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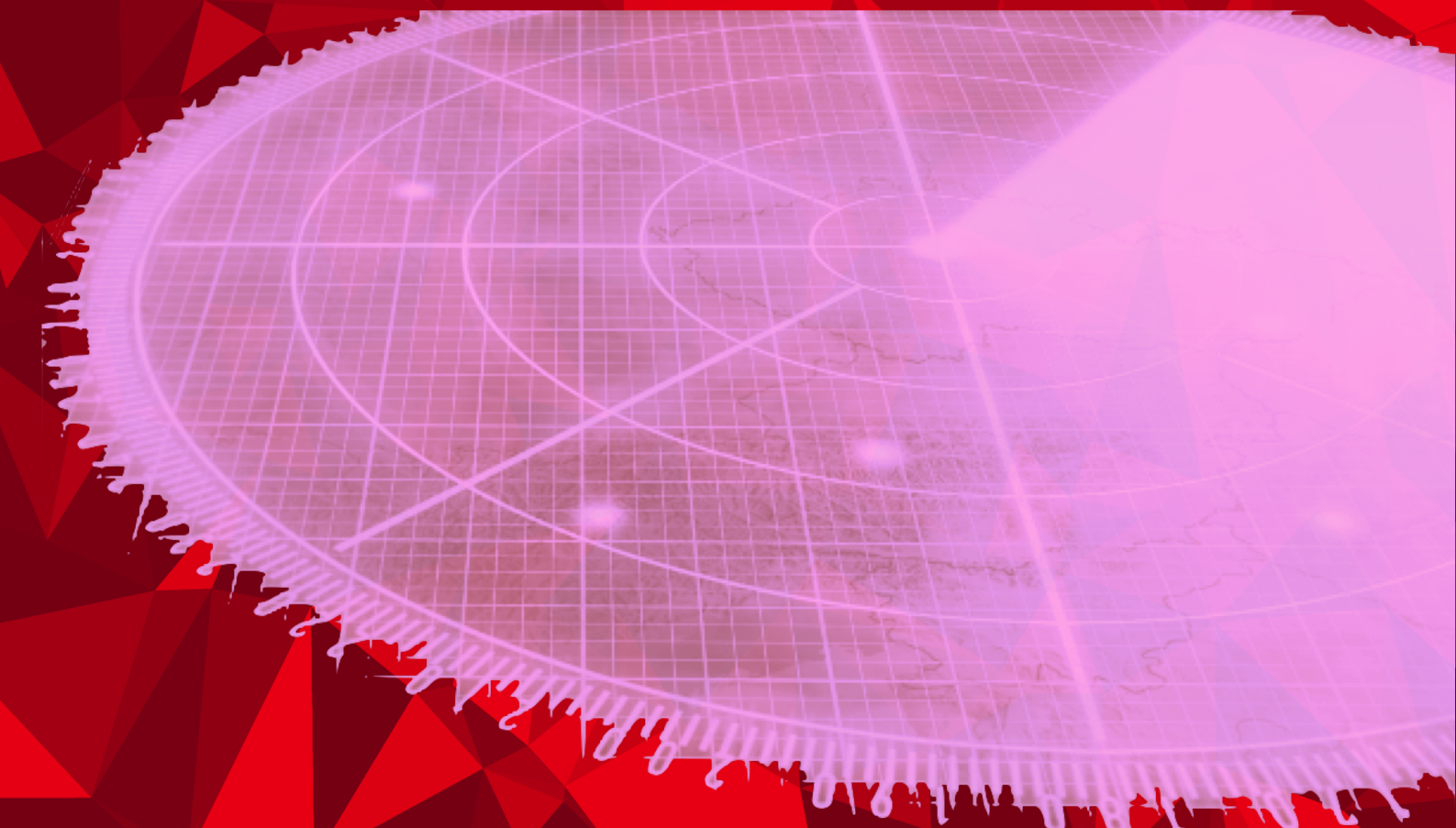
Deftech Scan

December 2021



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Dear Reader,

The last deftech.scan of the year is full of amazing products that some of you might want to receive under the Christmas Tree. From visual augmentation systems to electric hybrid vehicles, one can realize how quickly civilian and military research areas can leverage each other and how thin a boundary can become between the two.

We would like also to take advantage of this edition to inform you on the topics and dates of the 3 deftech.days 2022. Do not hesitate to register already to save the date in your calendar. We will contact you early enough for you to confirm your participation!

2nd February | **Uncertainty·Innovation·Resilience**
👉 https://event.armasuisse.ch/deftech-02-02-2022

15th June | **Future Situational Awareness**
👉 https://event.armasuisse.ch/future-situational-awareness

30th November | **New invisibility for future battlefields**
👉 https://event.armasuisse.ch/new-invisibility-for-future-battlefields

If you are doing research in one or the other topic and would like to present at the event, don't hesitate to contact me!

We hope you enjoy the reading and we wish you a happy holiday season.

Foresightly Yours,

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Introduction and Executive Summary

This DEFTECH SCAN of 2021 examines occurrences in military technology and capability development taking place from mid-October to mid-December with references to related events that took place earlier in the year. It contains reporting on recent military, security, and industry activities and announcements in the United Kingdom, United States, Israel, Iran, UAE, China, Russia, Belarus, and Egypt. Key developments and themes captured in the report include:

Major Weapons Tests: The reporting period saw two surprising weapons tests that both raised concerns about the accelerating weaponization and militarization of space and offered insight into the technological advancement of Russia and China's modernization efforts. On 15 November, Russia became the fourth nation to shoot a satellite out of space with a direct ascent anti-satellite (ASAT) weapon, which created over 1,500 pieces of space debris and threatened the International Space Station to take emergency steps. A month earlier, reports emerged that on 27 July China had successfully tested a nuclear capable fractional orbit bombardment system (FOBS) that included a hypersonic glide vehicle. The system was launched into space, orbited the earth, released a hypersonic glide vehicle that maneuvered to its target in China along a trajectory that was shallower (and therefore more difficult to intercept) than a ballistic missile.

Norms for Space and Cyber Conflict? These weapons tests reinforced the need for international discussion on new norms for weapons tests and kinetic conflict in orbit while the escalation of the on-going Israel-Iran cyber conflict raised questions about the need for norms in cyber conflict. This escalation included attacks against critical infrastructure, doxing of individuals, and theft and release of highly sensitive and personal information, among other tactics all of which demonstrated the potentially debilitating, cascading, and difficult to deter and regulate effects of sub-threshold / grey-zone conflict.

Challenges Incorporating Dual-Use Technologies: Overlapping interest and parallel development of emerging technologies by commercial industry and large and small defence and security communities has created new opportunities and avenues for the development of advanced military capabilities. However, beyond the organizational and process changes required for governments to engage commercial industry more efficiently, incorporating these new technologies is not always as simple as adapting commercial technologies for military purposes as evidenced by the discussion of electrical vehicles and the US Army's IVAS headset included in this report.

New Reports on China's Military Modernization and Technology Investments: Three reports were released during the reporting period that provided insight into the pace and scale of China's continuing military modernization. While not explicitly covered in this report, each report offers a useful perspective on China's advancing capabilities in key areas of development and how they align with China's geopolitical ambitions.

- In October, the Center for Security and Emerging Technologies (CSET) at Georgetown University released "Harnessed Lightning: How the Chinese Military is Adopting Artificial Intelligence", which draws insights on China's defence AI efforts from analysis of 343 AI-related People's Liberation Army (PLA) equipment contracts
- On 3 November, the US Department of Defense released its annual – and much anticipated— "Military and Security Developments Involving the People's Republic of China 2021." The Congressionally mandated report details new and verifiable insights about China's military modernization. This year's iteration had a particularly strong focus on the unexpected growth in China's nuclear missile arsenal
- On 17 November, The US-China Economic and Security Review Commission released its annual report. The wide-ranging report addresses many areas of US-China relations including its expanding nuclear forces and military capabilities related to Taiwan

Energy, Power, and Design

Key Insights:

- **All-Electric Propulsion Takes Off, but Constraints Remain for Military Ground Vehicles:** Electric propulsion for planes, vehicles, and ships is becoming a major priority for both commercial industry and large and small militaries throughout the world both to combat climate change and also due to the performance advantages electrical vehicles and aircraft can provide. And while militaries will be able to leverage some commercial developments in energy capture and storage and battery size and power, particularly those emanating from the commercial aerospace industry, there are challenges—design, safety, power requirements—to adopting commercial batteries for ground vehicles, especially heavy. As one author of a June 2021 US Army report on prospects for adopting electric vehicles noted, "We can't apply the commercial technology directly as is. Commercial vehicles don't typically get shot at on the highway, but our vehicles do. So, if you have a lithium-ion battery system you need to be able to take rounds without starting a fire or explosion." The result for both large and small militaries is that there is likely to be a prolonged period in which commercial electric vehicles are adopted at scale while militaries will focus on hybrid – electric vehicles

All-Electric Aircraft Speed Record and the Opportunities and Constraints of Electrical Military Vehicles: British aero-engine manufacturer Rolls Royce claims to have flown the world's fastest all-electric vehicle on 16 November. The *Spirit of Innovation* plane reached a top speed of 623 km / h (387.4 mph) during tests at the UK Ministry of Defence's Boscombe Down experimental aircraft testing site. The aircraft also travelled at 555.9 km/h (345.4 mph) over 3 km and reportedly also broke the fastest time to climb to 3,000 meters (m) by 60 seconds with a time of 202 seconds. Rolls Royce has submitted the flight data to the World Air Sports Federation, the organization that certifies aeronautical and astronautical records.[1]

Figure 1: The Spirit of Innovation aircraft. Source: Rolls Royce / Jane Stockdale

The Spirit of Innovation used a 400kW (500+ hp) electric powertrain and "the most power-dense propulsion battery pack ever assembled in aerospace", according to Rolls Royce.[2] The company worked with aviation energy storage specialist Electroflight and automotive powertrain supplier YASA. Rolls Royce CEO Warren East emphasized the importance of the test in progressing the objectives of a "jet zero" objective and in furthering the company's "ambition to deliver the technology breakthroughs society needs to decarbonise transport across air, land, and sea."[3]

He also stressed the importance of the achievement for the dual-use capability of air mobility, noting that the programme has "exciting applications for the Advanced Air Mobility market."[4] The electric urban air mobility market is attracting increasing attention and competition, which could benefit both small and large militaries around the world as they seek novel, environmentally sustainable logistics, resupply, and mobility solutions. Indeed, during comments at the Dubai Air Show in November, Balkiz Sarihan, the

[1] "'Spirit of Innovation' stakes claim to be the world's fastest all-electric vehicle", Rolls Royce media press release, 19 November 2021, Press releases | Rolls-Royce - 'Spirit of Innovation' stakes claim to be the world's fastest all-electric vehicle'Spirit of Innovation' stakes claim to be the... –undefined
[2] Ibid.
[3] Ibid.
[4] Ibid.

head of Airbus' urban air mobility strategy, revealed that the company was establishing a separate, independent entity to develop electric air mobility capabilities, such as its three-passenger, one polit electric vertical take-off and landing platform by 2023, to speedily react to the more than 300 start-ups that had entered the market.[5]

Electrification of aircraft and vehicles is also becoming a more pronounced priority for both large and small militaries as they seek to reduce carbon emissions and take advantage of the tactical and operational benefits that quieter vehicles with lower heat signatures and fewer supply chain / logistics requirements might bring. During an interview at the Reagan National Defense Forum held in California in December, BAE Systems Inc. CEO Tom Arseneault offered that the US military's adoption of electric vehicles was "a matter of timeline." The US DoD is seeking to be net-zero emissions by 2050, a significant task for a military currently tied to thousands of fuel reliant planes, ships, and ground vehicles.[6]

Figure 2: The Scarbee armored vehicle, developed by French company Arquus. On 10 March 2021, the company announced the hybrid electric vehicle was moving from the development stage and was ready for sales and exports, making it "the world's first truly hybrid armored vehicle." Source: Arquus, via Defense News

Kathleen Hicks, Deputy Secretary of Defense, noted in November that the short-term integration of electrical power sources for US ground vehicles will be hybrid as DoD simultaneously seeks to develop the infrastructure, designs, and logistical capacity to charge vehicles in the field. However, Hicks also stressed that electrical vehicles bring advantages that current vehicles do not that "can help give our troops an edge on the battlefield."[7]

This assessment of the impracticality of all-electric vehicles over the short or even moderate term was backed up by a report from the Academies' Committee on Powering the U.S. Army of the Future, which was released in June of 2021. The study assessed that challenges related to infrastructure, battery size and technology development, and safety are all unlikely to be resolved to a sufficient degree to allow the scaled use of all-electric vehicles in the US Army before 2035. John Luginsland, the committee's co-chair and senior scientist, noted the advantages of all-electric vehicles, but also concluded that the service's future inventory "should be hybrid-electric vehicles with internal combustion engines, not all battery electric vehicles."[8]

[5] Tony Osborne, "New Partners Beckon For Airbus Urban Mobility Unit", *Aviation Week,* 16 November 2021
[6] Andrew Eversden and Aaron Mehta, "Electric vehicles for military just a 'matter of timeline': BAE Systems Inc CEO, *Breaking Defense,* December 13, 2021, Electric vehicles for military just a 'matter of timeline': BAE Systems Inc CEO - Breaking Defense Breaking Defense - Defense industry news, analysis and commentary
[7] Ibid.
[8] Yasmin Tadjdeh, "Electric Vehicles for the Military Still a Pipedream", *National Defense,* 6 October, 2021, Electric Vehicles for the Military Still a Pipedream (nationaldefensemagazine.org)

Human Performance Enhancement and Protection

Key Insights:

- **Risk, Expectation Settings, and Challenges of Dual-Use Technology Integration:** Efforts to incorporate advanced technology, frequently being developed in the commercial sector, and the expanded capabilities these technologies enable will require defence and security communities to accept risk at the start of a development program. But integrating and leveraging these technologies for military purposes can be complicated and lead to technical and logistical / training challenges that slow development and hinder effective deployment, drawing criticism from without and within of defense communities. The report highlights two different examples of the challenges associated with adoption of advanced technologies. The US Army's ambitious IVAS program, which is built upon Microsoft's commercially available HoloLens headset, has been delayed and audited because of technical challenges while the F-35 has, after 18 months of development, released a smaller, cheaper, more portable, more usable training simulator to meet demand from the expanding number of countries operating the fifth generation F-35.

IVAS Morass? Key Technology Program Delayed and Audited: The reporting period saw a flurry of activity related to the status and future of the US Army's Integrated Visual Augmentation System (IVAS), a head's up visual display that enables soldiers to view video or other data from a network to enhance real-time situational awareness and also leverages augmented reality to support training. IVAS has been profiled in previous DEFTECH Scans and has been seen as a cutting-edge system and a useful example of how militaries are incorporating dual-use technology from high-tech commercial suppliers—in this case Microsoft—that do not traditionally work with defence and security communities.

Figure 3: The IVAS headset. The system has been tested for over two years, leading to the US Army awarding Microsoft a $21.88 billion contract to develop and field the system. Source: Microsoft

However, in October, a series of announcements and reports called into question the short-term development timelines as well as the longer-term ability of IVAS to deliver on all the functionality that has been promised.

On 18 October, *Janes* reported that the US DoD's Inspector General's office had on 4 October launched an audit into the program to determine whether the Army is "producing and fielding" a system that will "meet capability requirements and user needs."[9] *Janes* also reported that concerns exist that the system will not be able to carry out all the tasks it has been purported to be able to do, saying that "it is unclear if soldiers will even be able to use the device for activities such as the often-touted mixed-reality training capabilities" once fixes to the system are made.[10]

Previously, on 13 October, *Janes* had reported that the Army was pausing and potentially ending the IVAS programme.[11] In a statement released on Monday, 18 October, the Army did confirm it was delaying the programme, but that it was not cancelling IVAS. The Army had anticipated fielding the headsets in its

[9] Ashely Roque, "Hide and seek: Pentagon's inspector general auditing delayed IVAS programme, capabilities missing", *Janes.com,* 18 October 2021, Hide and seek: Pentagon's inspector general auditing delayed IVAS programme, capabilities missing (janes.com)
[10] Ibid.
[11] Ashley Roque, "AUSA 2021: US Army 'pauses' IVAS programme, fielding on hold", *Janes.com,* 13 October 2021, AUSA 2021: US Army 'pauses' IVAS programme, fielding on hold (janes.com)

first units by the end of 2021. It has now stated that operational tests of the equipment will take place in May 2022 and that the system will be fielded in September 2022 due to technical setbacks related to the resolution associated with one of IVAS' main distinguishing features: the incorporation of an expanded field of vision of 80 degrees, twice that of other systems currently available. According to an Army statement, "At 80 degrees, IVAS pushed the boundaries of waveguide technology capabilities, and the field of view began to lose resolution. By making minor reductions, developers are finding greater quality and clearer visibility."[12]

The IVAS headsets are based on Microsoft's HoloLens augmented reality headset. The US Army awarded an up to 10-year, $21.88 billion contract to Microsoft in March 2021 to produce and field the system at scale. The Army has said that the current year-long development delay will not affect the contract and that the Army will field the headset six to 10 years faster than it usually takes to introduce new kit.[13]

The still developing situation with IVAS reflects the difficult balances and trade-offs that militaries throughout the world must strike as they seek to incorporate new technologies and the capitalize on the novel capabilities these frequently commercial technologies enable. Acceptance of risk early in development processes is necessary in many cases to keep pace with technological change not to mention other militaries.[14] But doing so without effectively setting expectations about what is feasible in the short and longer-terms in terms of capability and delivery timelines can create both development vulnerabilities and lead to criticism, which, in turn, could dampen military willingness to accept risk.

Shrinking the Footprint of F-35 Trainers: Lockheed Martin unveiled the F-35 Mission Rehearsal Trainer Lightening Integrated Training Environment (MRT LITE) simulator during the Interservice / Industry Training, Simulation and Education Conference (ITSEC) held in Orlando, FL from 29 November to 3 December. The MRT LITE runs the same software as the F-35 Full Mission Simulator but has a much smaller footprint.

According to Lockheed Martin, the MRT LITE has 90% less hardware, and eight MRT LITEs can fit within the same space as a full mission simulator. The smaller trainer covers 75% of the F-35 mission set, including all the beyond-visual-range tasks that are so central to the advertised advantages of fifth generation aircraft generally and the F-35 in particular.[15] The trainer is fully modular allowing it to be broken down and reassembled within hours, opening up the possibility that the trainer could be set up at airfields as needed.

Figure 4: The MRT LITE F-35 trainer. Source: Lockheed Martin via Air Force Times

The smaller, more portable, and more affordable trainer appears to have been driven by demand from the F-35 user community—a community that has expanded in 2021 as Switzerland in June and Finland in December became the 15th and 16th countries respectively to sign on to the F-35 programme. Servicing the diverse set of F-35 operators has mandated a layered set of more flexible training solutions. As Raashi Quattlebaum, vice president of F-35 training and logistics observed, "basically, our customers are asking for something portable, something affordable and something that's got a smaller footprint. So, this option really supplies that to them, all of it."[16]

[12][12] Caitlin M. Kenney, "Army Delays IVAS Display Headset by a Year", *Defense One,* October 19, 2021, Army Delays IVAS Display Headset by a Year - Defense One
[13] Ibid.
[14] Ibid.
[15] Megan Eckstein, "Lockheed unveils pared-down F-35 trainer with same software capability but a 90% reduced footprint", *Air Force Times,* 1 December 2021, Lockheed unveils pared-down F-35 trainer with same software capability but a 90% reduced footprint (airforcetimes.com)
[16] Ibid.

Cyber and C4ISTAR

Key Insights:

- **Cyber, Space, and the No-Limits Future of Sub-Threshold Conflict:** The 2020 *Defense of Japan* white paper identified Cyber, Space, and the Electromagnetic Spectrum as the three "new domains" of warfare. Events during the reporting period demonstrated not only how sub-threshold conflict in cyber and space is already nearly constant, but also is, at least in some cases, unconstrained as actors use these domains to attack societal, economic, and political cohesion. The escalation of the cyber war between Iran and Israel in October and November involved each country attacking "the soft underbelly" of the other's cyber ecosystem—individuals, companies, and critical infrastructure providers—demonstrating the growing and potentially geopolitically consequential vulnerabilities in cyberspace. In space, an interview with the US Space Force deputy commander revealed the scale and *daily* frequency of non-kinetic attacks against US satellites, including those that provide both critical communications and position, navigation, and timing (PNT) information. The non-kinetic counterspace threat is one that is difficult to deter and can be difficult to detect, but it is relevant for all small and large militaries that rely on space-based intelligence, surveillance, and reconnaissance (ISR); command, control, and communications (C3), and PNT.

Cyber-War, Civil Society, Critical Infrastructure and the Future of Conflict: Distrubing visions of the future of conflict in which individuals are doxxed and targeted for harrassment and embarrassment and attacks against critical ifnrastructure are used to stimulate societal unrest were on display as the cyber-conflict between Israel and Iran escalated in October and November.

In October, Israel reportedly carried out a cyberattack that shut down service at 4,300 gas stations across Iran for between seven and twelve days in an effort to undermine the Iranian public's confidence in Iran's leadership and cause societal unrest. Accoridng to a *New York Times* report, "Gas pumps suddenly stopped working and a digital message directed customers to complai to Iran's Supreme Leader, Ayatollah Ali Khamenei, displaying the phone number to his office."[17]

Days after the attack on Iran's gas stations, an Iranian-linked hackng group known as Black Shadow, targeted an Israeli web-hosting company, temporarily shutting down access to several websites and stealing user data from "Atraf", an Israeli LGBTQ dating site, including private photos and sensititve personal information. The information was subsequently posted on-line.[18]

Dark Shadow also claimed attacks against Israeli public transportation companies Dan and Kavim, a children's museum, public radio's online blog, tourism company Pegasus, and Doctor Ticket, a service that has sensitive medical data. Previously, Dark Shadow had reported stolen information frm Israeli insurance company Shirbit in 2020 and sold it on the dark web when the company refused to pay a ransom.[19]

Iran also "doxed" a leading Israeli cyber security expert who specializes in Iranian hacking efforts, releasing his name, photograph, phone number, birth date, email address, social media handles, and home address on Fars News, an Iranian media outlet operated by the Islamic Revolutionary Guard Corps. [20]

Of course, cyberattacks against critical infrastrutcure have happened in the past and appear to be occuring more regularly. The ransomeware attack against the US Colonial pipeline in May 2021 stands out as a recent example of a successful cyber attack against critical infrastrutucre, though the motive was more

[17] Farnaz Fassihi and Ronen Bergman, "Israel and Iran Broaden Cyberwar to Attack Civilian Targets", *New York Times,* 27 November 2021, Israel and Iran Broaden Cyberwar to Attack Civilian Targets - The New York Times (nytimes.com)
[18] Ibid.
[19] Judah Ari Gross, "Amid ongoing cyberwar, Iran uses new tactic: Doxing Israeli foes", *Times of Israel,* 17 November 2021, Amid ongoing cyberwar, Iran uses new tactic: Doxing Israeli foes | The Times of Israel
[20] Ibid.

centered on economic enrichment rather than inflicting lasting and cascading societal unrest. The discussion below on resilient position, navigation, and timing (PNT) also reveals the frequent use of "reversible" cyberattacks against infrastructure in space to demonstrate a capability and willingness to use it.

Cyber theft of sensitive personal information has been covered in previous DEFTECH Scans as well, particularly the scale of China's breaches of US government databases such as those possessed by the Office of Personnel Management, and the Solar Winds attack carried out by Russian hackers earlier in 2021.

However, developments in the Israel-Iran cyberwar offer a more visceral and tangible view of how attacks against the "soft-underbelly"[21] of cyber-security—individuas, companies, and critical infrastrutcure assets—that are not as protected as government and national secuirty agencies can have real and debilitating consequences not just for governments and militaries, but also for individuals. Even individuals with no affiliation with the government or military of a given state are at risk of some of their most personal information and medical histories being revealed for all to see and whose livelihoods may be put at risk by lack of access to gas, transportation, or other frequently taken-for-granted resources.

National efforts to shore up cyber defenses, then, first requires a broadened understanding of a threat that has expanded well-beyond stealing government data, technical secrets, or holding military and security assets at cyber risk and then a comprehensive approach in which governments provide guidelines for and support industry in enhancing cybersecurity across sectors.

Lotem Finkelsteing, head of intelligence at cyber-security company Check Point captured the complexity of the situation assessing that Iranian hackers understood "thay do not need to attack a government agency, which is more protected." Rather they could go after small companies and infratstucture service providers with less robust security "that control enormous amounts of information, including financial or intimate personal" data.

Return to Route: The Quest for Resilient and Assured PNT: US Space Force second in command General David Thompson revealed in an interview at the Halifax International Security Forum that US satellites are under attack every day by Chinese and Russian "reversible" attacks such as electronic warfare jamming, using directed energy to temporarily dazzle or blind satellites, and cyberattacks. The attacks are described as "reversible" because their effects—unlike the direct ascent ASAT attacks discussed above—can be temporary. Once the attacking side ceases the attack, the satellite can return to normal functionality relatively quickly. Thompson observed that "the threats are really growing and expanding every single day. And its really an evolution of activity that's been happening for a long time. We're really at a point now where there's a whole host of ways that our space systems can be threatened."[22]

Certainly, this concern over non-kinetic counterspace activities is not unique to the United States. Cyber threats and electromagnetic jamming were both called out in France's 2019 Space Defense Strategy[23] while a newly contested envirnment in space has been a feature of many defence white papers over the last two years, especially the *Defense of Japan 2020*[24] white paper, which included space, cyber, and the electromagnetic specturm as the three "new domains" of warfare and Australia's 2021 Strategic Update.[25]

Among the most attracttive targets for counter-space activities are Global Navigation Satellite Systems (GNSS), such as GPS or GALILEO. These systems are important for personal, civil, and commercial activities. In the military context, though, assured PNT is essential for effective and timely navigation and

[21] Yossi Melman, "Israel's Cyber Capabilities Are Superior to Iran's, but It Has a Soft Underbelly", *Haaretz,* 2 November 2021, Israel's cyber capabilities are superior to Iran's, but it has a soft underbelly - Israel News - Haaretz.com
[22] Joseph Trevithick, "U.S. Satellites Are Being Attacked Every Day According To Space Force General", *The Drive,* 30 November 2021, U.S. Satellites Are Being Attacked Every Day According To Space Force General (thedrive.com)
[23] "Space Defense Strategy", The French Ministry for the Armed Forces, 2019, page 23.
[24] Defense of Japan 2020, Japan Ministry of Defense, Special Feature: New Domains, e_04_防衛白書R2_特集_0630.indd (mod.go.jp)
[25] "Strategic Update 2020", Australian Department of Defense, 1 July 2020

targeting of assets. The risk of degraded or denied access to GPS led the US DoD in early December to order $315 million worth of BAE's Common GPS Modules that use the M-Code, a military – only GPS signal that is described as "more accurate and provides anti-jamming and anti-spoofing capabilities." [26] DoD had previously ordered $325 million worth of the Common GPS modules in May. BAE also received an initial order in June for M-Code capable GPS receivers from Germany, signalling the broad concern about GPS jamming and assured PNT in the current contested space environment.[27]

DoD is also examining ways to ensure assured PNT without using GPS or other GNSS systems. In November, scientists at Sandia National Laboratory announced they had developed a quantum sensor that does not require the power or support machinery of previous prototypes and has been able to run for a year and a half in a laboratory environment mitigating concerns over the durability of quantum sensors. In an email to *Defense One*, Sandia National Labs scientists Peter Schwindt "these inertial sensors can be used wherever there is a need for positional or navigational information, and where a GPS outage is unacceptable or GPS is unavialable", including in several civilian and commercial applications such as in the operation of autonomous vehicles, in underground or underwater environmets, and in oil, gas, and mineral exploration.[28]

Crewed Platforms

Key Insights:

- **New Designs and Capabilities:** This volume's crewed platform section looks at the development of new variants of existing aircraft and designs of new aircraft being introduced to take on new missions and, in possibly in the case of a two-seater J-20 fighter, adapt tactical air forces to emerging concepts of airpower that incorporate smaller numbers of 5th generation fighter aircraft with small swarms of force multiplying attritable and expendable systems. These new concepts are intended to add range, lethality, precision, and survivability to expensive and exquisite fighters. The display of the massive Calidus B-350 light attack aircraft during the Dubai Airshow stands out as another novel design approach to increasing lethality and flexibility in carrying out a range of missions.

New Variants of Chinese Stealth Fighters Revealed: Two new variants of Chinese stealth aircraft were revealed in late October, hinting at new capabilities for the People's Liberation Army Air Force (PLAAF).

Photos and video taken outside of Chengdu Aircraft factory showed a two-seat J-20 stealth fighter. It is unclear what value a two-seat J-20 would provide, though some reporting has suggested that it could serve as a crewed-uncrewed teaming mothership that would partner with loyal wingman or other attritable uncrewed aerial systems.[29]

[26] Nathan Strout, "Department of Defense orders $316 million more in anti-jam GPS devices", *Defense News,* 2 December 2021, Department of Defense orders $316 million more in anti-jam GPS devices (defensenews.com)
[27] Nathan Strout, "BAE Systems to deliver first M-Code GPS User Equipment to Germany", *C4ISRNet,* 29 June 2021, BAE Systems to deliver first M-Code GPS User Equipment to Germany (c4isrnet.com)
[28] Patrick Tucker, "Quantum Sensor Breakthrough Paves Way for GPS-Free Navigation", *Defense One,* 2 November 2021, Quantum Sensor Breakthrough Paves Way For GPS-Free Navigation - Defense One
[29] Mike Yeo, "New variants of Chinese stealth fighters break cover", *Defense News*, 29 October 2021, New variants of Chinese stealth fighters break cover (defensenews.com)

While there is little publicly available reporting on China's loyal wingman and human-machine teaming efforts, both the LJ-1 target drone[30] and the Sky Hawk UAS[31] have been linked to teamed operations with crewed aircraft. Another role the back-seat inhabitant could play is as a primary sensor operator coordinating other networked, manned assets.[32]

Shifting Concepts of Air Power, Crewed-Uncrewed Teaming, and Loyal Wingman Programs Around the World

Concepts of air power are shifting away from reliance on squadrons of expensive and exquisite aircraft and toward teams of these advanced crewed aircraft with uncrewed systems. Several countries have either accelerated, expanded, or begun development of "loyal wingman" and other attritable UAS programmes designed to serve as force multipliers for crewed aircraft. Key loyal wingman and future combat air power programs include:

- **US:** Skyborg, Next Generation Air Dominance, Low-Cost Attritable Aircraft Technology (Valkyrie), others
- **Australia:** Airpower Teaming System (ATS)
- **UK:** Project Mosquito / LANCA, as part of the Future Combat Air Power Teaming System / Tempest program
- **India:** Combat Air Teaming System
- **Russia:** Grom, Okhotnik
- **France / Germany / Spain:** Future Combat Air System (FCAS), which includes research on attritable UAS and a loyal wingman
- **Japan:** Future fighter program (F-X) includes research and development on a UAS capable of teaming with the crewed F-X
- **Kelley Aerospace (Singapore-based Private Company):** Arrow

Photos also surfaced on 29 October of what looks like a stealthy carrier-borne fighter taking off for the first time. The photos show the catapult launch bar on the nose landing gear and what appears to be hinges on the wings that allow them to be folded, a common feature of carrier-based aircraft to cope with the limited space on deck and in aircraft carrier hangers. The design is based on the J-31 stealth aircraft, which was p thought to have been developed for export. The new aircraft is expected to equip the Type 003 carrier currently being built and will be the first of China's aircraft carriers to be equipped with catapults to shorten the take-off and landing cycle.[33]

"Bizarre Monster" of a New Plane: UAE-based company Caldius unveiled a mock-up of its new "light attack" aircraft, known as the B-350, during the Dubai Airshow 2021. The aircraft is notable for its size. With a reported wingspan of more than fifty feet and a maximum take-off weight (MTOW) of over 20,000 pounds, it is considerably larger than the A-29 Super Tucano light attack aircraft, which has a wingspan of 36.5 feet and a maximum take-off weight of 12,000 pounds. The most common comparison in reporting on the B-350 has been to the Skyraider, a Cold War era aircraft that had a similar wingspan and a MTOW of 18,000 pounds.[34]

[30] Steve Trimble, "China Exhibitors Display Loyal Wingman Model", *Aviation Week,* August 22, 2019,
[31] Kristin Huang, "China's Sky Hawk stealth drone has capability to 'talk' to fighter pilots, developer says", *South China Morning Post,* January 11, 2019, China's Sky Hawk stealth drone has capability to 'talk' to fighter pilots, developer says | South China Morning Post (scmp.com)
[32] Thomas Newdick, "Giant Turboprop Attack Plan Reminiscent of The A-1 Skyraider Unveiled at Dubai Airshow", *The Drive,* 16 November 2021, Giant Turboprop Attack Plane Reminiscent Of The A-1 Skyraider Unveiled At Dubai Airshow (thedrive.com)
[33] Mike Yeo, "New variants of Chinese stealth fighters break cover", *Defense News*, 29 October 2021, New variants of Chinese stealth fighters break cover (defensenews.com)
[34] Thomas Newdick, "Giant Turboprop Attack Plan Reminiscent of The A-1 Skyraider Unveiled at Dubai Airshow", *The Drive,* 16 November 2021, Giant Turboprop Attack Plane Reminiscent Of The A-1 Skyraider Unveiled At Dubai Airshow (thedrive.com)

The B-350 has twelve underwing hardpoints as well as an under-fuselage retractable electro-optic/infrared (EO/IR) sensor turret. According to *Janes*, it will have an endurance of seven hours, a range of 350 km, and a service ceiling of 35,000 ft.[35] The mock-up was shown alongside several possible offensive and defensive ordnance and payloads including the domestically produced Al-Tariq bomb kits. It is being built using carbon fibres and will include the same Collins Aerospace Pro Line Fusion avionics package as the much smaller B-250 light attack aircraft it revealed at the same event in 2017. [36]

Figure 5: The Callidus B-350 mock-up at the Dubai Air Show. Source: Janes / Akshara Parakala

As far as potential missions for the "bizarre monster of an aircraft",[37] speculation has centred on counter terrorism and counter insurgency as well as anti-helicopter operations.

Weapons Systems and Munitions

Key Insights:

Major Weapons Tests Reiterate the Risks of Kinetic Conflict in Space: Russia conducted a direct-ascent anti-satellite missile test in November, shooting down a Cosmos satellite in orbit and creating space debris that caused the International Space Station to take emergency measures to protect the astronauts and cosmonauts on board. Also, during the reporting period, reports emerged that China had carried out a test of fractional orbital bombardment system in July that incorporated a nuclear capable hypersonic glide vehicle. Individually, the tests displayed the advancing military capability of both Russia and China and generated concern in many countries—especially the United States. However, taken together they once again underscore the escalatory and destabilizing risks of weaponization of orbital space and reinforce the need for enhanced clarity on norms surrounding military use of space.

Lost in Space: Russia Tests a Direct Ascent ASAT Weapon: On 15 November, Russia tested a direct ascent anti-satellite (ASAT) missile against a live satellite target, joining China (2007) and India (2019) in the list of countries that have tested direct ascent ASAT weapons against a satellite in orbit. The United States also shot down a satellite in space in 2008, though it was not explicitly billed as a test of a new capability. Rather, the US Navy claimed it shot down a defunct spy satellite that malfunctioned soon after reaching orbit to avoid it re-entering the earth's atmosphere with a fuel tank filled with hydrazine, which could have caused significant damage if it had landed in a populated area.[38]

Russia used a PL 19 Nudol interceptor missile to strike a defunct COSMOS 1408 satellite at an altitude of 480 km (300 miles). As with the other tests and operations that involved shooting a live satellite in space, the Russian test drew criticism for exacerbating the problem of space debris and space situational awareness, especially in Low Earth Orbit, and posing a threat to the International Space Station, which had to take emergency actions.

[35] Gareth Jennings and Akshara Parakala, "Dubai Airshow 2021: Calidus showcases B-350 'light attack' aircraft", *Janes,* 15 November 2021, Dubai Airshow 2021: Calidus showcases B-350 'light attack' aircraft (janes.com)
[36] Ibid.
[37] Thomas Newdick, "Giant Turboprop Attack Plan Reminiscent of The A-1 Skyraider Unveiled at Dubai Airshow", *The Drive,* 16 November 2021, Giant Turboprop Attack Plane Reminiscent Of The A-1 Skyraider Unveiled At Dubai Airshow (thedrive.com)
[38] "Pentagon: Missile Scored Direct Hit on Satellite", *NPR,* 21 February 2008, Pentagon: Missile Scored Direct Hit on Satellite : NPR

The October DEFTECH Scan featured reporting on the worsening problem of space situational awareness, including data from the US Space Command that the organization was tracking 35,000 objects in LEO, a 22% increase from just two years ago, due to "mega constellations" and "some debris-generating events."[39] Within two days of the Russian test US Space Command noted that the test had created "more than 1,500 pieces of trackable orbital debris" with "hundreds of thousands of smaller [fragments] likely to surface."[40] Given that the test satellite was destroyed at a higher altitude than either the Indian or Chinese test, "the debris generated after the intercept could end up significantly dispersed, including to higher orbits—where it may linger for years if not decades", according to Ankit Panda of *The Diplomat* writing for the Carnegie Endowment for International Peace.[41]

The series of kinetic tests and operations against satellites in space over the last fifteen years is a worrying, if slow-moving, trend. Space—especially LEO—has simultaneously become more cluttered and more important to modern military, commercial, and civilian communications and observation infrastructure. Shooting down satellites not only reduces the resilience of these crucial infrastructures, but also can create cascading challenges in which collisions between space debris and spacecraft will create new debris—a destabilizing and distinctly unvirtuous cycle. As with other emerging technology and capability areas, including the use of cyberattacks against individuals and infrastructure, the development and diffusion of advanced missile systems capable of shooting satellites out of space should catalyse a reinvigoration of discussion of global norms on the use of kinetic weapons against objects in orbital space.[42]

It's a Bird, It's a Plane, No, It's a FOBS and a (Sort of) Sputnik Moment: On 16 October the *Financial Times* reported that on 27 July China had successfully tested a nuclear-capable hypersonic glide vehicle (HGV) that was launched into orbit, circled the earth, and then re-entered the earth coming within approximately 25 miles of its intended test target.[43]

The test caused initial confusion and then—once there was more clarity on the nature of the capability being tested and what it could enable—considerable alarm among the US DoD and China military watchers around the world. A nuclear armed orbital HGV capable of entering the atmosphere at nearly any point in its orbit and manoeuvring to its target at hypersonic speeds along a shallow trajectory is not a capability that current missile defence systems are capable of reliably combating. According to Secretary of the US Air Force Frank Kendall, "if you use that kind of an approach, you don't have to use a traditional ICBM trajectory. It's a way to avoid defences and missile warning systems."[44]

In an interview with Bloomberg Television, US Joint Chiefs of Staff Chairman General Mark Miley underscored the degree of DoD concern, observing that he was not sure "if it's quite a Sputnik moment, but I think it's very close to that. It has all of our attention."[45]

After several weeks of speculation and conflicting reports about what the test included—some reports suggested that the HGV released its own hypersonic missile, which would be a remarkable technical development—US Space Force Lt. General Chance Saltzman confirmed that the test involved a fractional orbital bombardments system (FOBS) that deployed an HGV.[46]

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[39] Tara Copp, "Number of Objects in Low Earth Orbit Jumps 22% in 2 Years: Space Operations Command", *Defense One,* August 25, 2021, Number of Objects in Low Earth Orbit Jumps 22% in 2 Years: Space Operations Command - Defense One

[40] Ankit Panda, "The Dangerous Fallout of Russia's Anti-Satellite Missile Test", *Carnegie Endowment of International Peace,* 17 November 2021, The Dangerous Fallout of Russia's Anti-Satellite Missile Test - Carnegie Endowment for International Peace

[41] Ibid.

[42] Ibid.

[43] Dmitry Sevastopulo and Kathrin Hille, "China tests new space capability with hypersonic missile", *Financial Times,* 16 October 2021, China tests new space capability with hypersonic missile | Financial Times (ft.com)

[44] Ibid.

[45] Tara Copp, "'It Did Circle the Globe': US Confirms China's Orbital Hypersonic Test", *Defense One,* 27 October 2021, 'It Did Circle the Globe': US Confirms China's Orbital Hypersonic Test - Defense One

[46] Theresa Hitchens, "It's a FOBS, Space Force's Saltzman confirms amid Chinese weapons test confusion", *Breaking Defense*, 29 November 2021, It's a FOBS, Space Force's Saltzman confirms amid Chinese weapons test confusion - Breaking Defense Breaking Defense - Defense industry news, analysis and commentary

Saltzman explained that while HGVs are generally associated with sub-orbital trajectories, a FOBS "is a categorically different system, because a fractional orbit is different than suborbital. A fractional orbit means it can stay on orbit as long as the user determines and then it de-orbits it as part of the flight path." Saltzman added that the Chinese test constituted a "very forward-edge technology capability."[47] Previously, the Soviet Union deployed a nuclear weapons capable FOBS from 1969-1983, though obviously this capability did not involve an HGV.[48]

Robotics and Uncrewed Systems

Key Insights:

- **Uncrewed Systems Demonstrating Value, Developing New Roles and Missions, Diffusing Widely:** Uncrewed systems have demonstrated exceptional value over the last several years as more countries have embraced the uncrewed revolution, particularly uncrewed aerial systems, but also uncrewed ground, surface, and subsurface systems. As demand has increased, more states have come to view uncrewed systems development as a low-cost and low barrier to entry means of enhancing domestic industrial bases, both to satisfy domestic demand and potential to create export opportunities in niche capabilities. The diffusion of uncrewed systems is not limited to states. Non-state actors are able in some cases to acquire uncrewed systems from patron countries or in many cases are able to develop flying improvised explosive devices from commercially available drones. In fact, a swarm of three drones were used in an unsuccessful assassination attempt against the Prime Minister of Iraq in the reporting period. Militaries are also investing in uncrewed systems and supporting capabilities to enable new applications for uncrewed systems, especially human-machine teaming, semi-autonomous drone swarms, and the use and recovery of attritable / reusable systems.

Everybody's Doing It: Diffusion of uncrewed aerial systems (UAS) has been a common theme in DEFTECH Scans, especially the diffusion of the ability of more and more countries to domestically develop and produce UASs. The February 2021 DEFTECH Scan highlighted several countries—especially the UAE, but also Armenia and South Africa—that had demonstrated new domestically developed UASs at the IDEX 2021 in Abu Dhabi.

Figure 6: The Kvadro-1400 during a 2020 test. Source: YouTube.

Further evidence of the focus of nascent and emerging domestic defence industrial basses on UAS development was seen in multiple countries during the reporting period. In late October, Belarus' Deputy Prime Minister Yuri Nazarov told the national parliament that "work is nearing completion to create the domestic Kvadro-1400 strike unmanned aerial platform capable of spotting, identifying, and striking light armoured and unarmoured enemy targets and manpower day and night."[49] Reporting from 2020 reveals that the Kvadro-1400 quadcopter drone is equipped with two rocket launching tubes allowing it multiple shots at targets.[50] The UAS is being developed by Belarus' Delivery Design Bureau.

[47] Ibid.
[48] Ibid.
[49] "Belarus at final stage of developing its own strike drone-deputy PM", *Tass,* 28 October 2021, Belarus at final stage of developing its own strike drone — deputy PM - Military & Defense - TASS
[50] Kelsey Atherton, "For Belarus, two rockets on a drone are better than one", *C4ISRNet,* 19, February 2020, For Belarus, two rockets on a drone are better than one (c4isrnet.com)

During the Egypt Defence Expo (EDEX) held in Cairo from 29 November to 2 December, two locally produced drones were displayed. The Nut tactical reconnaissance drone has a maximum payload of 50 kilograms and endurance of 10 hours. It is co-developed by the Arab Organization for Industrialization and the Military Technical College. The UAS is named after the ancient Egyptian goddess of the sky.[51]

Figure 7: The Egyptian Nut drone displayed at EDEX. Source: Egypt Today

The EJune-30 SW drone—made by Industrial Complex Engineering Robots and the Egyptian Ministry of Military Production—was also displayed during the show. The EJune-30 SW is likely the Egyptian version of the Yabhon United 40 UAS, which Egypt procured from the UAE. It is a medium-altitude, long-endurance UAS capable of autonomous flight. It is 8.9 m long, has a 12 m wingspan, a maximum take-off weight of 1,400 kgs, maximum speed of 260 mph, endurance of 24 hours, and maximum operating altitude of 7,000 m.

Supporting the Attritable / Expendables Revolution: As militaries increase focus on the development and use of swarms of expendable and attritable UAS, emphasis has also been placed on developing supporting technologies and capabilities that will optimize the force multiplying effects of expendable and attritable systems.

For example, on 16 November at the Dubai Air Show, Russian defence firm Kronstadt displayed a drone control workstation that can be placed on an aircraft or warship allowing for a move away from direct remote control of individual systems and towards semi-autonomous drone swarms.[52]

Operators will set general goals for the drone swarms rather than directly controlling each system. Instead, operators will perform supervisory / mission management tasks. Operations related to flight control, managing systems, coping with target task, and ensuring interoperability inside drone swarms will be handled by an AI-enabled computer. The system also features a new graphical interface and uses AI and augmented reality with 3D terrain mapping.[53]

In addition, in the United States, the Defense Advanced Research Projects Agency (DARPA) achieved an important milestone in efforts to launch and recover attritable drones from a mothership. On 29 October, the agency successfully used a C-130 aircraft to recover an X-61 Gremlin attritable drone for the first time. The recovered X-61 was refurbished and then flew again within 24 hours.

[51] Agnes Helou, "Egypt unveils locally made drones at EDEX 2021", *Defense News,* 30 November 2021, Egypt unveils locally made drones at EDEX 2021 (defensenews.com)
[52] "Russia rolls out cutting-edge system to control swarm of drones from aircraft or warship", *Tass,* 16 November 2021, Russia rolls out cutting-edge system to control swarm of drones from aircraft or warship - Military & Defense - TASS
[53] Leonid Nersisyan, "Dubai Airshow 2021: Kronstadt displays new Russian unmanned capabilities", *Shephard Media,* 15 November 2021, Dubai Airshow 2021: Kronstadt displays new Russian unmanned capabilities - Shephard Media

Previous attempts to recover X-61s had come close, but had been unsuccessful, including in an October 2020 test when DARPA failed to recover three Gremlin drones nine separate times. While seen as an overwhelmingly positive development, the recovery test was not 100% successful. A second Gremlin was destroyed during the flight test, demonstrating the need for continued development of the capability. Gremlins program manager Lt. Colonel Paul Calhoun noted, "airborne recovery is complex. We will take some time to enjoy the success of this deployment, then get back to work further analysing the data and determining the next step for the Gremlins technology."[54]

Figure 8: The Kronstadt drone swarm operator system. Source: Leonid Nersisyan, Shephard Media

The Gremlins program is designed to enable the US to release groups of small attritable / reusable sensor drones from crewed cargo planes or even fighter aircraft. The crewed aircraft will be able to stay outside of contested environments while the swarms of UAS would conduct a range of missions before returning to be collected by the mothership, being refitted, and used again. DARPA hopes that each X-61A will have a lifespan of approximately 20 flights.[55]

Drone Swarms Used in Attempted Assassination: Of course, not all drone swarms will be "intelligent" or semi-autonomous. The tactic of using multiple small, commercially available or 'homemade" remotely operated drones has been used multiple times in conflict, including on several occasions against Russia's Kheimeim Airbase in Syria. [56]

On November 7, Iraqi Prime Minister Mustafa al-Kadhimi survived an assassination attempt that involved the use of three explosive laden drones. Two of the drones were shot down in the attack, but a third drone hit al-Kadhimi's home in Baghdad's Green Zone, injuring six of the PM's body guards.[57] It is not yet known which group carried out the attack, though there had been recent political violence in Iraq following national elections.

[54] Steven Losey, "DARPA nabs Gremlin drone in mid-air for first time", *Defense News*, 5 November 2021, DARPA nabs Gremlin drone in midair for first time (defensenews.com)
[55] Ibid.
[56] Charlie D'Agata, "Russian military base in Syria attacked by mysterious drone swarm", *CBS News,* 11 January 2018, Russian military base in Syria attacked by mysterious drone swarm - CBS News
[57] John Davison and Ahmed Rasheed, "Iraqi PM decries 'cowardly' attack on his home by drones carrying explosives", *Reuters*, 8 November 2021, Iraqi PM decries 'cowardly' attack on his home by drones carrying explosives | Reuters


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