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# TEAMJANUS

Latent Variable Environment, Time, And Symbiotic Concepts Through 2045

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Authored by: Andrew Culbreath John Hosey Brennan Kemper Michael Stevic Michael Wacker The views expressed herein are those of the author(s) and do not necessarily reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government. The U.S. Army War College is accredited by the Commission on Higher Education of the Middle States Association of Colleges and Schools, an institutional accrediting agency recognized by the U.S. Secretary of Education and the Council for Higher Education Accreditation. Documents produced by International Fellows may be protected by copyright. (This page intentionally left blank)

## About This Document

The researchers on Team Janus prepared this report as a group Strategic Research Project as part of the requirements to complete the Master of Strategic Studies degree from the United States Army War College (USAWC). The research, analysis, and preparation of this document were conducted from October 2021 through April 2022 as part of the Army Futures Seminar for Academic Year 2022. This report answers a strategic question posed by MG Bradley T. Gericke, Deputy Chief of Staff, G3/5/7, U.S. Army, based on available open-source information and interviews with subject-matter experts.

#### **Requirement:**

What revolutionary concepts and technologies will likely shape the future of land warfare within the continuum of competition, crisis, and conflict through 2045?

- Which adversaries will likely employ any of the revolutionary concepts and technologies identified?
- Where, geographically, will any of the revolutionary concepts and technologies identified likely be employed?

The team's findings were produced in multiple mediums, including a digital PDF version (primary) and a soft-bound book format. Multiple methodologies were used to determine key findings and convergences,



Figure 1: Counter-drone startup Epirus raises \$70M, plans to hire 100 people. Source: Defense News. https://www.defensenews.com/2020/12/17/counter-drone-startup-epirus-raises-70m-plans-to-hire-100-people/

including interviews with subject-matter experts, scholarly publications, open-source reporting, and the Nominal Group Technique.

#### Analytic Confidence

Unless otherwise indicated, the analytic confidence in the findings of this report is MODERATE. The questions posed were complex, and the research timeline was relatively short due to the competing academic requirements of the USAWC curriculum. Corroboration and source reliability were consistently moderate to high. The research team worked individually and collaboratively to answer the questions and utilized several different structured analytic techniques. The team utilized <u>Peterson's Analytic</u> <u>Confidence Factors</u> and <u>Friedman Corollaries</u> to evaluate the analytic confidence of their findings.

#### Words of Estimative Probability

The research team used Kesselman's List of Estimative Words as the guide for determining their Words of Estimative Probability (WEP). These WEPs were selected to reference the likelihood of the converging technologies and concepts within the next 10-25 years.



# **Kesselman List of Estimative Words**

#### Source Reliability

Source reliability is noted at the end of each citation as low (L), moderate (M), or high (H). The citation is hyperlinked to the source. Source reliability is determined using the Trust Scale and Website Evaluation Worksheet (See <u>Annex H</u>) and the Standard Primary Credibility Scale (See <u>Annex J</u>). Sourced figures and photos embedded in the report are hyperlinked to their source.

# **Key Findings**



"The art of war teaches us to rely not on the likelihood of the enemy's not coming, but on our own readiness to receive him; not on the chance of his not attacking, but rather on the fact that we have made our position unassailable."

Sun Tzu, The Art of War

"We need men who can dream of things that never were."

John F Kennedy

## Introduction

What revolutionary concepts and technologies will likely shape the future of land warfare within the continuum of competition, crisis, and conflict through 2045?

• Which adversaries will likely employ any of the revolutionary technologies and concepts identified?

• Where, geographically, will any of the revolutionary technologies and concepts identified likely be employed?

Due to at least 14 revolutionary technologies and a shifting world order, it is highly likely that three concepts will shape the future of land warfare through 2045:

- (1) A Latent Variable Environment The Hidden Phenomenon
- (2) Time as a Domain Weaponizing The Fourth Dimension
- (3) Symbiotic Warfare Human Machine Synergy At The Speed Of Thought



## (1) A Latent Variable Environment – The Hidden Phenomenon

In the discipline of statistics, latent variables are variables not directly observed, but are hidden phenomenon that influence outcomes. A Latent Variable Environment is the concept where hidden entities weaponize publicly available technology to disrupt, deceive, deny, and destroy chosen adversaries, outside of a military commander's control. Accordingly, it is highly likely (71-85%) that



these hidden entities—these "Latent Warriors"—will use at least four key technologies, Nano Observation, Vigilante Drones, Teleporting Influence, and Omnidirectional Network Exploitation, to revolutionize competition, crisis, and conflict through 2045 by eroding nation-state abilities to monopolize violence.

- Innovation Hub Warfighting Project 2040, the National Intelligence Council's, Global Trends 2040: A More Contested World, and NATO's Science and Technology Trends 2020–2040, estimates that technology weaponized by nonstate entities will only increase in availability, deployability, and lethality over the next two decades.
- Cognizant, an information technology consulting firm, reports that exponential developments in advanced technologies are no longer subject to high entry barriers or costly production operations and, cutting-edge technologies once reserved for government use are now wide-spread and available to public consumers.
- Defense News author Stephen Losey reports that SpaceX, a private aerospace company, chose to intervene in war operations between two sovereign states by shutting down a Russian electronic attack against Ukraine in 2022. Such action reveals the presence and effects of a Latent Variable Environment.

#### Nano Observation

Given the estimated quintupling of deployed satellites by 2030 and expansion of the earth observation industry through 2045, it is almost certain (86-89%) that Nano Observation, weaponizing small (less than 22 lbs.) satellites (See Figure 2) to collect and disseminate earth observation data, will continue to be a major aspect of the Latent Variable Environment.

• There are currently 193 companies providing publicly accessible satellite imagery that was formerly limited to government audiences only.

- Earth observation company Spire is using low orbit nanosatellites to collect and release imagery of Russia's military movements in Ukraine to public audiences.
- Tech newsletter, The Hustle, estimates that there will be nearly 50,000 hi-tech satellites orbiting the earth, up from approximately 6,000 today. Likewise, according to a recent RAND study, these newer



observation data. Source: <u>Eutelsat.com</u>. https://www.eutelsat.com/en/home.html

constellations will boast a higher revisit rate, improved spatial resolution, and sophisticated sensing capabilities across the electromagnetic spectrum.

#### **Vigilante Drones**

Latent Variable Warriors are weaponizing private drones to gather intelligence, conduct swarm attacks, and deliver payloads against chosen adversaries (See Figure 3). Due to growing evidence of drone effectiveness in warfare, it is almost certain (86-89%) that Latent Warriors will continue to weaponize commercially available drones through 2045.



Figure 3: Image of private carrying improvised explosives during Russia-Ukraine War 2022 Source: <u>DroneDJ</u>. https://dronedj.com/2022/03/11/ukrainereportedly-adapts-small-drones-to-drop-



Figure 4: Drone video team turns the tables on hiding Russian vehicles Source: <u>https://www.youtube.com/watch?v=PAyl2XiWZyo</u>

- The Russia-Ukraine War in 2022 broadcasts the rise of vigilante drones, where private citizens used drones to fight a professional military by providing real-time intelligence, surveillance, reconnaissance, and rudimentary delivery of improvised explosives (See Figure 3).
- Global industry consultant, the Market Statsville Group, estimates strong future growth of drone availability and technology, with declining production costs.

• Future drone technology is almost certain to include artificial intelligence enabled decision making, increased energy storage for greater operating ranges, and print on-demand manufacturing capacity for supply support.

Lethality of Vigilante Drone use through 2045 will grow by way of Human-Out-Of-The-Loop decision making, Advanced Hive-mind Swarm Technology, and Ionic Thrust Propulsion technologies discussed in this report's Symbiotic Warfare section.

#### **Print On-Demand Logistics**

Portable technology capable of manufacturing weapons, support equipment, and spares for use in Latent Variable operations, specifically Vigilante Drone production (See Figure 5). Due to recent advancements in print ondemand technology, it is almost certain (86-89%) that portable, print on-demand logistics capabilities will be available to public consumers within three to five years.

> • In Businesswire, Berkshire Hathaway reports that



Figure 5: Illustration of portable, print on-demand logistics capability. Source:<u>https://www.ibtimes.co.uk/first-ever-</u>hologram-protest-held-spain-against-gag-law-1496077

additive manufacturing markets are growing by 16-22% each year, with valuations expected to increase from \$15 billion to \$61 billion by 2027.

• During the 2022 Russia-Ukraine War, Ukraine is using portable, on-demand printing technologies to manufacture over 10,000 products for use in battlefield operations. Printed components included protective gear, drone parts, and components for projectile guidance.

#### **Teleporting Influence**

Use of advanced social media platforms to interpersonally influence select audiences through augmented reality interactions is highly likely (71-85%) to expand recruitment, coordination, and actions of future Latent Warriors (See Figure 6).

 Harwell and Lerman of the Washington Post note that social media has already opened a new dimension in modern war, making it new territory to fight over. An example of Latent Warrior actions includes Ukrainian citizens using social media to conduct unofficial information operations against Russian audiences by posting demoralizing videos of Russian losses.



Figure 6: Illustration of a holographic protest to recruit supporters. Source: <u>https://www.ibtimes.co.uk/armed-drones-damage-2-saudi-oil-pumping-stations-oil-output-not-affected-1667504</u>

Social media technology through 2045 will capitalize on augmented reality technology that merges real and virtual worlds into a single view for users. The result is that during digital conversations between people, three dimensional images of participants will be projected, or "teleported," to other members of the conversation.

- Dr. Pam Rutlege of Media Psychology concludes that interpersonal communications using augmented reality will possess persuasive power over human cognition that has not previously existed in distance communications.
- According to a recent report from Stanford, augmented reality, the next frontier for social media, will have powerful psychological effect on humans. According to the study's leader, Dr. Jeremy Bailenson, "We've discovered that using augmented reality technology can change where you walk, how you turn your head, how well you do on tasks, and how you connect socially with other physical people in the room."

This forthcoming power to teleport influence creates opportunities to expand recruitment and mobilization of future Latent Warriors, without regard for time and distance constraints.

#### **Omnidirectional Network Exploitation**

What is currently known as hacking and hacktivism is highly likely (71-85%) to evolve into Omnidirectional Network Exploitation, where distributed Latent Warriors aggregate to inflict a range of cyber effects against selected state targets. Omnidirectional attacks make it challenging for state adversaries to prioritize vulnerability reduction efforts and determine attack origins for counterattack purposes.

According to CNBC • author Monica Pitrelli, hacktivist group Anonymous declared a cyber war against Russia in response to their invasion of Ukraine in 2022. Initial results of their cyber-attacks exploited a range of state vulnerabilities including meddling with hundreds of Russian government databases, releasing personal information



Figure 7: Russia-Ukraine Crisis: Anonymous Hacker Takes Down Russian Govt Sites, Unleashed Cyber War Source: <u>https://www.youtube.com/watch?v=Rdns1BOgC-0</u>

for 120,000 Russian soldiers, and commandeering Russian state television to broadcast atrocities of the invasion (See Figure 7).

• The Washington Post and Bloomberg news outlets report on the growing explosion of volunteer hackers and hacktivists engaging in wide ranging cyber operations beyond state or military control. These Latent Warriors gather over encrypted social media platforms such as WhatsApp and Signal, coordinate multipoint attacks against state institutions and infrastructure, execute operations, disband, and regroup to repeat the cycle.

Omnidirectional Network Exploitation actions through 2045 are likely to increase asymmetric threats by compromising AI enabled human-machine devices to the point where humans, states, or populations are overwhelmingly influenced by complex deception operations. NATO's *Science and Technology Trends 2020–2040* report forecasts that compromised AI systems will be used to "deep fake" communications, and spoof decision makers.

# (2) Time As A Domain – Weaponizing The Fourth Dimension

Advances in new warfighting concepts and revolutionary technologies will highly likely (71-85%) drive the creation of time as the most unique, all-inclusive, warfighting domain in the next decade. Four emerging technologies under development (Directed Energy Weapons, Advanced Hypersonic Weapons, Active and Passive Camouflage, and Artificial Intelligence Advisors) will significantly alter the decision cycle in both offensive and defensive warfighting time-space. Time is the fourth dimension and is also the only warfighting domain that is interwoven and fundamental to all other warfighting domains. Not unlike the Cyber domain, the principal effect of time warfare is to deny the enemy freedom of action in time-space.

A warfighting domain is defined as a dimension where offensive and defensive military operations take place. Time is the fourth dimension and is also the only warfighting domain that is interwoven and fundamental to all other warfighting domains. Not unlike the Cyber domain, the principal effect of time warfare is to deny the enemy freedom of action in time-space.

#### **Directed Energy Weapons (DEW)**

It is highly likely (71-85%) that directed energy weapons will either surpass the capabilities of or entirely replace existing traditional kinetic weapon roles on the battlefield by 2030. High-Energy Lasers (HEL) High-Powered Microwave (HPM) weapons engaging at the speed of light can aim and strike a target in a millisecond, thus substantially shrinking the sensor to shooter decision cycle (See Figure 8).

> • According to BGEN Arvind Dhananjayan



Figure 8: Raytheon's 50-kilowatt laser has been chosen for the U.S. Army's directed energy short-range air defense system on a Stryker combat vehicle. The Army will initially outfit a platoon's worth of the system. Source: <u>https://www.defensenews.com/land/2021/08/18/northropbows-out-of-competition-to-build-laser-weapon-for-strykers/</u>

(Ret.), Consulting Editor for Defence for the Chanakya Forum, DEW provide a number of capabilities and advantages over traditional weapons due to speed-of-light delivery, precision engagement, controlled/scalable effects, logistical benefits of minimal replenishment and low cost per shot. Furthermore, DEWs are silent, offer plausible deniability, cause minimal collateral damage, can travel immense distances relative to conventional weapons and engage multiple targets.

• U.S. competitors are also developing DEWs to include Israel's new "Iron Beam" laser interception system, to replace the existing kinetic missile "Iron Dome" system. This is the world's first energy-based weapons system that uses a laser to shoot down incoming UAVs, rockets, and mortars at a cost of only \$3.50 per shot.

#### **Advanced Hypersonic Missiles**

Due to their speed, unorthodox flight paths, increased accuracy, and reduced costs, Advanced Hypersonic weapons, both conventional and nuclear, will highly likely (71-85%) become the favored strategic and operational deterrent in lieu of current Intercontinental Ballistic Missiles (ICBM) by 2035.



*Figure 9: Graphic depiction of an artillery fires effect compressed decision cycle executed via hypersonic weapons. Source: Michael E. Stevic.* 

• To achieve a desired artillery fire effect on a target requires current conventional heavy weapons to be transported to the battlefield (see Figure 9). When transported by sea, that time is measured in weeks, or days by strategic air, while the same desired fires effect can be measured in less than an hour, anywhere in the world, using advanced hypersonic

weapons.

 Current Hypersonic Missiles are less accurate than today's precision-guided weapons. Lt Gen (Dr) V K Saxena (ret.), former DG, Air Defence, Indian Army envisions future designs will highly likely become more accurate, smaller, with advanced warhead capabilities like the ability to launch from a CONUS Multiple Launch Rocket System-like system with warheads containing



Figure 10: Drone swarms-the future of aerial warfare. Source: https://www.vifindia.org/print/7407

deployable drone-swarms and loitering munitions anywhere in the world in under 30 minutes.

The Defense Department needs to appreciate that hypersonic weapons won't just be an aspect of the future battlefield but its defining feature.

> - Mark Lewis, the executive director of the National Defense Industrial Association's Emerging Technologies Institute stated

#### Adaptive and Passive Camouflage

Although recent events in the Ukrainian war have demonstrated the vulnerability of tanks and armored vehicles, recent developments in both adaptive and passive camouflage technology will highly likely (71-85%) reduce those threats through the thermal and visual spectrums over the next decade. This will likely render the enemy virtually invisible on the battlefield, giving them the element of surprise, and thus significantly reducing the decision cycle in time-space.



Figure 11: BAE ADAPTIV Car Signature. Source: <u>https://www.baesystems.com/en-us/feature/adativ-cloak-of-invisibility</u>

- BAE's "ADAPTIV" is working on a unique adaptive camouflage system (see Figure 11) that allows a vehicle to blend into its surroundings, effectively becoming invisible to hostile thermal imaging systems.
- HyperStealth Biotechnology Corp. has patented a material (see Video 1) that not only hides a target in the visible spectrum, but in the Ultraviolet, Infrared, and Shortwave Infrared while blocking the Thermal Spectrum, making it a true "Broadband Invisibility Cloak" when applied to military vehicles in the future.



Video 1: 'Invisibility cloak' that could hide tanks and troops looks closer to reality. Source: <u>https://www.hyperstealth.com/</u>

#### **Artificial Intelligence Advisors**

It is highly likely (80-95%) that artificial intelligence, in the form of an artificial intelligence advisor, will vastly augment the decision-making of nation-state militaries from the strategic level down to the individual Soldier level by 2045. These Artificial Advisors will likely shorten the decision-making process and help develop adaptive cross-domain kill-webs as an evolutionary leap from the kill chain concept.

• Traditional military decision models are serial processes that are inefficient and too slow to react to today's rapidly changing battlefield environment. Parallel processes, where actions and decisions occur simultaneously or near-simultaneously can only be achieved at the speeds of artificial intelligence decision-making.



Figure 12: How AlOps Makes DevOps Less Noisy Source: <u>https://devops.com/how-aiops-</u> makes-devops-less-noisy/

Multi-domain operations and Joint All Domain Command and Control (JADC2) must evolve from a sensor-to-shooter targeting philosophy to a command-and-control philosophy.

- GEN Wallace, former commander of TRADOC

# (3) Symbiotic Warfare – Human Machine Synergy At The Speed Of Thought

Revolutionary research in mass Advanced Drone Technologies, Cutting-Edge Energy Storage, Nanoscience, Brain-Machine Interfaces (BMI), and Trusted Digital Soldiers makes it highly likely (71-85%) that command functions, combatants, and technology will merge to form interdependent systems of automated and decentralized command and control. This concept, Symbiotic Warfare, implies that the integration of humans, AI, and teamed machines at thought speed will likely allow military combatants an exponential increase in combat power by 2045.



*Figure 13: Drones against Great Powers. Source: <u>https://madsciblog.tradoc.army.mil/261-how-big-of-a-</u><u>deal-are-drone-swarms/</u>* 

#### Advanced Drone Technologies, Three Characteristics

Due to the rapid development of converging drone technologies, an adversary's ability to manufacture, arm, and deploy vast numbers of autonomously coordinated drone swarms (See Figure 13) to overwhelm their opponent's conventional anti-aircraft defenses and to strike highly mobile targets is likely (56-70%) by 2040. The ability of both state and non-state actors to temporarily neutralize an enemy's control of the airspace will likely result in the air domain remaining contested throughout the period of armed conflict. This is likely due to three advances in drone technology: Human-Out-Of-The-Loop, Advanced Hive-mind Swarms, and Ionic Thrust Propulsion.

#### Human Out-Of-The-Loop Drone Technology

Drones are fully autonomous when they can select and engage targets without human control. It is likely that drones will achieve this level of autonomous action by 2045. This has become utilized more recently in the Middle East.

- In 2019 and 2021, respectively, the governments of Libya and Israel reported deploying small groups of drones to locate and engage enemy targets allegedly without "human in the loop" control.
- According to Marco Giordani of the University of Padova, most research is moving in the direction of increasing autonomy, stating, "UAVs need to follow the soldiers into the battlefield, so they must have a sort of automation that makes it possible for this to work properly. We don't want human intervention or maybe sometimes we don't even have the possibility to use humans to control them."

#### Advanced Hive-mind Swarm Technology, with Edge AI

Due to the rapid development of Edge Artificial Intelligence (AI), it is highly likely (80-95%) that Hive-mind Swarm attack drones will become commercially available for military application in the next three to five years.

> Dr. David Diller, senior engineer and Project Manager at Raytheon's Unmanned Innovations



Figure 14: Citadel Defense Lands Multi-Million US Contract for Al Counter-Drone System. Source: <u>https://www.thedefensepost.com/2021/02/02/citadel-titan-</u> <u>counter-drone-contract/</u>

Laboratory, stated during a recent interview that the current challenge regarding swarm drone technology is the swarm's ability to individually communicate within the swarm, mainly when traditional communications platforms such as 5G or GPS satellites are denied or unavailable (e.g., operating deep inside a building) (See Figure 14).

• The use of peer-to-peer self-healing wireless mesh networks, currently in development by the University of Hail and Islamic University of Madinah, mitigates the concern of limited communications and GPS signaling.

#### Ionic Thrust Propulsion

Due to rapid advancement in battery technology, the first solid-state ion thrust-powered drone aircraft (See Figure 15), a form of electric propulsion generally used for spacecraft propulsion in which thrust is created by accelerating positively charged atoms, will likely (56–70%) be available for commercial use within three to five years. The concept of ionic thrust technology has been used for decades in the zero atmospheres of space to help satellites position themselves inside a specific orbit and is now being developed for use on earth.



Figure 15: Ion Thrust drone prototype. Source: <u>https://www.nature.com/articles/s41586-018-0707-9</u>

 Mr. Tomas Pribanic, lead scientist and chief executive officer of Undefined Technologies, Inc., explained that his scientists are developing a drone for commercial deliveries that weighs two pounds and will ultimately achieve flight durations of up to 30 minutes without moving parts and completely silent (See Video 2).



Video 2: New Drone Tech: No Propellers, and Yet It Flies! Source: https://www.youtube.com/watch?v=UGM4JXVB5FM

#### **Cutting Edge Battery Research**

Due to a four-fold increase in funding for battery research and development since 2019, it is highly likely (71-85%) that this rapidly advancing field of technological innovation will enable nation-states to exploit the technology for military use by 2045.

- In early April 2022, the Biden Administration passed an Infrastructure Bill that included \$3 Billion for advanced energy storage research. Along with the renewed investment, the speed of adoption of technology has increased exponentially as science and technology have become more democratized.
- Chinese researchers from the School of Physics, Northwest University, X'ian, China, are using rapidly maturing machine learning in the chemical engineering field allowing for leaps in design and battery architecture.
- Mr. Steve Levine, who writes *The Electric* and wrote *The Powerhouse: America, China, and the Great Battery War,* states that the only limitation to minimizing batteries that are more powerful is the cost and access to materials.

#### Increasing Strength And Duration Through Nanoscience

Despite a lack of research on the negative impacts of nanoscience, it is almost certain (86 - 99%) that incremental improvements in nanotechnology will facilitate warfare technologies (nano weapons) that increase durability, lethality, and precision. It is highly likely (71-85%) that revolutionary changes in weapons due to nanotechnology are 30 years or more away.

- General Nano, LLC, a leading nanotech research firm has successfully manufactured several products for the defense industry including, material coatings that last years instead of hours, nano-structured silicate manipulation, reducing insulation weight, and high-power microwave devices with reduced weight, shape, and power consumption.
- Other lines of effort, from Boeing, Airbus, and BAE Systems that are close to fruition are lighter missiles, projectiles, or mortar rounds, with reduced mass, greater destructive force, increased penetration capability, tailored energy release, smaller size, or improved accuracy.

#### **Brain-Machine Interfaces**

All the previous technologies are presently controlled through some type of manually operated device, such as a tablet or computer. Current research on brain-machine interfaces is highly likely (71-85%) to be commercialized and used by militaries by 2045.

• The best source of the brain-machine interface is currently invasive, but the University of Arizona and others, are researching cutting-edge technology and signaling to allow for extracranial reading of brain signals to control drones, which then could be adapted for other automation (See Video 3).

• Gabe Newell, President and Co-Founder of Valve, is currently working on an open-source BMI software project, allowing developers to begin to interpret the signals being read from people's brains using hardware like modified VR (virtual

reality) helmets. This direct interface would allow for faster humanautonomy teaming, as the technology, both hardware and software, becomes another signaled extension of the body.



Video 3: Formation Control of Robotic Swarms Using Brain Interface. Source: <u>https://www.youtube.com/watch?v=BymnXeuSLcY</u>

#### **Trusted Digital Soldiers**

Even though some experts perceive an artificial intelligence (AI) winter, the science behind AI's progression with deep learning techniques and natural language processing (NLP) continues with new models allowing the science to highly likely (71-85%) catalyze within the next decade. It is almost certain (80-95%) that artificial intelligence, in the form of a Trusted Digital Soldiers, will vastly augment the decision-making of nation-state militaries from the strategic level down to the individual Soldier level by 2045, during all phases of the competition continuum with conflict being the greatest beneficiary.

- Renaissance Technologies, and other even more secretive investment funds, are fully committed to letting AI take the enterprise to new frontiers in innovation, profitability, and risk.
- Through OmniSci, an advanced AI company, businesses can interactively query, visualize, and power location intelligence workflows over billions of records. Their innovative offering is used by the likes of pharma giant Pfizer, as well as Ericsson, Nvidia, and Skyhook.

# Which adversaries Will Likely Employ Any Of The Revolutionary Concepts And Technologies Identified?

Figure 16 displays estimates of competitors and adversaries likely to employ the revolutionary concepts and technologies identified. Due to time constraints, comprehensive exploration of all nation-states was not possible, so estimates are made with low confidence.

WHAT ADVERSARY?		
Concept	Technology	Competitors/Adversaries
Time As A Domain	Directed Energy Weapons	China, Russia
	Advanced Hypersonic Missiles	China, Russia
	Active & Passive Camouflage	China, Russia, India
	Artificial Intelligence Advisors	China, Russia, EU
Symbiotic Warfare	Trusted Digital Soldier	China, Russia, Iran, EU, Turkey
	Advanced Drone Technology	China, Russia, Iran, EU, Turkey
	Nanoscience	China, Russia, Iran, EU, Japan
	Ionic Thrust Propulsion	China, Russia, EU
	Advanced Energy Storage	China, Russia, EU, Japan, Turkey
Latent Variable Environment	Energy Storage	China, Russia, EU, Japan, Turkey
	Nano Observation	China, Russia
	Vigilante Drones	China, Russia, EU, Japan, Turkey
	Teleporting Influence	China, Russia, EU, Turkey
	Omnipresent Network Exploitation	China, Russia

Figure 16: Adversary Likelihood Of Employing the Technology and Concepts.

# Where, Geographically, Any Of The Revolutionary Concepts And Technologies Identified Likely Be Employed?

To estimate the geographic location of where revolutionary concepts and technologies are likely to be employed for competition, crisis, and conflict through 2045, the team scoped its research to locations with indications of future conflict. Due to time constraints, comprehensive exploration of all geographic regions was not possible, so estimates are made with low confidence. Figure 17 displays the results.



Figure 17: Likelihood Of Conflict In Geographic Location

#### **Highly Likely**

- Central and Southeast Asia despite comparatively low quality of life and less developed industrial bases, it is highly likely (71-85%) that Central and Southeast Asia will be the location of future state-sponsored war through 2045. This results from circumstances where hegemonic state influence, developing nation ambitions, and China's Belt and Road Initiative (BRI) converge to create conditions for competition, crises, and ultimately state versus state war.
- Urban Areas due to a forecast that 68% of the world's population will live in cities by 2045, it is highly likely (71-85%) that future conflicts will occur in urban settings. This estimate concludes that urban sprawl and megacity growth are highly likely to foster conditions that will cause future crises and conflict in urban environments.

• **Space Domain** – due to increasing reliance on the space domain for communications, positioning, reconnaissance, and a range of other military applications, it is highly likely (71-85%) that US space assets will incur covert or overt attacks by adversary anti-satellite weapons prior to 2045. This estimate concludes that strategic competitor anti-satellite capabilities and adversary threats of future attacks are increasing the potential for future attacks on US space assets.

#### Likely

- United States despite prevention of significant homeland attacks since 11 September 2001, probability of complex and coordinated attacks within the United States is likely (56-71%) through 2045. This estimate results from growing use of social media platforms to radicalize marginalized groups and increasing public access to cyber, drone, and other advanced technologies that may be weaponized for insider attacks.
- European Union due to a shifting world order, waning US support, and Russian aggression, it is likely (56-71%) that European Union members will consolidate governance and security structures, coalescing into a unified superpower by 2045. This estimate stems from 2022 events where Russia's invasion of Ukraine sparked regional security and economic concerns, energizing the EU to gather consensus and take actions to safeguard their collective interests.

#### Unlikely

- **Taiwan** despite threats of aggression and military posturing that signals invasion, it is unlikely (31-45%) that China will forcefully invade Taiwan by 2045. This estimate concludes that the People's Republic of China is achieving reunification with Taiwan through diplomatic, economic, and "gray zone" military means, rendering future military force as unlikely.
- The Arctic despite increasing maritime traffic, growing resource discoveries, and expanding military presence among strategic competitors, probability of conflict in the Arctic region is unlikely (31-45%) through 2045. This estimate concludes strong cooperation among Arctic Council members and ongoing NATO security assurances are likely to prevent conflict escalation in the region.

#### **Highly Unlikely**

• Latin America – despite growing competition over accessing rare earth metals within Latin America's "Lithium Triangle" in Argentina, Chile, and Bolivia, the probability of conflict among strategic competitors in this region is highly unlikely (16-30%) through 2045. This estimate concludes that the low strategic value of the region and the presence of lithium ore deposits in other locations makes it unlikely that military activity within Latin America will rise above the level of competition.

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# Latent Variable Warfare Is Highly Likely To Revolutionize Competition, Crisis, And Conflict Through 2040+

#### **Executive Summary**

Despite extensive state investments in advancing military technology, it is highly likely (71-85%) that Latent Variable Warfare will revolutionize competition, crisis, and conflict through 2040+. Latent Variable Warfare uses weaponized technology to conduct a range of military operations by non-traditional entities. Due to lower entry barriers and declining production costs, cutting-edge technology that was once reserved for official government use is now widespread and available to the masses. This empowers non-traditional, hidden entities to acquire and employ weaponized technologies that shape outcomes of state-sponsored war.

#### Discussion

It is highly likely that the evolving concept of Latent Variable Warfare will revolutionize competition, crisis, and conflict through 2040+, by empowering hidden entities to shape outcomes of state-sponsored war. In the discipline of Statistics, latent variables are variables that are not directly observed, but are hidden phenomenon that influence outcomes.<sup>M</sup> Latent Warfare is just that, actions where non-traditional entities disrupt, deceive, deny, and destroy adversaries (See <u>*Gray Zone*</u>). These non-traditional entities are known as Latent Warriors.

The operating environment for future competition, crisis, and conflict is almost certain (86-99%) to rely on use of technological applications enabled by the electromagnetic spectrum.<sup>H</sup> Exponential developments in technology are no longer subject to high entry barriers or costly production operations; so, cutting-edge technology that was once reserved for official government use is now wide-spread and available to the masses.<sup>H</sup> As a result, agile, innovative organizations can develop and deliver advanced technologies to consumers faster than militaries can acquire and field them, creating brief competitive advantages (See <u>Artificial Strategic Advisor</u> by COL John Hosey).<sup>H</sup> Latent Warriors weaponize these technologies to exploit the advantages (See <u>Energy Storage</u> by COL John Hosey).

The emerging problem is that state vs. state warfare is no longer defined by battles between professional militaries; now, hidden third party entities are acquiring and employing weaponized technologies to shape outcomes of state-sponsored war.M Accordingly, ally and adversary military forces may be strengthened or weakened by Latent Warriors operating beyond their control, setting conditions for a revolutionary change in the character of war.<sup>H</sup> Latent Variable Warfare is use of weaponized technology to conduct a range of military operations by Latent Warriors. Example warriors include corporations, paramilitary forces, activists, hacktivists, and any person that chooses to participate in military operations. Depending on one's perspective, Latent Variable Warfare is official or unofficial actions that include gray zone or overt operations against an adversary (See *Gray Zone*). Its effectiveness results from mass effects. Traditional state-sponsored militaries have finite force structure, require lots of resources to operate, and occupy large footprints. This constrains their ability to maneuver and cover all domains. Latent Warriors do not require extensive resources, rather they use many disaggregated open-source technologies to aggregate effects against adversary forces.

Latent Variable Warfare works by non-traditional entities conducting intelligence, information, cyber, and kinetic operations to disrupt, deceive, deny, and destroy adversaries (See <u>*Gray Zone*</u>). Common means of Latent Warfare include imagery sharing, drone operations, social media networking, and hacking.<sup>MMMH</sup>

For imagery sharing, Latent Warriors use commercial satellite imagery, geotagged photos, videos, and social media messages to plot and track the movements of adversary forces. This is possible because the earth observation industry is expanding, creating publicly accessible satellite imagery that was formerly reserved for official government use only.<sup>M</sup> For example, companies like Spire deploy nano-satellites to develop data solutions for anyone with a need for imagery.<sup>H</sup> During Russia's invasion of Ukraine in 2022, Latent Warriors maintained a Russia-Ukraine Monitor Map that tracked Russian military movement in Ukraine by aggregating publicly accessible data.<sup>H</sup> This type of mass intelligence collection assists with evacuations, targeting, and attack planning.

For drone operations, Latent Warriors use them for gathering intelligence and delivering payloads. Drone availability and technology is exponentially growing while production costs are declining, expanding their availability to the public (See <u>Autonomous Drone</u> <u>Technology</u> by LTC Andrew Culbreath).<sup>H</sup> Drones, also known as unmanned vehicles, are operable over land, air, sea, and space domains. Though range, payload capacities, and optic effectiveness are limited for non-military drones, more lethal drone technology will be available to the public in the near future. During the Russia-Ukraine War, Ukrainian officials broadcast a social media message calling for private citizens to put their drones to use fighting Russian soldiers, thus officially recruiting Latent Warriors.<sup>M</sup> Also, private drones are being used to drop Molotov cocktails and grenades on invading Russian forces, furthering the effectiveness of Latent Variable Warfare.<sup>M</sup>

For social media networking, Latent Warriors use publicly available social media platforms to communicate anonymously, gather intelligence on adversaries, and

broadcast information campaigns. This is possible because social media platforms are accessible to anyone with an internet connected device that can reach 4.5 billion users over 190 countries.M Social media messaging systems such as Signal provide Latent Warriors with anonymous, encrypted means to communicate and mass broadcast real-time information among others in their networks.<sup>H</sup> For example, during the Russia-Ukraine War, Twitter and TikTok social media sites were data scraped to gather near real-time intelligence on Russian troop activities.<sup>M</sup> Also, the Ukrainian government conducted information operations by establishing a social media site that reported killed or captured Russian soldiers, so Russian families could circumvent domestic information denials to obtain status on deployed family members.<sup>M</sup>

For hacking, Latent Warrior hacktivists are not constrained by time and space obstacles of geography. They can operate from disaggregated locations to aggregate cyber effects against state adversaries. For example, the hacktivist group Anonymous declared a cyber war against Russia in response to their invasion of Ukraine in 2022.<sup>H</sup> Reported results of their cyber-attacks on Russia include meddling with hundreds of government databases, releasing personal information for 120,000 Russian soldiers, and commandeering Russian state television to broadcast atrocities of the invasion.<sup>H</sup> In addition to hacktivists, corporations may choose to participate in Latent Variable Warfare. SpaceX, a private aerospace and communication company, disrupted a Russian electronic warfare attack on Ukraine by quickly shutting down Russia's operations.<sup>H</sup> This was a feat that could not be completed by a government entity in such a short period of time.<sup>H</sup>

Though Latent Variable Warfare is happening now, it is highly likely that its influence on shaping outcomes of state-sponsored war will continue to grow through 2040+. Estimates for 2040 and beyond conclude that the technologies discussed will only increase in availability, deployability, and lethality for Latent Warriors that choose to employ them.<sup>HHH</sup> Latent Variable Warfare displaces military actions previously controlled by state entities, setting conditions for a revolutionary change in the character of war.

#### Analytic Confidence

The analytic confidence for this estimate is *moderate*. Unclassified sources from reputable news sources, research organizations, and government reports corroborate one another. Adequate time was available to gather information, but the analyst relied solely on publicly available published content.

Author: Brennan J. Kemper

# Near-Peer Weaponization Of Synthetic Biology Is Highly Likely For Military Use In 2040+

#### **Executive Summary**

Near-peer competitors continue to invest in synthetic biology research, making it highly likely (71 - 85%) that newfound capabilities will be weaponized for military use in 2040+. Despite positive aspects of advertised use cases, applications of synthetic biology can be modified to re-create known pathogens, make existing pathogens more dangerous, and create new pathogens. The COVID-19 pandemic revealed that sovereign states and strong militaries struggle to defend against pathogenic viruses that do not require military force or action to be effective. Accordingly, increased lethality is achievable by developing overt or covert pathogens capable of impairing or destroying life-sustaining elements of adversaries.

#### Discussion

Biotechnology, biowarfare, and bioterrorism are not new concepts, they have existed for centuries in both wide and narrow forms of deployment. An example of wide-scale deployment occurred during the Second World War, when the Imperial Japanese Army poisoned over 1,000 Chinese



Figure 2: Illustration of military aircraft deploying biological weapons Biological weapons video: Source: <u>TheInfoGraphicsShow.com</u>

water wells for the purposes of studying bacterial outbreaks.<sup>H</sup> A more recent narrow scale deployment occurred in 2001, when four letters containing anthrax bacteria were mailed to media and government locations within the United States, resulting in five deaths, 17 injuries, contamination of dozens of buildings, and hundreds of millions of dollars in decontamination costs.<sup>H</sup>

Synthetic biology is scientific research that redesigns organisms for useful purposes.<sup>H</sup> Specifically, it is a process where selected DNA strings are combined and added to an organism's existing genetic code.<sup>H</sup> By doing this, organisms can be engineered for resiliency and life sustainment. Applications include improvement of materials and organisms for pharmaceuticals, crops, livestock, and fuel.<sup>H</sup> Despite positive aspects of advertised use cases, synthetic biology can be weaponized as well. Weaponized applications include re-creating known pathogens, making existing pathogens more dangerous, and creating new pathogens.<sup>M</sup>

Near-peer competitors such as the People's Republic of China and Russian Federation continue to invest in synthetic biology research, making it highly likely that newfound capabilities will be weaponized for military use in 2040+<sup>MM</sup>. Specifically, China's Military-Civil Fusion strategy identifies it as a priority effort, and seeks to fund and fuse national defense and civilian biotech research into applications for military use.<sup>H</sup> Also, various texts from sources associated with the People's Republic of China, People's Liberation Army classify biological warfare as means for specific ethnic genetic attacks and bloodless victories.<sup>M</sup> Throughout the Cold War to present day, the former Soviet Union and now Russian Federation continues to fund robust biological warfare research and development.<sup>H</sup> Transparency of programs and developmental purposes for both states remains doubtful.<sup>L</sup>

The COVID-19 pandemic revealed biological vulnerabilities for sovereign states and their military forces, showing that no amount of border security or conventional military capabilities can completely stop or contain mass spread of highly contagious viruses, within a short period of time.<sup>H</sup> The United States recognizes these potential threats, and both the Department of Defense and Army identify synthetic biology as part of their priority research and modernization strategies.<sup>HH</sup>

Wide-scale deployment of these weapons is likely (56 - 70%) beyond 2040. Synthetic biological weapons may spread through airborne transmission (See Figure 1), contaminated food, water, and a variety of other sources, which are vehicles of deployment that already exist.<sup>H</sup>

Origin tracing of a biological weapons further adds to the complexity of defending against them. They may be deployed in ways that are difficult to detect, which provides deniability for adversaries that choose to deploy them.<sup>M</sup>

#### **Analytic Confidence**

The analytic confidence for this estimate is *moderate*. Unclassified sources from reputable news sources, academic journals, research organizations, and government reports corroborate one another. Adequate time was available to gather information, but the analyst relied solely on publicly available published content. Given the 20+ year projection of the estimate, this report is sensitive to change due to new information and changing priorities of near-peer adversaries.

Author: Brennan J. Kemper

# Central, Southeast Asia Highly Likely Location Of State Vs. State War In 2040+

#### **Executive Summary**

State sponsored war in 2040+ is highly likely (71-85%) to take place within Asia, specifically Central and Southeast Asia. Despite comparatively low quality of life and less developed industrial bases, 2040+ represents the period where projected emergence of developing nations and China's Belt and Road Initiative (BRI) converge to create conditions for crises, conflict, and ultimately state versus state war.

#### Discussion

Example conditions that create crises and conflict include poverty, food insecurity, mass migration, working age population changes, loss of confidence in political leadership, cultural clashes, safeguarding access to strategic resources and markets, aggressive nationalism, and chance events.<sup>HH</sup> The first five conditions fester as civil



Figure 3: Illustration of Asia regions. Source: https://www.mapsofworld.com/asia/regions/

unrest and result in humanitarian crises, but are highly unlikely to spark state versus state war. Conversely, the latter five set conditions for state-sponsored war.<sup>H</sup>

Asia, specifically Central and Southeast Asia (See Figure 1), lie where future culture clashes, strategic access competition, aggressive nationalism, and chance events are highly likely to occur. Two issues will converge to drive these conditions: emergence of developing nations within Asia, and China's growing influence in Central and Southeast Asia through their BRI.<sup>HH</sup>

2040+ projections estimate fast growth among developing nations and slower growth among developed nations.<sup>H</sup> Developing nations are sovereign states with a comparatively low quality of life and less developed industrial base, where developed nations possess a high quality of life, developed economies, and advanced technological infrastructure.M By 2050, four of the world's six largest economies are expected reside within Asia, consisting of China, India, Indonesia, and Russia in order of estimated Gross Domestic

Product.<sup><u>H</u></sup> Variables such as urbanization, working age population, national debt, infrastructure investments, and technology growth determine this estimate.<sup><u>H</u></sup>

Estimates project that China and Russia, both nuclear powers and developing nations, will maintain large economies through 2050, despite declining forecasts of their populations and industry investments.<sup>H</sup> India, another nuclear power and developing nation, will incur rapid economic growth over the next 30 years, placing it as one of the top two largest economies in the world by 2050.<sup>HH</sup> Estimates also forecast that Indonesia, a geographically strategic nation, will place in the top five largest economies as well.<sup>H</sup> Along with these estimates, all four states have steadily increased annual defense investments since 2000.M As a result, it is highly likely that these events will shift the future balance of power away from Western states toward Asia, bringing hefty geopolitical, economic, and military influence along with it.

In 2013, Chinese President Xi Jinping announced an economic expansion initiative that has since evolved into BRI, a plan to expand PRC access to strategic geographical locations for the purposes of commerce.<sup>H</sup> If executed as planned, the initiative constructs land, maritime, and communication infrastructure in regions west and south of the PRC, especially in Central and Southeast Asia.<sup>M</sup> End results are almost certain to open and solidify China's access to new strategic resources and markets.

At a macro level, BRI messaging claims it will benefit states hosting infrastructure investments; however, skeptics caution that China will use these investments to gain financial leverage and influence over recipients.<sup>H</sup> Estimates project that BRI will accelerate conditions where Central and Southeast Asian countries become heavily indebted to China and dependent on receiving Chinese imports.<sup>M</sup> Accordingly, both conditions will push Western values and economic standards out of these regions and create opportunities for PRC coercion to disrupt Asian state sovereignty.<sup>H</sup>

Also, BRI expands China's access to external energy resources and rare earth elements (REE). Over the last 30 years, China's economic rise has been highly correlated with increasing demand for energy imports, and the PRC is now the world's largest importer of oil and natural gas energy resources.<sup>HHH</sup> Similarly, China's demand for REE has also increased along with growth of its technology industries. REE are critical materials needed for production of high-tech components and electronics.<sup>H</sup> The PRC recognizes that losing access to energy and REE resources threatens their future stability and prosperity, and is pursuing BRI as a hedge to secure resource access.<sup>H</sup>

#### **Analytic Confidence**

The analytic confidence for this estimate is *moderate*. Unclassified sources from reputable academic journals, research organizations, and government reports corroborate one another. Adequate time was available to gather information, but the analyst relied solely on publicly available published content. Furthermore, given the 20+ year projection of the estimate, this report is sensitive to change due to new information and changing priorities of developing nations.

Author: Brennan J. Kemper

# US Competitors Are Highly Likely To Prioritize "Gray Zone" Operations Over Overt Conflict Through 2040+

#### **Executive Summary**

Adversaries are highly likely (71-85%) to avoid overt conflict in favor of strategies that disrupt, deceive, deny, and develop advanced weapons for use against the United States and its allies—i.e. "Gray Zone" operations. Despite increasing weapon tests, military exercises, and other demonstrations of conventional force, estimates report that major competitors will seek victory by influencing partners and populations through 2040+.

#### Discussion

Gray Zone operations encompass varying degrees of competition and consist of escalating actions short of triggering armed conflict.<sup>H</sup> Examples include economic coercion, information operations, cyber-attacks, and other indirect uses of force that sum to produce strategic



Figure 1: Understanding Gray Zones. Source: https://www.youtube.com/watch?v=LyH-htfjLHU

effects. Gray Zone victories are not achieved through destruction of enemy forces, rather they are achieved by gaining influence over partners and populations of adversaries.<sup>H</sup>

Geopolitical estimates for 2040+ carry on previous assessments that China, Iran, and North Korea will remain as major competitors to US interests.<sup>HHH</sup> Though each of them has experienced some internal and external turmoil, all continue to invest in fielding advanced military capabilities that preserve their spheres of power and influence.<sup>HH</sup> Russia's invasion of Ukraine in 2022

Disruption operations alter or destroy the structure of something, such as geopolitical power structures, organizational influence, state stability, or lines of communication.<sup>H</sup> Recent trends in disruption operations are use of armed proxies, private military companies, hackers, and terrorist organizations that are state sponsored to create civil unrest. Use of proxy forces preserves plausible deniability for entities that employ them.<sup>H</sup> In 2013-2014, Russia used proxy forces in Ukraine to foster separatist disruptions for the purpose of expanding its influence and control in the former Soviet territory.<sup>H</sup> President Putin initially denied the agents were paid and equipped by the government of Russia.<sup>H</sup> Though China promotes a policy of non-intervention in domestic affairs of other states, it
allegedly provides financial support and military hardware to rebels and insurgents that safeguard its national interests.<sup>H</sup> Examples include arming Wa rebels in Myanmar and insurgents in northeast India.<sup>H</sup> Iran's Quds Force, part of the Islamic Revolutionary Guard Corps, funds, equips, and trains proxy forces across the Middle East, including Iraq, Lebanon, Pakistan, Palestinian Territories, Syria, and Yemen. Their intent is to remove Western influence and promote Iran's hegemony status, while the Iranian government maintains deniability of involvement.<sup>H</sup>

Deception operations are actions taken to deliberately mislead adversary decision makers and populations.<sup>H</sup> Recent trends in deception operations seek to exploit the information domain by spreading propaganda and disinformation through media outlets, proxy websites, bots, fake social media personas, and other cyber platforms.<sup>H</sup> Russia continuously engages in disinformation campaigns aimed at destroying the creditability of democratic institutions and creating discord between the United States and its partners.<sup>H</sup> For example, Russian proxies claim that the United States is a lawless rogue state that created COVID-19 and that NATO countries are preparing for an attack on Russia.<sup>H</sup>. In the cyber realm, North Korea ranks in the top four nation-state threats of cyberspace.<sup>H</sup> An example includes the Democratic People's Republic of Korea use of cyber trolls to hack and display morale diminishing propaganda on South Korean websites.M Similarly, Iran uses cyber troll farms to threaten and spark social turmoil within the United States.<sup>H</sup> Iran denies these cyber-crime allegations.<sup>H</sup>

Denial operations prevent an entity from accessing or operating in a particular area.<sup> $\underline{H}$ </sup> Recent trends in denial operations include information denial, communication denial, and Anti-Access/Area Denial (A2/AD). North Korea executes information denial operations on its own citizens, where algorithms search phone and computer networks to delete files and applications not approved by the government.<sup>H</sup> During Russia's runup to its 2008 invasion of Georgia, Russian cyber operations denied Crimea's access to landline, internet, and mobile communication networks.<sup>H</sup> China's Belt and Road Initiative plans to invest heavily in physical and virtual infrastructure development in countries that will host its transportation corridors.<sup>H</sup> This includes roads, railways, seaports, power grids, and communication networks. These investments will give China unprecedented control over international lines of communication, and the ability to deny access to whomever it chooses. All four competitors continue to invest and develop A2/AD weapons capable of denying access to geographic areas. Capabilities include anti-ship cruise missiles, integrated air defense networks, maritime mines, and offensive space weapons. In 2007 and 2014, China tested anti-satellite missiles designed to destroy, damage, and interfere with enemy reconnaissance and communication satellites.<sup> $\underline{H}$ </sup>

Gray Zone operations require continuous development and fielding of advanced technologies that enable disruption, deception, and denial operations. Russia, China, Iran, and North Korea military projections signal ongoing investments in hypersonic missiles, sensors, automation, long-range fires, cyber attacks, and other weapons that will provide competitive capabilities for use Gray Zone operations.<sup>HHHH</sup> Development and fielding of these technologies is expected to continue through 2040+.<sup>H</sup>

## Analytic Confidence

The analytic confidence for this estimate is *moderate*. Unclassified sources from reputable academic journals, research organizations, and government reports corroborate one another. Adequate time was available to gather information, but the analyst relied solely on publicly available published content.

Author: Brennan J. Kemper

# China's Growing Leverage and Control Over Central Asia Is Highly Likely to Escalate Multipolar Tensions Through 2040+

## **Executive Summary**

Despite cultural oppression and perceptions of mistrust, it is highly likely (71-85%) that China will possess strategic leverage and control lines of communication within Central Asia, escalating multipolar tensions in the 2040+ world order. Due to its strategic location, natural resource deposits, and potential for development, Central Asia possesses regional frontiers where China can fuel its grand strategy of "national rejuvenation," by expanding to emerging economic markets, diversifying access to energy resources, and influencing the stability of states on its western border.

## Discussion

The Chinese Communist Party (CCP) is pursuing a grand strategy for "great rejuvenation of the Chinese nation" by 2049.<sup>HM</sup> This includes reunification with Taiwan, integration of Hong Kong and Macau, and reorganizing international order to recognize China as a global leader.<sup>HM</sup> Year 2049 is the symbolic culmination date because it represents the



Figure 1: The Silk Crossroad – Discussing Central Asia Gray Zone Source: <u>https://www.youtube.com/watch?v=eJ4bR4S-Ink</u> Source: Figscape

100<sup>th</sup> anniversary of the People's Republic of China.M Interim strategies of this grand strategy include "Made in China 2025" and "China Standards 2035," explained as follows:

- "Made in China 2025" seeks to shift China from low-end manufacturing to highend production in robotics, information technology, transportation, energy, and high-tech innovation, where 70% of core components will be made in China by 2025.<sup>M</sup>
- "China Standards 2035" seeks to set and govern interoperability standards for agriculture, manufacturing, and emerging technologies, while reducing China's reliance on foreign technologies by 2035.<sup>MM</sup>

Central Asia (See Figure 1) lies at the crossroads of an emerging multipolar world order, encircled by four of five competitors identified in the *Joint Operating Environment 2040* summary.<sup>H</sup> China, Russia, Iran, and violent extremist organizations represent long-term strategic competition to US national security interests through at least the next three

decades, all of whom have proximity to Central Asia.<sup>H</sup> Furthermore, Central Asia encompasses strategic opportunities and lines of communication that China needs for its "great rejuvenation," where it can expand to emerging economic markets, diversify access to energy resources, and influence the stability of states on its western border.<sup>M</sup> Examples include:

- Central Asia provides China with land routes to develop new markets in Eurasia, Europe, and Africa, bypassing maritime routes subject to transiting the Straits of Malacca<sup>H</sup>
- Central Asia possesses large energy and mineral deposits, providing China with resources needed to advance their "Made in China 2025" strategy<sup>HHM</sup>
- Central Asia lags in modern infrastructure development, creating opportunities for China to export control over regional infrastructure, commerce, and telecommunications developments, as part of "China Standards 2035"<sup>HM</sup>
- Growing China-Pakistan relations provide China with control over the Gwadar deep water port in the Arabian Sea, equipping China with port access to the Indian Ocean and fostering speculation on future presence of the People's Liberation Army Navy in the Indo-Pacific<sup>H</sup>
- Possessing strategic leverage and control over Central Asian states equips China with means to influence the stability of states on its western border<sup>M</sup>
- Fading Russian influence in Central Asia creates opportunities for China to replace Russia as the dominant sphere of security in the region<sup>M</sup>

It is highly likely that China's possession of strategic leverage and control over lines of communication in Central Asia will culminate in 2040+, escalating multipolar tensions in a new world order. This estimate stems from points referenced above and the following additional indicators:

- China's modernization strategy to build a "world class" military by 2049<sup>HH</sup>
- Russia's declining economic and military influence in Central Asia<sup>™</sup>
- India's rising economy and population by 2050<sup>HH</sup>
- Turkey's rising regional status<sup>MM</sup>
- China's growing partnership with Pakistan<sup>H</sup>
- Pakistan's increasing imports of Chinese military hardware<sup>H</sup>
- Growing tensions between India and Pakistan, both of whom are nuclear powers<sup> $\underline{H}$ </sup>

China's growing presence in Central Asia is not without friction, it carries cultural oppression and perceptions of mistrust. In terms of cultural oppression, the Chinese Communist Party is accused of oppressing Muslim groups in its Xinjiang Uygur Autonomous Region.<sup>H</sup> Actions include displacing, suppressing, and repressing Muslims that inhabit this area in favor of furthering Communist Party control.<sup>H</sup> Central Asia

experiences negative effects of this because Central Asian Muslims working in Xinjiang are victims of this oppression, and Xinjiang province Muslims are fleeing Central Asia to escape the oppression.<sup>M</sup> Also, working class people within Central Asia hold perceptions of mistrust with China because they fear Chinese migrants and workers will displace their employment opportunities.<sup>M</sup> For example, in Kazakhstan and Pakistan, Chinese companies bring their own workers to support BRI projects, reducing opportunities for host nation workers.<sup>M</sup> Regardless of oppression and mistrust, Central Asian political leaders are highly likely to overlook drawbacks of working with China in favor of boosting their country's economic prosperity and strengthening their regimes.<sup>M</sup>

It is highly likely that China will possess strategic leverage in Central Asia through growing use of "financial diplomacy," where China uses its wealth to provide loans, debt relief, and humanitarian aid to states within the region. The tradeoff is that Central Asian states receive BRI infrastructure investments to boost their economies in exchange for accepting loans and access conditions from China. Accordingly, China accumulates large percentages of Central Asia's foreign debt.<sup>MM</sup> Speculation labels these acts as "debt trap diplomacy" because China buys strategic leverage to influence future decisions of Central Asian states.<sup>MM</sup>

It is highly likely that China will control lines of communication within Central Asia through exporting infrastructure development projects and setting standards.<sup>H</sup> BRI creates opportunities for China to shape disconnected frontiers of Central Asia as it sees fit. In accordance with "China Standards 2035," this means China is setting standards for rail, energy, and telecommunications networks that crisscross the region.<sup>M</sup> By setting these standards, China gains implicit control over who can and cannot access the networks, which may be interpreted as area denial.<sup>M</sup> Also, BRI investments provide China with impressive levels of access to foreign states receiving the investments. This includes access to foreign energy reserves, transportation corridors, and BRI port operations. Controlling these resources is essential to prevailing in competition, crisis, and conflict, should hostile events occur in the region. For example, in exchange for development of the Gwadar port in Pakistan, China becomes the port owner and the Pakistani government becomes the tenant.<sup>H</sup> Also, China's control extends to military hardware where it is subtlety displacing Russia as lead exporter of major arms to Central Asian states.<sup>HM</sup> Through exporting arms, China implicitly gains control over shaping regional security agreements by expanding the availability of interoperable military equipment and narrowing sources of military resupply. China is now a top-three arms exporter to Kazakhstan and Pakistan.<sup>HM</sup>

## Analytic Confidence

The analytic confidence for this estimate is *moderate*. Unclassified sources from reputable news sources, academic journals, research organizations, and government reports corroborate one another. Adequate time was available to gather information, but the analyst relied solely on publicly available published content.

Author: Brennan J. Kemper

# Autonomous Drone Swarms On The Battlefield Will Likely Prevent Combatants From Maintaining Air Superiority In Armed Conflict By 2040

## **Executive Summary**

Due to the rapid development of converging drone technologies, an adversary's ability to manufacture, arm, and deploy vast numbers of autonomously coordinated drone swarms to overwhelm their opponent's conventional antiaircraft defenses is likely (56-70%) by 2040. The ability of both state and non-state actors to develop and employ armed autonomous drone swarm technology during armed conflict will likely result in the air domain remaining contested throughout the armed conflict. To facilitate this convergence, the necessary



Figure 1: How Big of a Deal are Swarm Drones. Source: https://madsciblog.tradoc.army.mil/261-howbig-of-a-deal-are-drone-swarms/

development of parallel technologies to enable autonomous drones and direct drone swarm formations will likely converge within three to five years. These technologies, coupled with the current ability to 3D-print drones on the battlefield, rapid advances in energy storage, and emerging ionic propulsion technology, will likely converge to create a commercially available unoccupied autonomous weapon system that will change the future of land warfare by 2040. In light of the clear threat this developing technology poses to both state and non-state combatants, several countries are developing countermeasures to drone swarm attacks to mitigate the operational risks presented by hundreds of armed autonomous drones on the battlefield.

## Discussion

Drones are fully "autonomous" when they can select and engage targets without human control (i.e., no "human-in-the-loop").<sup>M</sup> Until early 2020, the use of drones by state and non-state actors around the globe has been almost exclusively a "human-in-the-loop" system controlled remotely or preprogrammed by one or more people on the ground.<sup>M</sup> Recent attacks by state and non-state actors against



Figure 2: The 11th Armored Cavalry Regiment and the Threat Systems Management Office push a swarm of 40 drones through a town at a training center in 2019. Source: <u>Release the hounds: Army event to feature drone swarms</u> that behave like a wolf pack (defensenews.com)

adversary targets utilizing armed autonomous drones demonstrate that the "autonomous" technology once considered decades away is currently in the final stages of development.<sup>M</sup>

Within three to five years, it is highly likely that existing autonomous attack drone formations will incorporate swarm technology.<sup>M Annex C</sup> A "swarm of drones" differs from a basic multi-drone system because an operator does not control all the drones individually. Instead, the operator commands a small subset of the swarm that responds collectively as a complex collection of nodes.<sup>M</sup> Dr. David Diller, senior engineer and Project Manager at Raytheon's Unmanned Innovations Laboratory, stated during a recent interview that the current challenge regarding swarm drone technology is the swarm's ability to individually communicate within the swarm, mainly when traditional communications platforms such as 5G or GPS satellites are denied or unavailable (e.g., operating deep inside a building).<sup>Annex C</sup> However, a planned test in the Spring of 2022 by the United States Army intends to demonstrate technology that allows a "wolfpack" drone swarm formation that will operate in a "GPS-denied" environment and carry lethal effects capable of neutralizing a target.<sup>M</sup>

Technologies involving different ways to power drone flight are also evolving rapidly. Mr. Tomas Pribanic, founder, CEO, and lead scientist with Undefined Technologies, Inc. in Florida, developed a prototype drone powered by an ionic thrust propulsion system.<sup>M</sup> <u>Annex B</u> The propulsion



Figure 3: New Drone Tech: No Propellers, and Yet It Flies! Source: https://www.youtube.com/watch?v=UGM4JXVB5FM

system has no moving parts and operates in almost complete silence.<sup>M Annex B</sup> Excessive battery weight relative to the amount of thrust created is the primary factor hindering further development. <sup>Annex B</sup> Still, Mr. Pribanic believes emerging battery technology will enable commercial-scale development of this technology within five years. <sup>Annex B</sup> Significant investment in research and development of energy storage technology tends to corroborate Mr. Pribanic's estimation regarding the availability of lighter and more durable batteries in the future. (See *Energy Storage* SFAR by COL John Hosey).

Due to the contested environment within which drone swarms must operate on future battlefields, maintaining a sufficient supply of drones and related equipment will be of

critical importance. Sustained innovation in Additive Manufacturing (also called "3D printing") demonstrates how this technology allows combatants to manufacture replacement drones on the battlefield.<sup>M</sup> Since the beginning of the armed conflict between Russia and Ukraine in February 2022, deployed 3D printing technology is enabling the creation of more than 10,000 combat-related items, including protective gear, tourniquets, and uncrewed aerial drones.<sup>M</sup>



Sygnis' 3D printing machine park in Warsaw. COURTESY OF SYGNIS

Figure 4: Entrepreneurs in Poland rush printers to the stricken neighboring country for use creating protective gear, tourniquets, periscopes—and even drones—for the Ukrainian defense. Click on image or go to: <u>https://www.forbes.com/sites/amyfeldman/2022/03/31/putting-3d-printers-to-work-in-ukraines-war-zone/?sh=41f358775015</u>

In light of the clear threat this developing technology poses to both state and non-state combatants, several countries are developing countermeasures to drone swarm attacks to mitigate the operational risks presented by hundreds of armed autonomous drones on the battlefield.<sup>M</sup> The United Arab Emirates (UAE) and Israel are collaborating on new technology they hope will provide some level of protection against this emerging threat.<sup>M</sup> An agreement between the two countries in March 2022 allows for the development and



Figure 5: South Korea is testing a new counter-UAV system aimed at protecting military facilities. Click on image or go to: <u>South Korea to test new counter-UAV</u> system aimed at protecting military facilities (janes.com)

fielding of a fully autonomous counter-UAS system that requires no human involvement and utilizes 3D radar, communications intelligence technology, and electro-optics integrated into a unified command-and-control system.<sup>M</sup> Additionally, media reports from India in December 2021 state "[t]he newly developed counter-drone system will enable mitigation of the impact of drones posing a threat to national security." M<sup>·</sup> South Korea is also developing portable counter-UAS systems to protect military installations.<sup>M</sup> Despite advances in counter-UAS systems, it is likely that future autonomous drone swarms will utilize sheer volume to overwhelm counter-UAS systems and establish temporary local air superiority.

Despite rapidly developing counterdrone technologies by state actors across the globe, the concept of establishing and maintaining air superiority will likely change by 2040.<sup>M</sup> Drone swarm technology gives nonstate actors access to the air without the need for expensive aircraft.<sup>™</sup> Although the scope of air



Figure 6: Inexpensive drone swarms could quickly overwhelm complex antiaircraft defenses. Source: <u>https://madsciblog.tradoc.army.mil/261-how-bigof-a-deal-are-drone-swarms/</u>

superiority through deployed drone swarms may be localized, low altitude, and temporary, it can provide valuable close air support, reconnaissance, and the ability to strike soft targets.<sup>M</sup>

#### **Analytic Confidence**

Analytic confidence in this estimate is moderate. Sources were generally reliable but limited in scope and availability. A high-quality primary source was available and tended to corroborate other available research. The researcher worked alone and utilized an unstructured research technique. Given the rapid pace of proprietary technology advancement in this area and the limited availability of open-source information, this report is sensitive to change over time, thus warranting a moderate level of analytic confidence.

Author: Andrew S. Culbreath

# Fully Autonomous Swarm Attack Drone Technology In Final Stages Of Development; Highly Likely To Be Commercially Available Worldwide For Military Use Within Three To Five Years

## **Executive Summary**

Despite current U.S. policy and concerns by international human rights groups, it is highly likely (80-95%) that autonomous swarm attack drones will become commercially available for military application in the next three to five years. Only a few years ago, this technology, collectively referred to as Lethal Autonomous Weapons Systems (hereinafter "autonomous swarm drones"), was considered at least a decade away. However, drones and autonomous swarm drone technology will soon become inexpensive and widely available offensive weapons available to state and non-state actors.

#### Discussion

Military forces can utilize drones in three distinct ways: attack, defend, and provide intelligence, surveillance, and reconnaissance (ISR).<sup>H</sup> Drone swarms are "large numbers of dispersed individual or small groups coordinating together and fighting as a coherent whole."<sup>H</sup> Specifically, drone swarms can operate



Figure 1. Raytheon's new technology allows 130 drones to be controlled by one operator. Source: <u>https://interestingengineering.com/raytheons-new-tech-allows-130-drones-to-be-controlled-by-one-operator</u>

in a dispersed formation, making them difficult to counter. Once programmed with a task, drone swarms can delegate tasks among themselves, identify gaps in the mission based on onboard sensors, and then autonomously work to fill those gaps.<sup>M</sup> The integrated swarm control technology tested in January 2022 by Raytheon BBE relies partly on inexpensive commercial off-the-shelf hardware.<sup>H</sup>

There are two key distinctions between today's commercially available drones and the autonomous swarm drone technology currently under development. First, drones are

"autonomous" when they can select and engage targets without human control (i.e., no "humanin-the-loop").<sup>H</sup> Because varying degrees of autonomy is possible, there is no international consensus on how "autonomous" should be defined. As one research analyst wrote, "Setting the threshold of autonomy is going to involve significant debate because machine decision-making



Figure 2. Israeli drones reportedly used in a May, 2021 attack on Hamas in Gaza. Source: <u>https://www.newscientist.com/article/2282656-israel-used-worlds-</u> first-ai-guided-combat-drone-swarm-in-gaza-attacks/

exists on a continuum."<sup>M</sup> Second, a "swarm of drones" differs from a basic multi-drone system because an operator does not control all the drones individually. Instead, the operator commands a small subset of the swarm that responds collectively as a complex collection of nodes.<sup>M</sup>

Until early 2020, the use of drones by state and non-state actors around the globe has been almost exclusively a "human-in-the-loop" system controlled remotely by one or more people on the ground.<sup><u>H</u></sup> However, in March 2020, the Libyan government reportedly ordered an attack against Haftar-affiliated forces using a fully autonomous attack drone.<sup><u>M</u></sup>



Figure 3. Turkish commercial video advertisement for a "Rotary Wing Attack Drone/Loitering Munition" system. Source: https://www.youtube.com/watch?y=9HCDQwRdk20&t=6s

According to a report to the UN Security Council, "[t]he lethal autonomous weapons systems were programmed to attack targets without requiring data connectivity between the operator and the munitions: in effect a true 'fire, forget, and find' capability."<sup>H</sup> Reports indicate that this attack is the first use

of a fully autonomous drone in combat.<sup>M</sup> A second instance occurred in May 2021 when the Israeli Defense Force reportedly utilized a collection of fully autonomous drones to

attack Hamas militants in Gaza.<sup>M</sup> These attacks demonstrate that the technology once considered being decades away is currently in the final stages of development. Within three to five years, it is highly likely that autonomous drone formations will incorporate the swarm technology currently under development.



Discussions regarding the legality of autonomous attack drones, referred to by Human Rights Watch as "killer robots," have generally focused on three key principles of the international law of armed conflict: distinction.

Figure 4. Department of Defense released its Counter-Small Unmanned Aircraft Systems Strategy on January 8, 2021. Source: <u>https://www.thedefensepost.com/2021/02/02/citadel-titan-counter-dronecontract/</u>

necessity, and proportionality.<sup>H</sup> Although the United States government does not support a ban on autonomous weapons systems, it does follow a long-established policy of keeping a "human-in-the-loop" for all weapons systems.<sup>H</sup> Moreover, approximately 30 countries and 165 non-governmental organizations have called for a preemptive ban on autonomous weapons systems due to ethical concerns and compliance with the proportionality and distinction requirements of the law of war.<sup>H</sup> A global survey conducted in 2020 by the Campaign to Stop Killer Robots found that 62% oppose the use of lethal autonomous weapons.<sup>M</sup> Despite these legal and ethical concerns, low-cost "loitering munitions" are commercially available and highly likely to incorporate "swarm" technology and proliferate globally within three to five years.

#### Analytic Confidence

Analytic confidence in this estimate is moderate. Sources were generally reliable and tended to corroborate one another. There was adequate time for this research, but the analyst utilized an unstructured research method working alone. The reliability of the sources was average, with several high-quality sources available. Due to the rapidly evolving nature of this field of technology, this report is sensitive to change due to new information.

Author: Andrew S. Culbreath

# Aircraft With No Moving Parts Powered By Ionic Thrust Propulsion Successfully Tested, Likely Commercially Available Within Three To Five Years

## **Executive Summary**

Due to rapid advancement in battery technology, the first solid-state ion thrust-powered drone aircraft will likely (56–70%) be available for commercial use within three to five years. The world's first electro-aerodynamic propulsion aircraft has no moving parts, flies silently, and was initially tested in 2018 by researchers at the Massachusetts Institute of Technology (MIT). Despite initial challenges with thrust/weight ratios and avionic stability, scientists at the Florida-based research firm Undefined Technologies, Inc. have made significant advances in thrust capacity, battery technology, and aircraft stability control. Undefined Technologies' successful test of their newly designed prototype validates numerous civilian and military applications for this type of drone technology.

## Discussion

The concept of ionic thrust technology has been used for decades in the zero atmosphere of space to help satellites position themselves inside a specific orbit.<sup>M</sup> In 2009, NASA began studying the feasibility of achieving sufficient ionic thrust within the earth's atmosphere to power an aircraft.<sup>H</sup> The basic principle for generating ionic



Figure 1: Concept design for an aircraft propelled by ionic wind. Image Credit: MIT Electric Aircraft Initiative. Source: <u>https://www.engineering.com/story/how-the-worlds-first-solid-state-aircraft-achieves-propulsion-with-no-moving-parts</u>

thrust propulsion involves attaching rows of long metal strands to the structure of a lightweight drone and energizing them with roughly 40,000 volts of electricity.<sup>H</sup> This high voltage causes ions to rush from the positively charged strip upfront to the negatively charged strip in the rear, shoving electrons off of nitrogen atoms in the atmosphere and creating positively charged ions.<sup>H</sup> This movement of positive ions rushing from the front to the rear of the aircraft structure creates an "ionic wind" that propels the aircraft forward.<sup>H</sup>



While this type of technology will not replace more conventional propulsion systems for high thrust applications, it is well-suited to power drones and small aircraft.<sup>H</sup> The technology has both civilian and military applications due to its solid-state design, completely silent operation, and ability to reach a much greater degree of miniaturization.<sup>™</sup>

Figure 2: Video overview of MIT solid state airplane. Source: https://electricaircraft.mit.edu/

Mr. Tomas Pribanic, lead scientist and chief executive officer of Undefined Technologies, Inc., was interviewed for this report and explained that his scientists are developing a drone that weighs two pounds and will ultimately achieve flight durations of up to 30 minutes.<sup>Annex B</sup> Mr. Pribonic explained that the current weight of the batteries is the primary factor slowing development. However, Mr. Pribanic is contracting with scientists designing batteries that are more powerful and weigh one-third of current battery technology. <sup>Annex B</sup> Stabilization issues have plagued earlier designs, but Mr. Pribanic explained that stability control in his drone design "is attainable and an item of



Figure 3: New Drone Tech: No Propellers, and Yet It Flies! Source: <u>https://www.youtube.com/watch?v=UGM4JXVB5FM</u>

low risk, at this point." <sup>Annex B</sup> These upgrades, along with a GPS-enabled guidance system under development, will enable Undefined Technologies, Inc. to ultimately market commercially viable ionic thrust drones for urban cargo delivery and media outlet on-scene accident reporting.<sup>M; Annex B</sup> Massachusetts Institute of Technology Professor Steve Barrett was the first scientist to achieve sustained flight of an aircraft using the ionic thrust propulsion system in 2018.<sup>H</sup> Professor Barrett's flight was followed by another ionic thrust breakthrough in 2019 when scientists at the University of California at Berkley flew the world's smallest ion thrust propulsion drone – a drone the size of a penny.<sup>M</sup> Building on these earlier successful prototypes, Mr. Pribanic is taking this technology a step closer to commercial viability.<sup>M</sup>

#### **Analytic Confidence**

Analytic confidence in this estimate is moderate. Sources were generally reliable but limited in scope and availability, and high-quality sources were available and tended to corroborate one another. Given the rapid pace of technology advancement in this area and the limited availability of open-source information on the topic, this report is sensitive to change over time, thus warranting a moderate level of analytic confidence.

Author: Andrew S. Culbreath

# Advancement Of "Ruggedized" 3D Printing Equipment Makes Full-Scale Deployment Of Additive Manufacturing Technology For Global Military Use Almost Certain Within Three To Five Years

## **Executive Summary**

Due to recent advancements in multi-material 3D printing and the ability to "ruggedize" 3D printing equipment, global near-peer militaries are almost certain (86-89%) to have full-spectrum combat-deployable printing capabilities within three to five years. The past five years have seen dramatic advancements in filament materials that can be 3D printed and the expanded application of 3D printing. For example, carbon fiber-reinforced nylon filament creates 3D printed lightweight machine parts, and aluminum filament allows scientists to 3D print an entire space-worthy rocket. Despite the somewhat delicate and sensitive equipment required for 3D printing, a recent pilot project conducted on behalf of the U.S. military successfully "ruggedized" the printer to make it more durable for military field use. Since the outbreak of the war in Ukraine, 3D printing has created over 10,000 parts in support of Ukrainian military forces.

#### Discussion

The 3D printing industry (technically referred to as Additive Manufacturing) has grown exponentially to approximately \$16 billion over the last decade.<sup>M</sup> One key area of growth is the types of materials used for printing, with six distinct types of material now available: polymers, metals, composites, ceramics, concrete, and sand.<sup>M</sup> As 3D printing becomes more commonplace within the manufacturing



Figure 1: The U.S. Marines recently tested a 3D printer capable of constructing entire buildings with quick-drying concrete. Source: <u>https://3duniverse.org/2020/10/21/3d-printing-uses-in-the-military/</u>

industry, companies across the globe are developing and adapting this technology for military use.<sup>M</sup> Uniformed Services University conducted a pilot program for the United States military in 2019 called Fabrication in Austere Environments.<sup>M</sup> The pilot program effectively demonstrated that 3D printing technology could be "ruggedized" for field use.<sup>M</sup> The Air Force printed a metal part for the F-22 Stealth fighter, the Marine Corps printed a concrete Rocket Launcher shelter in 36 hours, and the Navy printed a submarine.<sup>M</sup>



Figure 2: In 2015 the U.S. Navy tested the use of the onboard 3D printers to print out parts used to construct and assemble drones. Source: https://3dprint.com/85654/us-navy-3d-printed-drones/



John Wilczynski, America Makes' executive director, Collin Boring and YBI CEO Barb Ewing.

Figure 3: Rugged 3D has developed hard-shell cases to protect 3D printing equipment during transport. Source: <u>Rugged 3D</u> <u>Builds 'Ruggedized' 3D Printers for Military Use - Business</u> <u>Journal Daily | The Youngstown Publishing Company</u>

These recent 3D printing advances come several years after the most significant application of 3D printing technology in the future – the ability to print an operational drone.<sup>M</sup> In 2015, the U.S. Navy utilized a 3D printer aboard the USS Essex to print and deploy a small drone made with lightweight polymer materials.<sup>M</sup>

Another significant challenge of forwarddeploying equipment is transporting 3D printing equipment into austere environments without damaging the sensitive and often fragile components.<sup>M</sup> Rugged 3D, a California start-up company, has solved this problem by developing a hard suitcasetype shell where a multipoint suspension system tethers the equipment to absorb impacts during the

shipping phase.<sup>M</sup> Using the Rugged 3D system, the 3D printing equipment arrives fully intact, preventing damage and saving hours in setup time.<sup>M</sup>

Although the United States currently leads the world in 3D printing technology and investment, countries around the globe are gaining ground and developing new ways to incorporate this new manufacturing technology.<sup>M</sup> For example, in April 2021, a German firm announced successfully 3D-printing a working solid-state Lithium-metal and ceramic electrolyte battery cell that increases energy density at a lower cost.<sup>M</sup> In Asia, the Chinese government implemented the Additive Manufacturing Industry Development

Plan in 2017 and will likely outpace other countries by investing an estimated \$3.6 billion by 2026.<sup>M</sup>

3D printing proves extremely helpful in wartime because of its versatility, speed, and ability to mitigate the risks of transporting supplies across the warzone.<sup>M</sup> Only days after the start of the war in Ukraine, a Polish 3D printing firm shipped twenty 3D printers and 800 pounds of filament to Lviv, Ukraine.<sup>M</sup> To date, deployed 3D printing technology has created more than 10,000 items in Ukraine, including protective gear, tourniquets, and unoccupied aerial drones.M Andrzej Burgs, founder, and CEO of Warsaw-based 3D printing firm Sygnis, has now shipped hundreds of printers to Ukraine and describes the current printing capabilities by explaining, "We have maybe 1,000 printers, and now we are waiting for specific directions from Ukrainian defense which parts we need to print. . . . With 1,000 machines we can print 10,000 parts a day, to be honest. It's that kind of possibility for the future."<sup>™</sup>



Figure 4: 3D printers awaiting shipment to Ukraine. Source: <u>Putting 3D Printers To Work In Ukraine's</u> <u>War Zone (forbes.com)</u>

## Analytic Confidence

The analytic confidence for this estimate is moderate. Open-source information was generally reliable, and the sources tended to corroborate one another. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate and the rapid development of this technology, this report is sensitive to change due to new information.

Author: Andrew S. Culbreath

# Despite Competition Over Access To Rare Earth Metals Within Latin America's "Lithium Triangle," Conflict Between Great Powers In This Region Highly Unlikely Through 2040

#### **Executive Summary**

Despite the presence of vast lithium ore deposits in Chile, Argentina, and Bolivia (aka the "Lithium Triangle"), military activities rising above the level of competition in the region between the United States and China, either directly or through proxies, is highly unlikely (16-30%) through 2040 due to the presence of adequate alternative lithium ore deposits available across the globe. As a producer of almost 60% of the world's current lithium ore reserves, the Lithium Triangle region will experience increasing economic competition and political tensions between China and the United States. This is due, in part, to China's five-fold investment in the region over the last three years in an effort to gain control of the global lithium market. However, the availability of alternative large lithium deposits in U.S. allied nations makes armed conflict highly unlikely.



Figure 1. Source: Resource World Magazine. Source: <u>https://resourceworld.com/wp-</u> content/uploads/2018/05/Lithium-Triangle-Map.jpg

## Discussion

Lithium is an essential element for the manufacture of lithium-ion batteries, the most lightweight, efficient, and widely used type of battery.<sup>H</sup> Lithium-ion batteries power a wide range of technology, including cell phones, vehicles, and drones.<sup>M</sup> A geographic region in Latin America, often referred to as the "Lithium Triangle," contains a concentration of lithium deposits buried beneath the Andean salt flats region that encompasses the borders of Argentina, Bolivia, and Chile.<sup>M</sup> The Lithium Triangle has also been referred to as the "Saudi Arabia of lithium," referencing its rapid rise in value to similar to the oil boom of the 1970s.<sup>M</sup> The Lithium Triangle contains approximately 58% of the world's known lithium resources, but scientists are also discovering additional large deposits of lithium in allied countries outside the Lithium Triangle." <sup>MM</sup> Experts predict that control over the world's deposits of lithium will one day carry the

same geopolitical power as the oil-producing countries have enjoyed for over fifty years, attributable in large part to the global transition to clean energy sources.<sup>H</sup>



Figure 2: South America's Lithium Triangle: Opportunities for the Biden Administration. Source: https://www.csis.org/analysis/south-americas-lithium-triangle-opportunities-biden-administration



Figure 3: Known global Lithium reserves in 2020. Source: https://earth.org/wp-content/uploads/2020/10/Lithium-map.jpg

The global focus on climate change and the need to reduce fossil fuel consumption has exponentially increased the importance of lithium-ion batteries for vehicle technology.<sup>M</sup> Currently, the world's largest carmaker plans to launch 30 new battery-powered vehicle models by 2030.M Britain and the European Union have pledged to ban

petrol-powered vehicles by 2035.M Lithium prices have risen by as much as 600% in the past year, and China, Australia, and the Republic of Congo currently control most of the world's supply.<sup>M</sup> As competition for control of scarce resources like lithium increases, so will the risk for conflict.<sup>M</sup> However, Mr. Eric Farnsworth, an expert on Latin American geopolitics interviewed for this report, estimated that the strategic implications of lithium alone were not sufficient to result in an armed conflict within the next 25 years.<sup>Annex D</sup> Mr. Farnsworth attributed the likelihood of conflict over lithium mining rights between the United States and China to the relatively low strategic value of the region and supply of untapped lithium reserves across the globe. <sup>Annex D</sup>

## **Analytic Confidence**

Analytic confidence in this estimate is moderate. Sources were generally reliable, with several high-quality sources available, and tended to corroborate one another. There was adequate time to process the information. Given the lengthy period of the estimate and potential political and economic volatility in the region, this report is sensitive to change.

Author: Andrew S. Culbreath

# Despite Ongoing Security Dilemma In The Arctic Region, Armed Conflict Between Great Powers Is Unlikely Through 2040

## **Executive Summary**

Despite expanding Freedom of Navigation (FoN) access to the Arctic maritime commons, increases in commercial activity, and Russia's recent aggression in Europe, the potential for conflict in the Arctic region is unlikely (31-45%) through 2040. The Arctic region is sparsely populated and routinely experiences sub-zero temperatures, limited navigation options, and only minimal satellite navigation and communications capabilities. Despite the harsh operating environment, the impacts of climate change are expanding navigable waterways and easing access to natural resources in the region. This increased access to natural resources will prompt greater geopolitical competition and heighten security concerns among regional stakeholders, including NATO member countries. However, due to the history of cooperation between Arctic Council members and increasing security assistance efforts among regional NATO allies, armed conflict with Russia and China in the region remains unlikely.

#### Discussion

The Arctic region is experiencing a steady increase in strategic importance and economic potential.<sup>H</sup> The impacts of global warming on the Arctic Region prompted several scientists to predict that the region will be experiencing icefree summers as soon as the 2030s.<sup><sup>H</sup></sup> Penn



Figure 1. Arctic Open For Commerce. Source: <u>https://www.businessinsider.com.au/denmark-just-claimed-the-north-pole-2014-12</u>.

State Professor Francis X. Diebold states that "[U]sing statistical modeling, we're predicting a much faster reduction of Arctic sea ice than most climate models have, by about 2040 as opposed to 2060 or 2070."<sup>M</sup> These reduced ice flows result in a substantial increase in maritime traffic by 2040, thereby increasing both economic and security

competition between both regional Arctic states and countries like China which considers itself a "Near-Arctic State."<sup>M</sup>

Security experts assess that there are currently four drivers of Great Power Competition in the Arctic: (1) military developments, (2) energy resources and minerals, (3) transportation, and (4) food security (*See* Figure 1).<sup>H</sup> The primary Great Powers in the region are 1) a resurgent Russia, 2) a revisionist China, and 3) the United States pivoting to the Arctic.<sup>M</sup> Russia is a superior Arctic power relative to the United States and has a long history of establishing ports and bases throughout the region.<sup>M</sup> Russia currently claims the right to control maritime navigation in Arctic waters beyond the authority permitted under international law, and its deployment of missile technology in the region provocative and a significant contributor to the ongoing security dilemma.<sup>HM</sup> Although the Russian military has steadily increased the scale and capabilities of its presence in the Arctic, thereby signaling the region's importance to the Russian government, its current force deployment in the region is primarily defensive. (See Figure 2)<sup>H</sup>



Figure 2. Source: The Intensifying Great Power Politics of the Arctic. Source: <u>https://www.jstor.org/stable/pdf/resrep21443.5</u>.

China is now a rising peer competitor to the United States in the region and consistently demonstrates its ambition to be a key Arctic player. China's efforts to participate in the Arctic Council governing body as a self-described "Near-Arctic State" is seen as an effort to expand its economic. environmental, and strategic interests.<sup>M</sup> As set forth in its 2018 Arctic *Policy*, China is pursuing a "Polar Silk Road" initiative wherein it seeks investment in the Northern Sea Route

infrastructure and establishing ports and bases in Iceland and Greenland.<sup>M</sup> However, "[a]ny attempt by China to foster a military presence in the Arctic could meet with Russian opposition and challenge their mutual cooperation in the region."<sup>H</sup> Moreover, the United States declared in 2019 that it rejected any attempt by non-Arctic states to claim a role in Arctic governance.<sup>H</sup>



Figure 3: America's Arctic Moment; Great Power Competition in the Arctic to 2050. Source: <u>https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/Conley\_ArcticMoment\_layout\_WEB</u> FINAL.pdf?EkVudAIPZnRPLwEdAIPO.GlpyEnNzINx

With the escalation of Great Power Competition in the Arctic, the United States has taken steps to solidify and expand military cooperation and training with regional NATO and NATO-aligned allies.<sup>H</sup> Further, Defense Secretary Austin and GEN Mark A. Milley, CJCS, have stated a commitment to expand future budgetary requests to increase our military focus in this strategically important region.<sup>H</sup>

## Analytic Confidence

Analytic confidence in this estimate is low. Sources were generally reliable and tended to corroborate one another. There was adequate time to conduct this research project, but the analyst utilized an unstructured research method working alone. Given the lengthy timeframe of the estimate and recent actions of the Russian government and military, this strategic estimate is sensitive to change based on new information.

Author: Andrew S. Culbreath

# Disruptive Technologies Today, Highly Likely Converge to Symbiotic Warfare By 2045

## **Executive Summary**

Despite previous intermittent and limited successful research and development, disruptive technologies are now converging rapidly. Revolutionary research in drones, ion drive, energy storage, nanoscience, brain-machine interface (BMI), and artificial intelligence (AI) makes it highly likely (71-85%) that the Symbiotic Warfare operating concept that ingrates humans, AI, and teamed machines at thought speed potentially allowing military combatants an exponential boost by 2045, due to a variety of successful lab tests and heavy investment by global market competitors of the mentioned revolutionary technologies that are imaginably mergeable.

## Discussion

The Symbiotic Warfare operating concept is the amalgamation of disruptive technologies that will accelerate analysis, decision making, execution, and assessments through the symbiotic interactions at the thought speed of AI and human-autonomy teaming. Form a small, capable, synthetic, and multi-functional unmanned combat formation according to the power grouping rules; choose and adjust the strike position, timing, intensity, and effect according to the target strike rules; standardize the "discourse" system and unify state cognition according to the action coordination rules, connecting combat actions to generate swarm intelligence<sup>1</sup>.<sup>M</sup>

Technology needs foundational pieces to be able to operate in austere and potentially contested environments: energy generation and storage. There are several companies developing mobile fission nuclear reactors, which could be truck mounted and provide energy for everything from forward operating bases to logistics hubs throughout the continuum of conflict (See *Transportable Nuclear Power Plants* by Mr. Michael Stevic). Once systems create power it needs to be stored, facilitating the decisive use of warfare technology within the timing and tempo of the combatant. With the renewed investment in energy storage research, current plans are to increase battery capacity approximately three-fold within two years, from 290 kWh to 750 kWh.<sup>M</sup> This new technology facilitates longer duration or greater power capacity for warfighting technology.

More mobile high-capacity power generation and storage conceivably allow for further substantial integration of drone technology into tactical formations. Unlike the current employment of drones in a limited number, military formations in the future will be able

<sup>&</sup>lt;sup>1</sup> Translated from Chinese.

to control exponentially more drones in a near-autonomous swarm, such as in figure 1. (See <u>Autonomous Swarm Attack</u> <u>Drone</u> by LTC Andrew

Culbreath).<sup>M</sup> Other current research could potentially make these drone swarms silent through ionic propulsion, giving combatants the ability to potentially gain more intel and maintain numerous principles of war including mass, the economy



Figure 4: DARPA conducting drone swarm test with 130 drones. Source: <u>youtube.com</u>

of force, maneuver, and surprise on the battlefield. (See <u>*Ionic Thrust Propulsion*</u> by LTC Andrew Culbreath). The present research is driving these devices to be lighter, stronger, more durable, and smarter through nanotechnology.<sup><u>H</u></sup>

Disruptive technology is not only going to revolutionize the tactical level fight but the strategic level of conflict as well. Three initiatives that will affect Department of Defense level deterrence and closing the distance with an adversary are hypersonic missiles<sup>M</sup>, (See Weapons by Mr. Michael Stevic) directed energy weapons for protection and precision strikes<sup>H</sup> (See <u>Directed Energy Weapons (DEW)</u> by Mr. Michael Stevic), and space technology which are all highly likely (71-85%) to be utilized by competitors in the future.

With currently disruptive technologies becoming mainstays in future combat, mission command is foundational and crucial to developing adaptive crossdomain kill-webs as an evolutionary leap from the kill chain concept.<sup>H</sup> Current research into AI will



Figure 5: DARPA's Adapting Cross-Domain Kill-Webs (ACK). Source <u>www.darpa.mil</u>

facilitate rapid decision making at both the strategic and operational level. AI Strategic Advisers, who are assessing and analyzing data from multiple streams and presenting options to the commander, and the Soldier on the battlefield will have AI assistance with their Tactical Digital Companion allowing them to potentially control disaggregated systems and platforms to permit decision dominance through multiple actions across a variety of domains potentially sowing decision stagnation in an adversary.<sup>H</sup>

The previous technologies are presently controlled through some type of manually operated device, such as a tablet or computer. Current research on a brain-machine interface is highly likely (71-85%) to be commercialized and used by militaries by 2045.<sup>M</sup> The best source of the brain-machine interface is currently invasive, but universities, such as the University of Arizona, are researching cutting-edge technology and signaling to allow for extracranial reading of brain signals to control drones<sup>M</sup>, which then could be adapted for other automation. This direct interface would allow for faster human-autonomy teaming, as the technology, both hardware and software, becomes another signaled part of the body.

As a result of the converged technology, militaries are highly likely (71-85%) to utilize the Symbiotic Warfare operating concept by 2045. This concept utilizes artificial intelligence to rapidly analyze sensor inputs and synthesize possible courses of action to present to combatants at both the strategic and tactical level, facilitating more rapid decision cycles across several different domains. Through human-autonomy teaming an individual Soldier will partner, and trust, its Tactical Digital Companion with tasks that would normally have been accomplished by trusted human squadmates. This will allow the Soldier to control a variety of drone modalities and accomplish the same mission that would have been accomplished by a greater number of human actors at greater speed, sensor input, and effectiveness.<sup>M</sup> These same efficiencies are garnered at the operational and strategic levels as the leader can incorporate myriads of information and sensor input accumulated on the battlefield and environment into courses of action. The amorphous kill-web is generated from strategic to tactical level allowing for the disaggregation of assets, but massing of effects at thought decision speed, with some tasks being trusted to the digital partner controlling portions of the technology to accomplish certain tasks.<sup>H</sup>

#### **Analytic Confidence**

Analytic confidence in this estimate is *moderate*. There was adequate time allotted for this research, but the analyst worked alone, utilizing an unstructured research method with a complex task. The reliability of the sources was above average, with several high-quality sources available. The available research does not synthesize into a cohesive picture but must be analyzed into a holistic viewpoint.

Author: John J Hosey

# Artificial Strategic Advisor And Soldier Companions Very Likely By 2045, Exponentially Increasing Awareness And Decision Speed

## Executive Summary

Even though some experts perceive an artificial intelligence (AI) winter, the science behind AI's progression with deep learning techniques and natural language processing (NLP) continues with new models allowing the science to highly likely (71-85%) leap the gap within the next decade. It is very likely (80-95%) that artificial intelligence, in the form of a virtual strategic advisor, will vastly augment the decision-making of nationstate militaries from the strategic level down to the individual Soldier level by 2045, during all phases of the competition continuum with conflict being the greatest beneficiary.

## Discussion

Some experts currently believe that AI research and operationalization are on the decline with a potential AI winter<sup>L</sup>, but this theory is based on the lack of realization of general AI. There are two large categories of AI, narrow and general; each has two subcategories.<sup>H</sup> Most of the current AI models available today are within the narrow AI construct. which has two subcategories, reactive and limited memory.<sup> $\underline{H}$ </sup> General AI is seen as the pinnacle, including the theory of mind and self-aware subcategories. Because of the hype generated by movies and television and the lack of instantiation of general AI, experts falsely



Figure 6: Categories of Artificial Intelligence. Source: Forbes.com

assume that the world is entering another AI winter.<sup>L</sup>

Nearly all current top-of-the-line AI resides in the "Limited Memory" quadrant, including chatbots, virtual assistants, and self-driving cars.<sup>H</sup>AI-augmented decision-making occurs daily at some of the world's most successful enterprises – Google, Netflix, Amazon, Facebook, Alibaba, Renaissance Technologies – where autonomous algorithms, not managers, increasingly get the last word.<sup>H</sup> Gartner expects that by 2025, 70% of organizations will have operationalized AI architectures due to rapid maturity of AI orchestration initiatives.<sup>H</sup> Elements of deep learning and natural language process are feeding the learning models for more in-depth artificial intelligence<sup>M</sup>, as these effort process language as humans do. Today, companies are creating products that will allow

anyone to apply artificial intelligence without having to write a line of computer code.<sup>M</sup> This will not only drive AI to be more ingrained into society but will also build trust in AI models for future use.

Harvard Business Review (HBR) delineates four categories for operational use cases of AI, most of which resides in the Limited Memory quadrant. First is the autonomous/ autonomy advisor where AI is seen and treated as the best strategic advisor for organizations and they will never have to be replaced by military and or civilian promotion systems.<sup>H</sup> This category, which the AI Strategic Advisor is an example that could support the efforts of developing models for command and control of military forces, including communication links monitoring and rerouting, developing 3D common operational pictures through amalgamations of 2D compositions, and Intelligence, Surveillance, and Reconnaissance.<sup>H</sup> Currently Gartner Hype Cycle (Figure 2) sees heavy research in the Decision Intelligence area for the next two to five years until the sector begins to stagnate and plateau if there is not a significant breakthrough.<sup> $\underline{H}$ </sup> Renaissance Technologies, and other even more secretive investment funds, are fully committed to letting AI take the enterprise to new frontiers in innovation, profitability, and risk but the human oversight remains present to pre-empt AI executions.<sup>H</sup> This concept, would still fall into the Limited Memory quadrant as over most experts predict the probability of General AI not happening until between 40 years, in Asian countries, and 74 years, in North America.<sup>™</sup>

A subset of the strategic advisor could be the tactical digital companion. Currently, the research is very nascent with Siri, Sam, and Alexa being the most developed. By 2045 it is likely (56-70%), that Soldier AI companions will enable simple, rapid integration of collaborative, multi-agent AI technology into the Processing, Exploitation and Dissemination (PED) chain at the edge, sensor, and tactical PED level.<sup>M</sup> Tactical digital companions would facilitate friendly and adversary situational awareness through the synthesis of numerous of data feeds from sensors on the battlefield, which without the tactical companion would sow confusion and decision stagnation. If you combine the two, strategic advisor and tactical companion at echelon speed of awareness, decision-making, and action are sped up exponentially.

The second category Autonomous Outsourcer, meaning process, and decision owners determine the resource allocations and whether autonomy should lead to greater innovation,



lateau will be reached: 🔿 < 2 vrs. 🥚 2-5 vrs. 🐞 5-10 vrs. 🔺 >10 vrs. 🙁 Obsolete before ola

Figure 7: Gartner Hype Cycle for Artificial Intelligence 2021. Source: <u>Gartner.com</u>

optimization, or both.<sup>H</sup> The Autonomous Outsourcer shares characteristics with the concept of Mosaic Warfare, decision-centric warfare, where the sensing of a target is then rapidly processed through to the shooting platform through characteristics like a munition, distance, location, etc., gaining mass without having to mass formations together.<sup>H</sup>

The third HBR category is World-Class Challenging/Challenged Autonomous Employee with characteristics similar to eccentric geniuses, being treated as a valued and valuable colleague.<sup>H</sup> This category is similar to the autonomous advisor, where trust will need to be programmed into the organizational relationship through policy and training. Currently, many people see competition with AI, as illustrated through the percentages of people who trust AI.<sup>M</sup> The United States ranks 15 out of 24 of the most technologically advanced countries with 25% agree and 28% neutral, compared to some of our competitors having a higher trust value; Russia at 40% and 33%, and China at number one with 70% and 17% respectively. The human-machine partnership will continue to be needed with the average projection of General Artificial Intelligence not being realized until 2060.<sup>M</sup>

The final HBR category is All-In Autonomy where organizations allow a majority, or in some cases all, of the decisions to be made by AI. A current example is the Decentralized Autonomous Organization where all processes are transparent, rules are coded into the algorithm, and codified in a distributed ledger format.<sup>M</sup> All members of the organization are equal and choose the outcome of decisions generated by AI, with the ultimate goal of this process to be fully automated.<sup>L</sup> For strategic government and military decision-makers, dependent on the trust levels in AI, the idea of a fully autonomous organization ranges is unlikely (31%-45%).

Several challenges need to be worked out to inculcate AI into augmenting strategic and operational decision-making. The first challenge is coding out baked-in human bias in AI models, but researchers are conducting exploration into the blind-taste-test concept which would manage bias.<sup>H</sup> Another challenge is building trust in AI, where one solution is to build human values in AI, but this leads to more questions, such as whose values?<sup>M</sup> Finally, creating transparency is also a concern that is related to trust. It is projected that within the next five years, AI will be able to better explain why it's telling you to do what it is recommending.<sup>M</sup> This combined with education and the above-mentioned no-code AI will drive trust higher by 2030 allowing greater use by strategic decision makers by 2045.

#### **Analytic Confidence**

The analytic confidence for this estimate is *moderate*. Sources were generally reliable and tended to corroborate one another. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: John J. Hosey

# Lighter, More Supple, And Powerful Battery Breakthrough Will Highly Likely Revolutionize Character Of War By 2045

#### **Executive Summary**

Due to a four-fold increase in funding for battery research and development since 2019, it is highly likely (71-85%) that this rapidly advancing field of technological innovation will enable nation-states to exploit the technology for military use by 2045. Current limitations on battery technology and power generation cause limited power delivery to future warfare technologies. However, a high likely (71-85%) breakthrough in battery technology will produce greater power storage and delivery capacities for existing and future unmanned weapon systems, resulting in greater distances and longer durations.

#### Discussion

The most commercially viable energy storage for smaller-scale electronics is lithium-ion batteries.<sup>H</sup> First developed in the 1990s, lithium-ion batteries have become more prevalent and have decreased in size but grown in scale.<sup>H</sup> The use of these types of batteries has advanced to electronic vehicles, hybrids, and drones. Since the development of the first commercially viable lithium-ion battery, research and development for energy storage technology has stagnated. Recent<sup>M</sup> climate initiatives, as well as commercial pressures, catalyzed new research into energy storage research and facilitate the science

"cross the chasm".<sup>M</sup> U.S. Energy storage markets tripled in 2020<sup>H</sup> and are forecasted to be \$5.85 billion in fourth-quarter 2021.<sup>M</sup> In early April 2022, the Biden Administration passed an Infrastructure Bill that included \$3 Billion for advanced energy storage research.<sup>H</sup> Along with the renewed investment, the speed of adoption of technology has increased exponentially as science and technology have become more democratized.<sup>M</sup> The renewed global interest and potential for



Figure 1: Overall price decline of lithium-ion batteries-scaled by energy capacity...is a staggering 97%. Source: <u>IEEE Spectrum</u>

further commercialization make it highly likely that technological leaps will occur and drive change in utilization in a military context.

The United States military has discovered some issues upon researching the use of lithium-ion batteries in military vehicles.<sup>H</sup> Low cell density and power output duration has stagnated battery technology use and democratization, not just in the lithium-ion instantiation, but in other forms of energy storage as well.<sup>H</sup> These characteristics affect

the power-to-weight ratio. This means that the device that uses the battery for longer windows or massive power requirements, would need to be larger to carry the battery.<sup>M</sup>

The science behind artificial intelligence and machine learning has rapidly evolved to be more fruitful in the last decade. Artificial intelligence and machine learning used in the research and development of energy storage technologies<sup>M</sup> are not just 'hype'.<sup>H</sup> Chemical engineering, in particular, energy storage research progresses through analysis of large data sets and modeling, which is optimal for use with machine learning. Utilizing machine learning for each organization, creating a shared space for data<sup>M</sup>, and providing interfaces to access the data, will allow the use of swarm learning and will likely facilitate leaps in design.<sup>M</sup>

Challenges that should be overcome to meet the energy density, weight, and power output needed for future use require protection for many of the form features presently used.<sup>M</sup> For example, lithium-ion batteries can only operate optimally within a certain range of temperature; anything above the optimal temperature will cause it to melt, and dipping below the optimal temperature will cause a loss of storage capacity.<sup>M</sup> Materials used for current energy storage needs are another concern, as a majority of batteries are made from precious metals and require a significant investment in the mining and/or purchase as well as the development of manufacturing.<sup>H</sup>

Current efforts show promise for increased energy output at a comparable size.<sup>M</sup> Use of machine learning assisted the development of new materials that conduct and store energy at a greater capacity with less weight. With the renewed investment in energy storage research, current plans are to increase battery capacity three-fold within two years, from 290 kWh to 750 kWh. Capacity is only one characteristic that is being revolutionized. Figure two shows



Figure 2 The Korean team of Professor Keon Jae Lee from the Department of Materials Science and Engineering, KAIST has developed a high performance flexible all-solid-state battery... Source: <u>phys.org</u>

lines of research and prototyping for flexible solid-state batteries. Making it highly likely that by 2045, nations will be able to use technology to a greater capacity, fundamentally changing their doctrine and formations of machines in place of humans.

#### **Analytic Confidence**

Analytic confidence in this estimate is *moderate*. There was adequate time allotted for this research, but the analyst worked alone, utilizing an unstructured research method with a complex task. The reliability of the sources was above average, with several high-quality sources available. The available research does not synthesize into a cohesive picture but must be analyzed into a holistic viewpoint. Further analysis is warranted as indicated by U.S. bi-partisan laws for use of artificial intelligence and machine learning to solve hard technological problems.

Author: John J Hosey

# Not Killer Microbots; Nanotechnology Highly Likely To Augment Kinetic Weapons Technology, Not Revolutionize It

## **Executive Summary**

Despite a lack of research on the negative impacts of nanoscience and nanotechnology, it is almost certain (80-95%) that further revolutions in nanotechnology will facilitate warfare technologies (nanoweapons) that increase durability, lethality, and precision in future warfare. It is highly likely (71-85%) that by 2045 uses of nanotechnology will involve reengineering of current technology, with an unlikelihood (31-45%) of revolutionary weapon systems by that same time.

## Discussion

From the concept of nanotechnology created in 1959 to the first creation of carbon nanotubes in 1986, there has been an explosion of research. The beginning of the 21<sup>st</sup> century saw an increased interest in the emerging fields of nanoscience and nanotechnology.<sup>H</sup> Presidents Clinton and Bush created institutions to drive nanotechnology innovation, including the National Nanotechnology Initiative.<sup>H</sup> China, Russia, and Iran are not to be left behind; China, the closest near-peer competitor that can





commercialize nanotechnology, possess a national desire to strengthen its militaries and demonstrated an ability to partner with other leading nanotechnology nations.<sup>H</sup> Despite Russia's desire to for a similar glide path, its volatile and much lower GDPH is likely (56-70%) to hamper its ability to commercialize the nanoscience research. Finally, sanctions on Iran's economy<sup>H</sup> extremely limits the ability to commercialize the technology but not their desire to conduct the research. Since publishing 11,546 articles on nanoscience and nanotechnology in 2020, Iran places behind China, India, and the United States respectively.<sup>MM</sup>


Figure 9: Race for nanotechnology. Source: Nanotechnology and the New Arms Race

These countries are conducting research that is divided into the following categories: Augmented varieties of existing weapon types, tiny machines, such as robots that could create new types of destruction, hyper-reactive explosions due to the extremely small particle sizes and the unique physiochemical properties, and materials with superior electromagnetic properties that could disrupt the electrical grid and communications infrastructure.<sup>H</sup> Some research has leaped to successful defense production, such as material coatings that are more durable from hours to years, nano-structured silicate manipulation, reducing insulation weight by 980 lbs., and high-power microwave devices with reduced weight, shape, and power consumption.<sup>M</sup> Other lines of effort that are close to fruition are lighter missiles, projectiles, or mortar rounds, with reduced mass, greater destructive force, increased penetration capability, tailored energy release, smaller size, or improved accuracy.<sup>M</sup> Even though the greatest concern for technologists are nanobots, it is highly unlikely (16-30%) that the research will be useable by 2045; the research is still in infancy and is more likely to take 30 to 40 years for commercialization.<sup>H</sup>

A secondary concern to nanobots is the development of hyper-reactive explosives. Currently, scientists are conducting limited research on the explosiveness of energetic materials and how nanification affects these characteristics.<sup>H</sup> As of 2020, there is still no working theory of an energy release mechanism applicable to real, three-dimensional materials, where it would go from propellant to explosive.<sup>H</sup> Even though the potential outcome would be a five-pound explosive with the effectiveness of 100 tonnes of TNT.<sup>M</sup>

Finally, the development of more mature materials with superior electromagnetic properties is a potential dual-edged sword.<sup>M</sup> These materials could be used beneficially as a neural sensor array with edge computing and wireless communication abilities. An example is pervasive, distributed nanoscale sensor nets with computational and wireless communication



Figure 10: The Scale of Things. Source: <u>National</u> <u>Nanotechnology Initiative</u>

abilities ('smart dust'). Potentially these components could also be used nefariously as a payload to disrupt the same services that they are purported to enhance.<sup>M</sup> Gartner's Hype Cycle has smart dust for sensing commercialized in more than a decade making it likely

(56-70%) adversaries will utilize the technology by 2045, but employment as an effectsbased weapon is highly unlikely (16-30%).

#### Analytic Confidence

Analytic confidence in this estimate is *moderate*. There was adequate time allotted for this research, but the analyst worked alone, utilizing an unstructured research method with a complex task. The reliability of the sources was above average, with several high-quality sources available. The available research does not synthesize into a cohesive picture, but must be analyzed into a holistic viewpoint. Further analysis is warranted as indicated by current U.S. bi-partisan theory on laws for use of nanotechnology in warfare.

Author: John J Hosey

# Urbanization Trends Escalate; Urban Warfare Is Here To Stay – Mega-City Conflict To 2045

## **Executive Summary**

Despite some current theories, it is highly unlikely (16-30%) that future conflict will take place outside of urban settings. With 55% of the world's population currently living in cities and a projection of 68% by 2040, it is highly likely (71-85%) that conflict will continue to occur in urban settings through 2045, facilitated by disruptive technologies that will be commonplace. This probability increases to virtually certain (86-99%) with an attack on the United States homeland.

#### Discussion

As a whole, a growing proportion of the world's most violent conflicts are fought in cities like Aleppo, Raqqa, Mosul, Marawi, Gaza, Mogadishu, Donetsk, Saana, and many others, where conventional state forces fight against armed groups that exploit the urban terrain to make up for their relative weakness.<sup>M</sup> With trends in technological advances,

Sun Tzu's theory is weaker By approximately 2045, two out of every three people are likely to be living in cities or other urban centres,<sup> $\underline{H}$ </sup> In several countries the population will be concentrated in cities that are over 10 million inhabitants, named Megacities. Megacities will complicate and greatly challenge Army urban combat missions in the 2030-2040 timeframe.<sup>M</sup> The developing world congregates more into megacities (Figure 1),



Figure 11: Urbanization by Country 2010 and 2050.Source: <u>truehuenews.com</u>

while Americans are increasingly moving to both downtowns and the urban sprawl around dominant business and industry-specific hubs.<sup>M</sup> Additionally, there are 468 cities with a population of over 1 million, up from 83 in 1950. A Yale research group projects that urban land coverage will expand by 463,000 square miles by 2030 to cover just

under 10% of the planet's land, equivalent to 20,000 football fields being paved over every day.<sup>M</sup>

There are numerous characteristics and problems that will likely drive flashpoints by 2045 (Figure 2). First is the potential for massive poverty and social unrest, especially in third world megacities through migration from rural to urban environments looking for living wages.



Figure 12: Dredd (2012). Accessed at www.theDrive.com.

As that migration occurs, there is potential for massive infrastructure problems with communications services, basic infrastructure maintenance, transportation, and congestion. To continue the migration line of thought, environmental concerns, such as contaminated water, air pollution, and sewage are a strong possibility. Finally, there is a potential for increased disease transmission due to over-crowding, drug-resistant strains of infection, and lethal environmental conditions, with also a potential for ungoverned havens and spaces within the megacity. There is also a potential for littoralization- the prosperity for megacities to cluster on coastlines. All of the previous concerns facilitate a population that can be quickly mobilized (influenced) with social media during times of social unrest, exacerbated by higher birth rates, city migration, and young unemployed population.<sup>M</sup> COVID-19 has caused a reverse flow from urbanization, but urban areas are centers of growth ensuring the return to urbanization.<sup>H</sup>

It is certain (86-99%) that an attack and sustained conflict on the United States homeland would occur in a large city and as trends toward urbanization escalate potentially megacities. Seats of power, both political and financial, are focused into significant urban environments which would be seen as the United States Centers of Gravity. In future conflicts, American territory will not be a sanctuary. The U.S. is entering an era of homeland vulnerability, one in which technological advances are making it possible for geopolitical adversaries — not just terrorist groups — to bring the war to America itself.<sup>M</sup>

#### **Analytic Confidence**

Analytic confidence in this estimate is *moderate*. There was adequate time allotted for this research, but the analyst worked alone, utilizing an unstructured research method with a complex task. The reliability of the sources was above average, with several high-quality sources available. The available research does not synthesize into a cohesive picture, but must be analyzed into a holistic viewpoint. Further analysis is warranted as indicated by current U.S. bi-partisan theory on laws for use of nanotechnology in warfare.

Author: John J Hosey

# **Turkey A Non-Adversarial Regional Hegemon By 2045**

#### **Executive Summary**

Despite Turkey's current relationship with Russia and economic complications, several factors make it highly likely (71-85%) that Turkey will become a regional hegemon in the middle east by 2045. If the United States continues to have a mature international relationship with Turkey, it is unlikely (31-45%) that it will become a global adversary to the United States or its NATO member allies.

## Discussion

Recently Turkey has been walking a geopolitical tight rope between the United States and Russia. Turkey has been sitting on two chairs, doing geopolitical business with Russia and calling on the United States on a case-by-case basis when interests happen to converge.<sup>M</sup> Compounding the potential problems with maintaining a relationship with two superpower adversaries, Turkey is currently facing its worst economic crisis in almost two decades, he has few independent-minded experts at his side — a consequence of his efforts to centralize power, which have sidelined or hollowed-out financial institutions to which he once deferred, economists say.<sup>M</sup>

Vincent Ferraro, Ph.D., from Mount Holyoke College, states that to be a hegemon, a state must have the following three attributes: the capability to enforce the rules of the system, the will to do so, and a commitment to a system that is perceived as mutually beneficial to the major states.<sup>H</sup> Also, the capability rests upon the following three elements: a large, growing economy, dominance in a leading technological or economic sector, and political power backed up by projective military power.<sup>H</sup>

The factors of capability are the foundation of a country's ability to gain and maintain hegemonic status. The United Kingdom's Ministry of Defence believes that Turkey can be a key player in the Southwest Asian region if structural changes are applied today.<sup>H</sup> The path that Turkey is on gives it several industries that could become Turkish centers of excellence by 2041,



Figure 13: Turkish Drones Becoming Critical to Conflicts. Click or go to <u>https://www.youtube.com/watch?v=ASj\_AE3VK1Y</u>

driving Turkey toward a strong, mature economy.<sup>M</sup> The industrial sectors affecting Turkey are food and beverage processing, agricultural research, development and services, alternative energy, automobile production, and tourism. In addition to the above

potential growth sectors, Turkey has become the de facto drone manufacturer and drone distributor in the eastern European and Southwest Asia regions displayed during the Nagano-Karabakh and Ukraine conflicts respectively (Figure 1).<sup>M</sup>

For the past few years, Turkey has continued a political charm offensive to ameliorate tensions with a long list of countries, including Armenia, Israel, the UAE, Saudi Arabia, Egypt, Greece, and engaging in a protracted effort to reboot its strained relationship with the United States.<sup>M</sup> If it can continue this process potentially through another administration, Turkey would be in a well-established position to influence the political system of the Eurasia region.<sup>H</sup>



Figure 14: Shifting of Global Economic Centers of Gravity

The final element of the characteristic of capability is the ability to project military power. Turkey is likely to become increasingly important to European security, as the size, capability and increasing modernization of its armed forces mean that it may have one of the more capable militaries in Europe, as well as the Middle East.<sup>M</sup>

Membership in the European Union (EU) by 2045 will potentially encompass all the countries of the Balkans. Despite Turkey's growing importance, it will unlikely (31-45%) be a member of the EU by 2045, as existing members are likely to fear high costs of integration and disruptions to local labor markets.<sup>M</sup> As a current member of NATO and a potentially courting member of the EU, it is highly unlikely (16-30%) that Turkey will be a global competitor or State adversary by 2045.

#### **Analytic Confidence**

Analytic confidence in this estimate is *moderate*. There was adequate time allotted for this research, but the analyst worked alone, utilizing an unstructured research method with a complex task. The reliability of the sources was above average, with several high-quality sources available. The available research does not synthesize into a cohesive picture, but must be analyzed into a holistic viewpoint. Further analysis is warranted as indicated by current U.S. bi-partisan theory on laws for use of nanotechnology in warfare.

Author: John J Hosey

# Highly Likely That Time Will Become The Sixth Warfighting Domain Influencing All Other Domains In The Next Decade

## **Executive Summary**

Despite Space and Cyberspace being the most recent warfighting domains added to military doctrine that influence the other three traditional domains (Air, Land, Sea), advances in new warfighting concepts and technologies will highly likely (71-85%) drive the creation of time as the most unique, all-encompassing, warfighting domain in the next decade.

## Discussion

Several technologies under development will significantly accelerate the sensor to shooter OODA loop,<sup>M</sup> requiring faster and more precise target assessments on the battlefield:

- Directed Energy Weapons (DEW) can track and fire on targets measured in milliseconds, but the human decision-maker in the loop cannot react at that speed.<sup>M</sup>
- Hypersonic missiles move at Mach 5+ speeds traveling anywhere on the earth in less than an hour in erratic flight paths and, therefore, more difficult to counter than the predictable ballistic missile flight paths of traditional ICBMs.<sup>M</sup>
- U.S. adversaries will use anti-satellite weapons to deny or destroy U.S. space assets and capabilities at their leisure, at the most inopportune time.<sup>M</sup>

A GAO study finds that "individual services have undertaken various efforts to improve

their capability to attack timecritical targets. Although these efforts are helping DOD to make improvements in the sensor-toshooter process, considerably more needs to be done to significantly reduce the time it takes to strike time-critical targets." <sup>M</sup> The GAO study recommends that: the DOD needs to overcome cultural impediments to joint warfighting,<sup>M</sup> the DOD's current oversight and control mechanisms are simply not working,<sup> $\underline{M}$ </sup> and that the DOD lacks a joint service concept of



Figure 1: Conceptional Vision of JADC2. Source: <u>Congressional</u> <u>Research</u>

operations to defeat time-critical targets and, as a result, each military service plans and acquires systems to meet requirements under its concept of operations.<sup>M</sup>

Joint All Domain Command and Control (JADC2) (see Figure 1) is the DoD's most recent attempt to counter the impacts of the complexity of Command and Control and complex formations from emerging technologies by attempting to reduce the time to respond to the threat.<sup>M</sup> Emerging technologies like artificial intelligence and augmented reality will create "Artificial Advisors" at the sensor(s) and shooter(s) levels which will vastly augment the decision-making process, improving kill chain response times. [Artificial Strategic Advisor – COL Hosey, USAWC].

According to GEN Wallace, former commander of TRADOC, he identified why multidomain operations and JADC2 must evolve from a sensor-to-shooter targeting philosophy to a command-and-control philosophy (see Figure 2).<sup>M</sup>

Over the past 20 years, China and Russia have observed the United States' method of war, identifying asymmetric methods to challenge U.S. advantages. China's military modernization, in particular, focuses on preventing the United States from building large amounts of combat power (limiting logistics), increasing risks for high-valued aircraft (tankers, spy planes, command and control aircraft), and increasing its naval footprint (limiting U.S. naval advantages).<sup>30</sup> To counter these new threats, DOD initially proposed the idea of using multidomain operations (which has since transitioned into the term *all-domain operations*). DOD contends that using one or even two dimensions to attack an adversary is insufficient, and that challenging an adversary's targeting calculus thus requires more complex formations (additional dimensions). The increasing complexity, combined with potentially decreasing times to respond to threats from emerging technologies, DOD argues, requires new methods to manage forces.



Figure 2: Changes in Complexity of Command and Control. Source: Congressional Research

#### Analytic Confidence

Analytic confidence for this estimate is *moderate*. The analyst had sufficient time, and the task was not markedly complex. The analyst used several credible academic and government sources to compile information for this research. Sources were generally reliable and tended to corroborate one another. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new advancements and information.

Author: Michael E. Stevic

# Adaptive and Passive Camouflage Technology Will Highly Likely Render Objects On The Battlefield Virtually Invisible To The Enemy Over Next Decade

#### **Executive Summary**

Although recent events in the Ukrainian war have demonstrated the vulnerability of tanks and armored vehicles to air drone strikes, anti-tank missiles, and rocket-propelled grenades, recent developments in both adaptive and passive camouflage technology will highly likely (71-85%) reduce those threats through the thermal and visual spectrums over the next decade, rendering them virtually invisible to the enemy on the battlefield.

## Discussion

Military camouflage has been the subject of continuous improvement, design, and research for over one hundred years. Camouflage comprises any combination of materials, coloration, or illumination for concealment, either by making object hard to see (crypsis) or by disguising them as something else (mimesis).<sup>M</sup>

Researchers are developing active camouflage or adaptive camouflage technology that adapts, often rapidly, to the surroundings of an object such as a soldier's uniform or a

military vehicle. HyperStealth Biotechnology Corp. has patented a material (see Video 1) that not only hides a target in the visible spectrum (crypsis) but also bends in the Ultraviolet, Infrared, and Shortwave Infrared while blocking the Thermal Spectrum, making it a true "Broadband Invisibility Cloak" when applied to military vehicles in the future.<sup>M</sup>



Video 1: 'Invisibility cloak' that could hide tanks and troops looks closer to reality. Source: <u>HyperStealth Biotechnology Corp.</u> <Ctrl-Click video to play>

BAE Systems is working on a unique camouflage system called "ADAPTIV" that allows a vehicle to blend into its surroundings, effectively becoming invisible to hostile thermal imaging systems. The system uses modules that look like cells in a honeycomb to cover the vehicle that can be cooled or heated very quickly and controlled individually, creating different patterns, thus enabling the vehicle to mimic its surroundings or copy other vehicles or objects.<sup>M</sup>



Figure 1: BAE ADAPTIV Car Signature. Source: BAE Systems

With recent advances in passive camouflage, two technologies will soon be arriving on the battlefield to protect vulnerable ground vehicles and stationary objects; one is a patterned fabric that attaches to vehicles, while the other is a unique textile for covering stationary objects or vehicles.

- Multisorb camouflage made by MBDA is attached directly to a vehicle. It is a fabric comprised of two layers of polyester netting attached with hooks and magnets with deep ruches, bows, folds, and layers that trap the air, giving the camouflage its effectiveness against infrared detection.<sup>M</sup>
- Saab Barracuda has created a new textile named ARCASe that consists of textile panels printed on both sides with different colors and visual patterns. The fabric seems to move like oil on water, or a mirage when folded. The textile and proprietary coating work together to break the thermal signature, which means that the heat of a vehicle is masked to blend in with the background.<sup>M</sup>

#### **Analytic Confidence**

Analytic confidence for this estimate is *moderate*. The analyst had sufficient time, and the task was not markedly complex. Several credible academic and government sources were used to compile information for this research. Sources were generally reliable and tended to corroborate one another. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new advancements and information.

Author: Michael E. Stevic

# Directed Energy Weapons (DEW) Will Highly Likely Replace Several Traditional Kinetic Weapon Roles By 2030

## **Executive Summary**

It is highly likely (71-85%) that directed energy weapons will either surpass the capabilities of or entirely replace existing traditional kinetic weapon roles on the battlefield by 2030. Despite several false starts by the Department of Defense (DoD) and other peer state allies and adversaries with directed energy weapon research since the 1970s, costing billions of dollars, High-Energy Lasers (HEL) and High-Powered Microwave (HPM) weapons have reached the point of operational test and evaluation readiness and, in some cases, operational battlefield use replacing current kinetic anti-ballistic missile defenses and anti-armor/personnel weapon systems.

#### Discussion

A Directed Energy Weapon (DEW) is a weapon that destroys, damages, or incapacitates its target with highly focused energy, including laser, microwaves, or particle beams.



Figure 1: Directed energy weapons use in the battlespace. Source: Chanakya Forum

DEW fall into two primary categories, High-Energy Lasers, and High-Powered Microwave weapons, and to a lesser degree, Particle-Beam, Plasma, and Sonic weapons:

- HEL weapons engaging at the speed of light can strike a target in a millisecond, thus making HELs particularly suitable for engaging fast-moving targets.<sup>M</sup>
- HPM weapons have a microwave range between 300 MHz and 300 GHz. These DEWs disrupt electronic components and can produce graduated effects,

depending upon the amount of directed energy. Unlike lasers, microwave frequencies are insensitive to weather and can penetrate clouds, rain, and dust.<sup>M</sup>

- Particle-Beam DEW's use of a directed flow of charged or neutral particles as a • damaging factor has applications against ground forces, in aviation, and in targeting space-based assets.<sup>M</sup>
- Plasma DEWs fire a beam stream of plasma, which is an excited state of matter • consisting of atomic nuclei and free electrons. These DEWs offer long-range LASER accuracy, a high rate of fire, and "scalable effects," meaning that their lethality can be adjusted.<sup>™</sup>
- Sonic DEWs use sound to injure, kill, or incapacitate. These DEWs function in • the frequency range of 1 Hz to 30 and can target specific individuals or groups by producing audible sound.<sup>M</sup>

The two dominant DEW systems, HEL and HPM, have clear advantages over traditional kinetic weapon systems while exhibiting only minor disadvantages.

**HEL** - In addition to deeper magazines, lower logistics requirements, and lower costs per shot, potential advantages of HEL weapons include the following:<sup>H</sup>

• Fast engagement times, ability to counter radically maneuvering missiles, precision engagements, and graduated responses.

**HEL** weapons do, however, suffer from the following disadvantages:<sup>H</sup>

Line of sight, atmospheric absorption, scattering, turbulence, thermal blooming, saturation attacks, hardened targets, and countermeasures.

**HPM** - In addition to deep magazines, low costs per shot, fast engagement times, and graduated responses, potential advantages of HPM weapons include the following:<sup>H</sup>

Temporary or system-specific targeted effects, broad effects on targets, nonlethal applications, and the limitation of collateral damage.

**HPM** weapons do, however, suffer from the following disadvantages:<sup> $\underline{H}$ </sup>

The DoD's

increasing

impact on

Range constraints as the beams diffuse with distance, the potential for • fratricide due to the beam width, and the effectiveness of countermeasures against shielded targets.

2030+ MW class Strategic Missions with advanced 200-500 kW class Increasing Military Capability Directed Energy technology: 2025-30 Programs will < 100 kW class Tactical Missions with advanced technology: have an ever-2019-24 ounter Anti-Ship Cruise Missil ASCM), Counter Land Attack ruise Missile (C-LACM), Base Tactical Missions e. Aircraft De with current proven technology: DE Strike, Cov multi-domain System (C-UAS), Counter Rocke Artillery, Mortar(C-RAM), Counter rice Surveilance and sance (C-tSR)

Figure 2: Summary of DOD Directed Energy Roadmap. Source: Department of Defense Directed Energy Weapons: Background and Issues for Congress

operations on the battlefield over the next ten years. "The roadmap outlines DOD's plan to increase power levels of HEL weapons from around 150 kilowatts (kW), as is currently feasible, to around 300 kW by FY2022, 500 kW by FY2024, and 1 megawatt (M.W.) by FY2030." <sup>H</sup> DOD briefing documents (see Figure 2) suggest that a laser of approximately 100 kW could engage UASs, rockets, artillery, and mortars. In contrast, a laser of around 300 kW could additionally engage small boats and cruise missiles flying in certain profiles (i.e., flying across—rather than at—the laser). In contrast, lasers of 1 M.W. could potentially neutralize ballistic missiles and hypersonic weapons.<sup>H</sup>

U.S. competitors are also developing DEW's to include Israel's new "Iron Beam" laser interception system, to replace the existing kinetic missile "Iron Dome" system. This is the world's first energy-based weapons system that uses a laser to shoot down incoming UAVs, rockets, and mortars at a cost of only \$3.50 per shot.<sup>M</sup> The Turkish company Roketsan developed the AKLA system to destroy IEDs, mini/micro UAVs with fixed-and rotary-wing and mini/micro UAV swarms outside the sphere of influence, ALKA can direct both electromagnetic and laser energy intensively and precisely against the threat, achieving targets through hybrid and layered methods.<sup>M</sup>

#### Analytic Confidence

Analytic confidence for this estimate is *moderate*. The analyst had sufficient time, and the task was not markedly complex. Several credible academic and government sources were used to compile information for this research. A predominance of the sources used established that DEWs were being developed by both allies and adversaries, from peer to near-peer to emergent nations, for potential use across all warfighting domains by state and non-state actors.

Author: Michael E. Stevic

# Hypersonic Weapons Will Highly Likely Become The Favored Strategic Deterrent In Lieu Of ICBMs, By 2035

## **Executive Summary**

Although many Department of Defense (DoD) research projects are competing for limited resources in the upcoming budget cycle, hypersonic weapon research and development (R&D) will highly likely (71-85%) become the favored strategic deterrent in lieu of Intercontinental Ballistic Missiles (ICBM) by 2035. As the result of the People's Republic of China (PRC) and Russia's leading efforts in developing and testing hypersonic weapons, and as there are no existing countermeasures to hypersonic threats, this will highly likely (71-85%) drive the DoD to increase its hypersonic offensive and defensive R&D efforts.

#### Discussion

Hypersonic weapons are characterized by their speed (Mach 5+) and ability to maneuver at hypersonic speeds within the atmosphere, making them extremely difficult to counter.<sup>H</sup> Hypersonic weapons are further sub-divided into two different types of missile systems



Figure 1: Comparison of Ballistic and Hypersonic Flight Trajectories Source: <u>GAO-21-378</u>

(See Figure 1): hypersonic cruise missiles (HCMs) and hypersonic glide vehicles (HGVs).<sup>H</sup> HCMs keep a constant hypersonic speed (and usually altitude) and are powered

over the entire course of their flight.<sup> $\underline{H}$ </sup> In contrast, HGVs are typically launched on top of ballistic missiles (often called a boost-glide system) and then glide back through the atmosphere to their target at hypersonic speeds.<sup> $\underline{H}$ </sup>

Mark Lewis, the executive director of the National Defense Industrial Association's Emerging Technologies Institute, stated, "the Defense Department needs to appreciate that hypersonic weapons won't just be an aspect of the future battlefield but its defining feature." <sup>M</sup> Hypersonic weapon R&D total funding is highly likely (71-85%) to reach over \$14 billion from fiscal years 2015 through 2024 with 44% going to the Navy, 26% to the Air Force with the remaining 29% going to the Army, Defense Advanced Research Projects Agency, and the Missile Defense Agency (MDA).<sup>M</sup> The Pentagon requested \$3.8 billion for hypersonic weapons R&D in FY22, but the MDA only requested \$248 million for hypersonic weapon defense technology. All the DoD's services are developing separate offensive capabilities with the intent to produce operational prototypes by 2025, as described in Table 1.<sup>H</sup>

Name	Organization	Description
Air-launched Rapid Response Weapon	Air Force	Seeks to develop a hypersonic glide vehicle carried on a B-52 bomber. The glide vehicle is being developed under the Tactical Boost Glide program in a partnership with the Defense Advanced Research Projects Agency.
Conventional Prompt Strike	Navy	Seeks to develop a hypersonic glide vehicle for underwater submarine launch using the Common Hypersonic Glide Body. The missile system is built jointly with the Army, with the Navy building the missile booster and integrating the missile system.
Long Range Hypersonic Weapon	Army	Seeks to develop a hypersonic glide vehicle for land launch using the Common Hypersonic Glide Body. The missile system is built jointly with the Navy, with the Army producing the Common Hypersonic Glide Body.
Standard Missile-6 IB	Navy	Seeks to modify an existing Navy missile, the Standard Missile-6 IA, by integrating a new rocket booster that a DOD official reported will allow it to fly at hypersonic speeds.

 Table 1: Department of Defense Offensive Hypersonic Weapons in Product Development, as of November

 2020 Source:
 GAO-21-378

Several nations (US, France, Japan, North Korea, South Korea, Australia, and India) have hypersonic weapons programs with varying degrees of success, still, only China and Russia currently have operational HGVs, which they proclaim to have both conventional and nuclear capabilities.<sup>M</sup> In contrast, the U.S. does not yet have an operational weapon and is primarily focusing only on conventional hypersonic weapons.<sup>M</sup> China's DF-17 HGV became operational in October 2019, and Russia's allegedly nuclear-armed Avenged HGV became operational in December 2019.<sup>M</sup> China is currently developing a supersonic anti-ship ballistic missile, the CM-401, with a range of up to 900 km to counter the U.S. Navy's INDOPACIFC fleet presence.<sup>M</sup>

Concerning countering hypersonic missiles, according to a recent Chinese People's Liberation Army (PLA) report, there is a 78 percent chance on average of an air defense

system failing to intercept a missile traveling at five times the speed of sound.<sup>M</sup> This failure rate rises to 90 percent if it travels at six times the speed of sound. China can conventionally arm its hypersonic weapons against high-value targets such as aircraft carriers, making them more likely to be used while still maintaining China's no-first-use principle on nuclear weapons.<sup>M</sup>

#### **Analytic Confidence**

Analytic confidence for this estimate is *moderate*. The analyst had sufficient time, and the task was not markedly complex. Several credible academic and government sources were used to compile information for this research. A predominance of the sources used stated that the DoD's hypersonic weapons programs are largely classified; therefore, the data's confidence is low. The unclassified academic sources available tended to support this estimate, but there were differing levels of project prioritization and funding levels amongst the DoD services.

Author: Michael E. Stevic

# Small, Transportable Nuclear Power Plants Will Highly Likely Enable Evolutionary Combat Operations by 2030

#### **Executive Summary**

Although large-scale nuclear power plants have fallen out of favor in recent years, emerging new technologies will highly likely (71-85%) revitalize the nuclear power industry with safer, smaller, transportable nuclear power plants with minimal nuclear waste generation by 2030. These small transportable nuclear power plants will be used in all warfighting domains, including austere and remote land locations for field medical hospitals and command and control centers, to power ships of all sizes at sea, as the primary power source for large electrically powered aircraft and energy-intensive airborne laser or high energy weapons, a future space station, or Moon and Mars bases.

## Discussion

Numerous companies are developing and testing fission-based small, safe, transportable nuclear reactors. Researchers are experimenting with several promising technologies to create smaller and safer nuclear power plants, including the Sodium-Cooled Fast Reactor, the Very High-Temperature Reactor, and the Molten Salt Reactor.

- The sodium-cooled fast reactor<sup>M</sup> uses liquid metal (sodium) as a coolant instead of water typically used in U.S. commercial power plants. This allows for the coolant to operate at higher temperatures and lower pressures than current reactors—improving the efficiency and safety of the system.<sup>M</sup>
- The very high-temperature reactor<sup>M</sup> is cooled by flowing gas and is designed to operate at high temperatures that can produce electricity extremely efficiently. It is also possible to use high-temperature gas in energy-intensive processes that currently rely on fossil fuels, such as hydrogen production, desalination, district heating, petroleum refining, and ammonia production.<sup>M</sup>
- The molten salt reactor<sup>M</sup> uses molten fluoride or chloride salts as a coolant. The coolant can flow over solid fuel like other reactors, or it is possible to dissolve fissile materials directly into the primary coolant, so that they can be heated by fission directly. Their operation can be tailored for the efficient burn up of plutonium and minor actinides, which could allow MSRs to consume waste from other reactors.<sup>M</sup>

Lockheed Martin is currently working on a compact fusion reactor "small enough to fit on a truck to provide enough power for a small city of up to 100,00 people." <sup>M</sup> Potential applications of these compact fusion reactors include "providing aircraft with unlimited



Figure 1: Hyperion Power Generation is developing a "hot-tub"-sized 30-MW hydride reactor. The 10-ton unit, only 5 feet in diameter, is a sealed module with integrated radiation shielding that would be fueled and refueled every five to seven years at the factory. Source: <u>Power Magazine</u>

ranged and unmatched endurance, delivering energy to the developing world, safer power for safe seas, speeding up space travel, and making clean water available to the masses."  $\underline{M}$ 

The U.S. Army is pursuing a program known as "Project Pele" to provide deployable, reliable, resilient, and safe operational power for a variety of DoD missions which is currently planned in three phases to include a deployment demonstration



Protect by earth, barriers, and water jackets

Integrate into the base

Figure 2: The Army is seeking to develop and field a mobile nuclear reactor (Project Pele) to power forward operating bases. Source: <u>Army Times</u>

starting in 2024, lasting until 2027, encompassing airlifting at least one mobile nuclear power plant with fresh fuel to a remote domestic government facility, possibly in Alaska, operating the reactor, and then return airlifting the reactor including its irradiated fuel. The final phase being an NRC licensing process of about three years, to enable commercial entities to operate such plants and potentially provide electricity to the Army via power-purchase agreements' This transformative capability to deliver resilient electrical power for years without refueling and in a size small enough to be transported by existing defense infrastructure, while still being self-managing and inherently safe by design - even in the event of a total catastrophic disaster.

In contrast, there are critics of nuclear reactors on the battlefield. Alan J. Kiperman wrote a report titled "Proposed U.S. Army Mobile Nuclear Reactors: Costs and Risks Outweigh Benefits" <sup>M</sup> in his role as coordinator of the University of Texas at Austin's Nuclear Proliferation Prevention Project; he highlighted concerns about the high cost to develop and operate the reactors, no realistic mission requirements, high-energy weapons don't necessarily need reactors, the vulnerability to missile attacks, the potential for the reactors to be overrun and captured by the enemy on the battlefield, and international regulatory problems with transporting the reactors via proposed airlift.<sup>M</sup>

Criticism aside, safe, small, reliable nuclear power plants will bridge the significant gap between current fossil fuel-based (coal, oil, natural gas) energy sources until future green energy options (wind, solar, geothermal) are more efficient and less costly to deploy. Additionally, these new nuclear power plants will drive transformational changes in how the Department of Defense powers future weapon systems and how they are employed in all warfighting domains.

#### **Analytic Confidence**

Analytic confidence for this estimate is *moderate*. The analyst had sufficient time, and the task was not markedly complex. Several credible academic and government sources were used to compile information for this research. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information as time passes.

Author: Michael E. Stevic

# U.S. Adversary Highly Likely To Covertly Or Overtly Attack U.S. Space Asset Via Anti-Satellite Weapon Within Next Decade

## **Executive Summary**

Notwithstanding that space is already a naturally hazardous environment with man-made and environmental threats, it is increasingly becoming more congested, contested, and competitive. U.S. adversaries will highly likely (71-85%) covertly or overtly attack a U.S. space asset within the next decade to deny or impair the U.S.'s ability to operate effectively in the space domain.

## Discussion

U.S. Space Command (USSPACECOM) Commander Army Gen. James H. Dickinson recently noted the great strides China and Russia have made as emerging space powers. "Current People's Liberation Army (PLA) development is directed towards creating a joint, versatile, professional, and lethal force capable of power projection globally; and the space layer is critical to their efforts." <sup>M</sup>

All warfighting domains increasingly rely on the space domain for critical global applications, including communications. Position. Navigation, and Timing (PNT), meteorology, intelligence, reconnaissance, surveillance.



Figure 1: Spectrum of Threats and Hazards for Satellites and Expected impacts. Source: <u>Joint Air Power Competence Centre Journal 27</u>

missile warning, nuclear detonation detection, and environmental monitoring. Spacebased assets are indispensable but are also a vulnerable military resource and represent a high-value military target for our adversaries.<sup>M</sup> There are a broad spectrum of threats and hazards to vulnerable, low-resilient, space assets, which range from natural (solar weather) to man-made (space debris) and have impacts from temporary and reversible (jamming/spoofing) to permanent and irreversible (kinetic ground/space attacks) as depicted in Figure 1.<sup>M</sup> America, China, Russia, and India are all developing and testing a variety of advanced anti-satellite weapons, and their capabilities are becoming increasingly sophisticated. ASAT weapons can be land, sea, or space-based and have various methods of disrupting,



Figure 2: Threats to satellite systems. Source: Financial Times

incapacitating, or destroying the intended target as depicted in Figure 2.<sup>H</sup> Earth-based ASATs are primarily comprised of missiles and directed energy weapons, while space-based ASATs are mainly categorized as space mines, kinetic-energy weapons, and directed-energy weapons.<sup>H</sup>

The U.S. and U.S. near-peer adversaries (China, Russia, India) continue to develop and test various ASAT weapon systems which create hazardous debris fields in space that not only threaten military and civilian satellites, but the International Space Station (ISS) and the lives of the ISS crew as well. On January 11<sup>th</sup>, 2007, China successfully conducted a ground-based anti-satellite missile test against a Chinese weather satellite creating over 3000 pieces of debris that will remain in low earth orbit for hundreds of years.<sup>M</sup> Beijing is also developing jammers and directed-energy weapons for future ASAT missions.<sup>M</sup> Most recently, Russia launched a ground-based ASAT missile on November 15<sup>th</sup>, 2021, that destroyed one of its inoperable satellites, creating a debris field of over 1500 pieces of trackable orbital debris that threatened ISS crew and will remain a new space hazard for decades to come.<sup>H</sup> U.S. and India have been keenly aware of the dangers of creating low earth orbit debris fields from ASAT tests generated by satellite debris. The U.S. successfully tested a sea-launched ASAT capability which was intentionally designed to

minimize the creation of debris by deorbiting much of the satellite.<sup>H</sup> India successfully performed an ASAT test utilizing a version of an existing ballistic missile interceptor, directed against a micro-satellite in a low earth orbit to minimize debris via a decaying orbit where the satellite debris would fall harmlessly back onto earth.<sup>H</sup>

The Center for Strategic and International Studies (CSIS) stated in a recent study that the potential for a satellite attack is increasing.<sup>M</sup> The study says "China is greatly increasing" its development, testing, and fielding of non-kinetic physical and electronic counterspace weapons" and that operational deployment of dazzling or blinding lasers "seems imminent." It also finds that "China is growing bolder with its electronic jamming and spoofing capabilities," for example GPS spoofing of ship identification and locations in the port of Shanghai." <sup>M</sup> As for the Russian threat, CSIS says, "Russia has become one of the world's greatest perpetrators of electronic counterspace warfare, jamming and spoofing PNT and communications satellite signals in conflict zones, nearby territories, and within its own borders,"<sup>M</sup> Russia made public threats and warned it could blow up 32 GPS satellites with its new anti-satellite technology which it tested Nov. 15, 2021 on a retired Soviet Tselina-D satellite, according to numerous news reports.<sup>H</sup> Russia then claimed on state television that its new ASAT missiles could obliterate NATO satellites and "blind all their missiles, planes and ships, not to mention the ground forces," rendering the West's GPS-guided missiles useless.<sup>H</sup> "It means that if NATO crosses our red line, it risks losing all 32 of its GPS satellites at once."  $\frac{H}{2}$ 

#### Analytic Confidence

Analytic confidence for this estimate is *moderate*. The analyst had sufficient time, and the task was not markedly complex. Several credible academic and government sources were used to compile information for this research. A predominance of the sources used stated that ASAT programs are largely classified; therefore, the data's confidence is *low*. The unclassified academic sources available tended to support this estimate. Still, the data ranged from open-source observable tests to unsupported speculation on future ASAT capabilities based upon current and emerging technologies.

Author: Michael E. Stevic

## Emerging Technology Highly Likely To Accelerate Command And Control By 2045

#### **Executive Summary**

It is highly likely (71-85%) that new technologies will accelerate command and control (C2) decision-making by 2045. Despite the lack of proven future warfighting concepts, new technologies such as augmented reality and artificial intelligence will drive innovation in command and control concepts and systems. The challenge of layered standoff will increase as the rapid development of new weapon systems like attack drones, hypersonic missiles, and directed energy weapons bring more lethality to the battlefield. Command and control will become more automated and decentralized as enablers like artificial strategic advisors and augmented reality increase the pace and quantity of decision-making.

#### Discussion

Recent developments in weapons technologies and increased geopolitical competition will drive innovation in command and control concepts and systems.<sup> $\underline{H}$ </sup> Emergent superpowers like the European Union and regional powers like China and Turkey will continue to challenge U.S. hegemony and military overmatch capabilities (see other SFARs for more information).<sup>HHH</sup> Decision dominance



Figure 1. The Army's new Integrated Battle Command System (IBCS) successfully completed an intercept test at White Sands Missile Range, N.M. The new C2 system will link sensors and shooters on the battlefield using the IBCS. Source: Defense News. January 13, 2021, 2021. Source: <u>https://www.defensenews.com/land/2021/01/13/us-armys-future-battle-</u>command-system-is-cleared-for-production/

will be the intellectual high ground for the next fight as adversaries seek to out-pace and out-reach their opponents with faster weapons that have longer ranges that can be brought to bear simultaneously (known as convergence).<sup>H</sup> Attack drones, hypersonic missiles, and directed energy weapons will enable decision dominance as C2 systems like artificial strategic advisors and augmented reality converge to leverage these technologies to change the character of warfare.<sup>HH</sup>

Attack drones enable decision dominance by presenting multiple dilemmas to the enemy in the form of dispersed formations that can fight collectively or autonomously.<sup>H</sup> Military forces can utilize drones in three distinct ways: attack, defend, and provide intelligence, surveillance, and reconnaissance (ISR).<sup>H</sup> There are two key distinctions between today's commercially available drones and the autonomous swarm



Figure 1. Raytheon's new technology allows 130 drones to be controlled by one operator. Source: <u>https://interestingengineering.com/raytheons-new-tech-allows-130-drones-to-be-controlled-by-one-operator</u>

drone technology currently under development (See Figure 1). First, drones are "autonomous" when they can select and engage targets without human control (i.e., no "human-in-the-loop").<sup>H</sup> Second, a "swarm of drones" differs from a basic multi-drone system because an operator does not control all the drones individually. Instead, the operator commands a small subset of the swarm that responds collectively as a complex collection of nodes.<sup>M</sup>

Hypersonic weapons are characterized by their speed (Mach 5+) and ability to maneuver at hypersonic speeds within the atmosphere, making them extremely difficult to counter.<sup><u>H</u></sup> Hypersonic weapons are further sub-divided into two different types of missile systems (see Figure 1): hypersonic cruise missiles (HCMs) and hypersonic glide vehicles (HGVs).<sup><u>H</u></sup> HCMs keep



Figure 2. Comparison of Ballistic and Hypersonic Flight Trajectories. Source: GAO-21-378. Click on picture or go to: <u>https://www.gao.gov/assets/gao-21-378.pdf</u>

a constant hypersonic speed (and usually altitude) and are powered over the entire course of their flight.<sup>H</sup> In contrast, HGVs are typically launched on top of ballistic missiles (often called a boost-glide system) and then glide back through the atmosphere to their target at hypersonic speeds.<sup>H</sup>

High-Energy Lasers (HEL) and High-Powered Microwave (HPM) weapons have reached the point of operational test and evaluation readiness and, in some cases, operational battlefield use



Figure 3. Directed energy weapons use in battlespace. Source: Chanaka Forum. Source: <u>https://chanakyaforum.com/directed-energy-weapons1/</u>

replacing current kinetic anti-ballistic missile defenses and anti-armor/personnel weapon systems. The DoD's Directed Energy Programs will have an ever-increasing impact on multi-domain operations on the battlefield over the next ten years. "The roadmap outlines DOD's plan to increase power levels of HEL weapons from around 150 kilowatts (kW), as is currently feasible, to around 300 kW by FY2022, 500 kW by FY2024, and 1 megawatt (MW) by FY2030."<sup>H</sup> DOD briefing documents suggest that a laser of approximately 100 kW could engage UASs, rockets, artillery, and mortars. In contrast, a laser of around 300 kW could additionally engage small boats and cruise missiles flying in certain profiles (i.e., flying across—rather than at—the laser). In contrast, lasers of 1 MW could potentially neutralize ballistic missiles and hypersonic weapons.<sup>H</sup>

Augmented reality (AR) provides a new tool on social media to facilitate information operations like radicalization. capability becoming more common in social media and everyday use.<sup> $\underline{H}$ </sup> Augmented reality (AR) superimposes an image onto a user's view of the real world and enhances it with sound, touch, and even smell.<sup> $\underline{H}$ </sup> AR blurs the lines of reality and adds to it, projecting information on top of what you're already seeing.<sup>H</sup> AR acts as a digital companion that assists the user in their daily lives, a function that could be exploited by psychological means.<sup>H</sup> Harvard Business Review (HBR) delineates four categories for operational use cases of AI, most of which resides in the Limited



Figure 4. Categories of Artificial Intelligence. battlespace. Source: Forbes. Source: <u>https://www.forbes.com/sites/cognitiveworld/20</u> <u>19/06/19/7-types-of-artificial-</u> <u>intelligence/?sh=3c950a36233e</u>

Memory quadrant (See Figure 2). First is the autonomous/ autonomy advisor where AI is seen and treated as the best strategic advisor for organizations and they will never have to be replaced by military and or civilian promotion systems.<sup>H</sup> This category, which the AI Strategic Advisor is an example that could support the efforts of developing models for command and control of military forces, including communication links monitoring and rerouting, developing 3D common operational pictures through amalgamations of 2D compositions, and Intelligence, Surveillance, and Reconnaissance.<sup>H</sup>

#### Analytic Confidence

Analytic confidence in this estimate is moderate. Sources were generally reliable but limited in scope and availability. A high-quality primary source was available and tended to corroborate other available research. The researcher worked alone and utilized an unstructured research technique. Given the rapid pace of proprietary technology advancement in this area and the limited availability of open-source information, this report is sensitive to change over time, thus warranting a moderate level of analytic confidence.

Author: Michael R. Wacker

# Russia Highly Unlikely To Recover From Strategic Miscalculation In Ukraine By 2045

#### **Executive Summary**

Despite decades of social reforms and economic integration into the liberal world order, is highly unlikely (16-30%) that Russia will recover from its strategic miscalculation in Ukraine by 2045. Due to Russian Federation President Vladimir Putin and Ukrainian President Volodymyr Zelensky's inability to come to a political settlement and the resulting world condemnation of the invasion, the stage is set for a protracted war with an insurgency that will last for years. U.S. and NATO arms sales, U.N. economic sanctions, and Ukrainian resolve will converge to prolong the conflict and isolate Russia from the world as it lacks options other than a military victory.

#### Discussion

The 2022 Russian invasion of Ukraine marks the largest ground war in Europe since World War II with Russia seeking to change the balance of power and existing rules-based world order.<sup>H</sup> Russia's end game of Ukraine as a buffer state with a puppet government that answers to Moscow poses a direct challenge to NATO expansion and democracies in the European Union.<sup> $\underline{H}$ </sup> U.S. Intelligence agencies expect Putin to double down and escalate the conflict, creating a humanitarian crisis in order to accomplish his goals.<sup> $\underline{H}$ </sup> Moscow has offered to



Figure 1. A fragment of a destroyed Russian tank is seen on the roadside on the outskirts of Kharkiv, March 3, 2022. Source: Center For American Progress. Click on picture or go to <u>https://www.americanprogress.org/article/putins-quagmire-russias-invasion-of-ukraine-is-a-strategic-disaster-for-the-kremlin/</u>

halt military operations if Kyiv meets the following four conditions: Ukraine would have to end all military action, write into its constitution that it would not join NATO or the European Union, officially recognize annexed Crimea as Russian territory, and accept the independence of the two breakaway eastern regions.<sup>H</sup> Although Putin's unacceptable peace proposals mean an end to Ukrainian freedom, the Biden administration is not advocating for regime change at this time, setting the stage for a protracted struggle.<sup>H</sup>

Vladimir Putin's war on Ukraine and the global response to it will drastically alter Russia's economic future and will set the country back 30 years.<sup>H</sup> Western sanctions designed to inflict maximum pain on the country's economy by expelling it from global markets and freezing assets around the world will open a new chapter in Russia's economic history.<sup>H</sup> Its financial system and currency are collapsing on multiple fronts,



Figure 2. People stand in line to use an ATM money machine in Saint Petersburg, Russia February 27, 2022. Source: CNBC. Click on picture or go to <u>https://www.cnbc.com/2022/03/14/putins-invasion-of-ukraine-will-knock-the-russian-economy-back-by-30-years.html</u>

forcing the Kremlin to close the stock market and artificially prop up the ruble inside its borders.<sup><u>H</u></sup> Russia's 40-year effort to build a prosperous market-based economy that began under former leader Mikhail Gorbachev has come to a halt as blue-chip companies quit the Russian market. The United States and EU moved to reduce trade and tourism with Russia.<sup><u>H</u></sup>

U.S. Treasury officials predict Russia will experience a deep recession that will get worse in the coming decades and push the country toward becoming a closed economy, a status the country is ill-equipped to handle.<sup>H</sup> The economic consequences Russia is facing are severe: high inflation that will only get higher, and deep recession that will only get worse as the economic sanctions target major Russian banks and oligarchs and the main sector of its economy, oil and gas imports.<sup>H</sup> The economic sanctions will make Russia a poorer country and Mosco will have to make tough budgetary choices between keeping the economy afloat or investing in rebuilding its military.<sup>H</sup> Additionally, Russia being cut off from access to advanced technology will not just erode its long-term economic competitiveness but will also potentially harm its relative military strength.<sup>H</sup> The one scenario that could change the outcome for Russia is military victory.<sup>H</sup> This scenario would have far-reaching consequences not only for Ukraine but also for the broader security environment in Eastern Europe and any other theater where Russia sees its interests.<sup>H</sup> A Russian success would lead the Kremlin to embolden its assertive foreign policy behavior and possibly even further military expansionism.<sup>H</sup>

## Analytic Confidence

Analytic confidence in this estimate is moderate. Sources were generally reliable and tended to corroborate one another. There was adequate time allotted for this research, but the analyst utilized an unstructured research method working alone. The reliability of the sources was average, with several high-quality sources available.

Author: Michael R. Wacker

# Chinese Invasion Of Taiwan Unlikely By 2045 As China Looks To Economic Options To Achieve Reunification

#### **Executive Summary**

Despite threats of aggression over the last decade, China is unlikely (31-45%) to invade Taiwan by 2045. The Chinese invasion will be unlikely due to the success of the current "gray zone" and diplomatic efforts, dedicated military spending via sustained economic development, and lessons learned from Russia's failure to secure a quick victory in Ukraine. General Secretary Xi Jinping's resolve to change the status quo by symbolic dates and reunify China and Taiwan under the "one country, two systems" strategy will not occur as economic sanctions and internal pressure will coerce Taiwan towards reunification.

#### Discussion

China's mix of incentives and coercion over seven decades has linked the economics of the Taiwan island and the mainland but produced no movement toward Taiwan reunification.<sup>H</sup> China's current strategy of irregular "gray zone" warfare, which includes Air Defense Identification Zone (ADIZ) violations and sand dredging, is part of an escalation campaign designed to exhaust Taiwan's defenses and undermine the livelihoods of their residents.<sup>H</sup> China's



Figure 1. People march against the war in Ukraine during a rally in Taipei, Taiwan. Source: Foreign Policy. Source: <u>https://foreignpolicy.com/2022/03/31/china-taiwan-attack-russia-ukraine-expert-poll/</u>

efforts have stressed Taiwan's defenses and exposed its lack of military readiness, but have not decreased their resolve.<sup>H</sup> Taiwan's current deterrence relies heavily on U.S. intervention, a strategy that the Biden administration has not committed to, with military sales the primary means of bolstering Taiwan's defenses.<sup>H</sup>

General Secretary Xi Jinping seeks the "great rejuvenation of the Chinese nation" and in 2017 he laid out two People's Liberation Army (PLA) modernization goals during his speech to the 19th Party Congress: to "basically complete" PLA modernization by 2035 and to transform the PLA into a "world-class" military by 2049.<sup>H</sup> In 2020, the Chinese Communist Party (CCP) announced a new milestone for PLA modernization in 2027 broadly understood as the modernization of the PLA's capabilities to be networked into a system of systems for "intelligentized" warfare.<sup>H</sup> The 2027 goal is a new short-term

marker for ensuring that China's military modernization campaign continues to progress along with the CCP's long-established roadmap and coincides with the 100th anniversary of the founding of the PLA, a highly symbolic date that the CCP wants to honor.<sup>H</sup> The 2027 date also serves as a major propaganda tool and a reminder of China's growing power to the international community, however, China's defense budget remains approximately 1.3% of its gross domestic product (GDP), below the global level of 2.6%.<sup>HH</sup> Xi Jinping's provocative rhetoric does not match his actions as Beijing continues to bide its time, conscious of the consequences of armed conflict, including a possible confrontation with the US, whose longstanding policy of "strategic ambiguity" grows less and less ambiguous.<sup>H</sup>

Diplomatically, the fate of Hong Kong is a practical use case for the framework known as "one country, two systems" as a viable model for peaceful integration into the mainland.<sup>H</sup> Before the British government handed over Hong Kong in 1997, China agreed to allow the region considerable political autonomy for fifty years under a framework known as "one country, two systems." <sup>H</sup> The trends now in Taiwan are divided, led by Xi's behavior, events in Hong Kong, the strength of Taiwan's democratic institutions, and Taiwan's public opinion.<sup>H</sup> According to polls regularly conducted by National Chengchi University, the period 2018-2020 is characterized by a rapid increase (54.5% to 64.3%) in Taiwan resident respondents' identification as Taiwanese, while during the same period, identification as both Taiwanese and Chinese decreased from 38.2% to 29.9%.<sup>H</sup> Taiwan's identification as Chinese was at 2.6% in 2020, and has remained below 10% since 2002.<sup>H</sup>

The Russian invasion of Ukraine has led political analysts to conclude that Beijing will not invade Taiwan due to the risk that a large-scale, complex operation would entail, and one that the world could mobilize against beforehand.<sup>H</sup> An amphibious assault of this size would require a massive, time-consuming buildup of Chinese troops along the coast, with many indicators noticeable several months in advance through satellite images.<sup>H</sup> The Taiwan Relations Act codifies Taiwan as a U.S. security partner and that the United States has a vested interest in promoting its liberal democratic government in the Indo-Pacific region where autocratic governments are on the rise.<sup>H</sup> Economically, Taiwan is a much larger global trading partner than Ukraine, with Taiwan ranking as a major exporter of electronics and semiconductors.<sup>HH</sup>

#### **Analytic Confidence**

Analytic confidence in this estimate is moderate. Sources were generally reliable and tended to corroborate one another. There was adequate time allotted for this research, but the analyst utilized an unstructured research method working alone. The reliability of the sources was average, with several high-quality sources available.

Author: Michael R. Wacker

# European Union Highly Likely To Ascend To Superpower Status By 2045

#### **Executive Summary**

It is likely (56-70%) that the EU, despite long-standing member nation disputes regarding economics and cooperated military, will put aside its differences to coalesce into a world superpower, with consolidated governance and security structure. This is due to waning U.S. influence and security commitment, Russian aggression, and common national interests. Vladimir Putin's vision of a return to Russian dominance beginning with the invasion of Ukraine destabilized the European continent and prompted fears of another world war. The European Union, fearing Russian escalation and ambition to change the world balance of power and the rules-based international order, will continue to increase defense spending to establish a Common European Army with the capacity for autonomous action and fill the role of a traditional superpower that is able to project power and challenge the United States and China for dominance.

#### Discussion

The return of war to Europe in 2022 awakened the European Union (EU) from its singular focus on economic interests and towards a collective governance and security strategy more in line with other traditional superpowers.<sup> $\underline{H}$ </sup> A superpower is a state economically, diplomatically, and militarily powerful enough to defend national values and interests in all parts of the world.<sup> $\underline{H}$ </sup> The EU has not played a major role in world affairs since the 1956 Suez Canal crisis, and since then Western Europe has been relegated to a position of subservience to the United States, although there were occasional bouts of independent foreign policy by Europeans, with the Falklands War and the Second



Figure 1. Map of the 27 European Union countries. 2021. Source: <u>https://bpcdn.co/images/2020/06/02171959/EU-</u> ountries.png

Iraq War as prime examples.<sup>H</sup> The changing geopolitical environment shifted the focus from economic to security interests as war returned to the European continent for the first time since 1945 in the form of Russian aggression in 2022.

The United States ascension to superpower status after World War II along with European devastation presented the U.S with an opportunity in rebuilding the continent.<sup>H</sup> American foreign assistance aid to Europe in terms of economic development and
regional stability via NATO alliances and security cooperation agreements advanced U.S. strategic national interests and values for decades after the war.<sup>H</sup> This reliance on the United States and NATO for collective security is a risk the EU is no longer willing to accept as geopolitical events have changed both political will and public opinion.<sup>H</sup> The rise of China, the global pandemic, and the Afghanistan withdrawal have weakened U.S. influence in the European Union as polling indicates a decrease in confidence in America both as a



Figure 2. Western European public opinion poll on U.S. consideration of European interest. 2021. Source: Pew Research Center. <u>https://www.pewresearch.org/global/2021/06/10/americas-image-abroad-rebounds-with-transition-from-trump-to-biden/</u>

model for democracy and as a world leader and reliable partner that considers European interests.<sup>H</sup> These events have energized the European Union to take autonomous action and gain consensus on its collective interests at the expense of U.S. influence.

The Russian invasion of Ukraine has highlighted the lack of collective EU security to counter threats. German Chancellor Olaf Scholz assessed that Putin wants to build a Russian empire and fundamentally redefine the status quo within Europe in line with his own vision.<sup>H</sup> This new threat has hastened EU plans to rewrite its Strategic Compass, the plan of action for strengthening the EU's security and defense policy by 2030, with a plan to beef up the bloc's defenses in the wake of Russia's invasion of Ukraine.<sup>H</sup> The new plan will replace the existing diplomatic approach with plain language painting Russia as an aggressor against its neighbors.<sup>H</sup> The EU and NATO signed their first ever joint declaration on security, stating that the time has come to "give new impetus and new substance to the NATO-EU strategic partnership".<sup>H</sup> The document stipulates that the EU aims to become a more assertive security and defense actor by enabling more robust, rapid and decisive action, including for the resilience of the Union and our mutual assistance and solidarity.<sup>H</sup> Consolidating security and decision-making power at the EU level has traditionally met resistance, with nations such as France and Finland preferring to retain the authority to act autonomously on such measures such as arms sales and internal national defense.<sup>H</sup>

The Russian threat has changed the calculus in EU member nation policy. Germany and Poland have both agreed to provide defense forces for what is described as the Common EU Army, a dramatic shift in their respective policies. Militarily the total combination of all the military & naval forces of the EU countries would come close to matching Russia, on a conventional force basis.<sup>H</sup> What was once accepted in terms of lack of defense

spending and readiness is now an urgent requirement.<sup>H</sup> The chief of the German army lamented that the options the Bundeswehr can offer the government in support of the alliance are extremely limited, an opinion that met online praise both nationally and throughout the continent.<sup>H</sup> A key indicator of military commitment is defense budget spending as a percentage of Gross National Product (GDP). Due to the Russian invasion, European Union member nations have already committed to increasing overall defense budget spending to over 2% by 2025, a remarkable change given historical spending (see Figure 3).<sup>HH</sup>

The EU is a confederation that currently lacks the structure to be able to act in a unified way such that it could replicate the actions of a single and sovereign federated government to resolve these issues.<sup>H</sup> The Ukraine crisis has highlighted this weakness and the ineffectiveness of current EU defense policies.MH The current EU governing

structure does not have an elected president, and power is divided among the EU Council, Commission, and Parliament.<sup>H</sup> Federalizing the EU would allow the EU to compete with emerging powers like India and Turkey by consolidating fiscal and foreign policy.<sup> $\underline{H}$ </sup> The EU needs to address the democratic legitimacy of all its institutions, something that reflects the existence of primary sovereignty, the capability to raise taxes in order to finance the exertion of its competencies, and the ability to act effectively in the international sphere. H



Figure 3. European Union Military Spending/Defense Budget 1960-2022. EU spending has consistently been under 2% since 1993. Source: MacroTrends (World Bank). Click on picture or go to <u>https://www.macrotrends.net/countries/EUU/europeanunion/military-spending-defense-budget</u>

The major EU policy challenges are Brexit, Carbon Neutral by 2050, and the Multiannual Financial Framework (MFF), however recent polling indicates a preference for consensus in the form of codified agreements.<sup>MH</sup> Brexit is now a reality, however new polling indicates that the UK would vote to rejoin the EU by a wide margin, with 82% of those who did not vote in the 2016 referendum say they would now vote to re-join the EU.<sup>H</sup> The European Union recently reached a climate deal that should make the 27-nation bloc climate-neutral by 2050, with member states and parliament agreeing on the targets established by the 2015 Paris Climate Agreement.<sup>H</sup> The MFF, last adopted in 2018 for 2021-2027, saw a substantial increase in financial payments even with the Brexit deduction.<sup>H</sup> The big change was the inclusion of security and defense as a stand-alone

budget item.H The EU Speaking economically, the EU's current GDP (nominal \$) is nearly equal to the US and on a PPP basis is slightly better. These current numbers include UK's GDP which is 16% of the EU total.<sup>H</sup>

### **Analytic Confidence**

Analytic confidence in this estimate is moderate. Sources were generally reliable and tended to corroborate one another. There was the adequate time allotted for this research, but the analyst utilized an unstructured research method working alone. The reliability of the sources was average, with several high-quality sources available.

Author: Michael R. Wacker

### Annex A - Team Janus Terms of Reference

### Terms of Reference:

### **Revolutionary Technology and Concepts through 2045**

For:

Major General Bradley T. Gericke Director, Strategy, Plans, and Policy Office of the DCS G-3/5/7

By:

Team Janus

United States Army War College

December 2, 2021

### Terms of Reference:

### **Revolutionary Technology and Concepts through 2045**

### **Requirement:**

What revolutionary technology and concepts will likely shape the future of land warfare<sup>2</sup> within the continuum of competition, crisis, and conflict through 2045?

- Which adversaries will likely employ any of the revolutionary technologies and concepts identified?
- Where, geographically, will any of the revolutionary technologies and concepts identified likely be employed?

### Methodology:

To answer this question, Team Janus will gather information from various sources, including but not limited to, review of unclassified journals, publications, and media available through the US Army War College, as well as open-source materials available through other research, military, and professional institutions.

Team Janus will execute this project in accordance with the following notional timeline:

- Phase 1: Formulate the research plan (December 2021).
  - Evaluate the expected operating environment through 2045.
  - Estimate likely future ground warfare scenarios.
  - Explore evolving technologies that may influence future ground warfare.
  - Hypothesize how adversaries may exploit these evolving technologies.
- Phase 2: Data collection (January 2022).
  - Research resources itemized per this Terms of Reference.
- Phase 3: Analysis (February 2022 March 2022).
  - Analyze disparate technologies that may be unified and utilized from the individual Soldier to larger battle formations, providing a state adversary a technological advantage over the US Army.
  - Estimate impacts to land warfare and how military evolution should occur to ensure the Army maintains global dominance through 2045.
- Phase 4: Compile research report (March 2022 Apr 2022).
  - Document analysis and summarize key findings.
  - Report potential land warfare adversaries and technological roadmaps.

<sup>&</sup>lt;sup>2</sup> Efforts will focus on threats originating from state and coalitions of adversaries.

- Phase 5: Submit final deliverables (May 2022).
  - Deliver executive briefing and research report to MG Gericke, in coordination with sponsor availability.

### **Challenges:**

- Research is being conducted as part of the US Army War College Master's degree in Strategic Studies program. Team members are also engaged with concurrent coursework, which will limit time for project research.
- Due to limited availability of secure resources and communication means, only unclassified materials and communications will be used. This is to ensure overall security classification of the project remains unclassified.
- Research is being conducted as part of a classroom assignment that teaches research concepts. As such, the team does not have access to similar reports that may have been worked by other entities within the Department of Defense or intelligence communities, that are not available through unclassified, published sources.
- Dynamic COVID-19 protocols may limit on-site team engagement with military, government, academic, and commercial entities.
- Advanced analytic tools and modeling software are not available for use in the research.
- Knowledge of future technologies is limited to team estimates and is not necessarily professionally developed.

### **Resources:**

- Resources for this research project will include review of unclassified journals, publications, and media made available through the US Army War College, as well as open-source materials made available through other research, military, and professional institutions.
- Team efforts will seek to engage with domestic and international contacts spanning military, government, academic, and commercial entities.
- Additional resources may include interviews with organizations leading innovative and emerging technology development.
- Team members may embark on limited travel opportunities to engage with resource entities, pending availability of US Army War College funding and COVID-19 travel protocols.

### Administration:

- Final deliverables for this project will include an executive briefing to the senior sponsor and comprehensive research report in PDF format, documenting analysis of findings.
- Follow-on use or dissemination of the report is at the sole discretion of MG Gericke, Director, Strategy, Plans, and Policy, Office of the DCS G-3/5/7, United States Army.
- Deliverables will be provided May 2022, in coordination with sponsor availability.
- Team Janus contact information:
  - LTC Andrew S. Culbreath, USAR JAG Corps andrew.culbreath.mil@armywarcollege.edu
  - COL John Hosey, US Army Cyber Command john.hosey.mil@armywarcollege.edu
  - CDR Brennan Kemper, US Navy Logistician brennan.kemper.mil@armywarcollege.edu
  - Mr. Michael Stevic, US Army Civilian (USAF Col, Ret.) michael.stevic.civ@armywarcollege.edu
  - LTC Michael Wacker, US Army Signal Corps <u>michael.wacker.mil@armywarcollege.edu</u>
- Official Mailing Address:
  - US Army War College, 22 Ashburn Drive. Carlisle, PA 17013.

### Annex B - Interview with Mr. Tomas Pribanic, Undefined Technologies, Inc.

### Team Janus SFAR Expert Interview Summary:

On March 9, 2022, LTC Andrew Culbreath and Prof. Kris Wheaton interviewed Mr. Tomas Pribanic via Zoom to learn more about his current work on ion thrust propulsion drone technology and the recent test of a prototype drone aerial vehicle. Mr. Pribanic explained that the propulsion system is designed around high voltage electrons ionizing the air and accelerating it behind the aircraft. He stated what is slowing down the advancement of the technology is the weight of the batteries and the relatively short

life cycle of the batteries. However, he said he hired a battery design contractor nearing completion of a battery that will be 1/3 the weight of the current batteries with longer life. He said he has been able to increase the thrust output 3x, and his initial goal is to attain 30 minutes of flight and be able to carry two pounds of cargo.





When asked about the trajectory of this technology and where it is headed, he said the advancements will coincide with improving battery technology, as there will always be a tradeoff between thrust power and weight that you have to manage. When asked about early concerns over stabilization of the aircraft and how to gain better control, he stated stability "is attainable and an item of low risk at this point."

When asked about possible civilian applications, he said he was in discussions with a local television station to use the drones to surveil vehicle accident scenes. When asked how long he thought it would be before this technology would be commercially available, and he stated 2 -3 years with 70% confidence. His model will be GPS-enabled for guidance, and he is focusing on the urban cargo delivery market.

### Annex C - Interview with Dr. David Diller, Raytheon BBE

### 11 FEB 2022 via Zoom



**ISS Brief** Command and Control of Aggregate Swarm Tactics (CCAST)



David Diller, PhD 02/07/2022

Team members present: Professor Kris Wheaton, COL John Hosey, and LTC Andrew Culbreath. This interview was scheduled based on a press release published by Raytheon that reported on a significant swarm drone technology testing event conducted by the company in early January 2022. The representative referenced in the press release referred us to Dr. David Diller, the Project Manager for the swarm drone testing event.

### Below is an excerpt from the press release:

CAMBRIDGE, Mass. (Jan. 10, 2022) – Raytheon Intelligence & Space, a Raytheon Technologies business, recently supported the fifth OFFensive Swarm-Enabled Tactics, or OFFSET, DARPA program field exercise. Using integrated swarm technology developed by a Raytheon BBN-led team, a single operator successfully controlled a swarm—composed of 130 physical drone platforms and 30 simulated drone platforms—both indoors and outdoors in an urban setting.

- Introduce the Team War College students working on a research project
  - Team research on a number of emerging technology issues, one of those is the emerging area of swarm drone technology;
  - Thank him for his time and praise the testing accomplishment.
- Part of the Futures Seminar
  - Our research is technology-centric and our goal is to provide estimative probabilities about emerging technologies.
- One aspect of our research project involves the development and proliferation of inexpensive drone technology. Specifically, two types of drone technology: Autonomous Attack Drone and Swarm Attack Drone.

**Q:** Dr. Diller was read the following statement and asked if he agreed:

"Despite current U.S. policy and concerns by international human rights groups, it is highly likely that autonomous swarm attack drones will become commercially available for military application by both state and non-state actors within the next 3 - 5 years"

A: Dr. Diller replied, "I would agree with that."

### Q: Is "autonomous" different from "AI-enabled"?

A: The term AI is overly broad, drones use machine learning which is a subset of AI.

## Q: Are the "autonomous" and "swarm" technologies emerging, or have they already arrived?

A: The two technologies do currently exist, but to his knowledge have not yet been converged into one platform (although it would not be too difficult). The current challenge with low cost autonomous swarm drones is in their ability to communicate. Gave an example of drones flying into a building and losing contact with the other drones – that disruption in communication may negatively impact other drones in the swarm. He referenced the communications issue as one that could be overcome using more advanced (expensive) equipment.

### Q: If existing, is it commercially available?

A: Most likely - he has not been focused on similar types of commercial technologies

### Q: If not, what are the barriers to converging these technologies?

A: Not informed enough about what is available to form an opinion, but suspected it is out there.

### Q: How quickly do you think this will occur?

A: He concurred with 3-5 years, but gave the impression he would not be surprised to see it emerge sooner.

### Annex D - Interview with Mr. Eric Farnsworth, Council of Americas

### Team Janus SFAR Expert Interview:

On February 22, 2022 LTC Andrew Culbreath interviewed Mr. Eric Farnsworth to learn more about the possible impacts of the increasing global competition to extract the rich lithium metal deposits located in the South American region encompassing parts of Argentina, Bolivia, and Chile known as the "Lithium Triangle."

Mr. Farnsworth assessed the current status of Latin America in general and the Lithium Triangle specifically, as being a low or even remote risk of potential armed conflict relative to access to the rich lithium deposits in the region. Mr. Farnsworth acknowledged that both China and Russia have made substantial investments in the region over the last decade, China in particular with regard to lithium deposit mining. However, due to the low overall geopolitical significance of the

### **Experts & Leadership**



### **Eric Farnsworth**

Vice President, COA, Washington, DC Office

**Eric Farnsworth** leads the Washington office of the Council of the Americas and the Americas Society with a passion for promoting the importance of the Western Hemisphere for U.S. economic, security, and strategic interests. He maintains an important thought leadership and advocacy role across a broad range of issues, including U.S. relations, economic development, trade, and energy; Asia-Latin American relations and global governance; and security and democracy. He consults frequently with senior U.S. government and foreign officials and private sector leaders, is a widely-sought conference speaker and media commentator, and publishes regularly in leading newspapers and journals. Prior to the Council, Farnsworth spent almost a decade in government with the U.S. Department of State, Office of the U.S. Trade Representative, and Clinton White House. He also served in the U.S. Senate with Sam Nunn (D-GA). His private sector experience includes positions with ManattJones Global Strategies and also the Bristol-Myers Squibb Corporation.

In 2016, the King of Spain decorated him for his work to promote bilateral and regional relations. In 2022, the Government of Chile awarded him the Order of Bernardo O'Higgins, Grand Official, the country's highest civilian award for non-citizens.

region with regard to great power competition and the relative abundance of lithium ore depositions in both Australia and the United States, he assessed the risk of armed conflict between China and the United States through 2040 as "remote."

The significance of lithium to the development of high-yield batteries (i.e. "white petroleum") and its projected impacts to future development of commercial and military applications were not discussed during the interview.

# Annex E - Interview with Mr. Steve Levine, Author of "The Powerhouse"

### Mr. Steve Levine

"The Electric" - EV and Batteries "The Powerhouse" - Global race for super battery

### Do you mind if we record the video? Do you mind if we quote you in our research?

We have seen an increase since the 1990s for energy storage research with a growth in consumer electrics & how integrated into military uses as well?

Where do you see the research heading?

Flashpoints for to go to war over?

What battery technology will support future technologies? Inventing technologies -

US is the inventor of these technologies.

- fossil fuels are not going away. Well into the second half of the century
- the world still using 80 mil barrels of oil into 2070.
- Some will be using electrical tech but many will still be using fuel.
- Workhorse technologies:
  - Li-Ion
  - High Nickle
  - Cathode.
  - Graphite
  - Through the next several decades
  - Space anodes and cathodes where cost doesn't matter
  - Some silicone in anodes- LF and manganese

### Are there reasons for the same chemistries in this space?

Big reasons for same chemistries

- A lot of talk about Lithium metal, LTO, but no one is using those technologies
- Can find Li Metal solid-state but not there
- Doesn't look like it is going to be there until the next decade.

LFP - Lithium lon Phosphate is already here. The commercial can last decades all the way up until mid-century.

There is a technology coming along that may be more wanting to use in a military context. - Sodium lon.

Specialists who are working on new materials

- Lithium w/ high nickel cathode is super flammable
- LFP is much lower
- Solid states

What could generate potential breakthroughs are LFP solid-state with anode Lithium or Silicone, which can get very hot and not catch fire.

You can also use twin Lithium metal with Sodium and silicone to counterbalance for loss of energy.

### Whom should we be looking at for battery research?

Argonne knows the technology and what is practical.

### Can you give us an introduction to research engineer?

### How much smaller and full of energy?

Yes. No sign of flatlining, except for the cost of materials. The first silicone company to get into a commercial device added 20% more time of power.

Silicone: maximum 20 percent in graphite and Lithium metal: once optimized in a battery will be a big jump. The power would mean it would be 50% more

The reason that batteries are limited is that lithium clogs graphite anodes.

### How important is the Lithium Triangle?

It is not that important. The problem is the production and refinement of lithium. U.S. won't have its own battery supply chain for the next decade into the next. Australia has the biggest production of solid lithium. The U.S. is out of this world inventive! We just have not commercialized anything. There is no shortage of lithium in the United States, and even Serbiais mining Lithium. EU and the US, need to get past our inhibition to mining that is where the rubber hits the road. Resource and processing of the resource. **Are there any technologies that are comparable that are coming together into something "different kind of beast" in a unique way?** 

Yes. People have talked about capacitors with another type of cathode.

- Mujeeb Ijaz- Our Next Energy (One) is using a very inventive imaginative approach

### Any other combinations you can think of?

Key with batteries is the number of people who know, but very few can communicate that.

Data Science and machine learning are just now getting to batteries. Companies are trying to sell Data Science as a Service to improve the yield of production.

# Annex F – Interview with Mr. Gregory Nichols on Nanotechnology

Gregory Nichols Sub: nanotechnology

Science and Technology advisor for Homeland Defense and Security Information Analysis Center (HDIAC)

# Previously managed Nanotechnology Studies program at Oak Ridge Associated Universities.

Smart dust - people have written about it but dispersion is the issue. When you learn to control it is when it is going to be a concern.

National Nanotechnology Initiative (NNI)- make it its own field but it keeps converging back nanotechnology interface.

- 3D printing at the molecular level will be here within the next 10-20 years
- nano-sensors are small enough to fit anywhere

Nanotechnologies use within the next 20 years.

- Energy storage and generation nanogenerators.
- Kinetic energy
- Biomanufacturing, Molecular Foundry
- -

Five papers all related to Nanotechnology:

- Nanotech: The New Arms Race
- Nanotech in AI
- Nanotech in 3D Printing
- Nanotech in Synthetic Biology

Nanotechnology could produce or be new weapons of mass destruction

- The Department of Defense needs a new definition.
- Potential to hack new cars all at once.

HDIAC is researching materials with superior electromagnetic characteristics such as graphene.

"Graphene dust" could short out electronics as well as be a health hazard. Would have the same effects as a localized electromagnetic pulse and include a biohazard. Or you could use nano-scaled silver for heavier use.

3D printing is disruptive in the future.

- It May be able to affect at a nanoscale level
- Sandia National was able to print material in Nuclear was head.

MOAB is based on nano-scale materials

Russia has created a nanoscience research organization, Rusnano.

China coming leaps and bounds. They just built the world's largest Nanotechnology Research facility.

Iran has the will but no means to do it.

### Annex G - Kesselman's List of Estimative Words

Certainty 100%			
Almost Certain	86-99%		_
Highly Likely	71-85%		8
Likely	56-70%		ŏ
Chances a Little Better [or Less]	46-55%		- E
Unlikely	31-45%		e
Highly Unlikely	16-30%		- <b>1</b>
Remote	1-15%	•	_
Impossibility 0%			

### Kesselman List of Estimative Words

### Annex H - Trust Scale and Web Site Evaluation Worksheet

### Trust Scale and Web Site Evaluation Worksheet

					lopdati	00720	(3)						
Piece	of Evidence #:											Score:	Trust Scale
Criteria	Tips	Value	Y or N	Y or N	Y or N	YorN	Y or N	Y or N	Y or N	Y or N	Yor N	0	High
Content can be corroborated?	Check some of the site's facts	2											11-15 Moderate
Recommended by subject matter expert?	Doctor, biologist, country expert	2											6-10 Low
Author is reputable?	Google for opinions, ask others	2											5-0 Not Credible
You perceive site as accurate?	Check with other sources; check affiliations	1.5											
Information was reviewed by an editor or peers?	Science journals, newspapers	1.5											
Author is associated with a reputable org?	Google for opinions, ask others.	1.5											
Publisher is reputable?	Google for opinions, ask others.	1.5											
Authors and sources identified?	Trustworthy sources want to be known	1											
You perceive site as current?	Last update?	1											
Several other Web sites link to this one?	Sites only link to other sites they trust	1											
Recommended by a generalist?	Librarian, researcher	1											
Recommended by an independent subject guide?	A travel journal may suggest sites	1											
Domain includes a trademark name?	Trademark owners protect their marks	1											
Site's bias in clear?	Bias is OK if not hidden	1											
Site has professional look?	It should look like someone cares	1											
Total		20											
19 Dec 2001: The criteria and w 3 Feb 2012: Excel Spreadsheet w 26 Jan 2013: Trust Scale and W	eighted volves are based on a su which adds auto-sum was produc eb Site Evoluation Worksheet is in	rvey in put fri ed by Bill W the PUBLIC	om 66 analyst eich, Deputy D DOMAIN.	s. Far details se irector, Center	ee: http://daxrr for intelligence	arman.gsogie Research Ana	pages.com/ar lysis and Train	alysis. Edited ing, Mercyhur	(ar simplicity à it Callege.	y Kristan J. W?	eatan, OCT 20	13	

### **Annex I - Assessing Analytic Confidence**

### Assessing Analytic Confidence

The analysts that wrote this report are non-subject matter experts. They worked both individually and collaboratively to answer the questions. They utilized a combination of structured analytic techniques including nominal group technique and network analysis among others. The team evaluated their analytic confidence utilizing Peterson's Analytic Confidence Factors coupled with the Friedman Corollaries.

### Peterson Factors

- How reliable are the sources?
- How well do the independent sources corroborate each other?
- What is my/my team's level of expertise?
- How effective was my analytic collaboration?
- Did I use any structured techniques in my analysis?
- How difficult did I perceive the task to be?
- Did I have enough time to complete the task?

### Friedman Corollaries

- Is my estimate within the range of reasonable opinion surrounding the question?
- How likely is it that new information will change my estimate?



### Annex J - Standard Primary Source Credibility Scale

### Standard Primary Source Credibility Scale

Source reliability is noted at the end of each citation as low L, moderate M, or high H. The citation is hyperlinked to the source, unless the source is a paid subscription; in that instance a footnote is provided at the end of each writing illustrating the source for credibility. Source reliability is determined using the Trust Scale and Website Evaluation Worksheet found in Annex

Importance	Factor	Description	<u>Satisfies</u> <u>Criteria</u> (Yes /No)
HIGH	Has a good track record	Source has consistently provided true and correct information in the past	
	Information can be corroborated with other sources	Information provided by the source corroborates with information from other primary and/or secondary sources	
	Information provided is plausible	High probability of the information being true based on the analyst's experience of the topic/subject being investigated	
	Information is consistent and logically sound	Information provided is consistent when queried from different angles and is logically sound	
	Perceived expertise on the subject	Source is perceived to be an expert on the subject / topic being investigated and/or is in a role where subject knowledge is likely to be high	
	Proximity to the information	Source is close to the information – a direct participant or a witness to the event being investigated	
	Perceived trustworthiness	Source is perceived to be truthful and having integrity	
MEDIUM	No perceived bias or vested interest in the subject / topic being investigated or on the outcome of the research	Source has no perceived bias or vested interest in the subject / topic being investigated or on the outcome of the research	
	Provides complete, specific and detailed information	Information provided is specific, detailed and not generic	
LOW	Is articulate, coherent and has a positive body language	Source is articulate, coherent, has a positive body language and does not display nervousness or body language that can be construed to be evocative of deceptive behavior	
	Recommended by another trusted / credible third party	Source is recommended by others the analyst trusts but the analyst herself does not have any direct experience working with the source	
	Sociable	Source comes across as outgoing and friendly. Easy to get along with and talk to	
	Perceived goodwill to the receiver	Perceived intent or desire to help the receiver or the analyst	

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### Annex L – How to fight unmanned combat in future cities

Translated from Chinese

http://www.qstheory.cn/qshyjx/2020-11/03/c\_1126691646.htm

# How to fight unmanned combat in future cities

03 November 2020 13:01:31 Source: PLA Daily Author: Chen Wenchao, Wen Xiaopeng

The difficulty of urban warfare is that the urban environment is complex, the process is intense, and it is easy to defend and difficult to attack. It is called "war in hell". To solve this problem, the basic way is to use and integrate unmanned intelligent weapon systems in the whole process and all elements, and innovatively design unmanned combat operations in urban areas to minimize casualties and improve combat efficiency.

Stereoscopic penetration, continued reconnaissance. Distinguish key intelligence needs from far to near, from high to low-penetration urban high-risk areas, and from coarse to fine to complete information fusion and distribution. Outside the city, the drone swarms cooperate with aerial infiltration and reconnaissance to instantly generate a three-dimensional holographic image of the enemy's situation, which provides decision support for distinguishing tasks, deploying troops, and formulating tactics. The hidden threat of industrial obstacles provides a direct basis for grouping forces, coordinated attacks, and precise protection; regional stability control, portable small and micro drones, and robots infiltrating and reconnaissance in confined spaces can obtain building structures, identify dangerous targets, and silently covert tracking for search and suppression, Anti-terrorism and anti-riot to provide precise guidance.

Scene-driven, precise command. Build scenarios based on goals, preset rules based on scenarios, and command and collaborate based on rules. Distinguish between "military and civilian" target scene types, set different scene levels, intelligently extract key features of the scene and match the action rules of field elements, automatically trigger the rules to start the engine, and quickly generate combat instructions. Form a small, capable, synthetic, and multi-functional unmanned combat formation according to the power grouping rules; choose and adjust the strike position, timing, intensity, and effect according to the target strike rules; standardize the "discourse" system and unify state cognition according to the action coordination rules, connecting combat actions to generate swarm intelligence.

Cloud guidance, linkage attack. Taking the tactical mobile cloud as the fulcrum of the action, the remote access strategy, campaign cloud computing power, algorithms and data, and guide the front-end unmanned platform to strike together. The cloud accurately distinguishes and motion captures the signal frequency, and guides the implementation of high-intensity approaching network power attacks to block the enemy's communication; the cloud intelligently distributes and pushes target parameters in real time, guides the implementation of accurate fire strikes beyond the line of sight, and removes the enemy's fulcrum; Machine hybrid decision-making, dynamic adjustment and optimization of action plans, guide the implementation of obstacle breaking, assault, capture and clearing, and eliminate enemy remnants; cloud cross-domain tracking, accurate positioning of enemy key personnel, and guide the implementation of multi-path, multi-form, customized Cognitive intervention guides and destroys the enemy's will.

Star point deployment, area denial. Taking the key defense objectives of the urban area as the core, Starpoint deploys an unattended platform system to expand its combat functions layer by layer to prevent large-scale harassment and damage. Wide-area distribution "detection", low power consumption, all-weather concealed monitoring of urban battlefield dynamics, big data analysis and judgment of abnormal phenomena and dangerous targets, and timely warning information. Immediate response to "blocking", once a sign of harassment and damage is found, the unmanned attack platform preset program is quickly activated remotely, and it can autonomously complete precise positioning, advance obstacles, joint strikes, and effect evaluation. The man-machine cooperates to "guard", and adopts a variety of methods such as unmanned guidance - someone to attack, no one to coerce - someone to ambush, no one to consume - someone to attack, and so on, to eliminate the enemy in the movement.

Ubiquitous interconnection, no war protection. Taking the intelligent load as the sensing node, accurately obtain the support requirements of unmanned combat equipment; take the unmanned support equipment as the main body, and independently carry out intelligent support operations. Intelligently judge the damage level of the equipment, and automatically turn on the self-healing mode according to the preset repair threshold; intelligently monitor the energy consumption of the equipment, connect to the mobile, high-power wireless energy supply network whenever necessary, and automatically implement long-distance, multi-target energy transmission ; Intelligently coordinate materials, integrate packaging, and plan paths, and the unmanned delivery platform automatically finds support objects to achieve rapid rebirth of equipment on the battlefield and continuous and lasting combat operations.

Obviously, to form an urban unmanned combat capability, it is necessary to innovate combat concepts such as block penetration maneuver warfare, confined space clearance warfare, unattended refusal warfare, urban isolation and blockade warfare, psychological

cognitive control warfare, and bee colony decapitation warfare. ; Build a core algorithm model for urban operations, and form a digital, standardized, and generalized mobile cloud, data pool and rule base; Overcome many obstacles in urban areas and complex network communication environments, air-ground adaptive networking, over-the-horizon communication and sharing key technologies such as integration of detection and communication; accelerate the integration of "three modernizations" of equipment, improve the proportion of unmanned equipment and the level of intelligence, and form an unmanned combination of high and low, far and near, size, opening and closing, and war protection. equipment pedigree.



### Annex M - Team Janus Mind Map



Annex N – Team Janus Final Presentation



- LTC Andrew S. Culbreath, USAR JAG Corps
- COL John Hosey, US Army Cyber Operations
- **CDR Brennan Kemper**, US Navy Logistician
- Mr. Michael Stevic, US Army Civilian (USAF Col, Ret.)
- LTC Michael Wacker, US Army Signal Corps





# TERMS OF REFERENCE (TOR)

WHAT REVOLUTIONARY CONCEPTS AND TECHNOLOGIES WILL CONTINUUM OF COMPETITION, CRISIS, AND CONFLICT THROUGH LIKELY SHAPE THE FUTURE OF LAND WARFARE WITHIN THE 2045?

- WHICH ADVERSARIES WILL LIKELY EMPLOY ANY OF THE REVOLUTIONARY CONCEPTS AND TECHNOLOGIES IDENTIFIED?
- WHERE, GEOGRAPHICALLY, WILL ANY OF THE REVOLUTIONARY CONCEPTS AND TECHNOLOGIES IDENTIFIED LIKELY BE EMPLOYED?


















































WHAT ADVERSARY?		
Concept	Technology	Competitors/Adversaries
	Directed Energy Weapons	China, Russia, Australia, France, Germany, India, North Korea
Time As A Domain	Advanced Hypersonic Missiles	China, France, Germany, United Kingdom, Russia, India, Pakistan
	Active & Passive Camouflage	China, Russia, India
	Artificial Intelligence Advisors	China, Russia, EU
	<b>Trusted Digital Soldier</b>	China, Russia, Iran, EU, Turkey
	<b>Advanced Drone Technology</b>	China, Russia, Iran, EU, Turkey
Symbiotic Warfare	Nanoscience	China, Russia, Iran, EU, Japan
	Ionic Thrust Propulsion	China, Russia, EU
	Advanced Energy Storage	China, Russia, EU, Japan, Turkey
	Energy Storage	China, Russia, EU, Japan, Turkey
	Nano Observation	China, Russia
Latent Variable Environment	Vigilante Drones	China, Russia, EU, Japan, Turkey
	Teleporting Influence	China, Russia, EU, Turkey
	<b>Omnipresent Network Exploitation</b>	China, Russia





