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DEFTECH Military Capabilities Update

February 2019

OTH INTELLIGENCE GROUP
Trusted Expertise. Innovative Analysis. Forward Thinking.

Dear Reader,

We are definitely living a fascinating, high-paced technology developments period. What was only thinkable yesterday rapidly becomes a prototype and the sensation of acceleration in what could be possible today can create some dizziness even to the most forward-thinking people. Supporting this acceleration is definitely the dual-use (Civilian-Military) strategy pushed by some actors in certain areas to gain in speed, acceptance, affordability and experience.

As the technology megatrends are well identified, we are presenting here their declinations into envisioned and sometimes visionary practical and operational uses by different actors. Where possible, we also tried to indicate what it could mean to support and enable these different innovations.

Building on the previous release of the DEFTECH Update, we are bringing you these latest developments and efforts regrouped in the six initially selected categories:

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

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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Executive Summary

Key themes and insights that emerged across categories, both in the stories incorporated into this report and other developments over the reporting period not explicitly covered herein include:

Intersections with Commercial Innovations: Across nearly each of the six chapters of this volume, there is a notable convergence between commercial and military requirements and research and development priorities. Many defence communities are searching for more efficient and rechargeable batteries for their vehicle fleets while Honda is working with NASA's Jet Propulsion Lab to develop fluoride-ion batteries to drive electric car sales. Russia's new "futuristic mini-sub" that can be used for special forces insertion was originally commissioned by Russian gas and oil giant Gazprom. Lockheed Martin's OYNX exoskeleton featured in this report was reportedly originally developed to support medical purposes. New tunnel exploring robots were developed initially to inspect and monitor oil pipelines and facilities. These cross-functional connections are not necessarily new. The convergence of the high-tech and other capital-intensive industries and defence industry has been on-going for several years. Nonetheless, the connections are growing more substantial and offer an opportunity for defence and security communities to develop new models for engagement with and, critically, procurement of commercial off-the-shelf technologies.

Comfort of Use: Technical challenges are one component of the move from a compelling concept to an actual and impactful military capability. This report highlights some of the adjacent innovations required to complete this process. This challenge is particularly visible in U.S. Army efforts to develop and deploy mini-nuclear reactors to support forward operating bases. The Army believes this initiative will be constrained less by technical challenges—which it anticipates resolving within five years—than by regulatory and comfort of use issues related to portable nuclear energy. It is also seen in the on-going discussion in scientific and defence communities around the world focused on the ethics of artificial intelligence applications. In January of 2019, China's government appointed Chen Xiaoping, a leader in artificial intelligence development in China, was appointed to lead a commission on artificial intelligence ethics.

Catalysts of Innovation: Leveraging biological processes as a catalyst of and channel for innovation in military capabilities features prominently in this report, whether it be copying the morphing wings of gulls for long-endurance unmanned aerial vehicles or using synthetic biology to create new anti-submarine warfare capabilities. Similarly, the report also reveals a growing focus on new materials (and accompanying designs) enabled by innovation in composites, synthetic biology, and low observable technologies. For example, the testing of a Wing Loong I unmanned aerial system with a fully composite fuselage or the incorporation of exceptionally strong acrylic windows on a Russian manned deep-diving submersible. Or an additional development that does not feature in the report: collaboration between Boeing and NASA on new wing designs for commercial aircraft that incorporate below wing trusses, which will increase plane speed.

Integrating Domain Area Competitions: Last month's report emphasized the competitiveness of several critical domain areas shaping military balances and capability requirements. This report certainly reinforces the importance of space, the information domain, the electromagnetic spectrum, undersea and underground, and missile versus missile defence. However, it also seeks to augment this analysis by stressing the growing imperative for militaries to better integrate their offensive and defensive activities *across* those competitive domains to achieve coordinated effects. For example, the concept of multi-domain operations is the impetus behind the U.S. Army's new I2CEW (Intelligence, Information, Cyber, Electronic Warfare, and Space) organization as well as the PLA's (People's Liberation Army) Strategic Support Force, which turned three during the reporting period.

Energy, Power, and Propulsion

Defence and security communities are developing novel means of increasing the range, endurance, efficiency, and mission effectiveness of platforms and systems. The last volume highlighted some particularly promising developments in military technology—particularly hydrogen fuel cells and lithium-ion batteries. This reporting period revealed more creative commercial and military solutions—including miniature nuclear reactors—for the energy, power, and propulsion challenge.

Electric Vehicle Interest and Novel Research The UK Ministry of Defence (MoD) released a request for information (RFI) to evaluate hybrid and fully-electric drive technologies for its fleet of wheeled platforms in December 2018. The RFI described a two-phase effort. Phase One would focus on "capability investigation" into electric drive technologies while the Phase Two would centre on capability demonstration on in service vehicle. The MoD hopes the project will help identify benefits and constraints in electric vehicle drive technologies, including the potential vulnerability to electronic warfare attacks.[1]

Interest in electronic vehicle propulsion is not limited to military communities, of course. As the electronic vehicle market grows world-wide, auto manufacturers and applied research institutes are both working to develop technologies that can generate much higher degrees of energy efficiency while not adding weight or increasing the environmental impact of operations, many of which have potential applications for military vehicles and platforms.

In December 2018, researchers from Japanese auto-maker Honda, working with the California University of Technology and NASA's Jet Propulsion Laboratory published an article in *Science* magazine that described successful experimentation with fluoride-ion batteries (FIBs). FIBs are capable of significantly out-performing lithium-ion batteries "with a less severe environmental impact."[2] Honda claims the battery offers between eight-and-ten times greater energy per volume than lithium-ion batteries, meaning FIBs can store more energy and, as a result, create more range for the vehicles in which they are used.[3]

FIBs themselves are not a new technology. However, because they generate electricity by moving fluoride ions from one electrode to another through a solid fluoride-ion conducting electrolyte, they need to be heated above 150 C, which limits its utility. The breakthrough achieved by the Honda team was the development of a liquid electrolyte that is capable of moving fluoride ions at room temperature.[4]

Jun Liu, a specialist in energy storage materials at Pacific Northwest National Laboratory, noted that "These results open up new opportunities for the scientific community" to develop a sustainable FIB solution.[5] The results also potentially open up an opportunity for defence communities and the industry to address the challenges and opportunities associated with improving vehicle power issues.

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[1] Turnbull, Grant, "UK kicks off electric vehicle drive study", *Jane's.com*, 9 January 2019, https://www.janes.com/article/85620/uk-mod-kicks-off-electric-vehicle-drive-study
[2] Edelstein, Stephen, "Honda Claims Breakthrough in New Battery Tech That Offers Longer Range, Greener Operation", *The Drive,* 7 December 2018, http://www.thedrive.com/tech/25354/honda-claims-breakthrough-in-new-battery-tech-that-offers-longer-range-greener-operation
[3] Edelstein, Stephen, "Honda Claims Breakthrough in New Battery Tech That Offers Longer Range, Greener Operation", *The Drive,* 7 December 2018, http://www.thedrive.com/tech/25354/honda-claims-breakthrough-in-new-battery-tech-that-offers-longer-range-greener-operation
[4] Jacoby, Mitch, "Fluoride-ion battery runs at room temperature", Chemical and Engineering News, 10 December 2018, https://cen.acs.org/materials/energy-storage/Flouride-ion-battery-runs-room/96/web/2018/12
[5] Jacoby, Mitch, "Fluoride-ion battery runs at room temperature", Chemical and Engineering News, 10 December 2018, https://cen.acs.org/materials/energy-storage/Flouride-ion-battery-runs-room/96/web/2018/12

Mini-Nuclear Reactors: In January 2019, the U.S. Strategic Capabilities Office (SCO) put out a request for information on the viability of using small nuclear reactors to support deployed troops in places like Afghanistan.

"Project Dilithium" is designed to identify and develop designs for small nuclear reactors capable of fitting on a truck or in a C-17 cargo plane. The reactor would be capable of producing 1 – 10 mw of energy for three years without refuelling and would need to be stood up within 72 hours and taken down within a week. Reporting on the SCO's request indicated that it is already considering three prototype designs.[6]

U.S. Department of Defense (DoD) interest in mini-reactors as experienced a renaissance since a 2016 Defense Science Board report that stressed the "opportunity for exploration of the use of nuclear energy applications at forward and remote operating bases and expeditionary forces."[7] In October 2018, the U.S. Army released a report highlighting the operational, environmental and economic impacts of the use of modular nuclear energy, saying: "the return of nuclear power to the Army and DOD will have a significant impact on the Army, our allies, the international community, commercial power industry, and the nation."[8]

The initiative is a creative effort to fundamentally address the significant logistical and force protection challenge of delivering hundreds of thousands of gallons of fuel to forward-deployed bases. And it seems that the technology is unlikely to be the main challenge for deployment. According to *Defense One* reporting, Andy Erickson, the deputy principal associate director of Global Security at Los Alamos National Labs, recently forecast that microreactors could be ready for deployment in "less than five years."[9] Rather, the main obstacle will be around regulations and 'comfort of use' issues.

Figure 1: Using "tiny nuclear reactor" for deployed troops[6].

[6] Tucker, Patrick, "US Military Eyes Tiny Nuclear Reactors for Deployed Troops", *Defense One,* 24 January 2019, https://www.defenseone.com/technology/2019/01/us-military-eyes-tiny-nuclear-reactors-deployed-troops/154406/
[7] Tucker, Patrick, "US Military Eyes Tiny Nuclear Reactors for Deployed Troops", *Defense One,* 24 January 2019, https://www.defenseone.com/technology/2019/01/us-military-eyes-tiny-nuclear-reactors-deployed-troops/154406/
[8] Tucker, Patrick, "US Military Eyes Tiny Nuclear Reactors for Deployed Troops", *Defense One,* 24 January 2019, https://www.defenseone.com/technology/2019/01/us-military-eyes-tiny-nuclear-reactors-deployed-troops/154406/
[9] Tucker, Patrick, "US Military Eyes Tiny Nuclear Reactors for Deployed Troops", *Defense One,* 24 January 2019, https://www.defenseone.com/technology/2019/01/us-military-eyes-tiny-nuclear-reactors-deployed-troops/154406/

Human Performance Enhancement

For all the investment in unmanned systems and advanced platforms over the last decade, militaries around the world have not yet devised means of removing humans from defence and security operations. As a result, defence communities are now focused on how best to optimize human effectiveness, especially under the extraordinary physical, psychological, cognitive, and emotional duress of military operations. Some of the technologies and concepts being explored are not necessarily novel. Exoskeletons will reduce fatigue and enhance endurance, safety, and strength, and benefit greatly from advances in robotics and materials. However, research on exoskeletons is not a function of the last two or even five years. Other research focus areas are indeed novel, ranging from integration of human and machine learning, and manned – unmanned teaming to allow operators to better cope with the stresses of a complex, information saturated, and dynamic operating environment.

Exoskeleton Research Advancing: In January 2019, the Russian government announced that certification tests of Russia's first-ever passive exoskeleton, EO-1, will be completed by the end of 2019, according to Russian state media organization, TASS.[10] The EO-1 system began testing three years ago and has seen operational testing in Syria in March and April of 2017. Major Artyom Chistobayev told TASS that the "exoskeleton was used in combat conditions for clearing the terrain and Palymra's historical sites of mines."[11]

The exoskeleton will have multiple applications on the battlefield. It is currently envisioned as being used by operators of the mine-clearing robot Uran-6. The EO-1 is designed to ease the load on the body of a soldier carrying cargoes up to 50 kilograms during long marches and in assault operations. It requires no batteries, control systems, or sensors and provides protection for the joints and spine.[12]

The U.S. Army also sought to advance exoskeleton research and development during the reporting period. In mid-December, U.S. Army researchers and soldier equipment officials held the three-day User Touch Point event, which allowed technology vendors, requirement developers and engineers to gain soldier insights on current exoskeleton technology. According to Raul Esteras-Palos, who works in the Robotics Requirements Division of the Capabilities Development and Integration Directorate at Fort Benning, Georgia, the event "provided [hands-on] experience to the movement and manoeuvre soldiers of some of the top seven combat [military occupational specialties]".[13]

The event came on the heels of a $6.9 million, two-year Army contract to Lockheed Martin to improve Onyx, a powered, lower-body exoskeleton designed to increase a soldier's strength and endurance, allowing soldiers to arrive to a fight far less fatigued. According to Keith Maxwell, exoskeleton technologies program manager at Lockheed Martin, "innovative human/machine technologies like Onyx can improve human performance, decrease injury and reduce fatigue to help soldiers accomplish physically demanding tasks."[14] The system is being developed for military purposes, however, the exoskeleton was originally designed for medical purposes such as assisting people who are partially paralyzed in walking and other tasks. with mobility issues,[15] reflecting the growing demand for exoskeletons in the medical and healthcare industry spurred by the evolution of new and lighter composite materials and more advanced robotics.

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[10] "Certification testing of first combat exoskeleton to be over by 2020", *Tass,* 21 January 2019, http://tass.com/science/1040988
[11] "Certification testing of first combat exoskeleton to be over by 2020", *Tass,* 21 January 2019, http://tass.com/science/1040988
[12] "Certification testing of first combat exoskeleton to be over by 2020", *Tass,* 21 January 2019, http://tass.com/science/1040988
[13] Cox, Matthew, "Soldiers Tell Industry What They Want from Exoskeleton Technology", *Military.com*, 18 December 2018, https://www.military.com/kitup/2018/12/18/soldiers-tell-industry-what-they-want-exoskeleton-technology.html
[14] Carlson, Stephen, "Lockheed tapped for Onyx exoskeleton development, demonstration", *UPI,* 29 November 2018, https://www.upi.com/Defense-News/2018/11/29/Lockheed-tapped-for-Onyx-exoskeleton-development-demonstrations/5821543512432/
[15] Carlson, Stephen, "Lockheed tapped for Onyx exoskeleton development, demonstration", *UPI,* 29 November 2018, https://www.upi.com/Defense-News/2018/11/29/Lockheed-tapped-for-Onyx-exoskeleton-development-demonstrations/5821543512432/

Human Performance Workshop: In early February 2019, experts from the U.S. military, academia, and defence and high-tech industries attended the Human Performance Workshop, organized by the U.S. Department of Defense's Close Combat Lethality Task Force. The workshop was designed "to develop recommendations on potential programs that address the challenges of physical preparedness in close-combat formations and the increasing cognitive demands of modern combat," said the workshop coordinator Army Colonel Joey Polanco.[16]

A key area of focus of the workshop, according to DoD reporting, was the need to improve "squad decision-making at the time of need during complex, dynamic operations".[17] Some participants noted that squad-level technologies do not incorporate artificial intelligence-related capabilities that would enable warfighter / AI teaming. This is actually the specific focus of DARPA's on-going Squad X program. According to DARPA, the SquadX Core Technologies program is designed to develop precisely the sort of novel technologies of interest to the DoD workshop that would "extend squad awareness and engagement capabilities without imposing physical and cognitive burdens."[18] Specifically, the program seeks to facilitate development and deployment of "new, lightweight, integrated systems that provide infantry squads awareness, adaptability, and flexibility in complex environments" and to allow dismounted soldiers and Marines to "more intuitively understand and control their complex mission requirements."[19] The program is focused on four technological areas: precision engagement, non-kinetic engagement, squad sensing, and squad autonomy.

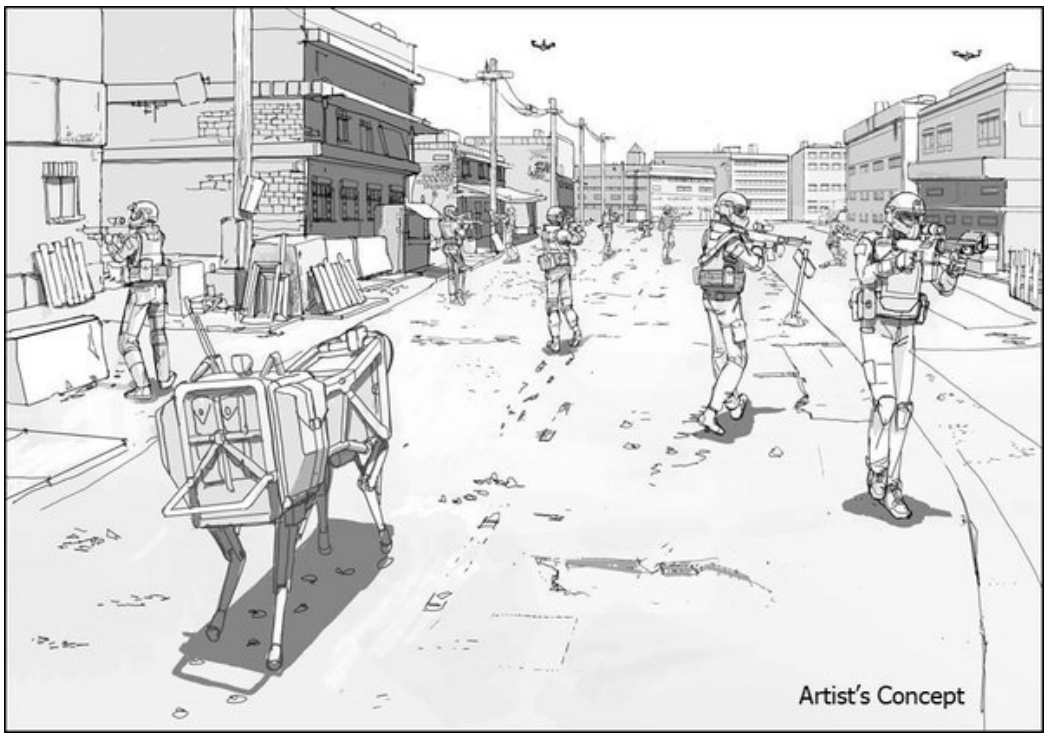

Figure 2: SquadX Artist Concept (18)

[16] Lopez, C. Todd, "Improving Combat Lethality Performance", *U.S. Department of Defense*, 5 February 2019, https://www.defense.gov/explore/story/Article/1748084/improving-combat-lethality-performance/
[17] https://www.defense.gov/explore/story/Article/1748084/improving-combat-lethality-performance/
[18] South, Todd, "DARPA program blending robots in the squad to find and destroy threats", *Military Times.com,* 30 December 2018, https://www.militarytimes.com/news/your-army/2018/12/30/darpa-program-blending-robots-in-the-squad-to-find-and-destroy-threats/
[19] [19] South, Todd, "DARPA program blending robots in the squad to find and destroy threats", *Military Times.com,* 30 December 2018, https://www.militarytimes.com/news/your-army/2018/12/30/darpa-program-blending-robots-in-the-squad-to-find-and-destroy-threats/

Cyber and C4ISTAR

The information domain has become a central part of modern conflict and geostrategic competition, and the volume of reporting on and analysis of cyber and C4ISTAR activity reflects this prominence. Increasingly, though, savvy military and security communities are seeking means of breaking down silos commonly associated with the information domain and modern military communications, connecting space, cyber, information warfare, and electronic warfare. Developing and deploying applications of artificial intelligence technology is an equally prominent component of the evolving Cyber and C4ISTAR discussion in defence and security communities throughout the world.

Organizing for Multi-Domain Warfare: The U.S. Army activated its first Intelligence, Information, Cyber, Electronic Warfare, and Space (I2CEWS) detachment in January 2019 in an effort to better organize and prosecute multi-domain warfare. The battalion-level command will be based at Fort Lewis, Washington and will have an Indo-Pacific focus. A second detachment is expected to follow with an emphasis on Europe and countering Russia.[20]

The unit will consist of four companies: Intelligence, Information Operations, Cyber and Electronic Warfare, and Space and Signal. It will also include "a long-range sensing section that will "enable precision fires and support artillery, air, and missile defence", though it is not entirely clear in which company this section will reside.[21]

The I2CEWS unit is similar in its purported function to China's Strategic Support Force, which the PLA established on 31 December 2015. The PLASSF combined then-extant PLA units focused on cyberspace, space, and electronic warfare. The establishment of this organization "reflects the on-going Chinese effort at being able to establish 'information dominance'[22] and is central to China's efforts to achieve more fully execute operations associated with the concept of "integrated network electronic warfare" (INEW). [23] In December of 2018, *The Diplomat* published analysis from Elsa Kania that assessed the PLASSF's development three years after its founding. Among the key take-aways was that "the PLASSF's construction appears to be advancing considerably."[24] Together, the establishment of the I2CEWS unit and the third anniversary of the founding of the PLASSF mark a fundamental shift, albeit at an early stage, in operational concepts and approaches to conflict in the modern strategic and operational environment by more effectively coordinating activities *across* each of these domains.

Synthetic Biology and Anti-Submarine Warfare: The United States Naval Research Lab (NRL) is examining the potential military applications for engineered organisms, including undersea detection of submarines and other military assets. One example: use of an abundant sea organism, such as marinobachter, and change its genetic make-up to react to certain substances created by enemy vessels or equipment—metals, fuels, exhaust, human DNA. According to NRL researcher Sarah Glaven "In an engineered context, we might take the ability of the microbes to give up electrons, then use (those electrons) to talk to something like an autonomous vehicle.

[20] Freedberg, Sydney J., "Hack, Jam, Sense & Shoot: Army Creates 1st Multi-Domain Unit", *Breaking Defense*, 24 January 2019, https://breakingdefense.com/2019/01/hack-jam-sense-shoot-army-creates-1st-multi-domain-unit/
[21] Freedberg, Sydney J., "Hack, Jam, Sense & Shoot: Army Creates 1st Multi-Domain Unit", *Breaking Defense*, 24 January 2019, https://breakingdefense.com/2019/01/hack-jam-sense-shoot-army-creates-1st-multi-domain-unit/
[22] Gertz, Bill, "PLA's new Strategic Support Force remains an enigma," *Washington Free Beacon,* December 18, 2017, http://freebeacon.com/national-security/asia-times-plas-new-strategic-support-force-remains-enigma/.
[23] Raska, Michael, "China's evolving cyber warfare strategies," *Asia Times*, 8 March 2017, http://www.atimes.com/article/chinas-evolving-cyber-warfare-strategies/.
[24] Kania, Elsa, "China's Strategic Support Force at 3", *The Diplomat,* 29 December 2018, https://thediplomat.com/2018/12/chinas-strategic-support-force-at-3/

They you can start imagining that you can create an electrical signal when the bacteria encounters some molecule in their environment."[25]

Reporting during the period noted that the research is about a year away from providing concrete evidence that such reactions can be engineered in abundant marine life that would be of use for the military, especially submarine hunting. However, the research is also notable as a—particularly interesting and innovative—application of on-going synthetic biology research tied to a $45 million program across the Army, Navy, and Air Force. The program has a range of applications, from the types of sensing capabilities being investigated by the U.S. Navy to developing new and dynamic materials and coatings that leverage the particular properties of 3-D (and, in the future, 4-D) printing.[26]

Artificial Intelligence Plans: Announcements during the reporting period demonstrated the growing focus of national governments and defence communities in particular on designing and implementing sustainable approaches to the development and deployment of a wide-range of artificial intelligence technologies and applications.

In January 2019, Russia announced that it expected to release a national roadmap for the development of AI technologies by mid-year 2019. The roadmap will provide for "the creation of a list of projects that will help identify and remove barriers to the development of end-to-end technologies, as well as predict the market demand for artificial intelligence in the country", according to state media reports from 2018.[27] Russian President Vladimir Putin has prioritized AI development, having noted in September 2017 that whoever wins the race to dominate artificial intelligence will "get to rule the world"[28], and the country certainly sees military advantages to artificial intelligence development, especially in cyberspace and information warfare.

Russia's national plan would become the 19th national AI development strategy published to date, to include multi-national plans released by the EU Commission and Nordic-Baltic region. To date, China's "Next Generation Artificial Development Plan" is considered the most wide-ranging and ambitious focusing on all components of AI developments from talent development, to scientific research, to government applications, national security, commercialization / industrialization, data, and ethics. Other plans tend to be more limited in focus, falling into one of three other categories of strategy: research and talent, industrialization, and guiding.[29] The United States does not have a national strategy for artificial intelligence development. However, the U.S. Department of Defense is expected to release an AI strategy document in February 2019.

AI and Communications: One of the growing list of applications for AI technologies was discussed at the Mobile Deployable Communications conference in Warsaw, Poland on 31 January 2019. According to *Jane's,* Captain Guillaume Journaux, the Deputy Head of the DGA's Telecommunications Branch, noted during the conference that France's Defence Procurement Agency (DGA) has an interest in using AI to support the French Army's mobile telecommunications requirements. Captain Journaux noted that DGA had already observed initial project demonstrations in the civilian domain, though he also expressed some reserve about the prospects, noting that using AI in software defined radio technology would have knock-on effects for the

[25] Tucker, Patrick, "The US Military is Genetically Engineering New Life Forms to Detect Submarines", *Defense One,* 1 December 2018, https://www.defenseone.com/technology/2018/12/us-military-genetically-engineering-new-life-forms-detect-enemy-subs/153200/
[26] Tucker, Patrick, "The US Military is Genetically Engineering New Life Forms to Detect Submarines", *Defense One,* 1 December 2018, https://www.defenseone.com/technology/2018/12/us-military-genetically-engineering-new-life-forms-detect-enemy-subs/153200/
[27] Bendett, Samuel, "Russia: Expect a National AI Roadmap by Midyear", *Defense One,* 8 January 2019, https://www.defenseone.com/technology/2019/01/russia-expect-national-ai-roadmap-midyear/154015/
[28] Vincent, James, "Putin Says the Nation That Leads in AI Will Be the 'Ruler of the World'", *The Verge,* 4 September 2017, https://www.theverge.com/2017/9/4/16251226/russia-ai-putin-rule-the-world
[29] Dutton, Tim, "Building an AI World: Report on National and Regional AI Strategies", *CIFAR*, November 2018, https://www.cifar.ca/docs/default-source/ai-society/buildinganaiworld_eng.pdf?sfvrsn=fb18d129_4

size, weight, and power of handheld, manpack, and vehicle-mounted systems including greater power consumption requirements, integration of larger or even additional microchip technologies and sensors on board radios.[30]

The comments, which also included a list of other areas that could benefit from AI, such as antenna design, channel estimation, and voice and data encoding, are consistent with a French MoD effort to increase its investment in and application of AI technologies. In March 2018, the MoD announced an intent to increase AI investment over time to an annual of €100 million.[31]

Figure 3: Marinobachter as a sensor to detect presence in marine environments [(25)]

[30] White, Andrew, "France considers integrating AI with software defined radios", *Janes.com,* 4 February 2019, https://www.janes.com/article/86154/france-considers-integrating-ai-with-software-defined-radios
[31] Tan, Pierre, "France to increase investment in AI for future weapon systems", *Defense News,* 16 March 2018, https://www.defensenews.com/intel-geoint/2018/03/16/france-to-increase-investment-in-ai-for-future-weapon-systems/

Manned Platforms

Speed and stealth dominated the manned platform capabilities in most demand during the reporting period as militaries seek means of dealing with the ubiquitous in contested environments. This report also highlights the indicative challenges associated with transforming military organizations and practices associated, in this case associated with platform maintenance, repair, and sustainment.

Special Forces Submersibles: In January 2019, *Defense One*, reported that the Russian Navy had ordered six manned "futuristic mini-subs" expected to be delivered in 2022. The submarines incorporate a particularly strong acrylic window in a titanium frame and can carry up to three individuals to a depth of 2.5 kilometres. It can operate for a full day on a single charge, according to Russia's state media organization TASS, as reported by *Defense One.*[32]

Analysts believe the platform offers Russia more flexibility in the way it uses its special forces. Russian military expert Samuel Bendett, who also works as a researcher at the CAN Corporation and a fellow in Russia Studies at the American Foreign Policy Council noted that "the fact that there are no limitations on what (the) vessel can carry means that there would be fewer limitations for the Russian special forces to act, via this deep-diving vessel."[33]

The platform was originally order by Russian energy company Gazprom for monitoring and working on underwater pipelines, underscoring one of the main themes of this volume: the convergence of commercial and defence requirements in emerging technologies.

Compound Helicopter: Sikorsky and Boeing have debuted he SB-1 Defiant high-speed / compound helicopter, built for the U.S. Army's Joint Multi Role technology demonstration. According to *Jane's,* the event constitutes an important milestone ahead of the first flight, which is expected in early 2019. The SB-1 Defiant is, along with the Bell V-280, one of two platforms down-selected for the U.S. Army's next-generation multi-role helicopter requirement in 2014. The requirement is now referred to as the Future Long-Range Assault Aircraft (FLRAA).[34]

One of the key requirements of the competition is the ability to sustain speeds of 230 kt while carrying 12 troops. The Defiant has a target speed of 250 kt and incorporates the X2 rigid coaxial-rotor compound helicopter configuration that buttressed Sikorsky's S-97 Raider, which has so far exceeded 200 kt. in flight tests. The earlier, 6,000-lb. X2 Technology Demonstrator reached 250 kt. in level flight in 2010. Bell's V-280 Valor has demonstrated an airspeed of 250 kt and aspires to at least 280 kt. Both the Defiant and the V-280 Valor use advanced tiltrotor technologies.[35]

The focus on speed adds operational performance and flexibility to meet fast-moving threats and operate in highly contested environments as well as forward presence, however, it can also add cost and complexity of logistics support as new designs are incorporated into the fleet. UK Air Commodore Al Smith touched on the shift in fleet composition and management in comments about UK interest in high-speed helicopters during

[32] Glass, Paulina, "Russia's Special Operators are Getting Futuristic Mini-Subs", *Defense One,* 11 January 2019, https://www.defenseone.com/technology/2019/01/russias-special-operators-are-getting-futuristic-mini-subs/154108/
[33] Glass, Paulina, "Russia's Special Operators are Getting Futuristic Mini-Subs", *Defense One,* 11 January 2019, https://www.defenseone.com/technology/2019/01/russias-special-operators-are-getting-futuristic-mini-subs/154108/
[34] Jennings, Gareth, "Sikorsky-Boeing team rolls out Defiant ahead of first flight", *Janes.com,* 27 December 2019, https://www.janes.com/article/85411/sikorsky-boeing-team-rolls-out-defiant-ahead-of-first-flight
[35] Jennings, Gareth, "Sikorsky-Boeing team rolls out Defiant ahead of first flight", *Janes.com,* 27 December 2019, https://www.janes.com/article/85411/sikorsky-boeing-team-rolls-out-defiant-ahead-of-first-flight

the reporting period: "If we pivot towards a high-speed platform, that changes the force mix."[36] The UK initiated a study examining the benefits of high-speed helicopters in February 2019.[37]

China's "Going Out": *Jane's* reported in early January 2019 that requests for proposals and tenders issued by the Shenyang Aircraft Design Institute indicate that Shengyang is pursuing a carrier-variant version of the stealthy fifth generation FC-31 combat aircraft.[38] The reporting was confirmed by the *Global Times,* typically considered to be a mouthpiece of the Chinese Communist Party regime, which stated that the FC-31 stealthy fifth generation aircraft would replace the J-15, which is currently the only Chinese plane with a carrier variant option.[39] The FC-31 is one of two fifth generation fighters developed in China (the J-20 is the other) and was primarily believed to be designated for export.

Reporting from the *South China Morning Post* in June of 2018 confirmed that the J-15 had been involved in a series of "deadly accidents" during carrier testing[40]. Analysts of China's military have long believed the J-15, which weighs 33 tons fully loaded at take-off, was too heavy for even advanced steam catapults to launch consistently. A Chinese military source noted to the *South China Morning Post* in 2017 that "even the U.S. Navy's new generation C 13-2 steam catapult launch engines, installed on Nimitz-class aircraft carriers, would struggle to launch the aircraft efficiently."[41] Originally, concerns about the J-15 had spurred development of an electro-magnetic launch capability to be included in future versions of China's indigenously developed aircraft carriers. And while this program continues apace, it is clear that the PLA is further hedging its bets by developing another plane capable of operating off the decks of its growing carrier fleet.

China's first carrier, the *Liaoning,* was commissioned into service in September 2012.[42] The ex-Ukrainian, Soviet-made carrier is viewed primarily as a "prestige" platform with a predominantly training mission. However, China is indigenously developing and building a larger number of more sophisticated platforms. China's first indigenously-built aircraft carrier, the Type 001A, was floated in April 2017, and Jane's expects it will be commissioned "in the 2020s."[43] Two additional carriers are expected to be built in the 2020s, including one that is expected to feature the electro-magnetic launch capability. China seeks to indigenously build four total aircraft carriers as a means of projecting power and helping to protect its growing interests outside of the Asia-Pacific.

[36] Perry, Dominic, "UK Military Studies High-Speed Helicopter Benefits", *Flight Global,* 5 February 2019, https://www.flightglobal.com/news/articles/uk-military-studies-high-speed-helicopter-benefits-455543/
[37] Perry, Dominic, "UK Military Studies High-Speed Helicopter Benefits", *Flight Global,* 5 February 2019, https://www.flightglobal.com/news/articles/uk-military-studies-high-speed-helicopter-benefits-455543/
[38] Tate, Andrew, "China could be developing carrier-borne variant of FC-31 fighter aircraft", *Janes.com,* 3 January 2019, https://www.janes.com/article/85512/china-could-be-developing-carrier-borne-variant-of-fc-31-fighter-aircraft
[39] "China's medium-sized stealth fighter jet FC-31 may be deployed on future aircraft carriers: sources", *Global Times,* 2 January 2019, http://en.people.cn/n3/2019/0102/c90000-9533815.html
[40] Chan, Minnie, "China is working on a new jet for aircraft carriers to replace its J-15", *South China Morning Post,* 4 July 2018, https://www.scmp.com/news/china/diplomacy-defence/article/2153803/china-working-new-fighter-jet-aircraft-carriers-replace
[41] Chan, Minnie, "China's aircraft carrier conundrum: hi-tech launch system for old, heavy fighter jets", *South China Morning Post,* 19 November 2017, http://www.scmp.com/news/china/diplomacy-defence/article/2120391/chinas-aircraft-carrier-conundrum-hi-tech-launch-system.
[42] "China hires Ukrainian engineer of aircraft carrier the Varyag (Liaoning)," People's Daily Online, September 6, 2017. http://en.people.cn/n3/2017/0906/c90000-9265324.html.
[43] Dominguez, Gabriel, "China Launches First Indigenously Built Aircraft Carrier," *Jane's Defense Weekly,* April 26, 2017. https://janes.ihs.com/Janes/Display/jdw65445-jdw-2017.

Missile Systems and Munitions

The missile versus missile defence competition is one of the most impactful and active shaping the future of warfare. Hypersonic weapons continue to feature prominently in discussions of this competition, both as an actual, achievable, and aspirational capability and as a central component of public statements designed to help rebalance deterrence for states like Russia and China that feel U.S. missile defence systems have undermined their deterrent capabilities. This report also focuses on some of the more notable novel technologies (and vulnerabilities) of missile defence systems and on the expanding range of counter-drone solutions.

Hypersonic Weapons Development Heats Up: The competition between the United States, China, and Russia to develop functional hypersonic weapons has become an increasingly important and visible driver of missile and missile defence system development in each country over the past two years. Several critical developments occurred during the reporting period.

Both China and Russia made announcements about advancing hypersonic capability. On 22 January, Chinese state media reported that the Donfeng – 17 (DF-17) will be equipped with a hypersonic gliding warhead that will make it "impossible" to be defeated by "Western missile defence", according to *UPI*.[44] Hypersonic glide vehicle weapons, such as the DF-17, are valued both for their speed—to be categorized as hypersonic, they must travel at speeds above Mach 5—and their ability to manoeuvre and change trajectory during their rapid descent to their target. Current missile defence systems are designed to deal primarily with missiles on a highly-predictable ballistic trajectory. The DF-17 is capable of carrying nuclear warheads and striking any target in the world within hours. Chen Guangwen, a Chinese military commentator, believed the technology could be deployed by 2020.[45]

In late December, international media outlets reported that Russian officials confirmed that the country had successful tested a hypersonic glide vehicle capable of going 27 times the speed of sound known as the Avangard. The system "essentially makes missile defence useless", according to Russian Deputy Prime Minister Yuri Borisov. The test was launched from the Dombarovskiy missile base in the Southern Ural mountains and reportedly successfully struck a practice target in Kamchatka, over 3,700 miles away. Russian Vladimir Putin suggested the weapon could be deployed as early as 2019.[46]

Russian and China investment in hypersonic glide vehicles over the last decade or longer—Russia's program reportedly began after the U.S. withdrew from the Anti-Ballistic Missile (ABM) Treaty in 2002—is well known. As is each country's progress against stated goals. In January 2018, Air Force General Paul Selva, the Vice Chairman of the Joint Chiefs of Staff claimed that "We (the United States) have lost our technical advantage in hypersonics. We haven't lost the hypersonics fight. The Russians and Chinese have moved out pretty smartly" on hypersonics. He noted that China, in particular, has been "willing to spend tens to hundreds of billions of dollars on its program."[47]

In fact, this investment from the two countries identified in the 2017 U.S. National Defense Strategy as being the main strategic competitors and national security challenges for the United States has led to increased investment in hypersonic programs in the United States. Over the course of the summer of 2018, Lockheed

[44] Shim, Elizabeth, "China's hypersonic weapons can sink U.S. aircraft carriers, state media says", *UPI,* 22 January 2019, https://www.upi.com/Top_News/World-News/2019/01/22/Chinas-hypersonic-weapons-can-sink-US-aircraft-carriers-state-media-says/2651548165420/

[45] Shim, Elizabeth, "China's hypersonic weapons can sink U.S. aircraft carriers, state media says", *UPI,* 22 January 2019, https://www.upi.com/Top_News/World-News/2019/01/22/Chinas-hypersonic-weapons-can-sink-US-aircraft-carriers-state-media-says/2651548165420/

[46] Georgiou, Aristos, "Russia Successfully Tests Weapon That Travels 27 Times Speed of Sound And Renders Missile Defense System 'Useless'—Officials", *Newsweek*, 28 December 2018, https://www.newsweek.com/russian-new-weapon-mach-27-avangard-hypersonic-glide-vehicle-intercontinental-1273729

[47] Morgan, Wesley, "Selva: We have lost our technical advantage in hypersonics", *Politico,* January 30, 2018, https://www.politicopro.com/defense/whiteboard/2018/01/selva-we-have-lost-our-technical-advantage-in-hypersonics-503866.

Martin was awarded two contracts worth nearly $1.5 billion dollars to accelerate development of hypersonic weapons.

Still, claims that any of these three countries would have a fully operational hypersonic glide vehicle that can credibly and reliably defeat advanced missile defence systems in service during 2019 seems ambitious, given some of the persistent technical challenges associated with hypersonic flight and in-flight manoeuvrability of missiles, especially those traveling at Mach 5, much less Mach 27.

In December 2018, The US Defense Advanced Research Projects Agency (DARPA) initiated the Materials, Architectures, and Characterization for Hypersonics (MACH) programme to help address the technical challenge of mitigating aerothermal effects on hypersonic vehicles. The programme seeks to develop and demonstrate new design and material solutions for sharp, shape-stable, high heat flux capable leading-edge systems for hypersonic vehicles travelling more than five times the speed of sound.

This is a persistent problem for all hypersonic vehicle research, according to Bill Carter, Program Manager in DARPA's Defense Sciences Office (DSO): "For decades people have studied cooling the hot leading edges of hypersonic vehicles but haven't been able to demonstrate practical concepts in flight."[48]

Carter continued: "The key is developing scalable materials architectures that enable mass transport to spread and reject heat. In recent years we've seen advances in thermal engineering and manufacturing that could enable the design and fabrication of very complex architectures not possible in the past. If successful, we could see a breakthrough in mitigating aerothermal effects at the leading edge that would enhance hypersonic performance."[49]

Ultimately, Russian and Chinese claims about advancing hypersonic glide vehicle capability should be taken seriously, but also seen within the context of a broader competitive strategic context in which concerns about advancing U.S. missile defence systems have undermined confidence in Moscow and Beijing in their capacity to deter the United States. Bold and loud statements of imminently operational hypersonic glide vehicle capability may help even that balance, at least until early next decade when these capabilities are likely to be operational.

U.S. Missile Defence Strategy . . . and Pervasive Vulnerability: The U.S. Department of Defense released the 2019 Missile Defense Review in January. The document discusses the evolving threat environment, the roles and strategy for missile defence in this environment, specific programs and capabilities central to the future of U.S. missile defence, and how better to coordinate missile defence efforts with allies and partners.

Some of the specific capabilities and technologies of interest include repurposing the SM-3 Block IIA interceptor and F-35 for ballistic missile defence missions; developing directed energy weapons that can operate on high-flying drones; and building a more robust space-based sensor network.[50]

The January release of the MDR was not the only relevant news about U.S. missile defence. On 10 December 2018, the Pentagon's Inspector General released an unclassified but highly redacted report that strongly criticized the U.S. Missile Defense System for long-standing and wide-spread cyber vulnerabilities.

The report detailed systematic failures to take even basic cyber-security precautions, such as enabling two-factor identification, encrypting removable files, physically locking server racks, and using cyber-security software to

[48] Hughes, Robin, "DARPA pursues material and architecture to cool hypersonic vehicles", *Janes.com,* 21 December 2018, https://www.janes.com/article/85391/darpa-pursues-materials-architecture-to-cool-hypersonic-vehicles
[49] Hughes, Robin, "DARPA pursues material and architecture to cool hypersonic vehicles", *Janes.com,* 21 December 2018, https://www.janes.com/article/85391/darpa-pursues-materials-architecture-to-cool-hypersonic-vehicles
[50] "Missile Defense Review: Executive Summary", *U.S. Department of Defense*, January 2019, https://www.defense.gov/Portals/1/Interactive/2018/11-2019-Missile-Defense-Review/The%202019%20MDR_Executive%20Summary.pdf

detect intrusions across five facilities associated with the U.S. Missile Defense System. The report noted that adversary cyber-intrusion could allow adversaries to undermine and circumvent the U.S. Missile Defense System.[51]

The revelation comes amid a series of eye-opening reports and activity related to the vulnerability of several countries to cyber – security threats. Most notably, in December 2018, the U.S. Department of Justice indicted two Chinese citizens living in China, accusing them of being part of the hacking organization known as Advanced Persistent Threat 10 (APT-10) Group. According to the indictment, APT-10 had stolen technical and commercial information from over 45 U.S. companies and from the U.S. government, including the personally identifiable information of over 100,000 U.S. Navy personnel. The indictment also noted that APT-10 activities had also targeted commercial and government entities in 11 other countries: Brazil, Canada, Finland, France, Germany, India, Japan, Sweden, Switzerland, the United Arab Emirates, the United Kingdom.[52]

Anti-Satellite Missile Tested: Russia conducted a successful flight test of an anti-satellite missile system in November 2018, according to reporting in December. The missile reportedly flew for 17 minutes and 1,864 miles before successfully splashing down in its target area.[53] The test aligns with the assessment of the above-mentioned Missile Defense Review, which asserted that "Russia is developing a diverse suite of anti-satellite capabilities."[54] Anti-satellite and counter-space capabilities are increasingly in demand given the growing reliance of modern militaries on space-based C4ISTAR architectures, such as global navigation satellite systems, communications links, and imagery and surveillance satellites, among other capabilities. Any ability to deny, disrupt, degrade, or destroy adversary architecture before or during a conflict or crisis could reduce adversary ability to bring the full-weight of their military capability to bear.

Anti-satellite missiles are commonly thought to be just one—and by far the most inelegant—component of a sophisticated counter-space capability, which can also include: Co-orbital satellites with robotic arms designed to break adversary satellites; Directed energy weapons that can 'dazzle' adversary satellites making them temporarily unavailable; and cyber intrusions that will take satellites off-line, jam, or spoof communications coming to and from given satellites.

These other measures are generally viewed as being preferred to anti-satellite missiles because unlike anti-satellite missiles they 1) are frequent difficult to detect and definitively attribute and b) they are far less likely to create space debris that will put the global space architecture at long-term risk. China infamously sparked international outrage in January 2007 when it launched an anti-satellite missile from the Xichang satellite launch centre at a defunct Chinese weather satellite in orbit 500 miles above the earth.[55] The impact generated thousands of pieces of debris into Earth's orbit, which continue to pose a serious threat to other satellites and spacecraft.[56]

Nonetheless, the test reflects a durable intensification of a military competition in space, even if space itself has not yet been materially weaponized.

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[51] Tucker, Patrick, "Inspectors Find Big Cyber Vulnerabilities in US Missile Defense System", *Defense One,* 17 December 2018, https://www.defenseone.com/technology/2018/12/inspectors-find-big-cyber-vulnerabilities-us-missile-defense-system/153613/
[52] APT-10 Group Indictment, *Federal Bureau of Investigations,* *https://www.fbi.gov/wanted/cyber/apt-10-group*
[53] Sheetz, Michael, "Russia conducted another successful test of an anti-satellite missile, according to a classified US intelligence report", *CNBC*, 18 January 2019, https://www.cnbc.com/2019/01/18/russia-succeeds-in-mobile-anti-satellite-missile-test-us-intelligence-report.html
[54] "Missile Defense Review: Executive Summary", *U.S. Department of Defense*, January 2019, https://www.defense.gov/Portals/1/Interactive/2018/11-2019-Missile-Defense-Review/The%202019%20MDR_Executive%20Summary.pdf
[55] Jane's by IHS Markit. "ASAT." September 27, 2017. https://janes.ihs.com/Janes/Display/jsws9047-jsws.
[56] Jane's by IHS Markit. "Fengyun series," June 30, 2017. https://janes.ihs.com/Janes/Display/jsd_0475-jsd.

Counter-Drone Weapons: On 21 December 2018, London area Gatwick Airport was nearly completely shut down for almost 36 hours due to the persistent presence of drones near Gatwick's runway. The disruption led to cancelling over 800 flights affecting 120,000 passengers. The situation highlighted the vulnerability of commercial aviation infrastructure to even low-level threats from emerging technologies, such as drones.

The situation was resolved only after the British Army deployed Rafael's Drone Dome system. Rafael describes the Drone Dome system as an "innovative end-to-end system designed to provide effective airspace defence against hostile drones used by terrorists and criminals to perform aerial attacks, collect intelligence, and other intimidating activities." The system has 360-degree circular coverage and is designed to rapidly detect, track, and neutralize drones primarily by jamming radio frequencies and preventing the drone from moving. The UK is reportedly the first export customer for the system in August 2018 when it purchased six systems for $20 million.[57]

While the Israeli counter-drone systems predominantly rely on some form of directed energy – either microwaves or lasers—reporting during the period also highlighted interest in a kinetic approach to counter-drone weapons. According to the *Warrior Maven* blog, the U.S. Army has fast-tracked delivery of an advanced targeting technology for the .50 calibre machine gun to widen its "mission envelope", including serving in a counter-drone role, especially in a forward base protection role.[58]

Figure 4: DARPA's MACH programme will pursue materials and designs for cooling the hot leading edges of hypersonic vehicles travelling at speeds of Mach 5 and beyond[(49)]

[57] Halon, Eytan, "Israeli anti-drone technology brings an end to Gatwick Airport chaos", *Jerusalem Post,* 21 December 2018, https://www.jpost.com/International/Israeli-anti-drone-technology-brings-an-end-to-Gatwick-Airport-chaos-575054

[58] Osborn, Kris, "New Precision Targeting on Historic .50-Cal Machine Gun Can Hit Enemy Drones", *Warrior Maven,* 8 January 2019, https://defensemaven.io/warriormaven/land/new-precision-targeting-on-historic-50-cal-machine-gun-can-hit-enemy-drones-IdW0lnQ8IEahJrMjnMk7Dw/

Robotics and Unmanned Systems

Innovation in robotics and unmanned systems is moving quickly. Developments covered in the report are largely representative of three areas of innovation and development: 1) new materials and designs to enhance utility and efficiency; 2) new capabilities, especially stealth and strike; and 3) diffusion of advanced capabilities

New Materials and Designs: Researchers from the University of British Columbia and University of Toronto have pooled their expertise in animal science and aerodynamics to complete a wind tunnel study of 12 different wing shapes in gulls. One of the objectives of the research experiment was to design drones that can glide for extended periods for a variety of commercial and natural disaster response purposes

Gulls were seen as an intriguing subject for the development of drone wings because during take-off and landing, gulls "morph" their wing profile by tucking in their elbows, a concept that Philippe Lavoie, a University of Toronto aviation expert and one of the study participants, believes can help a drone take advantage of "energy harvesting through soaring." According to Professor Lavoie, "if you can change the shape of the wings, you can create more stable configurations with lower drag when you want more endurance."[59]

Biomimicry—the incorporation of animal attributes into drone and platform design in order to deliver enhanced efficiency of movement or low-observability—was a feature of the December 2018 volume of this report and is a growing area of drone research, in particular.

New designs for drones are also increasingly incorporating new materials. In December 2018, China's domestically-developed Wing Loong I-D successfully completed its maiden flight. The test was notable because the Wing Loong I-D's fuselage is built completely with composite materials that enable "long-endurance functioning with high-performance, at medium altitude and on multiple missions."[60]

Dirty and Dangerous (and Cold) Missions: One of the main values of unmanned systems of across all domains is the capacity to do "dirty and dangerous" jobs that put human life at risk or are exceptionally difficult for humans to perform efficiently. Several demonstrations of unmanned or robotic systems designed to support these categories of missions occurred during the reporting period.

Notably, reporting from January 2019, detailed tests from the fall of 2018 of a four-legged robot named ANYmal that explored the tunnels below Zurich, Switzerland. The robot is the product of Switzerland-based ANYbotics and the ETH Zurich Robotic Systems Lab. The robot is 20-inches tall, weighs 66 pounds, and has a speed of around 2 mph with a battery that holds power for three hours. It can operate autonomously, but is typically operated via remote control. ANYmal is designed to carry out tunnel exploration and oil platform inspections.[61] The former of these roles is especially of interest to military and security communities. Increased surveillance and border security technologies and capabilities have pushed some threat actors under-ground (or under-sea), creating a difficult to detect and address challenge for defence and security communities as highlighted by Israel's December 2018 campaign explicitly designed to destroy Hezbollah tunnels in Lebanon.

The reporting period also saw important developments in explosive ordnance disposal robots. In December 2018, the British Army took delivery of the first four of 56 T7 unmanned ground vehicles (UGVs) made by the Harris Corporation. The UGVs are equipped with high-definition cameras, fast data – links, an adjustable manipulation arm, and all-terrain treads. According to UK Minister of Defence Gavin Williamson, "the robots will provide the Army with the latest bomb disposal technology and will prove to be trusted companions both

[59] Cranenburgh, Nadine, "'Morphing' gull-like wings could help drones soar farther", *CreateDigital.org,* January 2019, https://www.createdigital.org.au/morphing-wings-drones-soar-further/
[60] Xueqian, Mu, "China's Wing Loong I-D with complete composite fuselage makes successful maiden flight", *Xinhua Net*, 23 December 2018, http://www.xinhuanet.com/english/2018-12/23/c_137693984.htm
[61] Atherton, Kelsey, "This robot rumbles through tunnels too unsafe for people", *C4ISRNet.com,* 8 January 2019, https://www.c4isrnet.com/unmanned/robotics/2019/01/09/this-robot-rumbles-through-tunnels-too-unsafe-for-people/

on UK streets and in deadly conflict zones."[62] The robots were procured for £55 million in September 2017 under Project Starter. The T& replaces the Wheelbarrow Mk8B remote-controlled EOD robots, which, according to the UK MoD, "have been used across the globe by UK Armed Forces since 1972."[63]

In addition to enhancing the capacity of militaries (and commercial entities) to carry out dirty and dangerous jobs, drones are also being developed to operate in environments that are difficult for humans to access or to operate in, for example, the Arctic. In December, Russian state media service Tass reported that Kalashnikov Group had developed two drones to patrol the Arctic, monitoring oil and gas facilities and ice levels and to identify vessels approaching these facilities. The ZALA 421-08M and ZALA 421 -16E drones were unveiled in early December. They feature an automatic identification system that can gather information about a vessel at a distance of 100 kilometres away. Moreover, they do not rely on global navigation satellite systems, such as GLONASS or GPS for navigation.[64]

Stealthy Drone Development: Both Russia and China released images of under-development stealthy drones during the reporting period.

In January 2019, China state broadcaster CCTV released the first images of the Tian Ying "Sky Hawk" stealthy, jet-powered drone. The Tian-Ying is a long-range multi-mission stealth drone capable of carrying out ISR and combat missions.[65]

Approximately two weeks after CCTV released pictures of the Tian Ying, a photo of the Russian Sukhoi Okhotnik-B stealthy unmanned strike drone appeared on a Russian website for aviation enthusiasts, according to *Aviation Week*. The picture's appearance coincided with state media reports that Othotnik was being tested at the Novosibirsk Aircraft Production Organization, which manufactures aircraft designed by Sukhoi.[66]

China's Drones and Evolving Air Power in the Middle East / North Africa Region: The Royal United Services Institute (RUSI) released an Occasional Paper entitled "Armed Drones in the Middle East Proliferation and Norms in the Region" in December 2018. The paper reviewed the arsenals and air power strategies of countries across the MENA region and determined that China's exports of the CH-4 Rainbow and Wing Loong I and II strike-capability drones were driving demand and over time changing air power doctrine and use for the UAE as well as for countries with relatively robust indigenous unmanned systems development capability, such as Turkey and Iran.[67]

The Kingdom of Saudi Arabia stood out as a country that has not only procured armed unmanned systems from China, but signed an agreement in March of 2017 to produce CH-4 unmanned systems at the King Abdulaziz City for Science and Technology (KACST).

The report highlights both the broad global demand for strike unmanned assets as well as China's dominance of this market, largely due to the fact that the United States has previously not allowed its unmanned systems manufacturers to export unmanned combat aerial vehicles outside of to its closest allies due to fears of broader proliferation of the capability. An indicative example of China's competitive advantage in this market can be

[62] "British Army receives pioneering bomb disposal robots", *GOV.UK,* 23 December 2018, https://www.gov.uk/government/news/british-army-receives-pioneering-bomb-disposal-robots
[63] "British Army receives pioneering bomb disposal robots", *GOV.UK,* 23 December 2018, https://www.gov.uk/government/news/british-army-receives-pioneering-bomb-disposal-robots
[64] Glass, Paulina, "Russia's New Arctic Drones Are Built to Spot Ships", *Defense One,* 11 December 2018, https://www.defenseone.com/technology/2018/12/russias-new-arctic-drones-are-built-spot-ships/153444/
[65] "Chinese state broadcaster unveils first image of new stealth drone", *DefenceBlog.com,* 7 January 2019, https://defence-blog.com/news/chinese-state-broadcaster-unveils-first-image-of-new-stealth-drone.html
[66] Trimble, Steve, "New Photo May Reveal Russian Unmanned Strike Aircraft", *Aviation Week,* 23 January 2019, http://aviationweek.com/defense/new-photo-may-reveal-russian-unmanned-strike-aircraft
[67] Tabrizi, Aniseh Bassiri and Bronk, Justin, "Armed Drones in the Middle East", *RUSI,* Occasional Paper, December 2018, https://rusi.org/sites/default/files/20181207_armed_drones_middle_east_web.pdf

seen in the late July 2017 decision by Indonesia to procure UCAVs (Unmanned Combat Aerial Vehicules) from China. In announcing the commitment, Laksda Leonardi, head of Indonesia's Ministry of Defence's Defense Facilities Agency stated that "Only China can sell the drones to us and the others cannot".[68] In April 2018, the Trump Administration began the process of reviewing and rewriting regulations in order to enable UCAV exports on a case-by-case basis, largely to better compete with China in this growing market space.

Figure 5: Chinese Stealthy Drone - Tian Ying (65)

Figure 6: Russian Stealthy Done - Sukhoi Okhotnik-B (66)

[68] Grevatt, Jon, "Indonesia Looks to China for Combat UAVs," *Jane's Defense Weekly*, July 28, 2017, https://janes.ihs.com/Janes/Display/FG_600842-JDW.