上快速擴散的主要原因。體積小且成本低廉的商業用無人機，或許在許多方面能力不足，但他們和敵人更為複雜的無人機相比，一樣能執行諸如情報、監視、偵查(ISR)等任務。舉例來說，中國大陸大疆創新公司製造的可折疊四軸商用航拍無人機(DJI Mavic)，價格不到100美元，可以在衛星定位導航狀況下起飛、降落、按預定路線飛行，還能追蹤移動物體、感應並避開障礙物。[14] 這型無人機的自主飛行程度，甚至超過價值大約1千7百萬美元的美國空軍MQ-9死神無人機。[15]

13 Lynn E. Davis et al., Armed and Dangerous? UAVs and U.S. Security (Santa Monica, CA: RAND, 2014), 7-10; United States Army Counter-Unmanned Aircraft System (C-UAS) Strategy Extract (Washington, DC: Army Capabilities Integration Center, 2016), 5.

14 More information on the DJI Mavic can be found at Web site of SZ DJI Technology Co., Ltd., available at .

15 James Drew, "USAF to Automate MQ-9 Takeoffs and Landings," Flight Global, May 4, 2016, available at .

Israel is currently the largest exporter of military UAS, with over 60 percent of international transfers over the past 30 years.[16] But between 2010 and 2014, only approximately 2.5 percent of transferred drones were armed, so the majority of UAS transferred abroad have been unarmed systems primarily intended for reconnaissance.[17] The number of armed drone exports is increasing, however, given the number of countries actively developing UAS. In particular, China is quickly becoming a leader in exporting inexpensive, weapons-capable drones.[18]

以色列是目前全世界軍用無人機最大出口國，過去30幾年國際間購得的軍用無人機超過60%都來自以色列。[16] 但是在2010到2014年間，僅有大約2.5%以色列出口的無人機有武裝，所以這些以色列製的無人機，大部分都只具備偵查功能。[17] 然而，武裝無人機出口數量逐年增加，代表有些國家正主動研發無人機。尤其中國正迅速成為價格低廉武裝無人機的最大出口國。[18]

Commercial UAS are proliferating more rapidly than military variants because of the latter's higher cost and greater support infrastructure requirements, as well as existing international arms trade agreements.[19] The availability and proliferation of commercial systems throughout the security environment complicate military responses because these drones often have comparable capabilities to small military UAS and can be easily modified for military uses.[20] Next-generation commercial drone technology is making these systems more like military ones, and they are exploiting new operational concepts such as swarming.[21] As a result, as UAS technology continues to advance and proliferate, the distinctions between commercial

16 George Arnett, "The Numbers Behind the Worldwide Trade in Drones," The Guardian, March 16, 2015, available at .

17 Ibid.

18 Kyle Mizokami, "For the First Time, Chinese UAVs Are Flying and Fighting in the Middle East," Popular Mechanics, December 22, 2015, available at .

19 Andrea Gilli and Mauro Gilli, "The Diffusion of Drone Warfare? Industrial, Organizational, and Infrastructural Constraints," Security Studies 25, no. 1 (February 2016), 50-84.

20 Ben Watson, "The Drones of ISIS," Defense One, January 12, 2017, available at ; Michael C. Horowitz, Sarah E. Kreps, and Matthew Fuhrmann, "Separating Fact from Fiction in the Debate over Drone Proliferation," International Security 41, no. 2 (Fall 2016), 7-42.

21 Alexis C. Madrigal, "Drone Swarms Are Going to Be Terrifying and Hard to Stop," The Atlantic, March 7, 2018, available at /.

and military drones will become less clear, further enhancing operational risk.

商用無人機比軍用型的擴散更快，是因為軍用型成本較高，所需的相關硬體設備較多，而且目前國際間的武器交易協定，也不利於軍用無人機的大幅擴散。[19] 商用無人機在目前的安全環境中比較容易運用和推廣，這已經讓各國軍方難以抉擇；因為這些商用型無人機比起小型軍用無人機性能並不差，而且很容易稍作改裝就投入軍事用途。[20] 下一世代商用無人機的技術，已經讓這些系統更接近軍用，而且他們正試著用在一些新的作戰概念中，比如蜂群戰術。[21] 這樣發展下去的結果是，無人機技術持續精進並擴散，讓商用和軍用型之間越來越難區分，從而提高了作戰風險。

As drone proliferation continues, military leaders must understand the capabilities and limitations of each type of drone to develop effective countermeasures. Currently, DOD classifies drones into one of five categories based on a system's size, speed, and operational range.[22] While helpful in distinguishing between a system's potential use in tactical or operational roles, these categories do not provide a roadmap for understanding two important UAS characteristics as they relate to likely battlefield use: a systems degree of accessibility or availability, and the technology and infrastructure required to support using a system. These two characteristics result in a taxonomy of UAS with four categories: hobbyist drones, midsize military and commercial drones, large military-specific drones, and stealth combat drones.[23] Each category of drones has distinct capabilities and limitations that provide a foundation for determining how to counter a system.

當無人機持續擴散普及，軍方高層就必須瞭解每種不同型號無人機的能力與限制，以規劃有效的反制措施。目前，美國國防部根據尺寸、速度和作戰範圍，將無人機區分做5類。[22] 雖然做這種分類，有助於定位各種無人機在戰術或作戰運用時的角色，卻不能幫助軍方更加瞭解無人機在戰場上運用時的兩個重要特點：各系統可以取得的難易程度，以及需要哪些技術和周邊基礎設施的支援。根據這兩個特性，又可以將無人機區分出4類：業餘玩家無人機、中型軍／商兩用、大型軍用，以及隱形戰鬥無人機。[23] 每一種不同類型無人機有其特殊用途與限制，這也是決定其反制措施最重要的依據。

22 Micro-tactical, small tactical, tactical, persistent, penetrating. See Unmanned Systems Integrated Roadmap FY 2013-2038 (Washington, DC: Department of Defense, 2014), available at .

23 Kelley Sayler, A World of Proliferated Drones: A Technology Primer (Washington, DC: Center for a New American Security, June 2015), 8, available at .

Hobbyist drones are widely available for purchase by the public and generally cost less than $3,000. These systems come preassembled or may require assembly; however, they do not require training to operate or any support infrastructure. Midsize military and commercial drones are generally unavailable because of their cost and infrastructure requirements. However, these systems are often sold or transferred by states to foreign militaries and nonstate actors. Large military-specific UAS include reconnaissance and armed variants and are rarely operated by actors other than major militaries because of the systems' costs and infrastructure requirements. Stealth combat drones contain highly sophisticated technologies such as jamming resistance and low observability and are only accessible to those states that produce the systems. Currently, the United States is the only known operator of stealth UAS; however, several countries are developing stealth combat drones.[24]

業餘玩家無人機很容易以公開方式買到，通常一台不到3,000美元。這型無人機有的已經先裝配好，有的到貨以後要自己組合裝配；這種無人機不需要操作前訓練，或是任何支援的基礎設施。中型軍/商兩用無人機因為成本和所需相關硬體設備，比較不容易獲得，經常是由國家販售或運輸給他國軍方，以及非國家行為者。大型軍方專用無人機包括偵查型和武裝型，因為價格較高，也需要基礎設施的支援，所以使用者多是主要國家軍方，非國家行為者用得很少。隱形戰鬥無人機內含複雜科技，包括抗干擾和低可偵測性，要想獲得只能向有能力生產的國家購買。目前，美國是唯一已知能夠操作隱形無人機的國家，但是有好幾個國家正積極研發中。[24]

Patterns of Use. Drones are becoming more sophisticated and capable of conducting surveillance to lethal attacks, either as a delivery system or as an inexpensive precision-guided weapon. The ongoing pursuit and development of artificial intelligence and swarming ability suggest a future where numerous small and inexpensive systems might be used to achieve localized overmatch against a more capable force such as the U.S. Army.[25] The proliferation, sophistication, and weaponization of commercially available UAS mean that any state or nonstate actor will have access to this technology and will likely employ it in novel ways. Moreover, the use of drones may be strategically ambiguous because the international perception of the use of UAS in crises or conflicts is quite different than the use of traditionally

24 For details on the capabilities, limitations, and technological trends of these four categories of drones, see ibid.

25 Ibid.

piloted aircraft in similar circumstances.[26]

運用方式。無人機變得越來越精密複雜，並且能夠執行監視到致命攻擊各種任務，有時作為一種投遞系統，有時是精準導引武器。人工智慧和蜂群戰術的持續演進與發展，顯示未來大量、小型、廉價武器系統的使用，讓對手可以在特定區域贏過像美國這種軍事強權。[25] 透過商購方式可以買到的無人飛行系統，因為容易獲得、精密度夠，如果再加以武裝，任何國家或非國家行為者都可以獲得這種技術，也可能以新的方式運用這些技術。此外，無人機的使用可以造成戰略模糊，因為在國際認知中，某些情況下，無人機的使用與傳統戰機所造成的危機與衝突，有很大的差別。[26]

Wider use of drones may reshape military operational concepts and how states engage in conflict. The strategic ambiguity inherent in these systems increases the military options available to an actor, particularly in gray zone conflict or similar contested environments where multiple parties might claim control over airspace. Drones can lower the risks of certain actions such as violating another state's airspace because these systems operate without placing a human pilot at risk. But the lack of a human pilot also lowers the risk of a state using force against a drone during an incursion. Recent examples of this dynamic occurred in 2014 when Turkey shot down a suspected Russian UAS, and in 2015 when Syria reportedly shot down a U.S. Predator, neither of which resulted in escalation or retaliation.[27] For non-state actors, drones may provide a military capability they otherwise would not have.[28] For instance, Russian-backed Ukrainian separatists have used drones to spot artillery strikes.[29] Another example occurred in 2016 and 2017, when IS launched air attacks against Iraqi troops using small armed drones.[30]

無人飛機的廣泛使用，可以重新塑造軍事作戰概念，以及世界各國處理衝突的方

26 Michael C. Horowitz, Paul Scharre, and Ben FitzGerald, Drone Proliferation and the Use of Force: An Experimental Approach (Washington, DC: Center for a New American Security, March 2017), available at .

27 OrhanCoskun, "Turkey Shoots Down Drone Near Syria, U.S. Suspects Russian Origin," Reuters, October 16, 2015, available at ; Missy Ryan, "U.S. Drone Believed Shot Down in Syria Ventured into New Area, Official Says," Washington Post, March 19, 2015.

28 Horowitz, Kreps, and Fuhrmann, "Separating Fact from Fiction in the Debate over Drone Proliferation," 7-42.

29 Sydney Freedberg, Jr., "Russian Drone Threat: Army Seeks Ukraine Lessons," Breaking Defense, October 14, 2015, available at .

30 Michael S. Schmidt and Eric Schmitt, "Pentagon Confronts a New Threat from ISIS: Exploding Drones," New York Times, October 11, 2016, available at ; Watson, "The Drones of ISIS."

式。這些無人機與生俱來的戰略模糊性，讓行動發起一方有更多的軍事選擇，尤其是在各方都宣稱擁有制空權，且都處灰色地帶中衝突或競爭環境的狀況下。在某些行動中使用無人機可以降低風險，例如侵犯別國的領空，因為無人機不需要把飛行員派出去冒這個險。但也正因為上面沒有飛行員，在衝突之中某些國家要動用武力反制無人機，風險也相對較低。最近的例子是2014年，土耳其擊落疑似俄羅斯無人機，還有2015年，敘利亞據稱擊落一架美國的掠食者無人機，這兩起事件都沒有讓緊張情勢升高，或引發雙方報復行動。[27] 對非國家行為者而言，無人機可以提供他們用其他方式無法獲得的軍事能力。[28] 舉例來說，有俄羅斯作靠山的烏克蘭分離主義者，就使用無人機標定砲兵的攻擊目標。[29] 還有其他例子發生在2016、2017年，伊斯蘭國使用小型武裝無人機，對伊拉克部隊實施空襲。[30]

The level of tactical and operational risk to U.S. ground forces has increased dramatically, as more than 23 countries, including Russia, China, Iran, and North Korea, are known to possess or in the process of developing armed drone capabilities.[31] The list of hostile non-state actors with drone capabilities is also rapidly growing and now includes terrorist organizations such as IS, Hizballah, and Hamas and insurgent groups such as Houthi rebels in Yemen.[32] In Africa, Boko Haram recently started employing armed drones in cross-border attacks on Nigeria and Cameroon.[33] Lastly, given al Shabaab's ties with Hizballah, it is likely only a matter of time before the group begins using drones in support of its terror operations.[34]

當超過23個國家，包括俄羅斯、中國、伊朗、北韓等，都已經擁有或正在發展武裝無人機，美軍地面部隊所面臨的戰術或作戰階層的風險就大幅提高。[31] 擁有無人機能力的敵對非國家行為者，名單越來越長，目前包括伊斯蘭國、土耳其真主黨、哈馬斯等恐怖組織，以及葉門境內的胡塞武裝組織等暴亂團體。[32] 在非洲，博科聖地組織最近開始使用武裝無人機，在奈及利亞和喀麥隆邊界實施攻擊。[33] 與土耳其真主黨關係密切的索馬里青年黨，未來遲早也會使用無人機支援其恐怖行動。[34]

31 Davis et al., Armed and Dangerous? 9.

32 Peter Bergen, Melissa Salyk-Virk, and David Sterman, World of Drones (Washington, DC: New America Foundation, November 22, 2019), 4, available at .

33 Simon Ateba, "Boko Haram Terrorists Now Using Drones in Nigeria and Cameroon," The Nigerian Voice, September 4, 2017, available at .

34 "Nigerian Army Links Boko Haram to Hezbollah," Sahara Reporters, May 30, 2013, available at .

Russia, China, and Iran have armed drone capabilities, and these states have demonstrated operational innovation in the employment of small tactical drones. The behavior of these states in recent conflicts highlights how the use of drones increases the complexity of modern conflict, the effects of operational innovations and proliferation, and how a near-peer competitor might seek to exploit current U.S. military vulnerabilities. Together, Russia, China, and Iran's behaviors and capabilities highlight what the U.S. Army must expect from adversaries in every region of potential conflict.[35]

俄羅斯、中國和伊朗已經掌握武裝無人機的技術，而且這些國家也用小型戰術無人機，展現其作戰創新。這些國家在最近的衝突中，讓外界見識到如何在現代軍事衝突中提升複雜程度、如何發揮作戰創新與擴散的效果，以及如何在實力相當的對峙之間，設法探知美軍的軍事弱點。同樣的，美軍也在與俄羅斯、中國與伊朗每個區域潛在衝突之中，更加了解對手的實力。[35]

Russia rapidly implemented a drone development and acquisition program that entailed purchasing Israeli-made UAS while concurrently investing in domestic sourcing programs.[36] During its incursion into Crimea and Eastern Ukraine in 2014-the latter instance widely believed to be the first in which every belligerent used drones to produce decisive battlefield results-Russia and its proxies used tactical drones to provide ISR targeting information for supporting artillery units. The near real-time intelligence from these small platforms improved target location accuracy, counterfire response times, and fire mission lethality,[37] and in one instance in July 2014, Russia used this technique to destroy four Ukrainian army brigades preparing to conduct a cross-border attack against Russian-backed separatists' lines of supply.[38]

俄羅斯正加速執行無人機發展及獲得計畫，除了購買以色列製造的無人飛行系統之外，同時投資其國內研發及製造能量。[36] 在2014年俄羅斯入侵克里米亞及東烏克蘭期間，東烏克蘭那次就被廣泛認為，是以戰鬥無人機創造出決定性戰果的經典案例—俄羅

35 Karber, "'Lessons Learned' from the Russo-Ukrainian War," 12.

36 Nicholas Clayton, "How Russia and Georgia's Little War Started a Drone Arms Race," PRI, October 23, 2012, available at .

37 Karber, "'Lessons Learned' from the Russo-Ukrainian War," 12.

38 Shawn Woodford, "The Russian Artillery Strike that Spooked the U.S. Army," Mystics & Statistics blog, March 29, 2017, available at .

斯和它的戰場代理人，使用戰術無人機提供情報、監視、偵查等資訊，支援他們的砲兵單位執行後續任務。從這些小型即時平台傳回來的資訊，讓目標鎖定更精確、反擊火力反應時間更短、火力發揮更致命；[37] 其中一個例子是在2014年7月，俄羅斯用這種方式摧毀了烏克蘭陸軍的4個旅，這些旅是對手預備用來攻擊受俄羅斯支持分離份子的補給線。[38]

Whereas Russia demonstrates innovation in drone tactics, Iran displays an inclination toward technical innovation. Iran started its drone program decades ago during its conflict with Iraq, and it is now one of the most developed in the Middle East.[39] Iran has also demonstrated its willingness to share advanced drone technology with others throughout the region. It reportedly flew drones such as the Shahed-129 over Iraq and Syria, exported drone technology to Hizballah and Hamas, and may have provided an assortment of drones to Houthis in Yemen and shared advanced drone technology with Russia.[40] The U.S. military has also engaged and destroyed two Iranian-made drones in Syria that conducted an attack against U.S. ground forces. Incidents such as these highlight that Iran is continuing to expand its drone programs and is willing to employ drones as an asymmetric counter to U.S. military superiority. Iranian drones have been reported in locations from Pakistan to Syria and throughout the Persian Gulf region. They have also become the centerpiece of Iranian technology exhibits used to showcase their advanced security capabilities despite rigorous international sanctions.[41]

俄羅斯顯現了運用無人機的戰術創新，伊朗則展示了技術方面的創意。伊朗在兩伊戰爭期間開始無人機計畫，目前它已經是中東地區，在這方面發展得最好的國家之一。[39] 伊朗也很大方的分享無人機先進技術，給中東地區的夥伴。據報導，伊朗用自行發展的見證者-129型(Shahed-129)無人機在伊拉克、敘利亞上空執行任務，輸出無人機技術給真主黨和哈馬斯，提供各種類型的無人機給葉門胡塞武裝組織，甚至與俄羅斯交流無人機技術。[40] 美軍在敘利亞上空，還曾擊落兩架攻擊美軍地面部隊的伊朗製無人機。以上事例，說明伊朗正持續擴張其無人機計畫，而且正在使用無人機，作為反制美國軍

39 ArianeTabatabai, "Iranian Drone Program," Bulletin of the Atomic Scientists, October 12, 2017, available at .

40 Levi Maxey, "Next-Gen Drones: Making War Easier for Dictators and Terrorists," The Cipher Brief, December 12, 2017, available at ; John Kester, "Russian Drone Tech May Include Help from Iran," Foreign Policy, October 5, 2017, available at .

41 "U.S. Shoots Down Second Iran-Made Armed Drone Over Syria in 12 Days," The Guardian, June 20, 2017, available at .

事優勢的非對稱手段。伊朗無人機的蹤影，從巴基斯坦到敘利亞，幾乎涵蓋整個波斯灣地區。雖然遭受嚴厲的國際制裁，但是伊朗儼然用無人機，作為展示其先進安全能力的最佳工具。[41]

The extent of China's UAS development in support of its military remains unclear to Western military analysts andsenior leaders; however, there is evidence that China's efforts are a real cause for concern. Some experts believe that the Chinese military's drone efforts focus on swarming technology, increased payload and operational range, and the incorporation of artificial intelligence. In a congressionally mandated report, analysts noted that the number and types of China's domestically developed unmanned aerial vehicles continue to expand, with five new platforms displayed at the 2016 Zhuhai airshow.[42] China also appears to be betting that swarms of low-tech drones linked with high-tech artificial intelligence will become the weapon of choice in future conflicts and capable of countering any military force, including that of the United States. China's level of effort in developing UAS suggests the importance and relevance it perceives the technology holds for potential future conflict.[43]

對西方軍事分析專家和政府高層來說，中國軍用無人飛行系統的發展程度還不是很清楚；然而，事證顯示中國在這方面的努力，已到不容輕忽的階段。一些專家相信中國的軍用無人機發展，將重點置於無人機蜂群技術(swarming technology)，增加裝載量及作戰半徑，並與人工智慧技術相結合。根據國會正式文件披露，分析人員指出中國自行發展的無人飛行器數量與型式持續增加中，其中有5種在2016年珠海航空展中亮相。[42] 中國看來也在聯結人工智慧的低階科技無人機上面下了重本；這類裝備在未來軍事衝突中會成為武器選項之一，有能力對抗包括美軍在內任何部隊。中國在發展無人機方面投注的心力，顯示它很清楚瞭解這種技術，在未來潛在軍事衝突中所能發揮的重要性與實用性。[43]

Besides the activities of rival states, the recent employment of drones by non-state actors reveals how quickly and relatively easily these groups can disrupt advanced industrial

42 According to the Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2017 (Washington, DC: Department of Defense, May 15, 2017), 29, "China displayed five airframes: the Wing Loong I, Wing Loong II, WJ-600A/D, Yunying Cloud Shadow, and the CH-5 (Rainbow 5)."

43 Emily Feng and Charles Clove, "Drone Swarms vs. Conventional Arms: China's Military Debate," Financial Times, August 2017, available at .

militaries. Drones are attractive to these groups because of "the way they carry [destructive] power and the distance from which they allow an adversary to control its delivery."[44] Small commercially available drones give groups such as IS the ability to field an air force capable of collecting ISR and providing limited close air support. The evolution of non-state actors' use of small drones began in 2004 when Hizballah used drones to challenge the Israeli military.[45] Drone use by non-state groups continues to evolve and demonstrates the ability to conduct complex attacks. For instance, during the year-long fight to recapture Mosul, Iraqi security forces faced persistent armed drone attacks that slowed their efforts to liberate IS-held neighborhoods.[46] Of concern is the increasingly complex and disruptive ways in which non-state actors use tactical drones. Hizballah uses these systems for surveillance, manufacturing propaganda, armed strike missions, and kamikaze-type attacks.[47] The Russian ministry of defense recently reported that in January 2018, its forces in western Syria experienced an attack by a "swarm of home-made drones." According to the ministry, Russian forces at Khmeimim Air Base and Tartus naval facility faced a complex attack by 13 drones armed with small-diameter bombs that caused casualties and damaged facilities.[48] These types of swarm-like attacks are particularly threatening because existing kinetic defenses struggle to cope with the agility of small drones, and swarming would overwhelm most existing countermeasures.[49]

除了這些敵對國家的活動之外，非國家行為者最近在無人機方面的進展，顯示出這些團體如何快速又輕易地，讓先進工業化軍事強權遭受困擾。無人機之所以會讓這些團體那麼感興趣，主要是因為無人機能攜帶毀滅性武器，而且它的作戰範圍，不會超越這些團體的控制距離。[44] 靠商購管道可以獲得的小型無人機，可以讓諸如伊斯蘭國這種團體，具備空軍的情、監、偵蒐集能力，還能提供有限的密接空中支援。非國家行為者使用小型無人機，開始於2004年，當時真主黨以無人機挑戰以色列軍方國家的軍隊。[45] 非

44 Brian A. Jackson, Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles (Santa Monica, CA: RAND, 2008), xv.

45 Avery Plaw and Elizabeth Santoro, "Hezbollah's Drone Program Sets Precedents for Non-State Actors," Terrorism Monitor 15, no. 21 (November 10, 2017).

46 Jamie Crawford, "Report Warns of ISIS Developing Drones for Chemical Attacks," CNN, October 20, 2016, available at .

47 Plaw and Santoro, "Hezbollah's Drone Program Sets Precedents for Non-State Actors."

48 David Reid, "A Swarm of Armed Drones Attacked a Russian Military Base in Syria," CNBC, January 11, 2018, available at .

49 Madrigal, "Drone Swarms Are Going to Be Terrifying and Hard to Stop."

國家團體對無人機的使用持續演進，且顯示出執行複合式攻擊的能力。例如，在長達一年的摩蘇爾爭奪戰中，伊拉克安全部隊遭受武裝無人機持續攻擊，遲滯了他們解放伊斯蘭國控制下周邊地區的行動。[46] 值得注意的是，這些非國家組織使用戰術無人機所形成的複雜性和破壞程度持續增高。真主黨將這些無人機用來執行監視、宣傳、武裝打擊任務，以及自殺式攻擊。[47] 俄羅斯國防部最近報導在2018年1月，它的部隊在敘利亞西部，遭到「一群家庭代工製造無人機」的攻擊。根據國防部長所說，俄羅斯部隊在赫梅明空軍基地及塔特斯海軍基地，遭受13架裝配小型炸彈的無人機實施的複合式攻擊，造成人員傷亡及設施損壞。[48] 這種蜂群式的攻擊特別具威脅性，因為現行的機動防禦，針對的是小型無人機的機動性，而這種蜂群戰術，會讓大部分防禦機制無以因應。[49]

Recommendations for Countering the Threat
反制威脅的建議事項

U.S. policy must not only respond to today's problems, but it should also be flexible enough to adapt to tomorrow's challenges. A comprehensive counter-UAS strategy must address the different nature of threats presented bythe various types of UAS. It must also provide solutions for confronting the full scope of UAS challenges by potential state and non-state adversaries. The U.S. Army's current counter-UAS strategy does not do this. The discussion herein shows that U.S. adversaries are learning and adapting, but the Army is failing to keep pace. Russia's operational employment of drones in Ukraine, Iran's proliferation of drone technologies, China's emphasis on developing full-spectrum drone capabilities, and the evolution of drone use by non-state actors show that Army planners must anticipate extensive UAS employment in future conflicts. Changes in drone technologies and evolving adversary doctrines suggest that the Army must learn from recent conflicts, as the Russians did, and recognize that the changing character of warfare requires improved acquisition processes and training to effectively counter the UAS threat.

美國政策不能只針對目前的問題，還必須具備足夠的彈性因應明日的挑戰。一個全面反制無人飛行系統的策略，應該能因應各種不同型式無人機的威脅本質，也必須能根據對手國和非國家敵人所造成的所有類型挑戰，提供相應的解決方案。美國目前的無人機反制策略，並沒有做到這點。本文此前曾提到，美國的敵人正在學習和適應，但是美軍卻沒有來得及跟上。俄羅斯在烏克蘭對無人機的運用、伊朗在無人機技術方面的擴張、中國對全方位發展無人機的重視，以及非國家行為者對無人機使用方式的逐漸進化，都在提醒美軍規劃人員，必須預先考量無人機在未來衝突之中的廣泛運用。無人機

技術的進展和對手運用方式的變化，使美軍不得不像俄羅斯一樣，從近日的軍事衝突之中學習；此外，要有效反制無人機的威脅，還得清楚認知作戰特點的變化、改進武獲流程，以及強化訓練。

During the global war on terror, the Army made the deliberate decision based on budget priorities to emphasize longrange air defense systems by significantly reducing and eliminating short-range air defense systems. According to senior leaders, this decision was a calculated risk taken when leaders believed that the current and future capabilities of the Air Force would defeat any aerial threat and maintain air superiority.[50] As the assumptions underlying this decision have been proved invalid, the elimination of short-range air defense systems means the Army now relies on aging antiaircraft and missile intercept systems to counter every UAS threat.[51] Given the proliferation of tactical drones, the use of advanced air and missile defense systems is inappropriate due to cost, system availability, and an inability to defeat slow, low-flying drones.

全球反恐期間，軍方基於預算考量，將經費優先撥付長程防空系統的建置，對短程防空系統的經費一再縮減。根據資深高層人員透漏，如果領導階層認為空軍目前及未來的能力，足以擊退任何來自空中的威脅，確保空優，那就真的是大錯特錯了。[50] 如果依據這種假設做出的決定最後被證實無效，對短程防空的不夠重視，代表軍方必須依賴老舊的飛機和飛彈等攔截系統，來反制無人機造成的威脅。[51] 因為戰術無人機的大量擴散，先進防空與飛彈防禦系統因為成本、系統效益與能力不足的原因，將無法擊落飛得又低又慢的無人機。

Recently, the Israel Defense Forces employed their U.S.-made Patriot missiles against a single small drone from Syria that violated Israeli airspace. The Israelis used multiple $3 million PAC-2 missiles but failed to destroy the target.[52] This incident highlights the

50 Randall McIntire, "The Return of Army Short-Range Air Defense in a Changing Environment," Fires Bulletin (November-December 2017), 5.

51 Barry Pike, Program Executive Officer, Missiles and Space, statement, On Fiscal Year 2018 Priorities and Posture of Missile Defeat Programs and Activities: Hearing Before the Subcommittee on Strategic Forces, Committee on Armed Services, United States House of Representatives, 115th Cong., 8 (2017).

52 Callum Paton, "Iran Drone No Match for U.S. Patriot Missile as Israel Blows Hezbollah Aircraft Out of the Sky," Newsweek, September 2017, available at .

unsustainable cost and technical difficulty of employing limited theater-level air defense assets against tactical drones.[53] In 2017, then-commanding general of the U.S. Army Training and Doctrine Command, General David Perkins, told an audience, "If I'm the enemy, I'm thinking, 'Hey, I'm just going to get on eBay and buy as many of these $300 quad-copters as I can and expend all the Patriot missiles out there.'"[54] If the Patriot and Stinger missiles-which cost $3 million and $38,000 each, respectively-remain the primary defense means for countering drones, it may be possible for an adversary to employ tactics such as those IS used against Russia in Syria to deplete a theater-level air defense capacity that costs tens of millions of dollars. This low-cost act would make an entire area of operations vulnerable to subsequent air attack.

最近，以色列國防軍以美國製的愛國者飛彈，追擊一架從敘利亞起飛，入侵以色列領空的小型無人機。以色列使用價值3百萬美元並聯裝愛國者2式飛彈，卻無法摧毀目標。[52] 這次事件顯示，使用有限空層的防空武器對抗戰術無人機，在成本上不合算，技術部分也有難度。[53] 2017年，當時美國陸軍訓練準則指揮部指揮官大衛・柏金斯上將就曾說：「如果我是敵人，我就會想—我只需要到eBay購物網站去，看能買到多少組價值300美元的四旋翼直升機就買多少組，這樣就可把所有愛國者飛彈都消耗掉了」。[54] 如果愛國者和刺針飛彈(單價分別是3百萬和38,000美元)持續擔任防禦無人機的主要任務，敵人很可能用伊斯蘭國在敘利亞對付俄羅斯那種戰術，用無人機耗盡我們價值數千萬美元的戰區空層防禦飛彈。敵人這種低成本消耗戰，會讓我方整個作戰區，在往後遭受空中攻擊時，變得非常脆弱。

Though the U.S. Army has taken steps to improve its counter-UAS capabilities, these actions have been insufficient. The Army recently began the process of expanding the availability of short-range air defense systems in the Active force by having its Materiel Command overhaul legacy Avenger systems previously set to be destroyed. Though a step in the right direction, reintroducing short-range air defense systems will take time, during which maneuver forces will remain vulnerable. The Army took additional steps to mitigate this gap by training and assigning Stinger teams to its maneuver forces, along with developing

53 "IDF Fails 3 Times to Bring Down Drone over Golan," Times of Israel, July 17, 2016, available at .

54 Alexandra Larkin, "How Do You Shoot Down a $200 Drone? With a $3 Million Patriot Missile," CNN, March 16, 2017, available at .

Stinger upgrades to improve their effectiveness against tactical drones.[55] However, this is a solution that has already been proved ineffective. When the Army made a similar attempt to integrate Stinger teams in the 1990s, senior defense officials noted that the result "was not great, as we found that 80 percent, if not more, of all Stinger shots taken by maneuver Soldiers, were done in a revenge fashion, after the enemy had already destroyed most of the formation."[56] As the drone threat continues to evolve, so too must the solutions used to counter the threat.

雖然美軍已經採取許多措施，來強化反制無人飛行系統的能力，但這些作為顯然不夠。最近美國軍方開始針對短程防空系統的武獲流程加以修正，做法是要求美國陸軍物資司令部，將現役部隊中本來預計要銷毀的老式復仇者飛彈系統進行翻修。這是一個正確方向，因為重新發展、製造短程防空飛彈系統要花很多時間，這段空窗期會讓部隊防空能力顯得不堪一擊。為了填補戰力空檔，陸軍重新訓練、發配刺針飛彈部隊，還發展改良型刺針飛彈系統，以強化反制戰術無人機的效能。[55] 然而，這種作法早就證實沒有效果。美國陸軍在1990年代就執行過類似這種整合刺針飛彈系統的計畫，高階將領評論這種作為「不會有太大效果，因為我們都知道刺針飛彈超過80%都是由單兵操作發射，而且都是在反擊狀態下執行；這表示我軍主力，這時大部分都已被擊潰」。[56] 無人機造成的威脅不斷演化，我方對抗這種威脅的方案，也必須與時俱進。

The current drone threat is far too complex for a single solution to solve. A U.S. Army counter-UAS strategy must provide a framework for a persistent and comprehensive approach that links Soldier, materiel, and software solutions. The Army must creatively employ all means along these three lines of effort to regain operational initiative. Along the Soldier line of effort, the Army must retrain its troops to compete, fight, and win in a drone-saturated environment and to win in the counter-reconnaissance fight while restructuring its formations to meet the added demands of counter-drone requirements. Along the materiel solutions line, the Army must continue its reforms of an industrial age-acquisition process to promote rapid, creative, and independent technical solutions through public-private partnerships with corporate partners. Lastly, the Army must explore existing and emerging commercial technologies to

55 McIntire, "The Return of Army ShortRange Air Defense in a Changing Environment," 5-6.

56 Interview with senior Defense official, February 2017.

identify counter-UAS measures it can rapidly field along with innovative software solutions compatible with existing systems. If no such technologies exist, the Army will have to spearhead the development of effective counter-UAS systems. The newly created U.S. Army Futures Command, whose mission is intended to result in a more rapid acquisition process, can spearhead these efforts. Early success in this command along these lines might provide an opportunity for the Army to leap ahead in drone technology and in ways to counter the drone threat.[57]

目前，無人機所造成的威脅，已經複雜到絕非單一方案可以解決。美國陸軍所提出反制無人機的方案，必須是一個結合戰士個人、裝備物資與軟體，具有持續性和全面性作法的整體架構。軍方必須依循戰士、裝備物資和軟體這三大主軸，以富有創意的角度執行相關措施，重新獲取作戰主動。首先在戰士這一方面，軍方必須設法讓其部隊在無人機滿天飛的環境中，維持住競爭、戰鬥和獲勝的能力，並在反偵察戰鬥中重新組建防線，以因應反制無人機的需求，尋求勝利。在裝備物資方面，軍方必須持續進行工業時代的改革——從個人裝備到團體裝備，全面審視武獲流程，在技術方案這部分設法藉由公私合作企業夥伴，做到快速、創新與獨立。最後，軍方必須去探索現有和發展中的商業技術，確保反制無人機的手段，可以將軟體方案和使用中的現役裝備，快速且充分結合。如果所需技術目前尚未出現，軍方就必須帶頭發展有效的無人機反制系統。新近成立的美國陸軍未來指揮部，任務就是加快裝備獲得流程，以及研發最新技術。未來指揮部在上述3個主軸的初期成果，能夠讓軍方在無人機技術方面快速發展，面對敵人的無人機威脅，也能找到方法因應。[57]

The Army must place its primary emphasis on the Soldier line of effort, since this is arguably the most important in terms of near-term counter-UAS effectiveness. This requires redeveloping atrophied air defense war-fighting skills necessary in a contested drone environment. Capability and training in air defense skills declined during decades operating in uncontested airspace and counterinsurgency operations. The Army previously trained Soldiers in the fieldcraft necessary to conduct active and passive air defense. Active measures include tasks involving the detection and engagement of enemy aircraft; passive defense measures include skills related to camouflage, concealment, position hardening, dispersion, and mobility

57 Jen Judson, "Army Futures Command Taking Charge of Conjuring Up New Capability," Defense News, March 24, 2018, available at .

to guard against air attack.[58] To its credit, the Army is starting to reintroduce training related to these skillsets.[59]

以上3個主軸，軍方必須將重點放在戰士身上，因為就無人機反制作為的短期效應來說，這是最重要的。在競爭激烈的無人機發展領域，將已經停滯萎縮的防空作戰技能重新發展起來，是很重要的。過去幾十年反恐鎮暴行動中，因為對空域沒那麼重視，防空作戰的能力和訓練，已經慢慢衰退。軍方之前訓練士兵在戰場上，要進行必要的主動防空和被動防空。主動防空包括主動發現敵機，並與之交戰；被動防空就包括偽裝、隱藏、工事強化、分散與機動這些防衛敵人空中攻擊的行動。[58] 所幸，美國軍方已經將這些技能重新對士兵加以訓練。[59]

Reintroducing and strictly enforcing standards of the passive defense is a low-cost and rapid solution toimmediately counter enemy drone threats. If Ukrainian forces at Zelenopillya in July 2014 had implemented passive air defense measures, the results of the Russian attack likely would have been much less severe. The Army should invest in home-station training kits of commercial drone systems like it did following the emergence of the improvised explosive device threat in the battlefields of Iraq and Afghanistan. Once the Army realized the magnitude of the threat posed by these devices, it quickly integrated methods designed to train deploying units in how to counter and defeat the threat. The Service also tested preparedness during culminating training events at its three combat centers. The same approach must be applied to counter-UAS training.

重新導入被動防空，同時嚴格執行，是反制敵方無人機威脅時，馬上可以看到成效的低成本選項。如果烏克蘭軍隊2017年7月在澤列諾皮爾利亞，可以採行這種被動防空措施，俄羅斯攻擊所造成的損傷，應該不至於那麼嚴重。軍方應該在基地訓練中，投資足夠數量的無人機，就像以往訓練要派駐伊拉克和阿富汗的士兵，熟悉簡易爆炸裝置的緊急處理一樣。一旦軍方體會出這些訓練及相關設施的重要性，自然會想出辦法整合各項方案，來訓練相關單位如何反制並擊敗這些威脅。勤務單位也在3個訓練中心隨時備便，配合訓練工作執行。這些以往針對簡易爆炸裝置的訓練，如今在進行無人機反制訓

58 Christopher L. Spillman and Glenn A. Henke, "The New Threat: Air and Missile Defense for Brigade Combat Teams," AUSA Magazine, February 17, 2017.

59 Anne Chapman, The National Training Center Matures, 1985-1993 (Fort Eustis, VA: U.S. Army Training and Doctrine Command, 1997), 26.

練時，應該比照辦理。

The arrival and detection of any enemy UAS can no longer be considered a mere inconvenience to the detected formation but immediately elevated to the commander's attention, as that origination must actively engage the threat while breaking contact to ensure its survival. The kinetic options to engage an enemy UAS once detected vary from the simple to the complex, but what has proved most effective to date often merges both the traditional kinetic and emerging non-kinetic options to achieve a layering of joint effect against the UAS platform. It is with this approach that all following suggestions should be considered. No single line of effort will be enough to defeat or even suppress this threat alone. It will require the layering of all of these efforts for the U.S. Army and the joint force to achieve a desirable outcome in this new counter-reconnaissance fight.

任何敵人的無人機一旦出現對我方部隊進行偵查，就不再只是造成一時的不便而已，立即會成為指揮官的關切事項；對這類威脅必須主動處置，儘快脫離無人機，以保障部隊生存。面對敵方無人機的偵查行動，應對方案從簡單到複雜有很多種，但至今被證實最有效的，是融合了傳統開火和新的不開火方案，以分層法獲得反制無人飛行平台的效果。除了這個以外，其他所有建議方案都應該被納入考量，因為沒有一種單一方案足以擊敗，甚至壓制這種威脅。透過分層方式和其他努力，美國陸軍和聯合部隊在新的反偵察戰鬥中，才有機會獲致預期結果。

The blurred distinction between commercial and military drone production makes it necessary for the Army to study and understand the future potential of these systems by working with commercial industry partners. Given the current reliance of non-state actors on the commercial development of this technology, collaborating with major manufacturers, including foreign manufacturers, will offer the Army insights on the direction of system change and potential threats. This early understanding will provide time for the Army to develop appropriate responses before adversaries employ the systems on the battlefield. As the Under Secretary of the Army recently announced regarding the creation of Army Futures Command, "We have to get more agile in how we work with both of those key constituencies or communities." He also noted that the "entire Department of Defense really divested a lot of its systems engineering talent back in the 1990s and it's been a challenge for the department for weapon systems development because of not having that organic capability inside the

department."[60]

商用和軍用無人機之間模糊的分別，使得軍方必須跟工業夥伴合作，才能充分掌握未來潛在威脅。目前，非國家行為者因為對相關技術的商業發展，以及與主要製造商，包括外國廠商的合作充滿信心，讓軍方對相關系統的發展方向和潛在威脅，都能有所掌握。這種對狀況的先期瞭解，讓軍方面對敵人在戰場上的部署，可以爭取一些時間來做適切的反應。美國陸軍副部長最近在有關成立未來指揮部上說：「我們在跟關鍵供應商或是一般大眾交流合作時，必須更靈活有彈性」。他還說：「整個國防部放棄系統工程能力已經倒退回1990年代，對國防部來說，武器系統發展是一大挑戰；因為在部內，我們已經不再具有建制內系統工程能力」。[60]

Army Futures Command is the ideal organization to implement the search for and development of materiel solutions to counter drones. The Army must ensurethat the command is properly manned and given the necessary authorizations to become an institution that can reform an acquisition system that has become unable to keep pace with modern technological change. The U.S. Special Operations Command's relationship with SOFWERX provides a model for what larger scale Army materiel collaboration might look like. SOFWERX is a public-private technology incubator that has recently been preparing to host a series of drone competitions to explore how these systems and equipment might benefit the command.[61] This public-private model would benefit the larger conventional Army and provide a venue to not only discover how drones might benefit the Service but also devise ways to counter them.

陸軍未來指揮部，是尋求與發展反制無人機方案的理想單位。陸軍必須確保未來指揮部由適當的人才主導，並擁有必須的授權，讓它成為改善武獲管道，避免跟當代技術變革脫節的單位。美國特種作戰指揮部與SOFWERX公司(譯註：美國陸軍投資設立的創新中心之一)的合作關係，可以提供給軍方針對較大規模硬體整合方案的發展，一個很好的參考。SOFWERX是一家公私合營的科技培育公司，最近準備舉辦一系列無人機競賽，來探討這些系統和裝備可以對作戰指揮部提供哪些幫助。[61] 這種公私合營模式，對陸軍這種大型傳統單位來說，不但可以充分掌握無人機的妙用，還能引導出反制手段。

60 Judson, "Army Futures Command Taking Charge of Conjuring Up New Capability."

61 Michael Bottoms, "SOFWERX: A Smart Factory of Innovation Helping the Warfighter," U.S. Special Operations Command Office of Communication, February 2, 2018, available at .

While global reach on commercial drone systems is still an emerging technology, the areas that will have significant impacts on a commercial-to-military crossover remain steadily focused on improvements in autonomous flight, increased battery performance, and location technologies. Currently, there remain few commercial drones that can fly without the aid of a user-directed path, but this technology is quickly emerging along with the application of commercial artificial intelligence. Advances in location technologies will also present a significant challenge to the military. The stated goal of companies working in this area is to build systems that can identify their location without the aid of GPS.[62] Combining all the above technological advancements into a single commercial platform-and there is little reason to suspect that will not happen-will provide a potential adversary a commercial version of the most advanced military drones in the world. The Army must work with industry partners that could provide it with forewarning of when this may occur and perhaps influence the timing.

全球都買得到的商用無人機還是屬於新興科技，但是以技術層面來說，從商用過渡到軍用這個階段，仍然因為面對很大衝擊而持續受到關注，特別是自主飛行、加強電池效能和定位技術這些部分。目前，只有少數幾種無人機可以在沒有人員導引的狀態下自主飛行，但是隨著商用人工智慧的運用，這種技術進展快速。定位技術的發展對軍方而言還是令人頭大的問題；無人機製造公司在這部分設定的目標，是即使沒有全球定位系統(GPS)的協助，仍然可以確認定位。[62] 將上述先進技術整合到單一商業平台會讓潛在敵人擁有世界上最先進的，商業版的軍用無人機，這情況勢必會發生。軍方必須與工業夥伴密切合作，對這種狀況的發生留下反應時間，或者儘量讓這種狀況延後發生。

The final line of effort for developing a counter-UAS strategy is to link Soldier and materiel solutions with systems software within the existing structure of Army brigade combat team systems. The first step in formulating these solutions will require developing software for existing systems that enable detecting and tracking drones. Current air tracking systems are already capable of tracking larger operational drones, so the focus must be on smaller tactical UAS, which have smaller radar cross sections due to their small infrared and electromagnetic signatures. Therefore, the Army must invest in software for current and future sensors that can better detect tactical drones. The uncertain budget environment makes the acquisition of new radar systems unlikely, and previous acquisition failures suggest that the Army should

62 Judson, "Army Futures Command Taking Charge of Conjuring Up New Capability."

not invest limited funds in aspecialized counter-drone radar. Instead, it must develop better software for existing radars like the AN/MPQ-64 Sentinel and AN/TPQ-53 radar systems. The latter system was originally designed to track rocket, artillery, and mortar rounds, but the Army is testing its abilityto track drones. One advantage that modern radars have is active electronically scanned arrays.[63] Radars with this feature have proved more versatile than older systems, so developing software for these systems to track tactical drones provides a solution short of developing a new radar system.

發展無人機反制策略最後一條主軸，是在軍方現有旅級戰鬥團隊架構下，以系統軟體連結戰士和物資方案。規劃這些方案的第一步，是必須為現有系統，發展出能夠察覺和追蹤無人機的軟體。現有的空中追蹤技術早就可以掌握到大型作戰無人機，所以重點應該是擺在小型戰術無人機；那些無人機因為比較小的紅外線和電磁感應面積，所以在雷達螢幕上顯示出來的橫截面也比較小。因此，軍方應該在現有和未來感應軟體上加大投資力度，以利於更快偵測到戰術無人機。有限的預算支應，讓新雷達的獲得也變得不確定；這種困境讓軍方無法針對反制特殊型號無人機，而將有限預算投入雷達發展。比較適當的作法是為現有雷達系統開發更好的軟體，像是AN/MPQ-64哨兵雷達和AN/TPQ-53雷達系統。後者原始設計目的是為了要追蹤火箭、砲彈和迫擊砲彈，軍方正在測試這型雷達追蹤無人機的能力；這種系統的優勢是採用主動電子掃描陣列雷達(active electronically scanned arrays，譯註：藉由改變天線表面陣列所發出波束的合成方式，來改變波束掃描方向的雷達)。[63] 有這種配備的雷達，測試結果證實比以往的系統功能更強大；為這些老舊系統發展新的軟體，對於追蹤戰術無人機的任務來說，也會比重新開發新雷達更為適切。

General Mark A. Milley believes, "One of our most important duties as [military] professionals is to think clearly about the problem of future armed conflict." He also notes that fixed sites of any kind will be lethal magnets for destruction by enemies who will have a rich diet of targeting information.[64] This information will likely be provided in large part by hostile drones, some of which might conduct attacks. Recent conflicts involving state and

63 Sydney J. Freedberg, Jr., "Drone Defense: Army Anti-Artillery Radar Tracks UAVs," Breaking Defense, June 27, 2016, available at .

64 David Barno and Nora Bensahel, "Three Things the Army Chief of Staff Wants You to Know," War on the Rocks, May 23, 2017, available at .

non-state actors and the drone acquisition priorities of U.S. rivals seem to confirm this reality. Despite these threats and the observable lessons from recent conflicts, the Army remains vulnerable to the long-term operational risks resulting from the proliferation and use of drones by state and non-state adversaries. The reemergence of long-term geopolitical competition with rivals employing a variety of drones, rapid diffusion of drone technologies throughout every operational region, and adversary war-fighting concepts that integrate drones into effective offensive operations result in a strategic imperative for the Army to develop and implement a counter-UAS strategy based on Soldier, materiel, and software solutions. This type of strategy will provide a framework for improving the Army's acquisition process to better leverage emerging technologies and develop a comprehensive Soldier training program that integrates these technologies to regain the initiative through improved war-fighting. The Army has spent trillions of dollars in the last decade building and generating a force that can fight, dominate, and win in the land domain, yet states and groups with far fewer resources are rising to challenge the United States in the new arena of drone warfare. The Army must take all necessary steps to mitigate this threat or risk losing the next war. JFQ

現任參謀首長聯席會議主席馬克・麥力上將相信：「作為軍事專業人員，我們最重要的職責，是想清楚未來武裝衝突的問題」。他也指出，對於不缺定位選項的敵人來說，任何地點都可能對我方造成致命傷害。[64] 這些定位資訊大部分是由敵方無人機蒐集而來，有一些可能用來執行攻擊；近年與敵國或非國家行為者發生的衝突，以及美國的對手急於獲得無人機的事實，都可以證實以上的說法。雖然最近的衝突讓美國遭受損失，也學到一些教訓，但軍方處於長期作戰風險中，因為敵國和非國家敵方大量使用無人機，依然顯露出很多弱點。對手大量使用無人機而重新出現的地緣政治競爭、在各戰區快速擴散的無人機技術，以及敵人將無人機整合到作戰概念中產生出有效的攻擊行動，對軍方而言，確實需要從戰士、裝備物資和軟體這3個主軸中，摸索出一套發展和執行反制無人機的策略。這套策略需要一個改進武獲程序的架構，以求更適切的因應不斷出現的新科技，並發展出一套完整的戰士訓練計畫來整合相關技術，以利於在不斷變化的戰場上重新獲取先制優勢。過去10年，軍方已經花了好幾兆美元的經費來打造一支在地面戰中能戰鬥、掌控並取得勝利的部隊；但是敵國和敵方團體，在資源遠遠不及美軍的狀況下，卻在無人機作戰這個領域迅速崛起並挑戰美國。如果不想冒著在下一場戰爭中輸掉的風險，美軍就必須採取一切必要手段，來解除這種威脅。

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