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DEFTECH Military Capabilities Update

June 2019

OTH INTELLIGENCE GROUP
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19th June 2019

Dear Reader,

Based on the last survey about desired improvements of this document produced every second month, you will see that we have added some illustrations to best satisfy, we hope, your curiosity and materialize at the same time some abstract names or concepts. We can always add more, but we worry about a good balance between illustrations and explanations.

The analysis about what these new developments could mean for a country like Switzerland is a challenging part. We carefully thought about this, and decided it was not really the scope of such publication to enter such a debate. Despite the fact that both authors do not have military backgrounds, we believe that, for the sake of credibility, this aspect must be considered together with the armed forces, and the people with appropriate expertise. We hope however that such report could trigger the curiosity towards one or more topic. The impact, being considered as an opportunity or a threat, will then be discussed in a more restricted audience than for this publication.

In order to structure the approach, and as for the previous iterations of this report, we will center on six broad categories of military capability areas listed below.

- Energy and Power
- Human Performance Enhancement
- Cyber and C4ISTAR
- Manned Platforms
- Missile Systems and Munitions
- Robotics and Unmanned Systems

Each Update is **not** a comprehensive accounting of capabilities displayed, demonstrated, or discussed within each of these categories. Rather, it will draw attention to indicative or especially relevant capabilities and developments that incorporate novel technologies, including those associated with the 4th Industrial Revolution, among others. It will also emphasize, where appropriate, adjacent, non-technological innovations in operational concepts, organizational structure, and innovation and procurement models that facilitate design, procurement, and deployment of new capabilities.

We do hope you will find these "DEFTECH pills" insightful and look forward to any feedback for continuous improvement.

We wish you a very good reading,

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Introduction and Summary

The June 2019 volume of the DEFTECH report incorporates indicative examples across the six categories of capability areas from a wide-range of defence communities: the United States, Russia, China, the United Kingdom, France, Germany, the European Defence Agency, Israel, South Korea, Norway, and the private sector. It also includes initial reporting on the on-going Paris Air show. Key themes and insights that emerged across categories and that have relevance for small militaries as well as larger ones include:

Simplicity, Openness and Modularity: Simplicity of design was a common. Some indicative examples covered in this report include:

- France's Air Chief of Staff noting that the Future Combat Air System would be "an Android-like operating system—it is open"[1]
- A commercial developed, hydrogen fuel-cell-powered electronic vertical take-off and landing aircraft whose manufacturer repeatedly stressed the "simplicity" of the platform's architecture[2]

This focus on simplicity and openness is in part due to a compelling need to reduce the uncertainty and knock-on effects of integrating rapidly-developing emerging technologies and capabilities into modern platforms and systems. As France's Air Chief of Staff noted, "nobody knows what the threats or technologies will be in 2040"[3]

There is also a compelling need for manufacturers to legitimately allay defence and security community concerns about the escalating costs of complex capabilities—the F-35 is a useful, if extreme, example—and, significantly, the maintenance and operating costs of these platforms and systems. FLIR representatives highlighted this imperative during the IDEF show in May in Turkey, nothing that the third generation of the Black Hornet nano-UAV has a modular design so that militaries would not have to send the UAV "back to Norway"[4] if one part of it breaks.

Flexibility: Closely related to the need for simplicity and openness in design is the need—reflected by developments covered in this report—for flexibility of capabilities first and foremost to carry out multiple missions and engage multiple targets. Take, for example, Russia's Tactical Missile Company's efforts to create missiles that are "universal from the viewpoint of targets"[5] to new unmanned underwater vehicles capable of carrying out several missions. Flexibility also applies to the environments in which these platforms and systems can operate. This report highlights the growing relevance of urban combat, the electromagnetic spectrum, and even subterranean environments.

Four Fusions: Some capabilities highlighted in this report are being designed either to exploit or respond to other efforts to exploit the furthering of four fusions that increasingly mark the strategic and operational context facing all defence and security communities: the fusion of states of **peace** and **conflict**; of the **physical** and **digital**; of **reality** and **perception**; and of **defence and security** and **commercial** requirements and activities.

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[1] Dubois, Thierry and Osborne, Tony, "French Air Chief of Staff on Transformative New Aircraft and Upgrades", *Aviation Week*, 4 June 2019, https://aviationweek.com/defense/french-air-chief-staff-transformative-new-aircraft-and-upgrades

[2] Warwick, Graham, "Hydrogen Fuel Cells to Provide eVTOL Aircraft", *Aviation Week,* 30 May 2019, https://aviationweek.com/future-aerospace/hydrogen-fuel-cells-power-evtol-aircraft

[3] Dubois, Thierry and Osborne, Tony, "French Air Chief of Staff on Transformative New Aircraft and Upgrades", *Aviation Week*, 4 June 2019, https://aviationweek.com/defense/french-air-chief-staff-transformative-new-aircraft-and-upgrades

[4] "FLIR Unmanned Aerial System: Black Hornet UAV", Jane's by IHS Markit IDEF 2019 Coverage, *YouTube*, 24 May 2019, https://www.youtube.com/watch?v=uvGeYvtpPv8

[5] Cole, Brendan, "Russia's Military Wants its Supersonic Cruise Missiles to Go Hypersonic", *Newsweek,* 28 May 2019, https://www.newsweek.com/russias-military-wants-its-supersonic-cruise-missiles-go-hypersonic-1437116

Together these fusions create new and powerful vulnerabilities not just to military and security communities, but also societies and polities. The report cites growing concern about "deep fakes" and the employment of adversarial examples to deceive defence communities as well as targeted populations within competitor states and societies. Similarly, one of the main selling points of the Black Hornet UAV is that it allows for effective battle damage assessment that can be used either to counter pernicious and false narratives or create truthful ones that will help advance strategic objectives.

Energy, Power, and Propulsion

The Energy, Power, and Propulsion area was particularly busy over the course of the reporting period. Militaries throughout the world are seeking to develop more efficient and, in some cases, novel means of enhancing the energy independence of fixed bases as well as the endurance of individual soldiers and platforms in order to achieve longer range while also not creating new or exacerbating old challenges, such as adding weight or new safety concerns. As with previous reports, this volume seeks to highlight the considerable intersections between commercial and military / security community innovation and development activity in this capability area.

New Battery Technologies Tested: Several innovative efforts to develop better hybrid and fully-electric battery power for broad military and security use were revealed during the reporting period.

The United Kingdom's Ministry of Defence announce that has dedicated £750,000 for research into alternative for battery power through the MoD's Defence and Security Accelerator (DASA). The April edition of this report focused on DASA's increasing investment in drone swarming technologies as the UK MoD seeks to better leverage dual – use research taking place in the private sector and outside the traditional defence industrial base.

The MoD invited suppliers to an event on 28 May 2019 that included demonstrations of technologies developed through the MoD's Beyond Battery Phase 2 competition as well as panel discussions that focused on "the societal demands and challenges or future alternatives to battery power". Three DASA-funded suppliers: led the demonstrations:[6]

- University College London (USL) displayed a printed circuit board fuel cells technology
- University of Sussex showcased their semi-free piston high-energy density generator
- Arctec Vida. demonstrated an innovative prototype LPG-fuelled generator that is quieter, more durable, and more efficient than previous models."

Also during the reporting period, *Signal* magazine reported on the U.S. Army Research Laboratory's (ARL) research into a water-based electrolyte energy-source that can provide longer battery life for soldiers in the field. The water – based electrolyte was described as "remarkable" by Cynthia Lundgren, Electrochemistry Branch Chief at the Combat Capabilities Development Center of ARL because water's voltage is usually constrained to about 1.5 volts, which does not ordinarily lead to powerful batteries. But ARL's "aqueous battery" can generate beyond 4 volts and also can be configurable in design without adding weight or safety concerns as the battery is not explosion-prone. According to Lundgren "One of the great advantages of the aqueous battery is that it doesn't need a lot of packaging. Its really very abuse tolerant—it only needs some Kevlar-like cloth on it." ARL scientists are hoping to have a version ready by 2026, highlighting the work left to be done in the developing new battery technologies supporting soldiers in the field.[7]

[6] Channon, Max, "MoD looks for alternatives to battery power", *Cornwall Live,* 22 May 2019, https://www.cornwalllive.com/news/uk-world-news/mod-looks-alternatives-battery-power-2897888
[7] Ackerman, Robert, "Future Armies Will March on Their Batteries", *Signal,* 1 June 2019, https://www.afcea.org/content/future-armies-will-march-their-batteries

Hydrogen Fuel-Cells for eVTOL: Alaka'i Technologies, a Massachusetts-based start-up, is planning to fly a full-scale, five-seat electric vertical-take-off-and-landing (eVTOL) aircraft powered by hydrogen fuel cells allowing it to travel for up to three hours and 300 miles. The 4,000-lb-grosss-weight vehicle has three fuel cells producing a total of 450 horsepower using liquid hydrogen stored at 100 psi in a double -walled tank. According to Alaka'i. the fuel cell is a new-generation design that is lighter than other automotive units with greater output. No batteries are required to handle transient loads.

The aircraft—named Skai—has been co-designed with BMW Designworks to carry a pilot and four passengers and is designed to be able to accommodate complete autonomous flight. Another discriminator is the platform's "simple" design that reduces both manufacturing and maintenance cost. This simple architecture is also believed to accelerate the timeline for the first Federal Aviation Authority (FAA) certified aircraft in 5 – 6 more months—the process has been underway for 10 months so far. According to Brian Morrison, president and co-founder of Alaka'i, "We have such a simple architecture that our expectation, barring unexpected requirements, is we will certify next year."[8]

There is no indication that Alaka'i is planning on making the eVTOL platform available to defence and security communities. Indeed, the immediate objective is to disrupt the nascent air-taxi market by focusing on longer-distance trips between cities rather than 15 -30 minute trips mostly within cities.[9] Nonetheless, as the

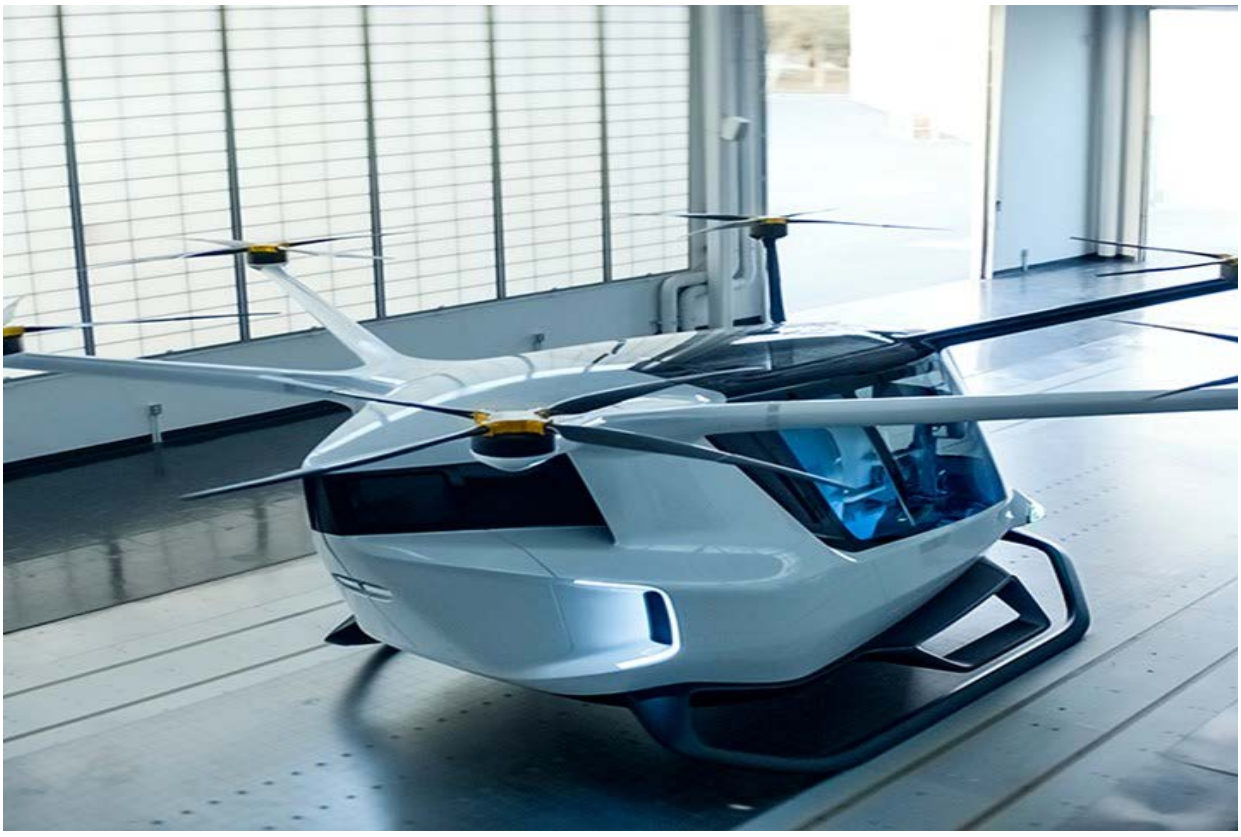

Figure 1: The Alaka'i Skai eVTOL hydrogen fuel-cell-powered aircraft (source: Alakai)

[8] Warwick, Graham, "Hydrogen Fuel Cells to Provide eVTOL Aircraft", *Aviation Week,* 30 May 2019, https://aviationweek.com/future-aerospace/hydrogen-fuel-cells-power-evtol-aircraft
[9] Warwick, Graham, "Hydrogen Fuel Cells to Provide eVTOL Aircraft", *Aviation Week,* 30 May 2019, https://aviationweek.com/future-aerospace/hydrogen-fuel-cells-power-evtol-aircraft

hydrogen fuel – cell technology matures and is certified, becoming viable for aircraft, both commercial and public sector organizations will seek to expand applications, including for military and security use.

Microgrids to Provide Energy Independence at Joint Base Pearl Harbor-Hickam In June 2019, the Hawaii Technology Development Corporation—in conjunction with a broader U.S. Department of Defense initiative—awarded U.S.-based Burns and McDonnell an $8.3 million contract as part of a multi-year initiative to develop a series of six microgrids on the U.S. military's Joint Base Pearl Harbor-Hickam 0PBPH-H). The program seeks to make use of a variety of on-site, renewable energy, storage and distribution technologies to design, build and operate the microgrid demonstration project to include: solar PV, wind, hydrogen, and battery-based energy storage. According to U.S. Senator Brian Schatz (D) who is on the Senate Appropriations Sub-Committee on Military Construction and Veterans Affairs, "The Department of Defense's investment in a microgrid test – bed in Hawaii will play dividends by proving that alternative energy and microgrid technologies can support the military's broader energy security and resilience goals."[10]

The initial test microgrid at JBPH-H is designed to serve as an R&D platform that ultimately will not only enable the base to "function independently of the power grid for extended periods of time", but also to serve as the "backbone for other proposed grids" that stress not only incorporation of new energy sources, but also "a cyber-secure SCADA system",[11] according to project manager David Molinaro. This conspicuous mention of cyber-security as a priority highlights both the pervasive importance of the cyber domain in security even a nearly entirely segregated microgrid and the need to consider the ways in which technology-driven improvements in capabilities may create new or enhanced risks.

Human Performance Enhancement

Militaries throughout the world are pursuing new means of driving **readiness** and ensure individuals are better prepared to deal with complex, high-stress, fast-moving modern operational and tactical environments. New bio- and neuro-technologies as well as applications of AI technologies are helping to drive many o these efforts at readiness, but increasingly militaries of all sizes are also pursuing accompanying non-technical skills and attributes, such as leadership. In addition, the employment of many of these technologies come with persistent, and in some—but not all—cases complicated ethical questions that some security and defence communities will approach differently.

"Genetic Passports": Russia is working to develop "genetic passports" for military personnel that would help determine which military personnel would be best suited for specific roles and functions, according to Alexander Sergeyev, the head of Russia's Academy of Sciences. The program reportedly also involves the Kirov Military Medical Academy, which conducts research in military medicine. Sergeyev described the objective in June 2019: "The idea is to understand on a genetic level who's more predisposed to serve in the Navy or who may be better-suited to become a paratrooper or tankman."[12]

The program's nomenclature and focus on genetic predispositions is, of course, understandably concerning to many, but its overall objective is not dissimilar to on-going U.S. Army research to find "chimera states" for soldiers performing specific tasks—essentially, to predict how humans might behave in "stressful, critical

[10] Burger, Andrew, "Contract Awarded to Build First of Six Demonstration Microgrids at Joint Base Pearl Harbor-Hickam", *Microgrid Knowledge*, 4 June 2019, https://microgridknowledge.com/military-microgrids-pearl-harbor/
[11] Burger, Andrew, "Contract Awarded to Build First of Six Demonstration Microgrids at Joint Base Pearl Harbor-Hickam", *Microgrid Knowledge*, 4 June 2019, https://microgridknowledge.com/military-microgrids-pearl-harbor/
[12] "Russian military seeks upper hand with genetic passports for soldiers, top scientist says", *Moscow Times,* 7 June 2019, https://www.themoscowtimes.com/2019/06/07/russian-military-seeks-upper-hand-with-genetic-passport-for-soldiers-top-scientist-says-a65927

situations that are associated with the military profession."[13] Overall, the debate over the ethics of various specific ways to drive enhanced endurance, strength, speed, resilience, survivability, accuracy, acuity, and decision-making in individual solders has become more prominent in military and security communities around the world.

Interest in genetic passports also reflect an expansion of the discussion of "cognitive warfare" beyond drone swarms, cognitive sensing, radios, and electronic warfare to incorporating ways to accelerate the fusion of the physical and digital worlds into the physiology of individual soldiers. As Sergeyev noted in a separate interview with RIA Novosti, "the wars of the future are already largely wars of intellects, those people who make decisions in conditions completely different from those that were before."[14]

Training and Readiness: China's President Xi Jinping gave a talk to cadets at the PLA Army Infantry Academy in Nanchang in May 2019 during which he stressed the need to increase the standard of China's combat forces to address two challenges. First, China has not been involved in a military conflict since its 1979 war with Vietnam. This lack of operational and command experience along with a rigid and centralized command structure are frequently cited as a vulnerability for China's military.

Second, the changing nature of warfare generally and the maturing of China's military capabilities has placed a premium on recruiting a different type of soldier than China—and many other militaries around the world—have typically recruited. According to Bates Gill of Australia's Macquarie University, "The Chinese military will

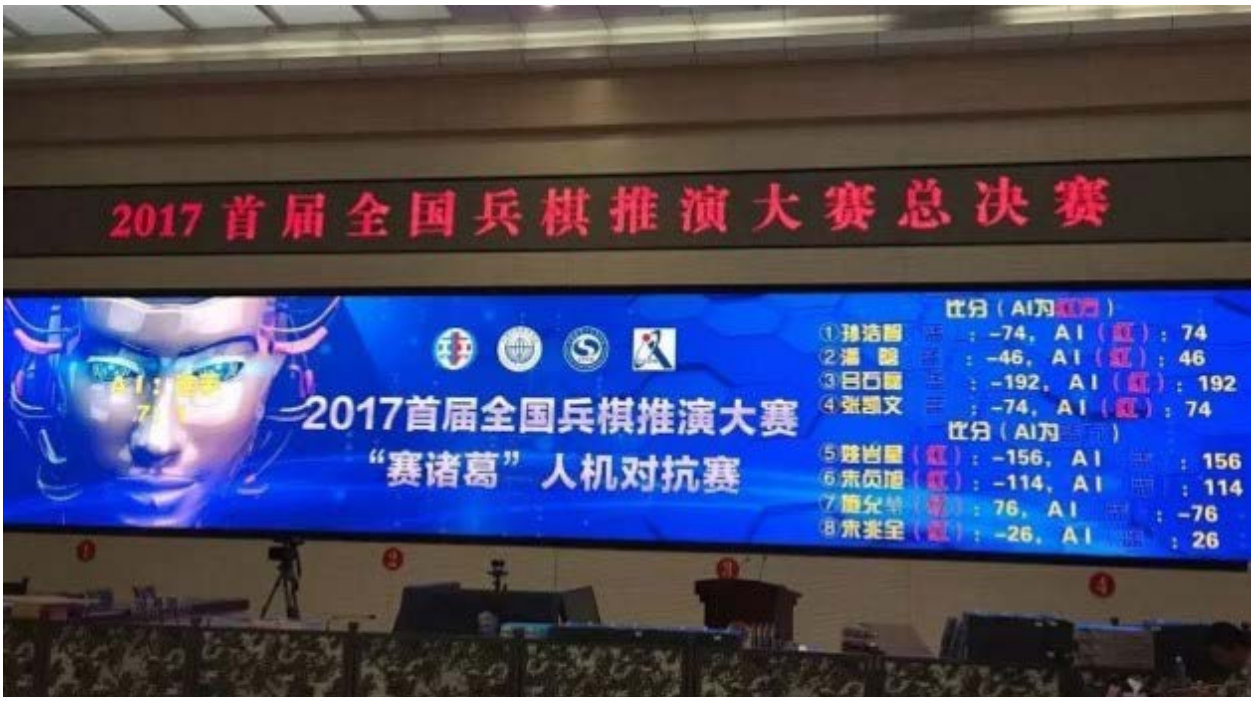

Figure 2: A video screen background from the 2017 "National Wargame Competition" (Quanguo Bingqi Tuiyan Dasai, 全国兵棋推演大赛) sponsored by the China Institute of Command and Control. (Source: The Jamestown Foundation)

[13] Doffman, Zak, "Russia Will Genetically Test Soldiers To Identify The Best Fighters And Thinkers", *Forbes,* 8 June 2019, https://www.forbes.com/sites/zakdoffman/2019/06/08/russias-new-genetic-military-passports-will-sort-the-fighters-from-the-thinkers/#68f66dcc2a6e

[14] Doffman, Zak, "Russia Will Genetically Test Soldiers To Identify The Best Fighters And Thinkers", *Forbes,* 8 June 2019, https://www.forbes.com/sites/zakdoffman/2019/06/08/russias-new-genetic-military-passports-will-sort-the-fighters-from-the-thinkers/#68f66dcc2a6e

increasingly depend on more technologically advanced weaponry systems, including in the cyber, aerospace, and outer space realms, all of which will demand more highly-skilled personnel." This can be a problem for China, which has a relatively low level of education for its military recruits. 2010 survey data showed that only about half of China's 2.3 million personnel had a middle-school education. This ratio has undoubtably improved in the decade since, but it still remains a frequently-cited challenge for China's military forces[15]—and one that.is shared by most militaries around the world who are confronted with trying to train personnel to better cope with fast-moving, complex, high-tech operational environments.[16]

This challenge is actually driving growing interest and, in some countries, tangible demand for the incorporation of new AI and big data technologies to enhance training and simulations. For example, the Director of Science, Models, and Simulations for the U.S. Army's Training and Doctrine Command (TRADOC) noted in early 2018, "If we can marry big data and AI with [modelling and simulation] … that's an unbeatable advantage for not only the nation but our DoD and where we're trying to go…I'm really excited about the potential here."[17] Similarly, in September 2016, the European Defence Agency (EDA) launched a study known as 'Big Data in Defence Modelling and Simulation' (BIDADEMS) aimed at better understanding how big data and deep learning could "potentially help to provide simplified military simulation designs, generate more realistic simulation scenarios and environments, improve the exploitation of simulation results or provide new opportunities for M&S support to military test and evaluation (T&E) activities."[18] The follow-on MODSIMMET program seeks to leverage these technologies to more accurately simulate "very complex scenarios like hybrid warfare."[19]

China analyst Elsa Kania noted in an April 2019 article on China's incorporation of AI into simulation and training hat "going forward, the PLA's evident interest in the application of AI to war-gaming constitutes a notable direction of development" and that "these activities can produce data that is valuable to training AI systems for advances in war-gaming and novel techniques for decision-making."[20]

Extreme Weather Gear and . . . Leadership: In June 2019, Military.com reported the U.S. Army is testing new, extreme cold weather gear designed to be lighter, better – fitting, and more effective in colder conditions than the current system. The system is designed to offer protection down to negative 65 degrees Fahrenheit. The current Gen III Extended Cold Weather Clothing System is a seven-level system built to offer protection

[15] For example, Nurkin, Tate et. al, "China's Advanced Weapons Systems", Jane's by IHS Market as published by the U.S.-China Economic and Security Review Commission, May 2018, https://www.uscc.gov/sites/default/files/Research/Jane%27s%20by%20IHS%20Markit_China%27s%20Advanced%20Weapons%20Systems.pdf

[16] Huang, Kristin, "China's long battle to build a better soldier for a modern fighting force", *South China Morning Post,* 25 May 2019, https://www.scmp.com/news/china/military/article/3011794/chinas-long-battle-build-better-soldier-modern-fighting-force

[17] Tadjdeh, Yasmin, "Big Data, AI to Advance Modeling and Simulation", *National Defense*, January 3, 2018, http://www.nationaldefensemagazine.org/articles/2018/1/3/big-data-ai-to-advance-modeling-and-simulation

[18] European Defence Agency, "EDA Studies Points Towards Big Data Potential for Defense", https://www.eda.europa.eu/info-hub/press-centre/latest-news/2017/12/18/eda-studies-points-towards-big-data-potential-for-defence

[19] European Defence Agency, "EDA Studies Points Towards Big Data Potential for Defense", https://www.eda.europa.eu/info-hub/press-centre/latest-news/2017/12/18/eda-studies-points-towards-big-data-potential-for-defence

[20] Kania, Elsa, "Learning Without Fighting: New Developments in PLA Artificial Intelligence War-Gaming", *Jamestown Foundation,* China Brief, Volume 19, Issue 7, https://jamestown.org/program/learning-without-fighting-new-developments-in-pla-artificial-intelligence-war-gaming/

at negative 60 degrees Fahrenheit, though researchers at the Army's Combat Capabilities Development Command Soldier Center believed the system only performs at "negative 40, negative 45."[21]

Next generation uniforms will incorporate lessons learned from an Army scientist research expedition to the Arctic with U.S. and Canadian forces in March 2019, in part to study the Canadian Inuit population. Army researcher Dr. Karl Friedl observed that "There are several lessons the U.S. Army can learn from the Canadian Inuit rangers in order to be a lethal Arctic force." And, critically, for any military – small or large—the advantages to enhancing human performance in these extreme cold weather environments goes well-beyond clothing or even physical preparation. Again from Dr. Friedl, "Most importantly, the role of great leadership and preparation in such an unpredictable environment, as well as learning how to be comfortably cold, is vital to success."[22]

Cyber and C4ISTAR

This report consolidates Cyber and C4ISTAR developments into two main themes that have been touched on in previous volumes; namely the centrality of the electromagnetic spectrum to modern conflict and the growing role of AI in exploiting the fusion of peace and conflict, the physical and digital, and reality and perception to create highly-destabilizing and difficult to detect threats to militaries, to be sure, but also to states and societies.

Electronic Warfare (EW) Conflict Charges Up: Competition in the electromagnetic spectrum has intensified over the last several months as new capabilities that could potentially affect the operations of all militaries throughout the world are fielded.

Russia and China have been particularly aggressive in developing and deploying EW capabilities, and the United States took several steps during the reporting period to reduce what is perceived as heightened vulnerability to these EW capabilities. Notably, the Department of Defense has reportedly established a team explicitly dedicated to dealing with the growing threat of Russian jamming of U.S. military technology, based on the U.S. military's experience in Syria. Members from across the DoD will work "to regain U.S. dominance in the electromagnetic spectrum" and identify existing gaps in the U.S. EW approach.[23]

In addition, on 3 June 2019, the U.S. Congress' House Armed Services Committee released a draft version of the annual defence policy bill that reassess the comptroller general of the Department of Defense to reassess its EW and electromagnetic spectrum operations strategy and implementation efforts. The comptroller general must brief the committee by 1 March 2020. According to the draft document: "The committee is concerned about the extent to which the Department is planning and preparing to defend itself and operate in an environment where peer and near-peer adversaries could use existing and emerging capabilities that degrade use of the electro-magnetic spectrum."[24]

It is this concern about state and non-state actors using "existing and emerging capabilities" that should concern militaries around the world, not just the United States. Threats to militaries of all sizes effectively leveraging the electromagnetic spectrum have already proliferated and are already being deployed—as evidenced both by the general concern within the most advanced military in the world and credible reporting of Russian jamming operations in Syria and of NATO exercises such as Trident Juncture 2018.

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[21] Cox, Matthew, "Full Details: Army to Test New Extreme Cold Weather Gear Next Year", *Military.com*, 7 June 2019, https://www.military.com/daily-news/2019/06/07/full-details-army-test-new-extreme-cold-weather-gear-next-year.html
[22] Roussel, Mallory, "Scientist Joins Soldiers to Study Cold Weather Gear in Arctic", *U.S. Army.mil*, 2 April 2019, https://www.army.mil/article/219607/scientist_joins_soldiers_to_study_cold_weather_gear_in_the_arctic
[23] Detsch, Jack, "After Syria, Pentagon Ramps Up Electronic Warfare Efforts", *Al-Monitor,* 31 May 2019, https://www.al-monitor.com/pulse/originals/2019/05/us-defense-pentagon-team-threat-russia-electronic-war.html
[24] Pomerleau, Mark, "A House panel wants to see these 5 data points on electronic warfare", *C4ISRNet,* 4 June 2019, https://www.c4isrnet.com/electronic-warfare/2019/06/03/a-house-panel-wants-to-see-these-5-data-points-on-electronic-warfare/

"Deep Fakes" Progressing: Artificial intelligence technologies are being applied in a growing range of ways to enable new or enhanced defence and security capabilities. Some of these capabilities build resilience for the security and stability of states and society while others create new opportunities for deception, such as "deep fakes", and, as a result, present real and present challenges to this stability and security. Deep fakes use computer programs to create realistic face or voice swaps in images or videos. AI is used to help stitch the replacement image onto the original.

One type of deep fake-related application garnering more concern is the use of adversarial examples to affect the representation of geography and topography. Adversarial examples are inputs to machine learning models and neural networks that an attacker has intentionally designed to cause the model to make a mistake. Artfully crafted adversarial examples are particularly challenging not only because they generate optical illusions for machines"[25], but also because the disconnect between the physical world reality supposedly being captured in an image and the manufactured perception the adversarial example has created is extremely difficult for either humans or machines to detect.

In a strictly military context, these applications can trick a neural network into seeing physical objects or aspects of landscape that do not exist or are, in fact, something else. Moreover, the use of adversarial examples outside of the explicitly military or security context could pose precisely the sort of threats to the faith in government's ability to keep up with modernity that are appealing in a world in which states of peace and conflict are fusing.

Manned Platforms

Unmanned systems are, of course, taking on more defence and security roles—as discussed in the Robots and Unmanned Systems section below. However, the representative samples included in this report demonstrate in stark relief the continued importance of manned platforms and the firepower they bring as well as the ability to drive new efficiencies in the design, manufacturing, and maintenance of these platforms.

Demand for the Fighters of Today . . . and Tomorrow: *Aviation Week* released analysis on 30 May 2019 that the current global fighter market is the strongest in the last 27 years. While fighter deliveries grew just 4% in 2018 (by value) over 2017, aircraft now on production lines indicate 24% growth year-on-year in 2019. The analysis highlighted five main reason for the rapidly expanding market:[26]

1) Delivery of an expected 130 F-35s, up from 91 in 2018. Growth is forecasted to peak at 164 deliveries in 2023
2) Increased global defence spending, which, according to the Stockholm International Peace Research Institute (SIPRI), reached $1.822 trillion in 2018, a new record
3) Ageing fleets and high utilization conspire to drive demand for new aircraft
4) The need for double (and even triple) sourcing in order to reduce geopolitical risks associated with shifting alliances, complications of increasing geostrategic competition, and the potential for exports being limited or eliminated to specific countries due to human rights concerns
5) The renationalization of fighter industrial bases has led to new competitors and demand in home countries for platforms such as the KF-X (Korea), TF-X (Turkey), and Ching Kuo (Taiwan's fast-trainer variant)

These trends bode well for many advanced fourth and fifth generation fighter manufacturers over the next several years. However, there is already considerable interest in and exploration what the fighter of the future might look like. Dassault Systems displayed its scale model of the Future Combat Air System (FCAS) at the Paris Air Show in June 2019. FCAS is a joint sixth generation fighter program sponsored by the French and

[25]"Attacking Machine Learning with Adversarial Examples", *OpenAI,* February 24, 2017, https://openai.com/blog/adversarial-example-research/

[26] Aboulafia, Richard, "Opinion: The Best Fighter Market in 27 Years", *Aviation Week*, 30 May 2019, https://aviationweek.com/combat-aircraft/opinion-best-fighter-market-27-years

German Ministries of Defence. The aircraft is being designed in conjunction with Airbus and is expected to fly for the first time in 2026 and come into service well into the following decade.[27] The concept is still being designed, but one frequently cited approach is or the aircraft to be manned and networked with other unmanned aircraft.

In a wide-ranging interview with *Aviation Week* in June 2019, Philippe Lavigne, France's Air Chief of Staff, commented on the joint production of the aircraft , noting that "in every cooperation, you have the bilateral parts and the national ones", indicating a need for the system to take on a wide-range of missions. Lavigne also focused on FCAS' flexible and modular design: "You have to consider the FCAS as an Android-like operating system—it is open", in order to accommodate the uncertainty associated with planning for threats and missions in 2040.[28]

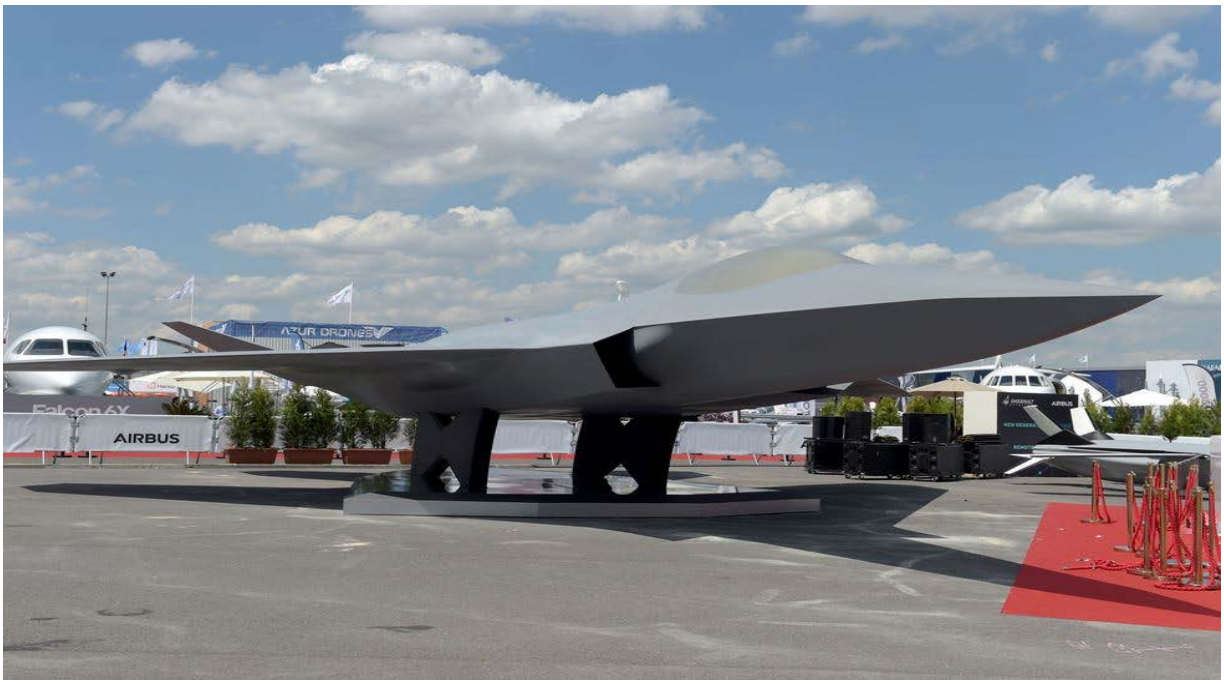

Figure 3: Dassault Systems FCAS scale model displayed at the Paris Airshow. (Source: Eric Piermont / Getty Images)

Russian Armor: More Platforms, More Firepower, More Flexibility: On June 4, 2019, Russian News Agency *TASS* reported that the Russian Army will receive more than 400 advanced and upgraded armoured vehicles later in 2019. Defense Minister Sergei Shoigu announced on the Ministry of Defense's conference call with media that the new platforms will "include T-72B3M tanks with the domestic sighting and observation system, T-90M 'Proryv-3' and T-80BVM tanks and BMP-1AM infantry fighting vehicles."[29]

Shoigu also listed a new T-15 infantry fighting vehicle based on the Armata platform and featuring the Kinzhal combat module and a 57mm gun. Approximately two weeks earlier on 21 May 2019, *TASS* reported that 57mm

[27] Insinnia, Valerie, "As Europe highlights sixth-gen fighters at Paris Air Show, US keeps its plans under wraps", *Defense News*, 16 June 2019, https://www.defensenews.com/digital-show-dailies/paris-air-show/2019/06/16/as-europe-highlights-sixth-gen-fighters-at-paris-air-show-us-keeps-its-plans-under-wraps/

[28] Dubois, Thierry and Osborne, Tony, "French Air Chief of Staff on Transformative New Aircraft and Upgrades", *Aviation Week*, 4 June 2019, https://aviationweek.com/defense/french-air-chief-staff-transformative-new-aircraft-and-upgrades

[29] "Russian Army to get over 400 advanced armored vehicles this year", *TASS,* 4 June 2019, https://tass.com/defense/1061575

were increasingly being considered to replace 30 mm guns on Russia's light and medium-armoured vehicles in order to "securely strike foreign armoured vehicles".[30] The article quoted Viktor Murakhovsky, the Editor-in-Chief of the Arsenal of the Fatherland journal, as saying that the additional firepower is required to deal with "the British (infantry fighting vehicle) from BAE Systems, the German and promising US vehicles, on which they have recently reopened their program", which "can withstand, as they claim, frontal armour hits by 30 mm projectiles." Murakhovsky also noted that a 57 mm gun could "in principle" be mounted on the Kurganets and Bumerang platforms as well.

The 57 mm guns offer an additional advantage beyond firepower: flexibility to strike the range of targets it is likely to confront on a modern battlefield: drones, loitering and guided munitions, combat helicopters, attack planes, and other low-speed and low-flying targets in addition to Western armoured vehicles[31].

A New Design Age?: New techniques—from additive and digital manufacturing, to virtual and augmented reality manufacturing to synthetic biology manufacturing—and new materials are fundamentally changing the way platforms and systems are designed and manufactured, potentially ushering in a new Design Age in which manufacturing processes no longer constrain design concepts.

Evidence of the antecedents of this change for all militaries and defence industrial bases is already being seen in the design and manufacturing process of some of the most expensive and complex platforms in the world. In May 2019, *Defense News* reported on how "robots and lasers" are being used to repair and overhaul the USS George Washington nuclear-powered aircraft carrier.[32]

Shipyard workers are beginning the overhaul by laser-scanning the ship in order to create a digital model that will serve as the basis for the design and planning of subsequent Nimitz – class carriers. In fact, the USS Gerald Ford—the Navy's newest carrier and first in its class—was designed using digital data, as are the new Colombia-class nuclear submarines. For the third Ford-class carrier, the USS Enterprise, data from the ship's computerized blueprints are being fed into machines that fabricate parts, driving new efficiencies and sturdier platforms.[33]

Clearly not many militaries throughout the world will have an interest in using digital manufacturing to build carriers or nuclear-powered submarines. However, the technology is easily applicable to smaller platforms and for smaller and more focused militaries than that of the United States and can help reduce costs not only of production, but also of operations and maintenance of modern platforms and systems. Moreover, defence industry companies will look to new methods such as digital manufacturing to provide competitive advantages and lower costs in an increasingly competitive global export market.

Missile Systems and Munitions

The developments selected for this volume seek to highlight innovation in advanced potentially game-changing weapons such as directed energy, which is being applied to an expanding range of missions—from close-in defence, to self-protection of airplanes and tactical vehicles, to strategic missile defence. It also focuses on the need for advancing weapons that can capably defeat new or enhanced defensive measures—in this case body armour and missile defence.

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[30] "New 57mm caliber to help Russia's armor securely strike foreign armored vehicles—expert", *TASS,* 21 May 2019, https://tass.com/defense/1059302
[31] "New 57mm caliber to help Russia's armor securely strike foreign armored vehicles—expert", *TASS,* 21 May 2019, https://tass.com/defense/1059302
[32] Weisgerber, Marcus, "Robots and Lasers are Bringing Shipbuilding into the Digital Age", *Defense One,* 5 May 2019, https://www.defenseone.com/technology/2019/05/robots-and-lasers-are-bringing-shipbuilding-digital-age/156763/
[33] Weisgerber, Marcus, "Robots and Lasers are Bringing Shipbuilding into the Digital Age", *Defense One,* 5 May 2019, https://www.defenseone.com/technology/2019/05/robots-and-lasers-are-bringing-shipbuilding-digital-age/156763/

Lasers, Lasers, and More Lasers: The U.S. Air Force confirmed that on 23 April 2019, it successfully tested a ground-based laser that shot down several missiles in flight. The test of the Self-Protect High Energy Laser Demonstrator (SHiELD) program run by the U.S. Air Force Research Lab (AFRL) that is designed to develop an airborne laser that can protect aircraft from incoming missiles.[34]

This application of directed energy weapons—self-contained self-protection of individual aircraft from missiles—is admittedly exotic and especially high-end and is just one more step in leveraging this technology to not only offer enhanced missile defence for a broader range of platforms and fixed sites, but also to fundamentally alter the asymmetric cost curves associated with air and missile defence. At approximately $1 a shot, the low cost-deep magazine capability is considerably more efficient than launching $1 million or more interceptors at incoming threats. Even considering the constraints of directed energy weapons, this could be a strategically and operationally disruptive application of a rapidly advancing military technology area.

But it certainly wasn't the only notably news related to the advancement of or growing interest in laser weapons that occurred during the reporting period. The U.S. Navy revealed in May 2019 that it was planning to place the High Energy Laser and Integrated Optical-dazzler with Surveillance (HELiOS) system on the Arleigh Burke-class destroyer USS Preble in 2021. Lockheed Martin was awarded a $150 million contract to develop the 60 kw HELiOS in 2018.[35]

Lockheed Martin and Dynetics were awarded a $130 million contract in May 2019 to develop a 100 kw laser weapon as part of the U.S. Army's High Energy Laser Tactical Vehicle Demonstrator (HEL-TVD) program designed to place laser weapons on a "medium – sized tactical vehicle platform" to defend against missiles, rockets, artillery, and drones.[36] The award came only a few days after Rolls Royce unveiled on 10 May 2019 a new hybrid power source intended to continuously power 100 kw laser weapons. The internally-funded and developed integrated power and thermal management system uses the company's M250 helicopter engine, which allows it to generate roughly 300 kw of electrical power and 200 kw of thermal management capacity, though it also is considered hybrid because it combines a battery with the engine. Lockheed Martin and Dynetics will incorporate this system into the weapon they are developing for the U.S. Army.[37]

But interest in and discussion of directed energy weapons went well-beyond activity in the U.S. military during the reporting period. German news outlet Die Welt reported in mid-June that the German Navy will release a tender for the development of a laser weapon to be placed on the Braunschweig -class corvette K130 this summer. German company Rheinmetall and the German branch of MBDA are expected to be the main competitors in the procurement.[38] In addition, Russian President Vladimir Putin announced on 17 May 2019 that new types of laser weapons developed in Russia will significantly enhance the nation's military capability, singling out the Peresvet system, the first laser system to enter service in fall of 2018.[39]

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[34] Ferguson, Brian, "Air Force SHiELD Shoots Down Airborne Missile with Laser", *Stars and Stripes*, 6 June 2019, https://www.stripes.com/news/us/air-force-s-shield-shoots-down-airborne-missiles-with-laser-1.579873
[35] Liptak, Andrew, "The US Navy is planning to equip a destroyer with a laser system by 2021", *The Verge,* 29 May 2019, https://www.theverge.com/2019/5/29/18644581/us-navy-uss-preble-helios-high-energy-laser-military-destroyer
[36] Judson, Jen, "Dynetics-Lockheed Team Beats Out Raytheon to Build 100 Kilowatt Laser Weapon", *Defense News*, 15 May 2019, https://www.defensenews.com/land/2019/05/16/dynetics-lockheed-team-beats-out-raytheon-to-build-100-kilowatt-laser-weapon/
[37] Judson, Jen, "Rolls Royce unveils hybrid power system for laser weapons", *Defense News,* 10 May 2019, https://www.defensenews.com/industry/2019/05/10/rolls-royce-unveils-hybrid-power-system-for-laser-weapons/
[38] "Germany Joins Race to Acquire Laser 'Weapon of the Future'-Reports", *Sputnik*, 14 June 2019, https://sputniknews.com/military/201906141075871872-germany-laser-weapon-reports/
[39] "Putin hails new Russian laser weapons", *The Associated Press,* 17 May, https://www.apnews.com/ff03960c48a6440bacc1c2512a7c197a

Figure 4: The Persevet directed energy system (Source: Russian Ministry of Defense)

Tiny, High-Powered Rifles: This report has previously examined efforts by several militaries to develop better body armour and soldier protection capabilities. The improving quality of these new capabilities—leveraging new materials and sensors—is now the focus of a U.S. Army Research Lab effort to develop a small, lightweight infantry rifle with the ability to perform like an M4 carbine and fire rounds at high rates and with exceptional power capable of penetrating improved body armour, especially in urban or close-quarters combat. The barrel is reportedly only 10 inches long, but the gun has reportedly hit a muzzle velocity of 2,900 feet per second.

According to ARL engineer Zac Wingard, "The goal is to get rifle-like velocities out of a very small weapon that is high-capacity, that's either adaptable for room-clearing or confined spaces. Like you're getting in and out of vehicles or a subterranean environment, but also applicable for remotely operated systems."[40] The reference to subterranean environment is particularly interesting, given the increasing need for modern militaries to meet a growing range of threats in the under-ground environment (as well as undersea) where it is more difficult for nearly ubiquitous sensors to detect activity.

The Need for Speed: The quest for exceptional high-speed missiles and weapons to penetrate ever improving air and missile defence systems—including the potential for the deployment of new capabilities such as directed energy—is accelerating and intensifying in many militaries throughout the world with significant implications for all militaries—including smaller and mid-sized militaries—for the types of weapons likely to be in service in the next five years.

Russia has been especially aggressive in its pursuit—or at least its public discussion of its pursuit—of supersonic and hypersonic weapons. In May of 2019, Alexander Leonov, CEO of Russia's Tactical Missiles Corporation, discussed his companies on-going efforts to develop ever-faster cruise missiles with *TASS*. Leonov noted a

[40] Keller, Jared, "The Army is working on a tiny assault rifle that can punch clean through body armor", *Task and Purpose,* 3 June 2019, https://taskandpurpose.com/army-tiny-machine-gun-prototype

"general trend in the improvement of cruise missiles is towards brining their speed to the hypersonic level and increasing the range of their operations. This is the direction we are headed."[41]

Tactical Missiles Corporation is currently developing the Onyx supersonic anti-ship missile, which can be fired from frigates and submarines. Its maximum speed is not hypersonic—that is, at least five times the speed of sound—but at 2.5 times the speed of sound it is supersonic. Leonov also noted the importance of modularity and flexibility in missile applications, saying that he was looking to "make the missile universal both from the viewpoint of its targets and the launch platform that is used." Earlier in May, Russian President Vladimir Putin visited the Chkalov Flight Test Center to inspect a MiG-31 fighter armed with the hypersonic Kinzhal ("dagger") missile. The Kinzhal is an air-launched ballistic missile that is also nuclear capable and, according to Russia, can travel Mach 10. Previous reports have highlighted Russia's on-going efforts to develop the 3K22 Tsirkon hypersonic cruise missile that can reach Mach 6 and the ICBM hypersonic glide vehicle Avangard.[42]

Robotics and Unmanned Systems

Several novel concepts were displayed or revealed during the reporting period, each reflecting the race by manufacturers to create new unmanned system capabilities that can match growing security and defence industry demand for more flexibility in individual systems to carry out more missions, enhance soldier and platform safety, and create operational advantages.

New Designs and Products: The reporting period once again demonstrating the expanding variety of unmanned systems being pursued to support more missions by both industry and defence and security communities throughout the world. A few indicative examples:

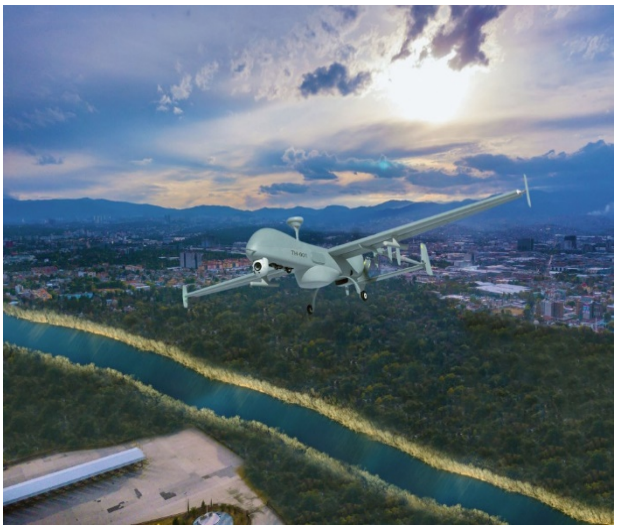

Figure 5: The T-Heron UAV (Source: IAI)

In June 2019 in advance of the Paris Air Show, Israel Aerospace Industries (IAI) revealed a new variant of its Heron unmanned aircraft system for the tactical end of the market. Known as the T-Heron, the UAV was described by *Jane's* as the "de facto entry-level platform for the Heron family of medium-altitude long-endurance UASs." It has a maximum speed of 120 kt and service ceiling of 24,000 feet and can carry a maximum payload of 180 kg. Other platforms in the family include the Heron 1, the Heron TP, the Heron TP-XP, and the Super Heron.[43]

IAI stressed the platform's "versatile design", noting that, according to Moshe Levy, IAI Executive Vice President and CEO of its Military Aircraft Division, "it rounds up the range of operational UAS solutions IAI offers to all forces on the battlefield: marine, air,

[41] Cole, Brendan, "Russia's Military Wants its Supersonic Cruise Missiles to Go Hypersonic", *Newsweek,* 28 May 2019, https://www.newsweek.com/russias-military-wants-its-supersonic-cruise-missiles-go-hypersonic-1437116
[42] Cole, Brendan, "Russia's Military Wants its Supersonic Cruise Missiles to Go Hypersonic", *Newsweek,* 28 May 2019, https://www.newsweek.com/russias-military-wants-its-supersonic-cruise-missiles-go-hypersonic-1437116
[43] Jennings, Gareth, "IAI launches new tactical T-Heron UAS", *Jane's, 4 June 2019*, https://www.janes.com/article/89032/iai-launches-new-tactical-t-heron-uas

ground and intelligence. IAI preserves its leadership position in UAS's with a continuous stream of solutions for the challenges posed in the field."[44]

Also in early June, BAE Systems completed the acquisition of Riptide Autonomous Solutions' unmanned underwater vehicle product line, the company will seek to integrate with new payloads and processing equipment to further develop the systems or emerging maritime mission roles, including electronic warfare roles. According to Riptide, it specializes in "sophisticated, yet simple" designs, further reinforcing an increasing common theme of the development of advanced military capabilities: exquisite technologies do not necessarily require exquisite designs.[45]

DZYNE Technologies announced in early June that it had developed an electric vertical take-off and landing (eVTOL) UAV that uses a whole wing as a rotor that does not compromise forward flight performance when transitioned to fixed-wing mode. The ROTORwing aircraft is not dissimilar to the manned tiltrotor aircraft discussed earlier in this report in that it is designed to optimize hovering and forward flight and leverages a simple design that uses motors on the wings to propel the aircraft directly, "eliminating the need for heavy and complex gearboxes, swashplates, and high-power tail rotors."[46]

A New Version for the Black Hornet: One particularly interesting new design or application of unmanned systems was seen during the IDEF 2019 exhibition held in Turkey from April 30 – May 3, 2019. FLIR Systems displayed a new version of the Black Hornet nano UAV. The system has been a popular one for individual soldier use and protection, according to Jens Olerud of FLIR, it has been sold to 34 countries throughout the world, including the United States, United Kingdom, and France.[47]

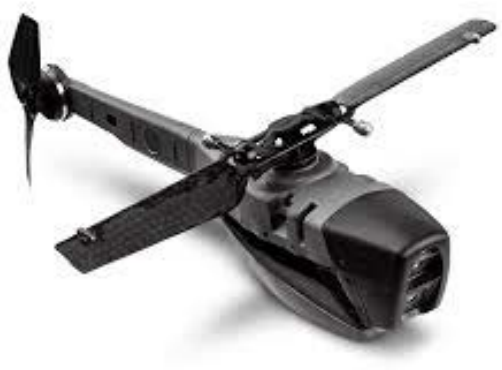

Figure 6: The Black Hornet UAV (Source: FLIR)

The new version allows the UAV to be integrated into a launch tube placed on a ground vehicle. The system has a range of 2 km and is designed primarily to provide vehicle and crew protection by offering close in flexible and 360-degree reconnaissance, especially in contested or static environments. Olerud noted in an interview with *Jane's* on the IDEF show floor that ground vehicle launched version is ideal for urban environments, rather than rapid manoeuvre missions over long-distances, given the relatively short range of 2 km, and that it could also provide life-saving intelligence of adversary or civilian placements inside buildings or in sub-terranean environments.

In addition to providing force protection, FLIR also stressed that the difficult to detect Black Hornet UAV can influence the battle of narratives that has become so central to modern warfare. In a strategic and operational environment in which the states of conflict and peace and reality and perception are fused, the ability to accurately depict the effects of kinetic strikes—battle damage assessment, essentially—and provide video evidence of those effects can be critical in establishing narratives and avoiding being placed on the defensive

[44] Ahronheim, Anna, "IAI Unveils Latest Tactical UAV: The T-Heron", *Jerusalem Post,* 4 June 2019, https://www.jpost.com/Israel-News/IAI-unveils-latest-tactical-UAV-the-T-Heron-591551
[45] Stevenson, Beth, "BAE Systems expands UUV offerings", *Jane's,* 4 June 2019, https://www.janes.com/article/89030/bae-systems-expands-uuv-offerings
[46] Host, Pat, "DZYNE Technologies develops electric whole-wing VTOL aircraft", *Jane's,* 4 June 2019, https://www.janes.com/article/89042/dzyne-technologies-develops-electric-whole-wing-vtol-aircraft
[47] "FLIR Unmanned Aerial System: Black Hornet UAV", Jane's by IHS Markit IDEF 2019 Coverage, *YouTube*, 24 May 2019, https://www.youtube.com/watch?v=uvGeYvtpPv8

by narratives that suggest effects different than those actually achieved—for example, an adversary claiming civilian casualties when none actually occurred.

Significantly, the new version of the Black Hornet—which was developed in conjunction with the Norwegian Ministry of Defence's research activity, FFI—is a modular system, distinguishing itself from earlier versions that were one piece. The rotor, battery, and camera can all be removed reducing costs of repair / replacement and down time of individual UAVs as they no longer have to be "sent back to Norway" to be fixed or replaced.[48]

Drone Biomimicry: Previous volumes of this report have focused on the advantages of biometric drones—drones that are designed to leverage the natural and adaptive movement of animals to create new or enhanced efficiencies in the movements or camouflage of unmanned systems Past reports have highlighted Russian drones designed to resemble the snowy owl and capable of "hiding in plain sight"[49] as well as European swarms based on the movement of "a school of fish and a flock of birds to help figure out how to make the drones fly together without colliding."[50]

In May 2014, South Korea's Yonhap News Agency reported that the Defense Acquisition Program Administration (DAPA) is pursuing the development of biomimetic robot systems designed to mirror the natural movements of animals and insects, with plans to field these biobots as early as 2024. According to DAPA spokesman Park Jeong-eun, "Biometric robots will be a game changer in future warfare, and related technologies are expected to bring about great ripple effects throughout the defence industry."[51]

[48] "FLIR Unmanned Aerial System: Black Hornet UAV", Jane's by IHS Markit IDEF 2019 Coverage, *YouTube*, 24 May 2019, https://www.youtube.com/watch?v=uvGeYvtpPv8
[49] Atherton, Kelsey, "New Russian owl drone will hunt tanks in northern warfare", *C4ISRNet,* 29 October 2018, https://www.c4isrnet.com/unmanned/2018/10/29/new-russian-owl-drone-will-hunt-tanks-in-northern-warfare/
[50] Kabash, Madis, "Scientists have invented an autonomous flock of drones that think collectively", *Quartz,* 24 July 2018, https://qz.com/1333190/scientists-have-invented-a-group-of-self-flying-drones-that-think-collectively/
[51] "South Korea to develop bio-inspired military robots for future warfare", *Yonhap News Agency,* 12 May 2019, https://en.yna.co.kr/view/AEN20190510008000325