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Emerging Military Technologies: Background and Issues for Congress

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SUMMARY

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Members of Congress and Pentagon officials are increasingly focused on developing emerging military technologies to enhance U.S. national security and keep pace with U.S. competitors. The U.S. military has long relied upon technological superiority to ensure its dominance in conflict and to underwrite U.S. national security. In recent years, however, technology has both rapidly evolved and rapidly proliferated—largely as a result of advances in the commercial sector. As former Secretary of Defense Chuck Hagel observed, this development has threatened to erode the United States' traditional sources of military advantage. The Department of Defense (DOD) has undertaken a number of initiatives to arrest this trend. For example, in 2014, DOD announced the Third Offset Strategy, an effort to exploit emerging technologies for military and security purposes as well as associated strategies, tactics, and concepts of operation. In support of this strategy, DOD established a number of organizations focused on defense innovation, including the Defense Innovation Unit and the Defense Wargaming Alignment Group.

More recently, the 2018 National Defense Strategy echoed the underpinnings of the Third Offset Strategy, noting that U.S. national security will likely be

> affected by rapid technological advancements and the changing character of war.... New technologies include advanced computing, "big data" analytics, artificial intelligence, autonomy, robotics, directed energy, hypersonics, and biotechnology—the very technologies that ensure we will be able to fight and win the wars of the future.

Similarly, the 2022 National Defense Strategy notes that artificial intelligence, quantum science, autonomy, biotechnology, and space technologies have the potential to change warfighting. The United States is the leader in developing many of these technologies. However, China and Russia—key strategic competitors—are making steady progress in developing advanced military technologies. As these technologies are integrated into foreign and domestic military forces and deployed, they could hold significant implications for the future of international security writ large, and will have to be a significant focus for Congress, both in terms of funding and program oversight.

This report provides an overview of selected emerging military technologies in the United States, China, and Russia:

- artificial intelligence,
- lethal autonomous weapons,
- hypersonic weapons,
- directed energy weapons,
- biotechnology, and
- quantum technology.

It also discusses relevant initiatives within international institutions to monitor or regulate these technologies, considers the potential implications of emerging military technologies for warfighting, and outlines associated issues for Congress. These issues include the level and stability of funding for emerging technologies, the management structure for emerging technologies, the challenges associated with recruiting and retaining technology workers, the acquisitions process for rapidly evolving and dual-use technologies, the protection of emerging technologies from theft and expropriation, and the governance and regulation of emerging technologies. Such issues could hold implications for congressional authorization, appropriation, oversight, and treaty-making.

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Introduction

Members of Congress and Pentagon officials are increasingly focused on developing emerging military technologies to enhance U.S. national security and keep pace with U.S. competitors. The U.S. military has long relied upon technological superiority to ensure its dominance in conflict and to underwrite U.S. national security. In recent years, however, technology has both rapidly evolved and rapidly proliferated—largely as a result of advances in the commercial sector. As former Secretary of Defense Chuck Hagel has observed, this development has threatened to erode the United States' traditional sources of military advantage.[1] The Department of Defense (DOD) has undertaken a number of initiatives in recent years in an effort to arrest this trend. For example, in 2014, DOD announced the Third Offset Strategy, an effort to exploit emerging technologies for military and security purposes as well as associated strategies, tactics, and concepts of operation.[2] In support of this strategy, DOD established a number of organizations focused on defense innovation, including the Defense Innovation Unit and the Defense Wargaming Alignment Group.

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Similarly, the 2022 National Defense Strategy notes that artificial intelligence, quantum science, autonomy, biotechnology, and space technologies have the potential to change warfighting.[4] Although the United States is the leader in developing many of these technologies, China and Russia—key strategic competitors—are making steady progress in developing advanced military technologies. As they are integrated into foreign and domestic military forces and deployed, these technologies could hold significant implications for congressional considerations and the future of international security writ large.

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- artificial intelligence,
- lethal autonomous weapons,
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[1] Remarks as delivered by Secretary of Defense Secretary of Defense Chuck Hagel, "Defense Innovation Days Opening Keynote," September 3, 2014, at https://www.defense.gov/Newsroom/Speeches/Speech/Article/605602/.

[2] The Third Offset Strategy is a strategy for maintaining U.S. military superiority. It succeeds the First and Second Offsets—nuclear weapons and the precision-guided munitions regime, respectively. Remarks as prepared for delivery by Deputy Secretary of Defense Bob Work, "National Defense University Convocation," August 5, 2014, at https://www.defense.gov/Newsroom/Speeches/Speech/Article/605598/.

[3] Department of Defense, "Summary of the 2018 National Defense Strategy of The United States of America," 2018, p. 3, at https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

[4] Department of Defense, *2022 National Defense Strategy of The United States of America*, October 2022, p. 19, at https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF.

- and quantum technology.

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Artificial Intelligence (AI)[5]

Although the U.S. government has no official definition of artificial intelligence, policymakers generally use the term AI to refer to a computer system capable of human-level cognition. AI is further divided into three categories: narrow AI, general AI, and artificial superintelligence. Narrow AI systems can perform only the specific task that they were trained to perform, while general AI systems would be capable of performing a broad range of tasks, including those for which they were not specifically trained. Artificial superintelligence refers to a system "that greatly exceeds the cognitive performance of humans in virtually all domains of interest."[6] General AI systems and artificial superintelligence do not yet—and may never—exist.[7]

Narrow AI is currently being incorporated into a number of military applications by both the United States and its competitors. Such applications include but are not limited to intelligence, surveillance, and reconnaissance;[8] logistics; cyber operations; command and control; and semi-autonomous and autonomous vehicles. These technologies are intended in part to augment or replace human operators, freeing them to perform more complex and cognitively demanding work. In addition, AI-enabled systems could (1) react significantly faster than systems that rely on operator input; (2) cope with an exponential increase in the amount of data available for analysis; and (3) enable new concepts of operations, such as swarming (i.e., cooperative behavior in which unmanned vehicles autonomously coordinate to achieve a task) that could confer a warfighting advantage by overwhelming adversary defensive systems.

Narrow AI, however, could introduce a number of challenges. For example, such systems may be subject to algorithmic bias as a result of their training data or models. Researchers have repeatedly discovered instances of racial bias in AI facial recognition programs due to the lack of diversity in the images on which the systems were trained, while some natural language processing programs have developed gender bias.[9] Such biases could hold significant implications for AI applications in a military context. For example, incorporating undetected biases into systems with lethal effects could lead to cases of mistaken identity and the unintended killing of civilians or noncombatants.

[5] For more information about artificial intelligence, see CRS Report R45178, *Artificial Intelligence and National Security*, by Kelley M. Sayler.

[6] Nick Bostrom, Superintelligence: Paths, Dangers, Strategies (Oxford, United Kingdom: Oxford University Press, 2014).

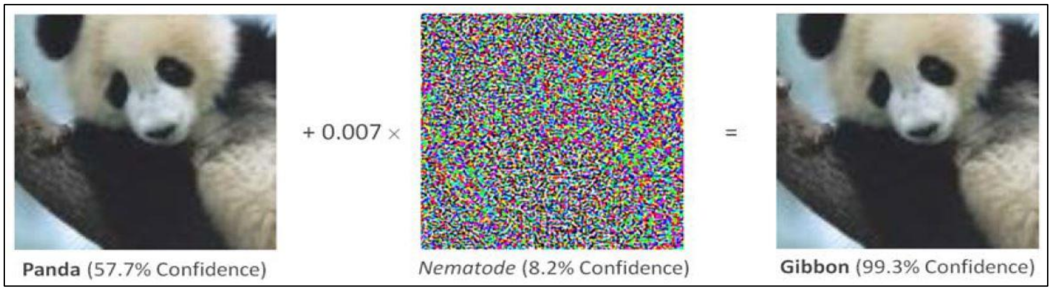
[7] For a discussion of narrow versus general artificial intelligence, as well as a range of expert opinions about the future of general artificial intelligence, see Nick Bostrom, *Superintelligence: Paths, Dangers, Strategies* (Oxford, United Kingdom: Oxford University Press, 2014).

[8] For a discussion of intelligence, surveillance, and reconnaissance, see CRS Report R46389, *Intelligence, Surveillance, and Reconnaissance Design for Great Power Competition*, by Nishawn S. Smagh.

[9] Brian Barrett, "Lawmakers Can't Ignore Facial Recognition's Bias Anymore," Wired, July 26, 2018, at https://www.wired.com/story/amazon-facial-recognition-congress-bias-law-enforcement/; and Will Knight, "How to Fix Silicon Valley's Sexist Algorithms," MIT Technology Review, November 23, 2016, at https://www.technologyreview.com/s/602950/how-to-fix-silicon-valleys-sexist-algorithms/.

Similarly, narrow AI algorithms can produce unpredictable and unconventional results that could lead to unexpected failures if incorporated into military systems. In a commonly cited demonstration of this phenomenon (illustrated in **Figure 1**), researchers combined a picture that an AI system correctly identified as a panda with random distortion that the computer labeled "nematode." The difference in the combined image is imperceptible to the human eye, but it resulted in the AI system labeling the image as a gibbon with 99.3% confidence. Such vulnerabilities could be exploited intentionally by adversaries to disrupt AI-reliant or -assisted target identification, selection, and engagement. This could, in turn, raise ethical concerns—or, potentially, lead to violations of the law of armed conflict—if it results in the system selecting and engaging a target or class of targets that was not approved by a human operator.

Figure 1. AI Failure in Image Recognition



Source: Andrew Ilachinski, *AI, Robots, and Swarms, Issues Questions, and Recommended Studies*, Center for Naval Analyses, January 2017, p. 61.

Finally, recent news reports and analyses have highlighted the role of AI in enabling increasingly realistic photo, audio, and video digital forgeries, popularly known as "deep fakes." Adversaries could deploy this AI capability as part of their information operations in a "gray zone" conflict.[10] Deep fake technology could be used against the United States and its allies to generate false news reports, influence public discourse, erode public trust, and attempt blackmail of government officials. For this reason, some analysts argue that social media platforms—in addition to deploying deep fake detection tools—may need to expand the means of labeling and authenticating content.[11] Doing so might require that users identify the time and location at which the content originated or properly label content that has been edited. Other analysts have expressed concern that regulating deep fake technology could impose an undue burden on social media platforms or lead to unconstitutional restrictions on free speech and artistic expression.[12] These analysts have suggested that existing law is sufficient for managing the malicious use of deep fakes and that the focus should be instead on the need to educate the public about deep fakes and minimize incentives for creators of malicious deep fakes.

[10] "Gray zone" conflicts are those that occur below the threshold of formally declared war. For more information about information operations, see CRS In Focus IF10771, *Defense Primer: Operations in the Information Environment*, by Catherine A. Theohary.

[11] Some social media platforms such as Twitter have established rules for labeling and removing certain types of synthetic or manipulated media. See Yoel Roth and Ashita Achuthan, "Building rules in public: Our approach to synthetic & manipulated media," *Twitter*, February 4, 2020, at https://blog.twitter.com/en_us/topics/company/2020/new-approach-to-synthetic-and-manipulated-media.html.

[12] Jessica Ice, "Defamatory Political Deepfakes and the First Amendment," *Case Western Reserve Law Review*, 2019, at https://scholarlycommons.law.case.edu/caselrev/vol70/iss2/12.

United States

DOD's unclassified investments in AI have grown from just over $600 million in FY2016 to approximately $1.8 billion in FY2024, with the department maintaining over 685 active AI projects.[13] Pursuant to the FY2019 National Defense Authorization Act (NDAA; P.L. 115-232), DOD established the Joint Artificial Intelligence Center (JAIC, pronounced "jake") to coordinate DOD projects of over $15 million; the JAIC was granted acquisition authority by Section 808 of the FY2021 NDAA (P.L. 116-283).[14] The JAIC has undertaken a number of National Mission Initiatives for AI, including predictive maintenance,[15] humanitarian aid and disaster relief, warfighter health, and business process transformation. In addition, the JAIC maintains the Joint Common Foundation, a "secure cloud-based AI development and experimentation environment" intended to support the testing and fielding of department-wide AI capabilities.[16] In December 2021, Deputy Secretary of Defense Kathleen Hicks directed the establishment of the Chief Digital and Artificial Intelligence Office, which is to "serve as the successor organization to the JAIC, reporting directly to the Deputy Secretary of Defense."[17]

The FY2019 NDAA also directed DOD to publish a strategic roadmap for AI development and fielding, as well as to develop guidance on "appropriate ethical, legal, and other policies for the Department governing the development and use of artificial intelligence enabled systems and technologies in operational situations."[18] In support of this mandate, the Defense Innovation Board (DIB), an independent federal advisory committee to the Secretary of Defense, drafted recommendations for the ethical use of artificial intelligence.[19] Based on these recommendations, DOD then adopted five ethical principles for AI based on the DIB's recommendations: responsibility, equitability, traceability, reliability, and governability.[20] On May 26, 2021, Deputy Secretary of Defense Kathleen Hicks issued a memorandum providing guidance on the implementation of Responsible Artificial Intelligence (RAI), in keeping with the ethical

[13] The amount listed as the FY2024 investment reflects DOD's FY2024 unclassified budget request for AI. DOD's actual investments in AI in FY2024 may be higher; based on historical precedent, they are unlikely to be lower. Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, *United States Department of Defense Fiscal Year 2024 Budget Request*, March 2023, p. 15, at hhttps://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2024/FY2024_Budget_Request.pdf; and Government Accountability Office, *Artificial Intelligence: Status of Developing and Acquiring Capabilities for Weapon Systems*, February 2022, at https://www.gao.gov/assets/gao-22-104765.pdf.

[14] P.L. 115-232, Section 2, Division A, Title II, §1051; and P.L. 116-283, Section 2, Division A, Title VIII, §808.

[15] Predictive maintenance uses AI "to predict the failure of critical parts, automate diagnostics, and plan maintenance based on data and equipment condition." Department of Defense, "Summary of the 2018 Department of Defense Artificial Intelligence Strategy," February 12, 2019, p. 11, at https://media.defense.gov/2019/Feb/12/2002088963/-1/-1/1/SUMMARY-OF-DOD-AI-STRATEGY.PDF.

[16] Joint Artificial Intelligence Center, "Joint Common Foundation," at https://www.ai.mil/jcf.html.

[17] Department of Defense, "Establishment of the Chief Digital and Artificial Intelligence Officer," December 8, 2021, at https://media.defense.gov/2021/Dec/08/2002906075/-1/-1/1/MEMORANDUM-ON-ESTABLISHMENT-OF-THE-CHIEF-DIGITAL-AND-ARTIFICIAL-INTELLIGENCE-OFFICER.PDF.

[18] P.L. 115-232, Section 2, Division A, Title II, §238.

[19] For a discussion of DOD's rationale for developing principles for ethical AI, as well as DOD's existing ethical commitments related to AI, see Defense Innovation Board, "AI Principles: Recommendations on the Ethical Use of Artificial Intelligence by the Department of Defense," October 31, 2019, at https://media.defense.gov/2019/Oct/31/2002204458/-1/-1/0/DIB_AI_PRINCIPLES_PRIMARY_DOCUMENT.PDF.

[20] For definitions of these principles, see Department of Defense, "DOD Adopts Ethical Principles for Artificial Intelligence," February 24, 2020, at https://www.defense.gov/Newsroom/Releases/Release/Article/2091996/dod-adopts-ethical-principles-for-artificial-intelligence/.

principles.[21] DOD then released an RAI strategy and implementation pathway in June 2022.[22] Section 1544 of the FY2024 NDAA (P.L. 118-31) directs DOD to assess whether a given AI technology operationalizes the RAI principles, "to report and remediate any artificial intelligence technology that is determined not to be in compliance with the [RAI] framework," and to discontinue the use of noncompliant technology "until effective remediation is achievable." E.O. 14110, *Executive Order (E.O.) on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence*, additionally provides guidance on standards for AI safety and security.[23]

Finally, Section 1051 of the FY2019 NDAA established a National Security Commission on Artificial Intelligence (NSCAI) to conduct a comprehensive assessment of militarily relevant AI technologies and to provide recommendations for strengthening U.S. competitiveness. The commission's final report to Congress was delivered in March 2021 and generally offers recommendations along five key lines of effort: (1) investing in research and development, (2) applying AI to national security missions, (3) training and recruiting AI talent, (4) protecting and building upon U.S. technology advantages, and (5) marshalling global AI cooperation.[24] A number of NSCAI's recommendations have been passed into law.[25] In addition, Section 247 of the FY2022 NDAA (P.L. 117-81) directs the Secretary of Defense to submit to the congressional defense committees annual status reports on the department's intent to implement NSCAI recommendations, as well as any associated timelines for implementation.[26]

China

China is widely viewed as the United States' closest competitor in the international AI market.[27] China's 2017 "Next Generation AI Development Plan" describes AI as a "strategic technology"

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[21] RAI is to focus on RAI governance, warfighter trust, AI product and acquisition lifecycle, requirements validation, responsible AI ecosystem, and AI workforce. For additional information about RAI, see Kathleen H. Hicks, "Implementing Responsible Artificial Intelligence in the Department of Defense," May 26, 2021, at https://media.defense.gov/2021/May/27/2002730593/-1/-1/0/IMPLEMENTING-RESPONSIBLE-ARTIFICIAL-INTELLIGENCE-IN-THE-DEPARTMENT-OF-DEFENSE.PDF.

[22] Department of Defense, *U.S. Department of Defense Responsible Artificial Intelligence Strategy and Implementation Pathway*, June 2022, at https://media.defense.gov/2022/Jun/22/2003022604/-1/-1/0/Department-of-Defense-Responsible-Artificial-Intelligence-Strategy-and-Implementation-Pathway.PDF. The Defense Innovation Unit (DIU) has additionally issued *Responsible AI Guidelines in Practice: Lessons Learned from the DIU Portfolio* to operationalize DOD's Ethical Principles for AI within DIU's commercial prototyping and acquisitions programs. Jared Dunnmon et al., *Responsible AI Guidelines in Practice: Lessons Learned from the DIU Portfolio*, November 14, 2021, at https://assets.ctfassets.net/3nanhbfkr0pc/acoo1Fj5uungnGNPJ3QWy/3a1dafd64f22efcf8f27380aafae9789/2021_RAI_Report-v3.pdf.

[23] For additional information, see CRS Report R47843, *Highlights of the 2023 Executive Order on Artificial Intelligence for Congress*, by Laurie Harris and Chris Jaikaran; and CRS Insight IN12286, *The AI Executive Order and Its Potential Implications for DOD*, by Alexandra G. Neenan and Kelley M. Sayler.

[24] National Security Commission on Artificial Intelligence, *Final Report*, March 2021, at https://www.nscai.gov/wp-content/uploads/2021/03/Full-Report-Digital-1.pdf. Pursuant to Section 238 of the FY2019 NDAA, RAND Corporation, a federally funded research and development center, additionally conducted a review of DOD's posture for AI. See Danielle C. Tarraf et al., *The Department of Defense Posture for Artificial Intelligence: Assessment and Recommendations*, RAND Corporation, 2019, https://www.rand.org/pubs/research_reports/RR4229.html.

[25] See, for example, Section 216 ("Improvements relating to Steering Committee on Emerging Technology and National Security Threats"), Section 228 ("Executive Education on Emerging Technologies for Senior Civilian and Military Leaders"), Section 903 ("Enhanced role for the Undersecretary of Defense for Research and Engineering on the Joint Requirements Oversight Council"), Section 909 ("Digital Talent Recruiting Officer"), and Section 1118 ("Occupational series for digital career fields") of the FY2022 NDAA.

[26] This requirement is to expire on December 27, 2023.

[27] See, for example, Kai-Fu Lee, *AI Superpowers: China, Silicon Valley, and the New World Order* (Boston, MA: Houghton Mifflin Co., 2018).

that has become a "focus of international competition."[28] Recent Chinese achievements in the field demonstrate China's potential to realize its goals for AI development. In particular, China has pursued language and facial recognition technologies, many of which it plans to integrate into the country's domestic surveillance network. Such technologies could be used to counter espionage and aid military targeting. In addition to developing various types of air, land, sea, and undersea autonomous military vehicles, China is actively pursuing swarm technologies, which could be used to overwhelm adversary missile defense interceptors. Moreover, open-source publications indicate that China is developing a suite of AI tools for cyber operations.[29]

China's management of its AI ecosystem stands in stark contrast to that of the United States.[30] In general, few boundaries exist between Chinese commercial companies, university research laboratories, the military, and the central government. China's National Intelligence Law, for example, requires companies and individuals to "support, assist, and cooperate with national intelligence work."[31] As a result, the Chinese government has a direct means of guiding military AI development priorities and accessing technology developed for civilian purposes.

Russia

Russian president Vladimir Putin has stated that "whoever becomes the leader in [AI] will become the ruler of the world."[32] At present, however, Russian AI development lags significantly behind that of the United States and China. As part of Russia's effort to close this gap, Russia has released a national strategy that outlines 5- and 10-year benchmarks for improving the country's AI expertise, educational programs, datasets, infrastructure, and legal regulatory system.[33] Russia has indicated it will continue to pursue its 2008 defense modernization agenda, which called for robotizing 30% of the country's military equipment by 2025.[34]

The Russian military has been researching a number of AI applications, with a heavy emphasis on semiautonomous and autonomous military vehicles. Russia has also reportedly built a combat module for unmanned ground vehicles that may be capable of autonomous target identification—and, potentially, target engagement—and it plans to develop a suite of AI-enabled autonomous systems.[35] In addition, the Russian military plans to incorporate AI into unmanned aerial, naval, and undersea vehicles and is reportedly developing swarming capabilities.[36] These technologies

[28] China State Council, "A Next Generation Artificial Intelligence Development Plan," p. 2.

[29] Elsa Kania, *Battlefield Singularity: Artificial Intelligence, Military Revolution, and China's Future Military Power*, Center for a New American Security, November 28, 2017, p. 27.

[30] Ibid., p. 6.

[31] Arjun Kharpal, "Huawei says it would never hand data to China's government. Experts say it wouldn't have a choice," *CNBC*, March 5, 2019.

[32] "'Whoever leads in AI will rule the world': Putin to Russian children on Knowledge Day," *RT.com*, September 1, 2017, at https://www.rt.com/news/401731-ai-rule-world-putin/.

[33] Office of the President of the Russian Federation, "Decree of the President of the Russian Federation on the Development of Artificial Intelligence in the Russian Federation" (Center for Security and Emerging Technology, Trans.), October 10, 2019, at https://cset.georgetown.edu/research/decree-of-the-president-of-the-russian-federation-on-the-development-of-artificial-intelligence-in-the-russian-federation/.

[34] Tom Simonite, "For Superpowers, Artificial Intelligence Fuels New Global Arms Race," *Wired*, August 8, 2017.

[35] Tristan Greene, "Russia is Developing AI Missiles to Dominate the New Arms Race," *The Next Web*, July 27, 2017, at https://thenextweb.com/artificial-intelligence/2017/07/27/russia-is-developing-ai-missiles-to-dominate-the-new-arms-race/; and Kyle Mizokami, "Kalashnikov Will Make an A.I.-Powered Killer Robot," Popular Mechanics, July 19, 2017, at https://www.popularmechanics.com/military/weapons/news/a27393/kalashnikov-to-make-ai-directed-machine-guns/.

[36] Samuel Bendett, "Red Robots Rising: Behind the Rapid Development of Russian Unmanned Military Systems," *The Strategy Bridge*, December 12, 2017.

could reduce both cost and manpower requirements, potentially enabling Russia to field more systems with fewer personnel. Russia is also exploring innovative uses of AI for remote sensing and electronic warfare, which could in turn reduce an adversary's ability to effectively communicate and navigate on the battlefield.[37] Finally, Russia has made extensive use of AI technologies for domestic propaganda and surveillance, as well as for information operations directed against the United States and U.S. allies.[38]

Despite Russia's aspirations, analysts argue that it may be difficult for Russia to make significant progress in AI development. For example, some analysts note that Russian academics have produced few research papers on AI—ranking 22nd in AI-related publications globally[39]—and that the Russian technology industry has yet to produce AI applications on par with those produced by the United States and China.[40] Other analysts counter that such factors may be irrelevant, arguing that while Russia has never been a leader in internet technology, it has managed to become a notably disruptive force in cyberspace.[41] Russia may also be able to draw upon its growing technological cooperation with China.[42]

International Institutions

A number of international institutions have examined issues surrounding AI, including the Group of Seven (G7), the Asia-Pacific Economic Cooperation (APEC), and the Organisation for Economic Co-operation and Development (OECD), which developed the first intergovernmental set of principles for AI.[43] These principles are intended to "promote AI that is innovative and trustworthy and that respects human rights and democratic values."[44] The United States is one of 42 countries—including the OECD's 36 member countries, Argentina, Brazil, Colombia, Costa Rica, Peru, and Romania—to have adopted the OECD AI Principles. These principles serve as the foundation for the Group of Twenty's (G20's) June 2019 Ministerial Statement on human-

[37] Jill Dougherty and Molly Jay, "Russia Tries to Get Smart about Artificial Intelligence"; *The Wilson Quarterly*, Spring 2018; and Margarita Konaev and Samuel Bendett, "Russian AI-Enabled Combat: Coming to a City Near You?," *War on the Rocks*, July 31, 2019, at https://warontherocks.com/2019/07/russian-ai-enabled-combat-coming-to-a-city-near-you/.

[38] Alina Polyakova, "Weapons of the Weak: Russia and AI-driven Asymmetric Warfare," Brookings Institution, November 15, 2018, at https://www.brookings.edu/research/weapons-of-the-weak-russia-and-ai-driven-asymmetric-warfare/; and Chris Meserole and Alina Polyakova, "Disinformation Wars," *Foreign Policy*, May 25, 2018, at https://foreignpolicy.com/2018/05/25/disinformation-wars/.

[39] Margarita Konaev et al., *Headline or Trend Line? Evaluating Chinese-Russian Collaboration in AI*, Center for Security and Emerging Technology, August 2021, p. 9.

[40] Leon Bershidsky, "Take Elon Musk Seriously on the Russian AI Threat," *Bloomberg*, September 5, 2017, at https://www.bloomberg.com/view/articles/2017-09-05/take-elon-musk-seriously-on-the-russian-ai-threat; and Alina Polyakova, "Weapons of the Weak: Russia and AI-driven Asymmetric Warfare," Brookings Institution, November 15, 2018, at https://www.brookings.edu/research/weapons-of-the-weak-russia-and-ai-driven-asymmetric-warfare/.

[41] Gregory C. Allen, "Putin and Musk Are Right: Whoever Masters AI Will Run the World," *CNN*, September 5, 2017.

[42] Samuel Bendett and Elsa Kania, *A New Sino-Russian High-tech Partnership*, Australian Strategic Policy Institute, October 29, 2019, at https://www.aspi.org.au/report/new-sino-russian-high-tech-partnership. Some analysts have cautioned, however, that "the extent and scope of Chinese-Russian collaboration in AI may be overstated by both Chinese and Russian sources as well as U.S. observers." Margarita Konaev et al., *Headline or Trend Line? Evaluating Chinese-Russian Collaboration in AI*, Center for Security and Emerging Technology, August 2021, p. 9.

[43] In May 2020, the United States joined the G7's Global Partnership on AI, which is "to guide the responsible adoption of AI based on shared principles of 'human rights, inclusion, diversity, innovation and economic growth.'" Matt O'Brien, "US joins G7 artificial intelligence group to counter China," Associated Press, May 28, 2020.

[44] Organisation for Economic Co-operation and Development, "OECD Principles on AI," June 2019, at https://www.oecd.org/going-digital/ai/principles/.

centered AI.[45] In addition, the OECD established the AI Policy Observatory in 2019 to develop policy options that will "help countries encourage, nurture, and monitor the responsible development of trustworthy AI systems for the benefit of society."

Similarly, in October 2021, the North Atlantic Treaty Organization (NATO) released its first AI strategy.[46] According to NATO Secretary General Jens Stoltenberg, the strategy is to "set standards for responsible use of artificial intelligence, in accordance with international law, outline how [NATO] will accelerate the adoption of artificial intelligence in what [it does], set out how [NATO] will protect this technology, and address the threats posed by the use of artificial intelligence by adversaries."[47] NATO has additionally established AI test centers and a data and AI review board to "ensure the 'operationalization' of the AI strategy."[48]

Finally, in September 2021, the United States announced that it had formed a trilateral security partnership with Australia and the United Kingdom.[49] This partnership, known as AUKUS, includes defense cooperation on artificial intelligence and autonomy, as well as hypersonic weapons, quantum technologies, and other advanced capabilities.[50]

Potential Questions for Congress

- What measures is DOD taking to implement its ethical principles for artificial intelligence? Are such measures sufficient to ensure DOD's adherence to the principles?
- How is DOD testing and evaluating AI systems to ensure that they have not been exploited by adversaries?
- Do DOD and the intelligence community have adequate information about the state of foreign military AI applications and the ways in which such applications may be used to harm U.S. national security?
- How has the establishment of the Chief Digital and Artificial Intelligence Office affected DOD's ability to adopt AI applications?
- How should national security considerations with regard to deep fakes be balanced with free speech protections, artistic expression, and beneficial uses of the underlying technologies? What efforts, if any, should the U.S. government undertake to ensure that the public is educated about deep fakes?

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45 "G20 Ministerial Statement on Trade and Digital Economy," June 9, 2019, at https://www.mofa.go.jp/files/000486596.pdf.

46 North Atlantic Treaty Organization, "Summary of the NATO Artificial Intelligence Strategy," October 22, 2021, at https://www.nato.int/cps/en/natohq/official_texts_187617.htm?mc_cid=8f2b5c99db&mc_eid=5a3e8d2b43.

47 Vivienne Machi, "NATO ups the ante on disruptive tech, artificial intelligence," *C4ISRNET*, November 3, 2021, at https://www.c4isrnet.com/digital-show-dailies/feindef/2021/11/03/nato-ups-the-ante-on-disruptive-tech-artificial-intelligence/.

48 Ibid. For additional information, see NATO, "NATO's Data and Artificial Intelligence Review Board," October 17, 2022, at https://www.nato.int/cps/en/natohq/official_texts_208374.htm; and NATO, "DIANA Network: Test Centers," July 20, 2023, at https://www.diana.nato.int/resources/site1/general/maps/diana-test-centres-en_v5.pdf.

49 The White House, "Joint Leaders Statement on AUKUS," September 15, 2021, at https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/15/joint-leaders-statement-on-aukus/.

50 The White House, "Fact Sheet: Implementation of the Australia – United Kingdom – United States Partnership (AUKUS)," April 5, 2022, at https://www.whitehouse.gov/briefing-room/statements-releases/2022/04/05/fact-sheet-implementation-of-the-australia-united-kingdom-united-states-partnership-aukus/. For additional information about AUKUS and advanced capability development, see CRS Report R47599, *AUKUS Pillar 2: Background and Issues for Congress*, by Patrick Parrish and Luke A. Nicastro.

Lethal Autonomous Weapon Systems (LAWS)[51]

Although there is no internationally agreed definition of lethal autonomous weapon systems, Department of Defense Directive (DODD) 3000.09 defines LAWS as a class of weapon systems capable of both independently identifying a target and employing an onboard weapon to engage and destroy the target without manual human control. This concept of autonomy is also known as "human out of the loop" or "full autonomy." The directive contrasts LAWS with human-supervised, or "human on the loop," autonomous weapon systems, in which operators have the ability to monitor and halt a weapon's target engagement. Another category is semi-autonomous, or "human in the loop," weapon systems that "only engage individual targets or specific target groups that have been selected by a human operator."[52]

LAWS would require computer algorithms and sensor suites to classify an object as hostile, make an engagement decision, and guide a weapon to the target. Although these systems are not yet in widespread development,[53] it is believed they would enable military operations in communications-degraded or -denied environments where traditional systems may not be able to operate. Some analysts have noted that LAWS could additionally "allow weapons to strike military objectives more accurately and with less risk of collateral damage" or civilian casualties.[54]

Others, including approximately 30 countries and 165 nongovernmental organizations, have called for a preemptive ban on LAWS due to ethical concerns such as a perceived lack of accountability for use and a perceived inability to comply with the proportionality and distinction requirements of the law of armed conflict. Some analysts have also raised concerns about the potential operational risks posed by lethal autonomous weapons.[55] These risks could arise from "hacking, enemy behavioral manipulation, unexpected interactions with the environment, or simple malfunctions or software errors."[56] Although such risks could be present in automated systems, they could be heightened in autonomous systems, in which the human operator would be

[51] For additional information about LAWS, see CRS Report R44466, *Lethal Autonomous Weapon Systems: Issues for Congress*, by Nathan J. Lucas.

[52] Department of Defense Directive 3000.09, "Autonomy in Weapon Systems," Updated January 25, 2023, at https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodd/300009p.pdf.

[53] Some analysts have argued that certain loitering munitions such as the Israeli Harpy meet the United States' definition of LAWS. See, for example, *Defense Innovation Board, AI Principles: Recommendations on the Ethical Use of Artificial Intelligence by the Department of Defense - Supporting Document*, October 2019, p. 12, at https://media.defense.gov/2019/Oct/31/2002204459/-1/-1/0/DIB_AI_PRINCIPLES_SUPPORTING_DOCUMENT.PDF. In addition, while a United Nations report concluded that Turkey's deployment of the STM *Kargu-2* constitutes the first use of a lethal autonomous weapon system in combat, the U.N. described the *Kargu-2* as being "*programmed* to attack targets" [emphasis added]. For this reason, it is unlikely that the *Kargu-2* meets the U.S. definition of LAWS. United Nations Security Council, "Letter dated 8 March 2021 from the Panel of Experts on Libya established pursuant to resolution 1973 (2011) addressed to the President of the Security Council," March 8, 2021, p. 17, at https://undocs.org/S/2021/229.

[54] U.S. Government, "Humanitarian Benefits of Emerging Technologies in the Area of Lethal Autonomous Weapons," March 28, 2018, at https://ogc.osd.mil/Portals/99/Law%20of%20War/Practice%20Documents/US%20Working%20Paper%20-%20Humanitarian%20benefits%20of%20emerging%20technologies%20in%20the%20area%20of%20LAWS%20-%20CCW_GGE.1_2018_WP.4_E.pdf?ver=O0lg6BIxsFt57nrOuz3xHA%3D%3D.

[55] See, for example, Paul Scharre, "Autonomous Weapons and Operational Risk," Center for a New American Security, February 2016, at https://s3.amazonaws.com/files.cnas.org/documents/CNAS_Autonomous-weapons-operational-risk.pdf.

[56] Ibid.

unable to physically intervene to terminate engagements—potentially resulting in wider-scale or more numerous instances of fratricide, civilian casualties, or other unintended consequences.[57]

United States

The United States is not known to currently have LAWS in its inventory; however, there is no prohibition on the development, fielding, or employment of LAWS. DODD 3000.09 establishes DOD guidelines for the future development and fielding of LAWS to ensure that they comply with "the law of war, applicable treaties, weapon system safety rules, and applicable rules of engagement."[58] This directive includes a requirement that LAWS be designed to "allow commanders and operators to exercise appropriate levels of human judgment over the use of force."[59] "Human judgment over the use of force" does not require manual human "control" of the weapon system, as is often reported, but instead requires broader human involvement in decisions about how, when, where, and why the weapon will be employed.

In addition, DODD 3000.09 requires that the software and hardware of all systems, including lethal autonomous weapons, be tested and evaluated to ensure they

> [f]unction as anticipated in realistic operational environments against adaptive adversaries; complete engagements in a timeframe consistent with commander and operator intentions and, if unable to do so, terminate engagements or seek additional human operator input before continuing the engagement; and are sufficiently robust to minimize failures that could lead to unintended engagements or to loss of control of the system to unauthorized parties.

Any changes to a system's operating state—for example, due to machine learning—would require the system to be retested and reevaluated to ensure that it has retained its safety features and ability to operate as intended. In addition to the standard weapons review process, a secondary senior-level review is required for covered autonomous and semi-autonomous systems. This review requires the Under Secretary of Defense for Policy (USD[P]), the Vice Chairman of the Joint Chiefs of Staff (VCJCS), and the Under Secretary of Defense for Research and Engineering (USD[R&E]) to approve the system before formal development. USD(P), VCJCS, and the Under Secretary of Defense for Acquisition and Sustainment (USD[A&S]) must then approve the system before fielding. In the event of "urgent military need," this senior-level review may be waived by the Deputy Secretary of Defense. DODD 3000.09 additionally establishes the Autonomous Weapon System Working Group—composed of representatives of USD(P); USD(R&E); USD(A&S); DOD General Counsel; the Chief Digital and AI Officer; the Director, Operational Test and Evaluation; and the Chairman of the Joint Chiefs of Staff—to support and advise the senior-level review process.[60]

Per Section 251 of the FY2024 (P.L. 118-31), the Secretary of Defense is to notify the defense committees of any changes to DODD 3000.09 within 30 days. The Secretary is directed to provide a description of the modification and an explanation of the reasons for the modification.

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[57] Ibid.

[58] Department of Defense Directive 3000.09, "Autonomy in Weapon Systems," Updated January 25, 2023, at https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodd/300009p.pdf. For an explanation of this directive, see CRS In Focus IF11150, *Defense Primer: U.S. Policy on Lethal Autonomous Weapon Systems*, by Kelley M. Sayler.

[59]Department of Defense Directive 3000.09, "Autonomy in Weapon Systems," Updated January 25, 2023, at https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodd/300009p.pdf.

[60] Ibid.

China

According to former U.S. Secretary of Defense Mark Esper, some Chinese weapons manufacturers, such as Ziyan, have advertised their weapons as having the ability to select and engage targets autonomously.[61] It is unclear whether these claims are accurate; however, China has no prohibition on the development of LAWS, which it has characterized as weapons that exhibit—at a minimum—five attributes:

> The first is lethality, which means sufficient pay load (charge) and for means [*sic*] to be lethal. The second is autonomy, which means absence of human intervention and control during the entire process of executing a task. Thirdly, impossibility for termination, meaning that once started there is no way to terminate the device. Fourthly, indiscriminate effect, meaning that the device will execute the task of killing and maiming regardless of conditions, scenarios and targets. Fifthly evolution, meaning that through interaction with the environment the device can learn autonomously, expand its functions and capabilities in a way exceeding human expectations.[62]

Russia

Russia has proposed the following definition of LAWS: "unmanned technical means other than ordnance that are intended for carrying out combat and support missions without any involvement of the operator" beyond the decision of whether and how to deploy the system.[63] Russia has noted that LAWS could "ensure the increased accuracy of weapon guidance on military targets, while contributing to lower rate of unintentional strikes against civilians and civilian targets."[64] Although Russia has not publicly stated that it is developing LAWS, Russian weapons manufacturer Kalashnikov has reportedly built a combat module for unmanned ground vehicles capable of autonomous target identification and, potentially, target engagement.[65]

International Institutions

Since 2014, the United States has participated in international discussions of LAWS under the auspices of the United Nations Convention on Certain Conventional Weapons (U.N. CCW). The U.N. CCW has considered proposals by states parties to issue political declarations about LAWS, as well as proposals to regulate or ban them. At the U.N. CCW, the United States and Russia have opposed a preemptive ban on LAWS, while China has supported a ban on the use—but not development—of LAWS, which it defines as weapon systems that are inherently indiscriminate and thus in violation of the law of war.[66] The United States has instead proposed the development

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[61] Patrick Tucker, "SecDef: China is Exporting Killer Robots to the Mideast," *Defense One*, November 5, 2019.

[62] U.N. CCW, "China: Position Paper," April 11, 2018, p. 1, at https://unog.ch/80256EDD006B8954/(httpAssets)/E42AE83BDB3525D0C125826C0040B262/$file/CCW_GGE.1_2018_WP.7.pdf.

[63] U.N. CCW, "Russian Federation: Potential opportunities and limitations of military uses of lethal autonomous weapons systems," 2019, at https://unog.ch/80256EDD006B8954/(httpAssets)/B7C992A51A9FC8BFC12583BB00637BB9/$file/CCW.GGE.1.2019.WP.1_R+E.pdf.

[64] Ibid.

[65] Kyle Mizokami, "Kalashnikov Will Make an A.I.-Powered Killer Robot," *Popular Mechanics*, July 19, 2017.

[66] For additional information about U.N. CCW discussions on LAWS, see CRS In Focus IF11294, *International Discussions Concerning Lethal Autonomous Weapon Systems*, by Kelley M. Sayler.

of a nonbinding Code of Conduct, which "would help States promote responsible behavior and compliance with international law."[67]

The United States has additionally issued the "Political Declaration on Responsible Military Use of Artificial Intelligence and Autonomy," which notes that "military use of AI must be in compliance with applicable international law" and occur within a "responsible human chain of command and control."[68] To date, 50 states have endorsed the declaration.[69]

Potential Questions for Congress

- To what extent are potential U.S. adversaries developing LAWS? How, if at all, should this affect U.S. LAWS research and development?
- What role should the United States play in U.N. CCW discussions of LAWS? Should the United States support the status quo or advocate regulation of or a ban on LAWS?
- If the United States chooses to develop LAWS, are current weapons review processes and legal standards for their employment in conflict sufficient?

Hypersonic Weapons[70]

A number of countries, including the United States, Russia, and China, are developing hypersonic weapons—those that fly at speeds of at least Mach 5, or five times the speed of sound. In contrast to ballistic missiles, which also travel at hypersonic speeds, hypersonic weapons do not follow a parabolic ballistic trajectory and can maneuver en route to their destination, making defense against them difficult.

There are two categories of hypersonic weapons:

- **Hypersonic glide vehicles** are launched from a rocket before gliding to a target.[71]
- **Hypersonic cruise missiles** are powered by high-speed engines throughout the duration of their flight.

Analysts disagree about the strategic implications of hypersonic weapons. Some have identified two factors that could hold significant implications for strategic stability: (1) the weapon's short time-of-flight, which, in turn, compresses the timeline for response, and (2) its unpredictable

[67] U.S. Delegation to the U.N. CCW, "Opening Statement, as delivered by Joshua Dorosin," December 2, 2021, at https://geneva.usmission.gov/2021/12/03/convention-on-ccw-group-of-governmental-experts-on-emerging-technologies-in-the-area-of-laws/.

[68] Department of State, "Political Declaration on Responsible Military Use of Artificial Intelligence and Autonomy," November 9, 2023, at https://www.state.gov/political-declaration-on-responsible-military-use-of-artificial-intelligence-and-autonomy-2/.

[69] For a list of endorsing states, see https://www.state.gov/political-declaration-on-responsible-military-use-of-artificial-intelligence-and-autonomy/.

[70] For additional information about hypersonic weapons, see CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*, by Kelley M. Sayler; and CRS In Focus IF11459, *Defense Primer: Hypersonic Boost-Glide Weapons*, by Kelley M. Sayler and Amy F. Woolf.

[71] When hypersonic glide vehicles are mated with their rocket booster, the resulting weapon system is often referred to as a hypersonic boost-glide weapon.

flight path, which could generate uncertainty about the weapon's intended target and therefore heighten the risk of miscalculation or unintended escalation in the event of a conflict.[72]

Other analysts have argued that the strategic implications of hypersonic weapons are minimal because U.S. competitors such as China and Russia already possess the ability to strike the United States with intercontinental ballistic missiles, which, when launched in salvos, could overwhelm U.S. missile defenses.[73] Furthermore, these analysts argue that in the case of hypersonic weapons, traditional principles of deterrence hold: "it is really a stretch to try to imagine any regime in the world that would be so suicidal that it would even think threating to use—not to mention to actually use—hypersonic weapons against the United States ... would end well."[74]

United States

The Pentagon requested $4.7 billion in FY2023 for hypersonic weapons and $225.5 million for hypersonic defense programs.[75] The Pentagon declined to provide a breakout of funding for hypersonic-related research in FY2024, but requested $11 billion for long-range fires—a category that includes hypersonic weapons.[76] DOD is currently developing hypersonic weapons under the Navy's Conventional Prompt Strike program, which is intended to provide the U.S. military with the ability to strike hardened or time-sensitive targets with conventional warheads, as well as through several Air Force, Army, and DARPA programs.[77] Analysts who support these development efforts argue that hypersonic weapons could enhance deterrence, as well as provide the U.S. military with an ability to defeat capabilities such as mobile missile launchers and advanced air and missile defense systems that form the foundation of U.S. competitors' anti-access/area denial strategies.[78] Others have argued that hypersonic weapons confer little to no additional warfighting advantage and note that the U.S. military has yet to identify any mission requirements or concepts of operation for hypersonic weapons.[79]

[72] See, for example, Richard H. Speier et al., *Hypersonic Missile Proliferation: Hindering the Spread of a New Class of Weapons*, RAND Corporation, 2017, at https://www.rand.org/pubs/research_reports/RR2137.html.

[73] David Axe, "How the U.S. Is Quietly Winning the Hypersonic Arms Race," The Daily Beast, January 16, 2019, at https://www.thedailybeast.com/how-the-us-is-quietly-winning-the-hypersonic-arms-race. See also Mark B. Schneider, "Moscow's Development of Hypersonic Missiles," p. 14.

[74] Jyri Raitasalo, "Hypersonic Weapons are No Game-Changer," The National Interest, January 5, 2019, at https://nationalinterest.org/blog/buzz/hypersonic-weapons-are-no-game-changer-40632.

[75] Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, *Defense Budget Overview: United States Department of Defense Fiscal Year 2023 Budget Request*, April 2022, p. 4-6, at https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2023/FY2023_Budget_Request_Overview_Book.pdf. For additional information about hypersonic missile defense, see CRS In Focus IF11623, *Hypersonic Missile Defense: Issues for Congress*, by Kelley M. Sayler.

[76] CRS correspondence with DOD Comptroller on October 12, 2023; November 27, 2023; and January 4, 2024.

[77] In a June 2018 memorandum, DOD announced that the Navy would lead the development of a common glide vehicle for use across the services. The services coordinate efforts on a Common Hypersonic Glide Body Board of Directors with rotating chairmanship. Sydney J. Freedberg, Jr., "Army Ramps Up Funding for Laser Shield, Hypersonic Sword," Breaking Defense, February 28, 2020, at https://breakingdefense.com/2020/02/army-ramps-up-funding-for-laser-shield-hypersonic-sword/. For a full history of U.S. hypersonic weapons programs, see CRS Report R41464, *Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues*, by Amy F. Woolf.

[78] Roger Zakheim and Tom Karako, "China's Hypersonic Missile Advances and U.S. Defense Responses," remarks at the Hudson Institute, March 19, 2019. See also Department of Defense Fiscal Year (FY) 2020 Budget Estimates, Army Justification Book of Research, Development, Test and Evaluation, Volume II, Budget Activity 4, p. 580.

[79] See, for example, Valerie Insinna, "Air Force's top civilian hints at changes to hypersonic weapons programs," *Defense News*, September 22, 2021, at https://www.defensenews.com/air/2021/09/22/air-forces-top-civilian-hints-at-changes-to-hypersonic-weapons-programs/.

The United States is unlikely to field an operational hypersonic weapon before FY2025; however, in contrast to Russia and China, the United States is not known to be developing hypersonic weapons for potential use with a nuclear warhead. As a result, the United States is seeking to develop hypersonic weapons that can attack targets with greater accuracy, which could be more technically challenging to develop than nuclear-armed—and less accurate—Russian and Chinese systems.

Section 237 of the FY2023 NDAA (P.L. 117-263) directs the Secretary of Defense to both assess DOD's capacity to test and evaluate hypersonic capabilities and "[identify] test facilities outside the Department of Defense that have potential to be used to expand [DOD] capacity ... including test facilities of other departments and agencies of the Federal Government, academia, and commercial test facilities." Section 218 of the FY2024 NDAA (P.L. 118-31) directs the Secretary to update this assessment at least once every two years. It additionally directs the Secretary to conduct a study to evaluate at least two possible locations in the United States that "have potential to be used as additional corridors for long-distance hypersonic system testing" and to submit to the congressional defense committees an annual report on DOD funding and investments in hypersonic capabilities.

China

According to Tong Zhao, a fellow at the Carnegie-Tsinghua Center for Global Policy, "most experts argue that the most important reason to prioritize hypersonic technology development [in China] is the necessity to counter specific security threats from increasingly sophisticated U.S. military technology" such as U.S. regional missile defenses.[80] China's pursuit of hypersonic weapons, like Russia's, reflects a concern that U.S. hypersonic weapons could enable the United States to conduct a preemptive, decapitating strike on China's nuclear arsenal and supporting infrastructure. U.S. missile defense deployments could then limit China's ability to conduct a retaliatory strike against the United States.[81]

China has developed the DF-41 intercontinental ballistic missile (ICBM), which, according to a 2014 report by the U.S.-China Economic and Security Review Commission, could carry a nuclear hypersonic glide vehicle.[82] General Terrence O'Shaughnessy, then-commander of U.S. Northern Command, seemed to confirm this assessment in February 2020, when he testified that "China is testing a [nuclear-capable] intercontinental-range hypersonic glide vehicle … which is designed to fly at high speeds and low altitudes, complicating our ability to provide precise warning."[83]

Reports indicate that China may have tested a nuclear-capable HGV[84]—launched by a Long March rocket—in August 2021.[85] In contrast to the ballistic missiles that China has previously

[80] Tong Zhao, "Conventional Challenges to Strategic Stability: Chinese Perceptions of Hypersonic Technology and the Security Dilemma," Carnegie-Tsinghua Center for Global Policy, July 23, 2018, at https://carnegietsinghua.org/2018/07/23/conventional-challenges-to-strategic-stability-chinese-perceptions-of-hypersonic-technology-and-security-dilemma-pub-76894.

[81] Ibid.; and Lora Saalman, "China's Calculus on Hypersonic Glide," August 15, 2017, Stockholm International Peace Research Institute, at https://www.sipri.org/commentary/topical-backgrounder/2017/chinas-calculus-hypersonic-glide.

[82] *U.S.-China Economic and Security Review Commission 2014 Annual Report*, p. 292, at https://www.uscc.gov/sites/default/files/annual_reports/Complete%20Report.PDF.

[83] General Terrence J. O'Shaughnessy, "Statement before the Senate Armed Services Committee," February, 13, 2020, at https://www.armed-services.senate.gov/imo/media/doc/OShaughnessy_02-13-20.pdf.

[84] It is not clear if this nuclear-capable HGV is the same model as that referenced by General O'Shaughnessy.

[85] Demetri Sevastopulo and Kathrin Hille, "China tests new space capability with hypersonic missile," October 16, 2021, at https://www.ft.com/content/ba0a3cde-719b-4040-93cb-a486e1f843fb. China's Foreign Ministry Spokesperson (continued...)

used to launch HGVs, the Long March, a fractional orbital bombardment system (FOBS), launches the HGV into orbit before the HGV de-orbits to its target. This could provide China with a space-based global strike capability and further reduce the amount of target warning time prior to a strike.[86]

China has additionally tested the DF-ZF hypersonic glide vehicle at least nine times since 2014. U.S. defense officials have reportedly identified the range of the DF-ZF as approximately 1,200 miles and have stated that the missile may be capable of performing evasive maneuvers during flight.[87] Although unconfirmed by intelligence agencies, some analysts believe the DF-ZF could have become operational as early as 2020.[88] In addition, in August 2018 China successfully tested Starry Sky-2, a nuclear-capable hypersonic vehicle prototype.[89] Some reports indicate that the Starry Sky-2 could be operational by 2025.[90] U.S. officials have declined to comment on the program.[91]

Russia

Although Russia has conducted research on hypersonic weapons technology since the 1980s, it accelerated its efforts in response to U.S. missile defense deployments in both the United States and Europe, and in response to the U.S. withdrawal from the Anti-Ballistic Missile Treaty in 2002.[92] Detailing Russia's concerns, President Putin stated in 2018 that "the US is permitting constant, uncontrolled growth of the number of anti-ballistic missiles, improving their quality, and creating new missile launching areas. If we do not do something, eventually this will result in the complete devaluation of Russia's nuclear potential. Meaning that all of our missiles could simply be intercepted."[93] Russia thus seeks hypersonic weapons, which can maneuver as they

Zhao Lijian has stated that "this was a routine test of [a] space vehicle," rather than a test of a nuclear-capable HGV. Zhao Lijian, "Remarks at Regular Press Conference," Ministry of Foreign Affairs of the People's Republic of China, October 18, 2021, at https://www.fmprc.gov.cn/mfa_eng/xwfw_665399/s2510_665401/t1915130.shtml.

[86] Greg Hadley, "Kendall: China Has Potential to Strike Earth From Space," *Air Force Magazine*, September 20, 2021, at https://www.airforcemag.com/global-strikes-space-china-frank-kendall/.

[87] "Gliding missiles that fly faster than Mach 5 are coming," *The Economist*, April 6, 2019, at https://www.economist.com/science-and-technology/2019/04/06/gliding-missiles-that-fly-faster-than-mach-5-are-coming; and Franz-Stefan Gady, "China Tests New Weapon Capable of Breaching US Missile Defense Systems," *The Diplomat*, April 28, 2016, at https://thediplomat.com/2016/04/china-tests-new-weapon-capable-of-breaching-u-s-missile-defense-systems/.

[88] *U.S.-China Economic and Security Review Commission 2015 Annual Report*, p. 20, at https://www.uscc.gov/sites/default/files/annual_reports/2015%20Annual%20Report%20to%20Congress.PDF.

[89] Jessie Yeung, "China claims to have successfully tested its first hypersonic aircraft," *CNN*, August 7, 2018, at https://www.cnn.com/2018/08/07/china/china-hypersonic-aircraft-intl/index.html. See also *U.S.-China Economic and Security Review Commission 2018 Annual Report*, p. 220, at https://www.uscc.gov/sites/default/files/annual_reports/2018%20Annual%20Report%20to%20Congress.pdf.

[90] *U.S.-China Economic and Security Review Commission Report 2015*, p. 20.

[91] Bill Gertz, "China Reveals Test of New Hypersonic Missile," *The Washington Free Beacon*, August 10, 2018, at https://freebeacon.com/national-security/chinas-reveals-test-new-hypersonic-missile/.

[92] United Nations Office of Disarmament Affairs, *Hypersonic Weapons: A Challenge and Opportunity for Strategic Arms Control*, February 2019, at https://www.un.org/disarmament/publications/more/hypersonic-weapons-a-challenge-and-opportunity-for-strategic-arms-control/.

[93] Vladimir Putin, "Presidential Address to the Federal Assembly," March 1, 2018, at http://en.kremlin.ru/events/president/news/56957.

approach their targets, as an assured means of penetrating U.S. missile defenses and restoring its sense of strategic stability.[94]

Russia is pursuing two nuclear-capable hypersonic weapons: the Avangard and the 3M22 Tsirkon (or Zircon).[95] Avangard is a hypersonic glide vehicle launched from an ICBM, giving it "effectively 'unlimited' range."[96] Reports indicate that Avangard is currently deployed on the SS-19 Stiletto ICBM, though Russia plans to eventually launch the vehicle from the Sarmat ICBM. Sarmat reportedly entered combat duty in September 2023.[97] Tsirkon has a range of between approximately 250 and 600 miles and can be fired from the vertical launch systems mounted on cruisers *Admiral Nakhimov* and *Pyotr Veliky*, Project 20380 corvettes, Project 22350 frigates, and Project 885 Yasen-class submarines, among other platforms.[98] Russian news sources assert that Tsirkon was successfully launched from a Project 22350 frigate in January, October, and December 2020 and May 2022, and from a Project 885 Yasen-class submarine in October 2021.[99] Russia reportedly deployed Tsirkon on the Project 22350 frigate *Admiral of the Fleet of the Soviet Union Gorshkov* in January 2023.[100]

International Institutions

No international treaty or agreement is dedicated to overseeing the development of hypersonic weapons. Although the New START Treaty—a strategic offensive arms treaty between the United States and Russia—does not specifically limit hypersonic weapons, it does limit ICBMs, which could be used to launch hypersonic glide vehicles.[101] Because Russia has deployed its Avangard hypersonic glide vehicle on an SS-19 ICBM, it has agreed that missiles equipped with Avangard count under New START. Furthermore, Article V of the treaty states that "when a Party believes that a new kind of strategic offensive arm is emerging, that Party shall have the right to raise the

[94] In this instance, "strategic stability" refers to a "bilateral nuclear relationship of mutual vulnerability." See Tong Zhao, "Conventional Challenges to Strategic Stability: Chinese Perceptions of Hypersonic Technology and the Security Dilemma," Carnegie-Tsinghua Center for Global Policy, July 23, 2018, at https://carnegietsinghua.org/2018/07/23/conventional-challenges-to-strategic-stability-chinese-perceptions-of-hypersonic-technology-and-security-dilemma-pub-76894.

[95] Although it is frequently characterized as a "hypersonic weapon"—including by U.S. defense officials, a third weapon, the Kinzhal, is a maneuvering air-launched ballistic missile. See, for example, CSIS Missile Defense Project, "Kh-47M2 Kinzhal," Updated March 19, 2022, at https://missilethreat.csis.org/missile/kinzhal/.

[96] Steve Trimble, "A Hypersonic Sputnik?," *Aviation Week*, January 14-27, 2019, p. 20.

[97] Al Jazeera, "Russia puts advanced Sarmat nuclear missile system on 'combat duty,'" September 2, 2023, at https://www.aljazeera.com/news/2023/9/2/russia-puts-advanced-sarmat-nuclear-missile-system-on-combat-duty#:~:text=Russia%20test%2Dfired%20the%20Sarmat,in%20Russia's%20far%20east%20region. Sarmat could reportedly accommodate at least three Avangard vehicles. See Malcolm Claus, "Russia unveils new strategic delivery systems," *Jane's* (subscription required), at https://janes.ihs.com/Janes/Display/FG_899127-JIR.

[98] "Russia makes over 10 test launches of Tsirkon seaborne hypersonic missile," *TASS*, December 21, 2018, at http://tass.com/defense/1037426. See also *Russia Military Power: Building a Military to Support Great Power Aspirations*, Defense Intelligence Agency, 2017, p. 79, at https://www.dia.mil/portals/27/documents/news/military%20power%20publications/russia%20military%20power%20report%202017.pdf.

[99] "TASS: Russia Conducts First Ship-Based Hypersonic Missile Test," *Reuters*, February 27, 2020, at https://www.voanews.com/europe/tass-russia-conducts-first-ship-based-hypersonic-missile-test; and Samuel Cranny-Evans, "Russia conducts first submarine test launches of Tsirkon hypersonic missile," *Jane's* (subscription required), October 4, 2021.

[100] Guy Faulconbridge, "Putin deploys new Zircon hypersonic cruise missiles to Atlantic," Reuters, January 4, 2023, at https://www.reuters.com/world/europe/putin-sends-off-frigate-armed-with-new-hypersonic-cruise-missile-2023-01-04/.

[101] For example, Russia's Avangard hypersonic glide vehicle is reportedly launched by an intercontinental ballistic missile. See Rachel S. Cohen, "Hypersonic Weapons: Strategic Asset or Tactical Tool?," *Air Force Magazine*, May 7, 2019, at https://www.airforcemag.com/hypersonic-weapons-strategic-asset-or-tactical-tool/.

question of such a strategic offensive arm for consideration in the Bilateral Consultative Commission (BCC).” Accordingly, some legal experts hold that it would be possible to negotiate provisions that would count additional types of hypersonic weapons under the New START limits.[102] However, because New START is due to expire in 2026, this may be a short-term solution.[103] In addition, the treaty would not cover hypersonic weapons developed in countries other than the United States and Russia.[104]

Finally, some analysts have noted that if any parties to the Outer Space Treaty were to launch a nuclear-armed HGV on a fractional orbital bombardment system, they would likely be in violation of Article IV of the treaty, which prohibits the placement of “any objects carrying nuclear weapons or any other kinds of weapons of mass destruction” into orbit.[105]

Potential Questions for Congress

- What mission(s) will hypersonic weapons be used for? Are hypersonic weapons the most cost-effective means of executing these potential missions?
- Given the lack of defined mission requirements for hypersonic weapons, how should Congress evaluate funding requests for hypersonic weapons programs or the balance of funding requests for hypersonic weapons programs, enabling technologies, and supporting test infrastructure?
- How, if at all, will the fielding of hypersonic weapons affect strategic stability? Is there a need for risk-mitigation measures, such as expanding New START, negotiating new multilateral arms control agreements, or undertaking transparency and confidence-building activities?

Directed Energy (DE) Weapons[106]

DOD defines directed energy (DE) weapons as those using concentrated electromagnetic energy, rather than kinetic energy, to “incapacitate, damage, disable, or destroy enemy equipment, facilities, and/or personnel.”[107] DE weapons could be used by ground forces in short-range air defense (SHORAD), counter-unmanned aircraft systems (C-UAS), or counter-rocket, artillery, and mortar (C-RAM) missions.[108] DE weapons could offer low costs per shot and—assuming

[102] James Acton notes: “during [New START] negotiations, Russia argued that boost-glide weapons might constitute ‘a new kind of strategic offensive arm,’ in which case they would trigger bilateral discussions about whether and how they would be regulated by the treaty—a position [then] rejected by the United States.” James M. Acton, *Silver Bullet?: Asking the Right Questions about Conventional Prompt Global Strike*, Carnegie Endowment for International Peace, 2013, p. 139, at https://carnegieendowment.org/files/cpgs.pdf.

[103] CRS Report R41219, *The New START Treaty: Central Limits and Key Provisions*, by Amy F. Woolf.

[104] In addition to China, countries with hypersonic weapons development programs include Australia, India, France, Germany, South Korea, North Korea, and Japan. For additional information, see CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*, by Kelley M. Sayler.

[105] Jeffrey Lewis, “China’s Orbital Bombardment System Is Big, Bad News—but Not a Breakthrough,” *Foreign Policy*, October 18, 2021, at https://foreignpolicy.com/2021/10/18/hypersonic-china-missile-nuclear-fobs/.

[106] For additional information about directed energy weapons, see CRS Report R46925, *Department of Defense Directed Energy Weapons: Background and Issues for Congress*, coordinated by Kelley M. Sayler.

[107] Joint Chiefs of Staff, *Joint Electromagnetic Spectrum Operations, Joint Publication 3-85*, May 22, 2020, GL-6.

[108] For more information about the role of DE weapons in C-UAS missions, see CRS In Focus IF11426, *Department of Defense Counter-Unmanned Aircraft Systems*, by John R. Hoehn and Kelley M. Sayler.

access to a sufficient power supply[109]—nearly limitless magazines that, in contrast to existing conventional systems, could enable an efficient and effective means of defending against missile salvos or swarms of unmanned systems. Theoretically, DE weapons could also provide options for boost-phase missile intercept, given their speed-of-light travel time; however, as in the case of hypersonic missile defense, experts disagree on the affordability, technological feasibility, and utility of this application.[110]

High-powered microwave weapons, a subset of DE weapons, could be used as a nonkinetic means of disabling electronics, communications systems, and improvised explosive devices, or as a nonlethal "heat ray" system for crowd control.

United States

Although the United States has been researching directed energy since the 1960s, some experts have observed that "actual directed energy programs … have frequently fallen short of expectations," with DOD investing billions of dollars in programs that were ultimately cancelled.[111] Others contend that developments in commercial lasers could be leveraged for military applications.[112] Directed energy weapons programs continue, however, to face questions about their technological maturity, including questions about the ability to improve beam quality and control to militarily useful levels and the ability to meet power, cooling, and size requirements for integration into current platforms.[113]

The U.S. Navy fielded the first operational U.S. DE weapon, the Laser Weapon System (LaWS), in 2014 aboard the USS *Ponce*. LaWS was a 30-kilowatt (-kW) laser prototype that "was capable of blinding enemy forces as a warning, shooting down drones, disabling boats, or damaging helicopters."[114] In addition, the Navy installed its 60-kW laser, HELIOS, on the USS *Preble* in FY2022 and plans to continue at-sea testing through at least the end of FY2028.[115] Similarly, the Army delivered a platoon of 50-kW Directed Energy Mobile Short-Range Air Defense System prototypes to the 4th Battalion, 60th Air Defense Artillery Regiment (Fort Sill, Oklahoma) in

[109] Although research has been conducted on chemically fueled lasers, most countries are now pursuing solid state lasers, which are fueled by electrical power. As a result, the cost per shot is equivalent to the cost of the electrical power required to fire the shot. See Ariel Robinson, "Directed Energy Weapons: Will They Ever Be Ready?," *National Defense*, July 1, 2015, at https://www.nationaldefensemagazine.org/articles/2015/7/1/2015july-directed-energy-weapons-will-they-ever-be-ready.

[110] See, for example, James N. Miller and Frank A. Rose, "Bad Idea: Space-Based Interceptors and Space-Based Directed Energy Systems," Center for Strategic and International Studies, December 13, 2018, at https://defense360.csis.org/bad-idea-space-based-interceptors-and-space-based-directed-energy-systems/; and Justin Doubleday, "Pentagon punts MDA's laser ambitions, shifts funding toward OSD-led 'laser scaling,'" *Inside Defense*, February 19, 2020, at https://insidedefense.com/daily-news/pentagon-punts-mdas-laser-ambitions-shifts-funding-toward-osd-led-laser-scaling.

[111] Paul Scharre, Preface to "Directed-Energy Weapons: Promise and Prospects," Center for a New American Security, April 2015, p. 4.

[112] See Ariel Robinson, "Directed Energy Weapons: Will They Ever Be Ready?," *National Defense*, July 1, 2015, at https://www.nationaldefensemagazine.org/articles/2015/7/1/2015july-directed-energy-weapons-will-they-ever-be-ready.

[113] Ibid.

[114] Kyle Mizokami, "The U.S. Army Plans To Field the Most Powerful Laser Weapon Yet," *Popular Mechanics*, August 7, 2019. Kilowatts are units of power. For example, 1 kilowatt is equal to 1,000 watts.

[115] DOD, *Department of Defense, Fiscal Year (FY) 2024 Budget Estimates, Navy Justification Book Volume 2 of 5*, Research, Development, Test & Evaluation, Navy, March 2023, p. 979, at https://www.secnav.navy.mil/fmc/fmb/Documents/24pres/RDTEN_BA4_Book.pdf.

2023.[116] The Air Force is currently conducting field assessments of several counter-UAS DE systems, including both laser and high-powered microwave systems.[117]

Overall, DOD requested approximately $1 billion for directed energy weapons programs in FY2024.[118] Many of these programs are intended to support DOD's Directed Energy Roadmap. According to OUSD(R&E), DOD's DE roadmap outlines DOD's plans to increase power levels of HEL weapons from around 150 kilowatt (kW), as is currently feasible, to 500 kW class—with reduced size and weight—by FY2025. DOD seeks "to further reduce size and weight and increase power to MW [megawatt] levels by FY2026."[119]

China

According to the US-China Economic and Security Review Commission, China has been developing DE weapons since at least the 1980s and has made steady progress in developing HPM and increasingly powerful HELs.[120] China has reportedly developed a 30-kilowatt road-mobile DE system, LW-30, designed to engage unmanned aerial vehicles and precision-guided weapons.[121] Reports indicate that China is also developing an airborne DE weapon pod and has used or proposed using DE weapons to interfere with U.S. and allied military aircraft and to disrupt U.S. freedom of navigation operations in the Indo-Pacific.[122]

According to the Defense Intelligence Agency, China is additionally pursuing DE weapons

> to disrupt, degrade, or damage satellites and their sensors and possibly already has a limited capability to employ laser systems against satellite sensors. China likely will field a ground-based laser weapon that can counter low-orbit space-based sensors by 2020, and by the mid-to-late 2020s, it may field higher power systems that extend the threat to the structures of non-optical satellites.[123]

[116] Venetia Gonzales, "Groundbreaking laser prototype systems delivered to 4-60th Air Defense Artillery Regiment," U.S. Army, September 21, 2023, at https://www.army.mil/article/270134/groundbreaking_laser_prototype_systems_delivered_to_4_60th_air_defense_artillery_regiment.

[117] For a more in-depth discussion of U.S. DE programs, see CRS Report R46925, *Department of Defense Directed Energy Weapons: Background and Issues for Congress*, coordinated by Kelley M. Sayler.

[118] CRS conversation with Principal Director for Directed Energy Dr. Frank Peterkin, May 17, 2023. See also Government Accountability Office, *Directed Energy Weapons: DOD Should Focus Transition on Planning*, April 2023, p. 1.

[119] CRS correspondence with the Office of the Under Secretary of Defense for Research and Engineering, September 8, 2022. For reference, although no consensus exists regarding the precise power level that would be needed to neutralize different target sets, DOD briefing documents suggest that a laser of approximately 100 kW could engage UASs, rockets, artillery, and mortars, whereas 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). Lasers of 1 MW could potentially neutralize ballistic missiles and hypersonic weapons. Dr. Jim Trebes, "Advancing High Energy Laser Weapon Capabilities: What is OUSD (R&E) Doing?," presentation at IDGA, October 21, 2020; and CRS conversation with then-Principal Director for Directed Energy Modernization Dr. Jim Trebes, November 17, 2020. Required power levels could be affected by additional factors such as adversary countermeasures and atmospheric conditions and effects.

[120] US-China Economic and Security Review Commission (USCC), *USCC 2017 Annual Report*, November 2017, p. 563, at https://www.uscc.gov/sites/default/files/2019-09/2017_Annual_Report_to_Congress.pdf.

[121] Nikolai Novichkov, "Airshow China 2018: CASIC's LW-30 laser weapon system breaks cover," *Jane's Defence Weekly*, November 9, 2018.

[122] Andrew Tate, "China aiming to procure airborne laser-based weapon pod," *Jane's Defence Weekly*, January 8, 2020; and Patrick M. Cronin and Ryan D. Neuhard, "Countering China's Laser Offensive," The Diplomat, April 2, 2020, at https://thediplomat.com/2020/04/countering-chinas-laser-offensive/.

[123] Defense Intelligence Agency, *Challenges to Security in Space*, February 2019, p. 20, at https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf.

Russia

Russia has been conducting DE weapons research since the 1960s, with a particular emphasis on HELs. Russia has reportedly deployed the Peresvet, a mobile, ground-based HEL, with several mobile intercontinental ballistic missile units. Although little is publicly known about Peresvet, including its power level, some analysts assert it is to dazzle satellites and provide point defense against unmanned aircraft systems.[124] Russia's deputy defense minister Alexei Krivoruchko has stated that efforts are underway to increase Peresvet's power level and to deploy it on military aircraft.[125] Reports suggest that Russia may also be developing HPMs as well as additional HELs capable of performing antisatellite missions.

International Institutions

DE weapons "are not authoritatively defined under international law, nor are they currently on the agenda of any existing multilateral mechanism."[126] However, certain applications of DE weapons are prohibited. For example, Protocol I of the CCW "Protocol on Blinding Lasers" prohibits the employment of "laser weapons specifically designed, as their sole combat function or as one of their combat functions, to cause permanent blindness to unenhanced vision."[127] Some analysts have suggested that multilateral agreements should be considered. For example, Congress may consider prohibitions on nonlethal anti-personnel uses of DE weapons—such as "heat rays" or lasers intended to cause temporary visual impairment—or on certain military applications of DE weapons—such as aircraft interference—in peacetime.[128] Other analysts have argued that DE weapons could be considered more humane than conventional weapons because their accuracy could potentially reduce collateral damage and because they could provide a nonlethal anti-personnel capability in circumstances in which lethal force might otherwise be used.[129]

Potential Questions for Congress

- Does the technological maturity of DE weapons warrant current funding levels? To what extent, if at all, can advances in commercial lasers be leveraged for military applications?

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[124] Defense Intelligence Agency, *Challenges to Security in Space*, February 2019, p. 23, at https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf; and "Putin hails new Russian laser weapons," *Associated Press*, May 17, 2019, at https://apnews.com/ff03960c48a6440bacc1c2512a7c197a.

[125] Bart Hendrickx, "Peresvet: a Russian mobile laser system to dazzle enemy satellites," *The Space Review*, June 5, 2020, at https://www.thespacereview.com/article/3967/1.

[126] "Directed Energy Weapons: Discussion paper for the Convention on Certain Conventional Weapons (CCW)," Article 36, November 2017.

[127] The protocol does not cover the development, procurement, or possession of such weapons, nor does it prohibit the employment of laser weapons that may cause blindness "as an incidental or collateral effect." *Additional Protocol to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May Be Deemed to Be Excessively Injurious or to Have Indiscriminate Effects*, Vienna, October 13, 1995, United Nations, Treaty Series, vol. 1380, p. 370, at https://treaties.un.org/doc/Treaties/1995/10/19951013%2001-30%20AM/Ch_XXVI_02_ap.pdf. For additional information about the protocol and its relationship to DE weapons programs, see Appendix I of CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke.

[128] Patrick M. Cronin and Ryan D. Neuhard, "Countering China's Laser Offensive," The Diplomat, April 2, 2020, at https://thediplomat.com/2020/04/countering-chinas-laser-offensive/.

[129] See, for example, Mark Gunzinger and Chris Dougherty, *Changing the Game: The Promise of Directed-Energy Weapons*, Center for Strategic and Budgetary Assessments, April 19, 2021, at https://csbaonline.org/uploads/documents/CSBA_ChangingTheGame_ereader.pdf.

- How successful have U.S. field tests of DE weapons been? Are any changes to operational concepts, rules of engagement, or tactics required to optimize the use of DE weapons or deconflict the use of DE weapons with other U.S. military operations?
- In what circumstances and for what purposes should the U.S. military's use of DE weapons be permissible? What, if any, regulations, treaties, or other measures should the United States consider with regard to the use of DE weapons in both war and peacetime?

Biotechnology

Biotechnology leverages life sciences for technological applications. A number of developments in biotechnology hold potential implications for the U.S. military and for international security writ large. As a 2018 Government Accountability Office report notes, the Departments of Defense, State, and Homeland Security, and the Office of the Director of National Intelligence assess that biotechnologies, such as the low-cost gene-editing tool CRISPR,[130] have the potential to

> alter genes or create DNA to modify plants, animals, and humans. Such biotechnologies could be used to enhance [or degrade] the performance of military personnel. The proliferation of synthetic biology—used to create genetic code that does not exist in nature—may increase the number of actors that can create chemical and biological weapons.[131]

Similarly, the U.S. intelligence community's 2016 Worldwide Threat Assessment cited genome editing as a potential weapon of mass destruction.[132]

In addition, biotechnology could be used to create adaptive camouflage, cloaking devices, or lighter, stronger, and—potentially—self-healing body and vehicle armor.[133] Concerns have been raised that U.S. competitors may not hold the same ethical standards in the research and application of biotechnologies, particularly regarding biological weapons, genome editing, or more invasive forms of human performance modification.[134]

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[130] For a general overview of CRISPR, see CRS Report R44824, *Advanced Gene Editing: CRISPR-Cas9*, by Marcy E. Gallo et al.

[131] Government Accountability Office, *National Security: Long-Range Emerging Threats Facing the United States as Identified by Federal Agencies*, December 2018, at https://www.gao.gov/assets/700/695981.pdf.

[132] James R. Clapper, "Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community," delivered before the U.S. Senate Committee on Armed Services, February 9, 2016.

[133] Patrick Tucker, "The US Army Is Making Synthetic Biology a Priority," *Defense One*, July 1, 2019; and "Army scientists explore synthetic biology potential," U.S. Army, June 24, 2019, at https://www.army.mil/article/223495/army_scientists_explore_synthetic_biology_potential.

[134] James R. Clapper, "Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community," delivered before the U.S. Senate Committee on Armed Services, February 9, 2016; and Daniel R. Coats, "Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community," delivered before the U.S. Senate Committee on Armed Services, March 6, 2018. Although the U.S. military has long used certain drugs such as caffeine, modafinil, dextroamphetamine, and various sleep aids to enhance soldier performance, it bans other performance-enhancing drugs and techniques such as anabolic steroids and blood doping. See Paul Scharre and Lauren Fish, *Human Performance Enhancement*, Center for a New American Security, November 7, 2018, at https://www.cnas.org/publications/reports/human-performance-enhancement-1.

United States

Overall, DOD requested $1.3 billion for biotechnology efforts in FY2023; the department did not provide a topline breakout of its request for biotechnology in FY2024.[135] Unclassified U.S. biotechnology programs with military applications center primarily on improving "readiness, resilience, and recovery." DARPA, for example, has a number of biotechnology programs devoted to battlefield medicine, diagnostics, and prognostics. It is also exploring options for mitigating the effects of traumatic brain injury, treating neuropsychiatric illnesses such as depression and post-traumatic stress, and protecting against infectious diseases and bio-engineered threats to the U.S. food supply. In addition, DARPA's Safe Genes program seeks "to [protect] service members from accidental or intentional misuse of genome editing technologies."[136]

DOD is also exploring "advanced development and operational testing of biomanufacturing capabilities to provide alternative sources for critical supply chain materials" and other "products needed for non-medical supply chain resiliency," and is to invest $1 billion in bioindustrial domestic manufacturing infrastructure over five years.[137] Similarly, DOD has announced the establishment of a Tri-Service Biotechnology for a Resilient Supply Chain program, which is to include "more than $270 million investment over five years … to support the advanced development of bio-based materials for defense supply chains, such as fuels, fire-resistant composites, polymers and resins, and protective materials."[138] In addition, Section 215 of the FY2023 NDAA directs the Secretary of Defense, subject to the availability of appropriations, to provide support for the development of a network of bioindustrial manufacturing facilities.[139] In support of these efforts, DOD released its *Biomanufacturing Strategy* in March 2023.[140]

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[135] Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, Defense Budget Overview: United States Department of Defense Fiscal Year 2023 Budget Request, April 2022, p. 4-7, at https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2023/FY2023_Budget_Request_Overview_Book.pdf.

[136] See Defense Advanced Research Projects Agency, "Our Research: Biological Technologies Office," at https://www.darpa.mil/our-research?tFilter=&oFilter=1.

[137] Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, *Defense Budget Overview: United States Department of Defense Fiscal Year 2023 Budget Request*, April 2022, p. 4-7, at https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2023/FY2023_Budget_Request_Overview_Book.pdf; and The White House, "FACT SHEET: The United States Announces New Investments and Resources to Advance President Biden's National Biotechnology and Biomanufacturing Initiative," September 14, 2022, at https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/14/fact-sheet-the-united-states-announces-new-investments-and-resources-to-advance-president-bidens-national-biotechnology-and-biomanufacturing-initiative/.

[138] The White House, "FACT SHEET: The United States Announces New Investments and Resources to Advance President Biden's National Biotechnology and Biomanufacturing Initiative," September 14, 2022, at https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/14/fact-sheet-the-united-states-announces-new-investments-and-resources-to-advance-president-bidens-national-biotechnology-and-biomanufacturing-initiative/.

[139] P.L. 117-263, Section 2, Division A, Title II, §215. DOD's FY2024 budget request notes that, following a $300 million congressional add in support of Section 215, the BioMADE Manufacturing Innovation Institute—a DOD-sponsored public-private partnership headquartered at the University of Minnesota in St. Paul—is to initiate the development of the network. DOD, *Department of Defense Fiscal Year (FY) 2024 Budget Estimates, Office of the Secretary of Defense, Defense-Wide Justification Book Volume 3 of 5 Research, Development, Test & Evaluation*, March 2023, p. 296, at https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2024/budget_justification/pdfs/03_RDT_and_E/OSD_PB2024.pdf.

[140] Department of Defense, *Biomanufacturing Strategy*, March 21, 2023, at https://media.defense.gov/2023/Mar/22/2003184301/-1/-1/1/BIOMANUFACTURING-STRATEGY.PDF.

Some reports suggest that the United States is also researching or has previously researched biotechnology and neuroscience applications to increase soldier lethality, including applications to make soldiers "stronger, smarter, [and] more capable, and … give them more endurance than other humans."[141] Some groups have expressed ethical concerns about this research; although the United States had a series of presidential bioethics commissions between 1974 and 2017, there is no current national framework for examining ethical concerns.[142]

Although there does not appear to be a DOD-specific biotechnology research strategy, the Biden Administration released the *National Biodefense Strategy and Implementation Plan for Countering Biological Threats, Enhancing Pandemic Preparedness, and Achieving Global Health Security*—as well as an associated *National Security Memorandum on Countering Biological Threats, Enhancing Pandemic Preparedness, and Achieving Global Health Security (NSM-15)*—in October 2022.[143] These documents outline "how the U.S. Government will manage its activities to more effectively assess, prevent, prepare for, respond to, and recover from biological threats, coordinating its biodefense efforts with those of [state, local, tribal, and territorial] entities, international partners, industry, academia, nongovernmental entities, and the private sector."[144] The Administration notes that, while it is currently "implementing key actions in the Strategy with existing funding," full implementation "will require the support of Congress to provide additional resources, including the President's $88 billion request over five years for pandemic preparedness and biodefense."[145]

Congress has expressed an interest in conducting oversight of the military applications of emerging biotechnologies. For example, per Section 263 of the FY2020 NDAA (P.L. 116-92), DOD is to conduct "a review of the military understanding and relevancy of applications of emerging biotechnologies to national security requirements of the Department of Defense" and provide recommendations for future legislative and administrative activities."[146] Section 278 of the FY2021 NDAA (P.L. 116-283) directs DOD to "conduct an assessment and direct comparison

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[141] Annie Jacobsen, *The Pentagon's Brain: An Uncensored History of DARPA, America's Top-Secret Military Research Agency* (New York: Little, Brown and Company, 2015). See also Michael Joseph Gross, "The Pentagon's Push to Program Soldiers' Brains," *The Atlantic*, November 2018, at https://www.theatlantic.com/magazine/archive/2018/11/the-pentagon-wants-to-weaponize-the-brain-what-could-go-wrong/570841/.

[142] For a history of these commissions, see Presidential Commission for the Study of Bioethical Issues, "History of Bioethics Commissions," archived January 15, 2017, at https://bioethicsarchive.georgetown.edu/pcsbi/history.html.

[143] The White House, *National Biodefense Strategy and Implementation Plan for Countering Biological Threats, Enhancing Pandemic Preparedness, and Achieving Global Health Security*, October 2022, at https://www.whitehouse.gov/wp-content/uploads/2022/10/National-Biodefense-Strategy-and-Implementation-Plan-Final.pdf; and The White House, *National Security Memorandum on Countering Biological Threats, Enhancing Pandemic Preparedness, and Achieving Global Health Security*, October 18, 2022, at https://www.whitehouse.gov/briefing-room/presidential-actions/2022/10/18/national-security-memorandum-on-countering-biological-threats-enhancing-pandemic-preparedness-and-achieving-global-health-security/. See also Diane Dieuliis, "Biotechnology for the Battlefield: In Need of a Strategy," *War on the Rocks*, November 27, 2018.

[144] The White House, *National Biodefense Strategy and Implementation Plan for Countering Biological Threats, Enhancing Pandemic Preparedness, and Achieving Global Health Security*, October 2022, at https://www.whitehouse.gov/wp-content/uploads/2022/10/National-Biodefense-Strategy-and-Implementation-Plan-Final.pdf.

[145] The White House, "Fact Sheet: Biden-Harris Administration Releases Strategy to Strengthen Health Security and Prepare for Biothreats," October 18, 2022, at https://www.whitehouse.gov/briefing-room/statements-releases/2022/10/18/fact-sheet-biden-harris-administration-releases-strategy-to-strengthen-health-security-and-prepare-for-biothreats/. This $88 billion request includes funds for the Department of Health and Human Services, the Office of the Assistant Secretary for Preparedness and Response, the Centers for Disease Control and Prevention, the National Institutes of Health, the Food and Drug Administration, the Department of State, and the U.S. Agency for International Development; it does not include funds for DOD.

[146] P.L. 116-92, Section 2, Division A, Title II, §263.

of capabilities in emerging biotechnologies for national security purposes ... between the capabilities of the United States and the capabilities of adversaries of the United States."[147] Similarly, Section 1312 of the FY2024 NDAA (P.L. 118-31) directs the Secretary of Defense to conduct "an analysis to determine if any biotechnology entity, or any subsidiary, parent, affiliate, or successor of such an entity, should be identified as a Chinese military company or a military-civil fusion contributor and included on [DOD's 1260H] list."[148]

Finally, Section 1091 of the FY2022 NDAA (P.L. 117-81) establishes the National Security Commission on Emerging Biotechnology, which is to "consider the methods, means, and investments necessary to advance and secure the development of biotechnology, biomanufacturing, and associated technologies by the United States to comprehensively address the national security and defense needs of the United States." The commission delivered an interim report to Congress in December 2023 and is to deliver its final report in December 2024.[149]

China

Motivated by an aging population and growing health care needs, China has been particularly interested in conducting biotechnology research. Biotechnology is cited as a key strategic priority within China's *Made in China 2025* initiative and is additionally highlighted within China's current five-year development plan.[150] In particular, China is aggressively pursuing biotechnologies for genetic testing and precision medicine. In 2016, Chinese scientists became the first to use the CRISPR gene-editing tool on humans, and in 2018, a Chinese scientist produced—perhaps with the approval of the Chinese government—the first "gene-edited babies."[151] In addition, China maintains one of the world's largest repositories of genetic information, the National Genebank, which includes U.S. genetic data. Such information could be used to develop personalized disease treatment plans or, potentially, precision bioweapons.[152]

Open-source information about China's research into specific military applications of biotechnology is limited; however, China's policy of military-civil fusion would enable the Chinese military to readily leverage developments in civilian biotechnology.[153] Furthermore, reports indicate that China's Central Military Commission "has funded projects on military brain science, advanced biomimetic systems, biological and biomimetic materials, human performance

[147] P.L. 116-283, Section 2, Division A, Title II, §278.

[148] For additional information about DOD's 1260H list, see Section 1260H of the FY2021 NDAA (P.L. 116-283).

[149] See National Security Commission on Emerging Biotechnology, *Interim Report*, December 2023, at https://www.biotech.senate.gov/press-releases/interim-report/.

[150] "Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035," *Xinhua News Agency*, March 12, 2021, Translated by Etcetera Language Group, Inc., at https://cset.georgetown.edu/wp-content/uploads/t0284_14th_Five_Year_Plan_EN.pdf.

[151] Amidst international outcry, China later sentenced the scientist to three years in jail and termed his work "extremely abominable in nature." Michael Standaert, "'Extremely abominable': Chinese gene-editing scientist faces law," *Al Jazeera*, November 26, 2018. See also, Elsa Kania, "Weaponizing Biotech: How China's Military Is Preparing for a 'New Domain of Warfare,'" *Defense One*, August 14, 2019.

[152] David J. Lynch, "Biotechnology: the US-China dispute over genetic data," *Financial Times*, July 31, 2017. See also Elsa Kania and Wilson VornDick, "China's Military Biotech Frontier: CRISPR, Military-Civil Fusion, and the New Revolution in Military Affairs," *The Jamestown Foundation*, October 8, 2019, at https://jamestown.org/program/chinas-military-biotech-frontier-crispr-military-civil-fusion-and-the-new-revolution-in-military-affairs/.

[153] Elsa Kania and Wilson VornDick, "Weaponizing Biotech: How China's Military Is Preparing for a 'New Domain of Warfare,'" *Defense One*, August 14, 2019, at https://www.defenseone.com/ideas/2019/08/chinas-military-pursuing-biotech/159167/.

enhancement, and 'new concept' biotechnology," while the Chinese military's medical institutions have conducted extensive research on CRISPR gene editing.[154]

Russia

Although Russia released BIO2020—a whole-of-government strategy for improving the standing of Russia's biotechnology sector—in 2012, biotechnology research in Russia continues to lag behind that of the United States and China.[155] BIO2020 identifies Russia's priority areas for biotechnology research as biopharmaceutics and biomedicine, industrial biotechnology and bioenergetics, agricultural and food biotechnology, forest biotechnology, environmental protection biotechnology, and marine biotechnology.[156]

Little information is publicly available on how Russia might employ such dual-use technologies within a military or national security context. However, the accusation that the country attempted to assassinate a former double agent for the United Kingdom using a Novichok nerve agent—in violation of the 1992 Chemical Weapons Convention—suggests that it may be similarly unrestrained in weaponizing biological agents, including those derived from synthetic biology.[157] Indeed, the Soviet Union is known to have maintained an extensive, long-standing biological weapons program, Biopreparat, in violation of the 1972 Biological Weapons Convention.[158] Furthermore, in August 2020, the End-User Review Committee (ERC)—composed of representatives of the U.S. Departments of Commerce, State, Defense, Energy, and, where appropriate, Treasury—stated that it has "reasonable cause" to believe that three Russian research institutes are associated with the Russian biological weapons program.[159]

International Institutions

Only the weaponization of biotechnology is prohibited under international law.[160] Some international institutions have demonstrated interest in considering broader implications of biotechnologies. For example, since 1983, ASEAN has maintained a subcommittee on biotechnology that facilitates coordination of regional biotechnology projects. Similarly, since 1993, the OECD has maintained an Internal Co-ordination Group for Biotechnology that monitors developments in biotechnology and facilitates coordination among various sectors involved in biotechnology research (e.g., agriculture, science and technology, environment, industry). In addition, the United Nations Convention on Biological Diversity is charged with

[154] Ibid.

[155] Russian Federation, "BIO2020: Summary of the State Coordination Program for the Development of Biotechnology in the Russian Federation," 2012.

[156] Ibid.

[157] Mark Urban, "Salisbury attack 'evidence' of Russian weapon stockpile," *BBC*, March 4, 2019. For a full assessment of the potential national security threats posed by synthetic biology, see the Committee on Strategies for Identifying and Addressing Potential Biodefense Vulnerabilities Posed by Synthetic Biology Consensus Report: *Biodefense in the Age of Synthetic Biology*, National Academy of Sciences, 2018, at http://nap.edu/24890.

[158] Lukas Trakimavičius "Is Russia Violating the Biological Weapons Convention?," Atlantic Council, May 23, 2018, at https://www.atlanticcouncil.org/blogs/new-atlanticist/is-russia-violating-the-biological-weapons-convention/.

[159] The ERC added these research institutes to the Entity List, which identifies entities acting "contrary to the national security or foreign policy interests of the United States." Department of Commerce, "Addition of Entities to the Entity List, and Revision of Entries on the Entity List," August 27, 2020, https://www.federalregister.gov/documents/2020/08/27/2020-18909/addition-of-entities-to-the-entity-list-and-revision-of-entries-on-the-entity-list.

[160] The United States, China, and Russia have ratified the 1972 Biological Weapons Convention, which is a legally binding treaty that bans the development and production of biological weapons.

governing the development and use of genetically modified organisms.[161] These entities are not, however, focused specifically on military applications of biotechnology.

In terms of potential militarization, the 1972 Biological Weapons Convention requires review conferences, which every five years assess both the implementation of the treaty and ongoing developments in biotechnology. Annual meetings are held between review conferences to informally consider relevant topics, as well as to address national bilateral and multilateral efforts to enhance biosecurity. Some analysts have argued that an international framework should be established to consider the militarization of biotechnologies and discuss potential regulation of or limits on certain applications.[162]

Potential Questions for Congress

- Is a DOD biotechnology strategy or organization needed to identify research priorities and coordinate department-wide research? What, if any, resources or organizational changes would be required to fully implement a national biodefense strategy?
- What military applications of biotechnologies are U.S. competitors developing? Is the U.S. military appropriately balancing the potential warfighting utility of biotechnologies with ethical considerations?
- What, if any, national and international frameworks are needed to consider the ethical, moral, and legal implications of military applications of biotechnologies such as synthetic biology, genome editing, and human performance modification?

Quantum Technology[163]

Quantum technology translates the principles of quantum physics into technological applications.[164] In general, quantum technology has not yet reached maturity; however, it could hold significant implications for the future of military sensing, encryption, and communications. GAO reports that DOD, State, DHS, and ODNI have assessed that "quantum communications could enable adversaries to develop secure communications that U.S. personnel would not be able to intercept or decrypt. Quantum computing may allow adversaries to decrypt [unclassified, classified, or sensitive] information, which could enable them to target U.S. personnel and military operations."[165]

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[161] The United States is not a party to this convention or its associated protocols.

[162] See, for example, Brett Edwards, "We've got to talk: The militarization of biotechnology," *Bulletin of the Atomic Scientists*, August 4, 2017, at https://thebulletin.org/2017/08/weve-got-to-talk-the-militarization-of-biotechnology/.

[163] See also CRS In Focus IF11836, *Defense Primer: Quantum Technology*, by Kelley M. Sayler.

[164] These principles include superposition—in which "a quantum system can exist in two or more states at once"—and entanglement—in which "two or more quantum objects in a system can be intrinsically linked such that measurement of one dictates the possible measurement outcomes for another, regardless of how far apart the two objects are." Emily Grumbling and Mark Horowitz, eds., *Quantum Computing: Progress and Prospects*, National Academy of Sciences, 2019, at https://www.nap.edu/read/25196/chapter/1. For additional information about quantum technology, see CRS Report R45409, *Quantum Information Science: Applications, Global Research and Development, and Policy Considerations*, by Patricia Moloney Figliola.

[165] Government Accountability Office, *National Security: Long-Range Emerging Threats Facing the United States as Identified by Federal Agencies*, December 2018, at https://www.gao.gov/assets/700/695981.pdf. Significant advances in quantum computing will likely be required to break current encryption methods. Indeed, some analysts believe that a (continued...)

Quantum technology could have other military applications, such as quantum sensing, which could theoretically enable significant improvements in submarine detection, rendering the oceans "transparent."[166] This could, in turn, compromise the survivability of the U.S. sea-based nuclear deterrent. Quantum sensing could also provide alternative positioning, navigation, and timing options that could in theory allow militaries to continue to operate at full performance in GPS-degraded or GPS-denied environments.

Military application of such technologies could be constrained, however, by the fragility of quantum states, which can be disrupted by minute movements, changes in temperature, or other environmental factors. As physicist Mikkel Hueck has explained, "if future devices that use quantum technologies [continue to] require cooling to very cold temperatures, then this will make them expensive, bulky, and power hungry."[167] As a result, widespread adoption will likely require significant advances in materials science and fabrication techniques.

United States

According to a Defense Science Board Task Force on Applications of Quantum Technologies assessment, three applications of quantum technologies demonstrate the most promise for the U.S. military: quantum sensing, quantum computing, and quantum communications.[168] The task force notes that quantum sensing could "dramatically improve" DOD's ability to conduct certain missions, providing precision navigation and timing options in environments in which GPS is degraded or denied; that quantum computers could "potentially give DOD substantial computation power" for decryption, signals processing, and AI; and that quantum communications could improve networking technologies.[169] The task force concludes that "quantum sensing applications are currently poised for mission use whereas quantum computing and communications are in earlier stages of development…. Quantum radar will not provide upgraded capability to DOD."[170] Both DARPA and the services fund an array of quantum technology programs across these and other research areas.

In addition, some analysts believe that an initial quantum computer prototype capable of breaking current encryption methods could be developed in the 2030 to 2040 timeframe.[171] For this reason, the United States is investing in post-quantum cryptography (also known as quantum-resistant cryptography). In May 2022, the Biden administration released *National Security Memorandum*

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quantum computer with around 20 million qubits—shorthand for "quantum bits," or computing units that leverage the principle of superposition—would be required to break these methods; the most advanced quantum computers today have around 256 qubits. See Siobhan Roberts, "This new startup has built a record-breaking 256-qubit quantum computer," *MIT Technology Review*, November 17, 2021, at https://www.technologyreview.com/2021/11/17/1040243/quantum-computer-256-bit-startup/.

[166] Michael J. Biercuk and Richard Fontaine, "The Leap into Quantum Technology: A Primer for National Security Professionals," *War on the Rocks*, November 17, 2017, at https://warontherocks.com/2017/11/leap-quantum-technology-primer-national-security-professionals/.

[167] U.S. Army Research Lab Public Affairs, "Army researchers see path to quantum computing at room temperature," April 30, 2020, at https://www.army.mil/article/235127/army_researchers_see_path_to_quantum_computing_at_room_temperature#:~:text=%E2%80%9CIf%20future%20devices%20that%20use,power%20hungry%2C%E2%80%9D%20Heuck%20said.

[168] Defense Science Board, *Applications of Quantum Technologies: Executive Summary*, October 2019, at https://dsb.cto.mil/reports.htm.

[169] Ibid.

[170] Ibid.

[171] See, for example, "Quantum computers will break the encryption that protects the internet," *The Economist*, October 10, 2018, at https://www.economist.com/science-and-technology/2018/10/20/quantum-computers-will-break-the-encryption-that-protects-the-internet.

on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems (NSM-10), which "directs specific actions for agencies to take as the United States begins the multi-year process of migrating vulnerable computer systems to quantum-resistant cryptography."[172] NSM-10 notes that the Director of the National Institute of Standards and Technology and the Director of the National Security Agency (NSA) are developing and expected to publicly release by 2024 technical standards for quantum-resistant cryptography. In September 2022, NSA issued a cybersecurity advisory stating that it "expects the transition to [quantum-resistant] algorithms for [national security systems] to be complete by 2035 in line with NSM-10."[173]

Per Section 234 of the FY2019 NDAA (P.L. 115-232), the Secretary of Defense—acting through the Under Secretary of Defense for Research and Engineering—is tasked with coordinating quantum technology programs and providing "for interagency cooperation and collaboration on quantum information science and technology research and development between the Department of Defense and other departments and agencies of the United States and appropriate private sector entities."[174] In addition, Section 220 of the FY2020 NDAA (P.L. 116-92) authorizes the Secretary of each military department to establish Quantum Information Science (QIS) Research Centers that may "engage with appropriate public and private sector organizations" to advance quantum research. To date, the Navy has designated the Naval Research Laboratory as its QIS Research Center, while the Air Force has designated the Air Force Research Laboratory as a QIS Research Center for both the Air Force and Space Force. The Army does not plan to establish a QIS Research Center at this time.[175]

Finally, Section 214 of the FY2021 NDAA (P.L. 116-283) directs the services to compile and annually update a list of technical challenges that quantum computers could potentially address within the next one to three years.[176] It also directs the services to establish programs with small and medium businesses to provide quantum computing capabilities to government, industry, and academic researchers working on these challenges. Section 1722 directs DOD to conduct an assessment of the risks posed by quantum computers, as well as current standards for post-quantum cryptography. In addition, Section 229 of the FY2022 NDAA (P.L. 117-81) directs the Secretary of Defense to establish activities to "to accelerate the development and deployment of dual-use quantum capabilities," while Section 511 expands the grant program for science, technology, engineering, and math education in the Junior Research Officers' Training Corps to include quantum information sciences.

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[172] The White House, *National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems*, May 4, 2022, at https://www.whitehouse.gov/briefing-room/statements-releases/2022/05/04/national-security-memorandum-on-promoting-united-states-leadership-in-quantum-computing-while-mitigating-risks-to-vulnerable-cryptographic-systems/.

[173] National Security Agency, "Cybersecurity Advisory: Announcing the Commercial National Security Algorithm Suite 2.0," September 7, 2022, at https://media.defense.gov/2022/Sep/07/2003071834/-1/-1/0/CSA_CNSA_2.0_ALGORITHMS_.PDF.

[174] Section 219 of the FY2024 NDAA amended this provision to authorize the Secretary of Defense to "carry out a program of fellowships in quantum information science and technology research and development for individuals who have a graduate or postgraduate degree." Similarly, Section 220 of the FY2024 NDAA (P.L. 118-31) directs the Secretary of Defense to "to establish public-private talent exchange programs with private-sector entities working on quantum information sciences and technology research applications."

[175] CRS correspondence with the Office of the Under Secretary of Defense for Research and Engineering, April 5, 2021.

[176] On behalf of the services, the Office of the Under Secretary of Defense for Research and Engineering identified these challenges as quantum chemistry, optimization, and machine learning. CRS correspondence with the Office of the Under Secretary of Defense for Research and Engineering, March 25, 2022.

Finally, Section 231 of the FY2024 NDAA (P.L. 118-31) authorizes the Secretary of Defense to carry out a pilot program on near-term quantum computing applications.

China

China has increasingly prioritized quantum technology research within its development plans.[177] Indeed, President Xi has cited quantum communications and quantum computing as key research initiatives "prioritized for major breakthroughs by 2030," an objective that is also cited in the country's National Science and Technology Innovation Program.[178] China is already a world leader in quantum technology. In 2016, China launched the world's first quantum satellite (Micius) to provide a "global quantum encrypted communications capability."[179] In 2017, China hosted the first quantum-secured intercontinental videoconference.[180] Furthermore, China is investing heavily in terrestrial quantum communications networks. It completed construction of a 2,000 kilometer (approximately 1,250 miles) Beijing-Shanghai quantum network in 2016 and plans to expand that network nationwide in the years to come.[181] While such advances in quantum technology have been driven primarily by academia, China has expressed its intent to leverage them for military applications in the country's Thirteenth Five-Year S&T Military-Civil Fusion Special Projects Plan.

Russia

Russian development of quantum technology, as with artificial intelligence, lags significantly behind that of the United States and China, with some analysts noting that Russia is likely "5 to 10 years behind" in quantum computing.[182] In an effort to spur development, Russia announced plans in December 2019 to invest $790 million in quantum research over the next five years and adopted a five-year Russian Quantum Technologies Roadmap.[183] These initiatives are not

[177] For a history of China's quantum technology research and development initiatives, see Elsa B. Kania and John Costello, *Quantum Hegemony?: China's Ambitions and the Challenge to U.S. Innovation Leadership*, Center for a New American Security, September 2018, p. 8, at https://s3.amazonaws.com/files.cnas.org/documents/CNASReport-Quantum-Tech_FINAL.pdf?mtime=20180912133406.

[178] Ibid., p. 6.

[179] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2019*, May 2, 2019, p. 146, at https://media.defense.gov/2019/May/02/2002127082/-1/-1/1/2019_CHINA_MILITARY_POWER_REPORT.pdf. This satellite—as well as the other communications networks discussed in this section—employ quantum key distribution (QKD), a subset of quantum communications. QKD enables secure communications that cannot be covertly intercepted during transmission. QKD communications can, however, be intercepted at the relay stations currently required for long-distance transmissions.

[180] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2019*, May 2, 2019, p. 101, at https://media.defense.gov/2019/May/02/2002127082/-1/-1/1/2019_CHINA_MILITARY_POWER_REPORT.pdf.

[181] Elsa B. Kania and John Costello, *Quantum Hegemony?: China's Ambitions and the Challenge to U.S. Innovation Leadership*, p. 14. This terrestrial network is reportedly connected to Micius, which provides a satellite link "spanning 2,600 km [1,600 miles] between two observatories—one east of Beijing and the other just a few hundred kilometers from China's border with Kazakhstan." See Hamish Johnston, "Quantum cryptography network spans 4600 km in China," *Physics World*, January 7, 2021, at https://physicsworld.com/a/quantum-cryptography-network-spans-4600-km-in-china/.

[182] Quirin Schiermeier, "Russia joins race to make quantum dreams a reality," *Nature*, December 17, 2019, at https://www.nature.com/articles/d41586-019-03855-z.

[183] For comparison, the U.S. National Quantum Initiative Act (P.L. 115-368), signed into law in December 2018, commits the United States to investing $1.25 billion in quantum research over five years.

military-specific, however, and limited information is available in open sources about how Russia might apply them to its military.

International Institutions

No major international institutions have formal initiatives devoted to monitoring or regulating military or other applications of quantum technology.

Potential Questions for Congress

- Does the maturity of military applications of quantum technology warrant current funding levels? To what extent, if at all, can advances in commercial quantum technology be leveraged for military applications?
- Are adequate measures being taken to develop quantum-resistant encryption and to protect data that has been encrypted using current methods?
- How mature are U.S. competitor efforts to develop military applications of quantum technologies? To what extent, if at all, could such efforts threaten advanced U.S. military capabilities such as submarines and fifth-generation stealth aircraft?

Potential Implications of Emerging Technologies for Warfighting

The implications of emerging technologies for warfighting and strategic stability are difficult—if not impossible—to predict, as they will be a function of many factors, including the rate of technological advancement in both the United States and competitor nations, the manner in which emerging technologies are integrated into existing military forces and concepts of operation, the interactions between emerging technologies, and the extent to which national policies and international law enable or inhibit their development, integration, and use.

Nonetheless, many emerging technologies exhibit characteristics that could potentially affect the future character of war. For example, developments in technologies such as AI, big data analytics, and lethal autonomous weapons could diminish or remove the need for a human operator. This could, in turn, increase combat efficiency and accelerate the pace of combat—potentially with destabilizing consequences.

Emerging technologies such as low-cost drones could shift the balance between quality—upon which U.S. military forces have traditionally relied—and quantity, as well as between offense and defense. For example, swarms of coordinated, unmanned vehicles could overwhelm defensive systems, providing a greater advantage to the attacker, while directed energy weapons that provide a low-cost means of neutralizing such attacks, could favor the defender. Thus, emerging technologies could shift the offense-defense balance multiple times over the coming decades.

Interactions among emerging technologies could also improve existing military capabilities or enable new capabilities—with unforeseen consequences for warfighting and strategic stability. For example, an enabling technology like AI could be paired with quantum computing to produce more powerful methods of machine learning, potentially leading to improvements in image recognition and target identification and enabling more sophisticated autonomous weapons. Similarly, AI could be paired with 5G communications technologies to enable virtual training environments or with biotechnology in a “brain-computer interface” to enhance human cognition or control prosthetics or robotic systems.[184] Such developments could, in turn, require new strategies, tactics, and concepts of operation.[185]

Emerging military technologies—particularly complex systems such as AI and LAWS—could additionally produce unintended consequences if they fail to perform as anticipated. These consequences could range from system failure to violations of the law of armed conflict. As analyst Paul Scharre has noted, "in the most extreme case, an autonomous weapon could continue engaging inappropriate targets until it exhausts its magazine, potentially over a wide area."[186] This could, in turn, result in mass fratricide or civilian casualties—a possibility that has led some analysts to call for a pre-emptive ban on LAWS.

Finally, emerging military technologies could raise an array of ethical considerations. For example, some analysts have argued that the use of LAWS would be inherently immoral—regardless of whether the weapon could be used legally—because a human operator would not make specific target selection and engagement decisions.[187] Others have countered that human operators would continue to exercise "appropriate levels of human judgement over the use of force" and would remain accountable for ensuring that the deployment of LAWS conforms to the requirements of the laws of armed conflict.[188] Those supporting a pre-emptive ban on LAWS have additionally appealed to the Martens Clause, which appears in the1899 Hague Convention preamble and states that weapons usage should conform to the "principles of humanity and the dictates of the public conscience."[189] These analysts believe that LAWS contravene that requirement; however, others have noted that the Martens Clause has not been used previously to ban a weapons system and, furthermore, that the legal status of the Martens Clause is questionable and instead constitutes "merely a recognition of 'customary international law'."[190] Similarly, some analysts have raised ethical concerns about applications of biotechnology that involve human testing or modification as well as the weaponization of biotechnology, which could potentially be used for targeted genetic attacks.[191]

[184] For additional information about military applications of 5G, see CRS In Focus IF11251, *National Security Implications of Fifth Generation (5G) Mobile Technologies*, by John R. Hoehn and Kelley M. Sayler.

[185] For a discussion of these and other military and security implications—including implications for deterrence, crisis stability, force posture, and military roles and missions—see Robert O. Work and Shawn Brimley, *20YY: Preparing for War in the Robotic Age*, Center for a New American Century, January 22, 2014, pp. 31-35, at https://www.cnas.org/publications/reports/20yy-preparing-for-war-in-the-robotic-age.

[186] Paul Scharre, "Autonomous Weapons and Operational Risk," Center for a New American Security, February 2016, at https://s3.amazonaws.com/files.cnas.org/documents/CNAS_Autonomous-weapons-operational-risk.pdf.

[187] See, for example, Bonnie Docherty, *Heed the Call: A Moral and Legal Imperative to Ban Killer Robots*, Human Rights Watch, August 21, 2018, at https://www.hrw.org/report/2018/08/21/heed-call/moral-and-legal-imperative-ban-killer-robots.

[188] Department of Defense Directive 3000.09, "Autonomy in Weapon Systems," Updated May 8, 2017, at https://www.esd.whs.

[189] See, for example, Bonnie Docherty, *Heed the Call: A Moral and Legal Imperative to Ban Killer Robots*, Human Rights Watch, August 21, 2018, at https://www.hrw.org/report/2018/08/21/heed-call/moral-and-legal-imperative-ban-killer-robots.

[190] Paul Scharre, *Army of None: Autonomous Weapons and the Future of War* (New York: W.W. Norton & Company, 2018), pp. 263-266.

[191] For a more in-depth discussion of ethical considerations related to biotechnology, see CRS Report R44824, *Advanced Gene Editing: CRISPR-Cas9*, by Marcy E. Gallo et al. See also Elsa Kania and Wilson VornDick, "China's Military Biotech Frontier: CRISPR, Military-Civil Fusion, and the New Revolution in Military Affairs," *The Jamestown Foundation*, October 8, 2019, at https://jamestown.org/program/chinas-military-biotech-frontier-crispr-military-civil-fusion-and-the-new-revolution-in-military-affairs/.

Issues for Congress

Congress has previously demonstrated interest in conducting oversight of emerging military technologies beyond technology-specific activities. In Section 247 of the FY2019 NDAA (P.L. 115-232), Congress specified "a set of classified reports that set forth a direct comparison between the capabilities of the United States in emerging technology areas and the capabilities of adversaries of the United States."[192] These areas include hypersonic weapons, AI, quantum technology, directed energy weapons, and other relevant technologies as determined by the Secretary of Defense. Similarly, Section 1251 of the FY2022 NDAA (P.L. 117-81) directs the Under Secretary of Defense for Research and Engineering, in coordination with the Director of the Office of Net Assessment, to "conduct a comparative analysis assessment of the efforts of the United States Government and the Government of the People's Republic of China to develop and deploy" emerging technologies such as directed energy weapons, hypersonic weapons, biotechnology, and quantum technology. Section 225 of the FY2019 NDAA additionally tasked the Under Secretary of Defense for Research and Engineering with generating procedures for developing "technologies that are urgently needed to react to a technological development of an adversary of the United States or to respond to a significant and urgent emerging technology [that are] not receiving appropriate research funding or attention from the Department of Defense."

Furthermore, Section 232 of the FY2020 NDAA (P.L. 116-92) tasked the Secretary of Defense with developing "a process to ensure that the policies of the Department of Defense relating to emerging technology are formulated and updated continuously as such technology is developed by the Department,"[193] while Section 236 of the FY2021 NDAA (P.L. 116-283) granted the Secretary the authority to establish a Steering Committee tasked with developing assessments of and a strategy for emerging technology and national security threats.

As Congress continues to review the Pentagon's plans for emerging military technologies during the annual authorization and appropriations process, it might consider issues surrounding funding considerations, management, personnel, acquisition, technology protection, governance and regulation, and oversight.

Funding Considerations

A number of emerging military technologies, including hypersonic weapons and directed energy weapons, have experienced fluctuations in funding over the years. According to a U.S. government interagency task force on the defense industrial base, such "fluctuations challenge the viability of suppliers within the industrial base by diminishing their ability to hire and retain a skilled workforce, [achieve] production efficiencies, and in some cases, [stay] in business."[194]

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[192] Each report is to include the following elements: "(1) an evaluation of spending by the United States and adversaries on such technology, (2) an evaluation of the quantity and quality of research on such technology, (3) an evaluation of the test infrastructure and workforce supporting such technology, (4) an assessment of the technological progress of the United States and adversaries on such technology, (5) descriptions of timelines for operational deployment of such technology, [and] (6) an assessment of the intent or willingness of adversaries to use such technology."

[193] Section 232 defines emerging technology as "technology determined to be in an emerging phase of development by the Secretary of Defense, including quantum computing, technology for the analysis of large and diverse sets of data (commonly known as 'big data analytics'), artificial intelligence, autonomous technology, robotics, directed energy, hypersonics, biotechnology, and such other technology as may be identified by the Secretary."

[194] Interagency Task Force in Fulfillment of Executive Order 13806, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States*, September 2018, p. 21, at https://media.defense.gov/2018/Oct/05/2002048904/-1/-1/1/ASSESSING-AND-STRENGTHENING-THE-MANUFACTURING-AND%20DEFENSE-INDUSTRIAL-BASE-AND-SUPPLY-CHAIN-RESILIENCY.PDF.

Other analysts have noted that such fluctuations are often due to unavoidable tradeoffs between technology investment priorities or to questions about a given technology's feasibility or maturity.[195]

Some analysts have suggested that, given the potential for technological surprise, funding for overall research and development is inadequate. Summarizing such views, technology expert Martijn Rasser notes that reducing overall research and development in order to enable "big bets" or heavy investments in a particular technology or technologies, can be a risky approach because "we just don't know where the next breakthroughs will come from."[196]

Management

In general, DOD manages each of the aforementioned emerging military technologies separately due to the distinct expertise required. For example, within the Office of the Under Secretary of Defense for Research and Engineering (USD[R&E])/Chief Technology Officer (CTO), there are separate principal directors for artificial intelligence and autonomy, hypersonic weapons, directed energy, biotechnology, and quantum technology—among other technology areas. Development of each of these technologies is guided by a standalone technology roadmap and, in the case of AI, a classified strategy. Although the USD(R&E)/CTO has oversight over emerging military technologies, some analysts have suggested that there is a need for a more holistic approach to portfolio management that better considers how such technologies might be combined and integrated.[197]

Furthermore, prior to May 2022, these principal directors reported to the USD(R&E)/CTO through a singular Director for Modernization, who was "responsible for managing the capability analysis and investments for the modernization priorities outlined in the National Defense Strategy," including the technologies discussed in this report.[198] In May 2022, DOD reorganized the office of the USD(R&E)/CTO and created separate reporting structures for "enabling technology"—including the Principal Director for AI and autonomy—and "applied technology"—including the Principal Directors for directed energy and hypersonic weapons (see **Figure 2**). The Directors for Enabling Technology and Applied Technology report to the Deputy CTO for Critical Technologies. In contrast, the Principal Directors for biotechnology and quantum science report through the Director of Science and Technology Futures to a different Deputy CTO—the Deputy CTO for Science and Technology.[199] Congress may consider the ways

[195] See, for example, Ariel Robinson, "Directed Energy Weapons: Will They Ever Be Ready?," *National Defense*, July 1, 2015, at https://www.nationaldefensemagazine.org/articles/2015/7/1/2015july-directed-energy-weapons-will-they-ever-be-ready.

[196] See, for example, Will Knight, "Trump Proposes a Cut in Research Spending, but a Boost for AI," *Wired*, February 11, 2020, at https://www.wired.com/story/trump-proposes-cut-research-spending-boost-ai/. For more information about federal R&D funding, including a discussion of DOD R&D funding, see CRS Report R46341, *Federal Research and Development (R&D) Funding: FY2021*, coordinated by John F. Sargent Jr.

[197] See, for example, Government Accountability Office, *Weapon System Acquisitions: Opportunities Exist to Improve the Department of Defense's Portfolio Management*, August 2015, at https://www.gao.gov/assets/680/672205.pdf; and Pete Modigliani, *After the divorce: How the Pentagon can position itself for speed, agility, and innovation in the new era of acquisitions*, MITRE, March 2019, at https://www.mitre.org/sites/default/files/publications/pr-18-03404-3-after-the-divorce-white-paper.pdf.

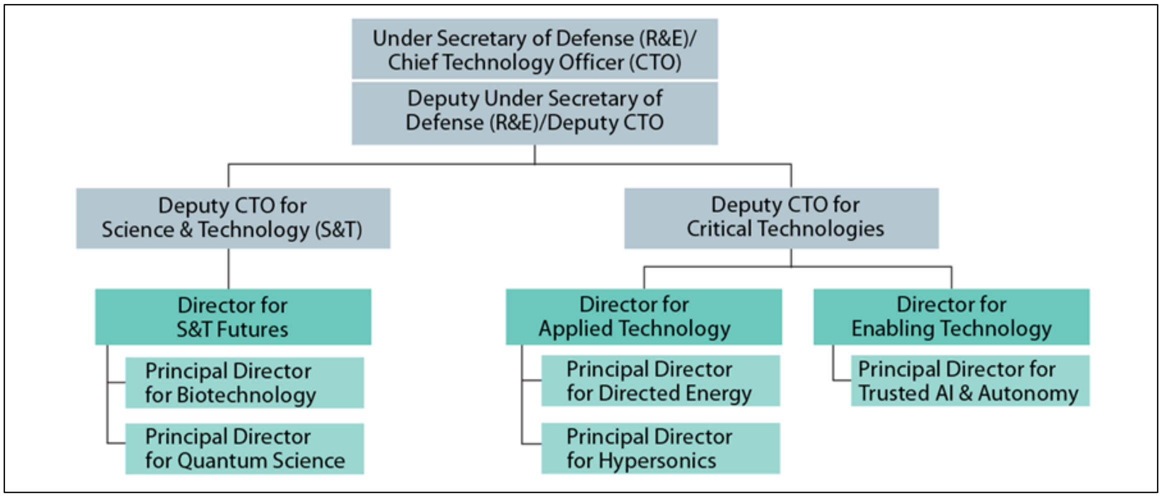
[198] CRS In Focus IF10834, *Defense Primer: Under Secretary of Defense for Research and Engineering*, by Marcy E. Gallo.

[199] See Department of Defense, "Organizational Improvements to the Office of the Under Secretary of Defense for Research and Engineering," May 10, 2022, at https://www.defense.gov/News/Releases/Release/Article/3026367/organizational-improvements-to-the-office-of-the-under-secretary-of-defense-for/.

in which this organizational change affects the oversight and integration of emerging technologies.

Finally, senior leaders do not always agree on the priorities among emerging military technologies—both in terms of effort and funding—and such priorities can shift frequently. This fluctuation has led some analysts to suggest that DOD should adopt a technology strategy "to set spending priorities that can be sustained over time, outlasting individual leaders."[200]

Figure 2. Selected Reporting Structure of the Office of the Under Secretary of Defense for Research and Engineering (R&E)



Source: CRS image, adapted from https://www.cto.mil/wp-content/uploads/2022/05/usdre_org_chart_09may2022_distro_a.pdf.

Notes: Chart depicts only the reporting structure for the OUSD(R&E) principal directors associated with the technologies discussed in this report. For a full OUSD(R&E) organizational chart, see "Office of the Under Secretary of Defense for Research and Engineering Organization," May 9, 2022, at https://www.cto.mil/wp-content/uploads/2022/05/usdre_org_chart_09may2022_distro_a.pdf.

Personnel

Some reports indicate that DOD and the defense industry have difficulty recruiting and retaining personnel with expertise in emerging technologies because research funding and salaries significantly lag behind those of commercial companies.[201] Other reports suggest that such challenges stem from quality-of-life factors, as well as from a belief among many technology workers that "they can achieve large-scale change faster and better outside the government than within it."[202] DOD faces additional challenges in training and educating its standing workforce. Examples of recommendations for addressing this set of challenges include increasing technology education opportunities at military academies, enhancing partnerships between DOD and research

[200] Paul Scharre and Ainikki Riikonen, "The Defense Department Needs a Real Technology Strategy," *Defense One*, April 21, 2020, at https://www.defenseone.com/ideas/2020/04/pentagon-needs-technology-strategy/164764/.

[201] M.L. Cummings, "Artificial Intelligence and the Future of Warfare," *Chatham House*, January 2017, p. 11, at https://www.chathamhouse.org/sites/default/files/publications/research/2017-01-26-artificial-intelligence-future-warfare-cummings-final.pdf.

[202] Amy Zegart and Kevin Childs, "The Divide between Silicon Valley and Washington Is a National-Security Threat," *The Atlantic*, December 13, 2018, at https://www.theatlantic.com/ideas/archive/2018/12/growing-gulf-between-silicon-valley-and-washington/577963/.

universities, creating government fellowships and accelerated promotion tracks for technology workers, and improving the technology literacy of human resource teams.[203]

Acquisition

DOD may need to continue adjusting its acquisition process to account for rapidly evolving dual-use technologies such as AI.[204] For example, a 2017 internal study of the process found that it takes an average of 81 months for information technology programs to move from the initial Analysis of Alternatives, defining the requirements for a system, to an Initial Operational Capability.[205] In contrast, commercial companies typically execute an iterative development process for software systems (such as those involved in AI capabilities), delivering an initial product in six to nine months.[206] These findings prompted DOD to issue an interim software acquisition policy intended to "[simplify] the acquisition model to enable continuous integration and delivery of software capability on timelines relevant to the Warfighter/end user."[207] Similar efforts may be needed for other emerging military technologies.

Furthermore, the commercial companies that are often at the forefront of innovation in emerging technologies may be reluctant to partner with DOD due to the complexity of the defense acquisition process. A Government Accountability Office (GAO) study of this issue found that, of 12 U.S. commercial companies who choose not to do business with DOD, all 12 cited the complexity of the defense acquisition process as a rationale for their decision.[208] DOD has created a number of avenues for rapid acquisitions—including the Strategic Capabilities Office, the Defense Innovation Unit, and Project Maven—that are intended to streamline cumbersome processes and accelerate the acquisitions timeline.[209] Project Maven, for example, was established in April 2017; by December, the team was fielding a commercially acquired prototype AI system

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[203] See Defense Science Board, *Applications of Quantum Technologies: Executive Summary*; National Security Commission on Artificial Intelligence, *First Quarter Recommendations*, March 2020, pp. 21-43, at https://drive.google.com/file/d/1wkPh8Gb5drBrKBg6OhGu5oNaTEERbKss/view; and Amy Zegart and Kevin Childs, "The Divide between Silicon Valley and Washington." For example, DOD is establishing a university consortium for hypersonic research and workforce development, while the Defense Digital Service now offers one- to two-year assignments for commercial technology workers. Similarly, the National Security Innovation Network seeks to create models and pathways for recruiting technologists to the U.S. government.

[204] Andrew Ilachinski, *AI, Robots, and Swarms: Issues, Questions, and Recommended Studies*, Center for Naval Analysis, January 2017, pp. 190-191. For an overview of recent acquisition reform efforts, see CRS Report R45068, *Acquisition Reform in the FY2016-FY2018 National Defense Authorization Acts (NDAAs)*, by Heidi M. Peters.

[205] Andrew Ilachinski, *AI, Robots, and Swarms: Issues, Questions, and Recommended Studies*, p. 189.

[206] Defense Science Board, "Design and Acquisition of Software for Defense Systems," February 2018, at https://apps.dtic.mil/dtic/tr/fulltext/u2/1048883.pdf. See also Defense Innovation Board, *Software is Never Done: Refactoring the Acquisition Code for Competitive Advantage*, May 3, 2019, at https://media.defense.gov/2019/Apr/30/2002124828/-1/-1/0/SOFTWAREISNEVERDONE_REFACTORINGTHEACQUISITIONCODEFORCOMPETITIVEADVANTAGE_FINAL.SWAP.REPORT.PDF.

[207] Office of the Under Secretary of Defense for Acquisition and Sustainment, "Software Acquisition Pathway Interim Policy and Procedures," January 3, 2020, at https://www.acq.osd.mil/ae/assets/docs/USA002825-19%20Signed%20Memo%20(Software).pdf.

[208] U.S. Government Accountability Office, *Military Acquisitions, DOD is Taking Step to Address Challenges Faced by Certain Companies*, GAO-17-644, July 20, 2017, p. 9. Other rationales cited include unstable budget environment, lengthy contracting timeline, government-specific contract terms and conditions, and inexperienced DOD contracting workforce.

[209] In certain circumstances, DOD may also use other transaction authorities (OTAs) to accelerate research, prototyping, and production. For additional information about OTAs, see CRS Report R45521, *Department of Defense Use of Other Transaction Authority: Background, Analysis, and Issues for Congress*, by Heidi M. Peters.

in combat.[210] Although some analysts argue that these are promising developments, critics point out that the department must replicate such results at scale and implement more comprehensive acquisitions reform.[211]

Intellectual Property

Commercial technology companies are often reluctant to partner with DOD due to concerns about intellectual property and data rights.[212] As an official interviewed for a 2017 GAO report on broader challenges in military acquisitions noted, intellectual property is the "life blood" of commercial technology companies, yet "DOD is putting increased pressure on companies to grant unlimited technical data and software rights or government purpose rights rather than limited or restricted rights."[213] In an effort to manage these concerns, DOD released an instruction that "establishes policy, assigns responsibilities, and prescribes procedures for the acquisition, licensing, and management of IP."[214] The instruction additionally establishes a DOD IP Cadre to advise and assist the acquisition workforce on matters related to IP and calls for the development of an IP strategy to "identify and manage the full spectrum of IP and related matters" for each acquisition program.[215]

Supply Chain Security

A number of recent reports have raised concerns about the security of the U.S. supply chain for emerging military technologies. For example, one assessment found that China "may have opportunities to jeopardize the development of hypersonics through industrial espionage, transfers of technology, or providing unreliable components" due to its potential exposure to low-level U.S. suppliers.[216] Similarly the National Security Commission on Artificial Intelligence found that "the United States lacks domestic facilities capable of producing, integrating, assembling, and testing" the microelectronics needed to enable AI, forcing the U.S. "to rely on foreign fabrication and complex global supply chains for production."[217] In response to such concerns, Title XCIX of the FY2021 NDAA (P.L. 116-283), Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America, authorized an incentive program for building and equipping semiconductor fabrication facilities in the United States. Congress subsequently provided funding for the program in the Chips and Science Act (P.L. 117-167).[218]

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[210] Marcus Weisgerber, "The Pentagon's New Artificial Intelligence is Already Hunting Terrorists," *Defense One*, December 21, 2017, at http://www.defenseone.com/technology/2017/12/pentagons-new-artificial-intelligence-already-hunting-terrorists/144742/.

[211] Andrew Ilachinski, *AI, Robots, and Swarms: Issues, Questions, and Recommended Studies*, Center for Naval Analysis, January 2017, p. 190.

[212] U.S. Government Accountability Office, *Military Acquisitions, DOD is Taking Steps to Address Challenges Faced by Certain Companies.*

[213] Ibid., p. 20.

[214] Office of the Under Secretary of Defense for Acquisition and Sustainment, "DOD Instruction 5010.44 Intellectual Property (IP) Acquisition and Licensing," October 16, 2019, at https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/501044p.PDF?ver=2019-10-16-144448-070.

[215] Ibid., pp. 8-11.

[216] Govini, *The 2020 Federal Scorecard: High-Intensity Warfare Edition*, p. 67, at https://www.govini.com/wp-content/uploads/2020/06/Govini-2020-Federal-Scorecard.pdf.

[217] National Security Commission on Artificial Intelligence, *First Quarter Recommendations*, p. 46.

[218] For additional information about these provisions, see CRS Report R47558, *Semiconductors and the CHIPS Act: The Global Context*, by Karen M. Sutter, John F. Sargent Jr., and Manpreet Singh.

Technology Protection

Estimates indicate "that American industry loses more than $600 billion dollars [each year] to theft and expropriation," including the theft and expropriation of emerging military technologies and related intellectual property.[219] The United States has a number of programs devoted to addressing this issue. For example, pursuant to the Foreign Investment Risk Review Modernization Act of 2018 (FIRRMA), the Committee on Foreign Investment in the United States (CFIUS) now reviews certain foreign investments, including those involving "emerging and foundational technologies." In addition, FIRRMA authorized CFIUS to consider "whether a covered transaction involves a country of special concern that has a demonstrated or declared strategic goal of acquiring a type of critical technology or critical infrastructure that would affect United States leadership in areas related to national security."[220] Similarly, DOD's Protecting Critical Technology Task Force helps protect universities, labs, and the U.S. defense industrial base against the theft of "classified information, controlled unclassified information, and key data."[221] As part of this effort, the task force intends to institute cybersecurity training programs for small businesses, enhance DOD's understanding of supply chain vulnerabilities, and develop a prioritized list of technologies that are critical to national security—as mandated by Section 1049 of the FY2019 NDAA—among other activities.[222] Some analysts have recommended expanding technology protection efforts to include U.S. allies and partners.[223]

Governance and Regulation

According to then-Director of National Intelligence Daniel Coats, "technology developments … are likely to outpace regulation, which could create international norms that are contrary to US interests and increase the likelihood of technology surprise."[224] To address this concern, some analysts have argued that "the United States should undertake broad, sustained diplomatic engagement to advance collaboration on emerging technologies, norms, and standards setting."[225]

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[219] Office of the Secretary of Defense, "Memorandum on the Establishment of the Protecting Critical Technology Task Force," October 24, 2018, at https://insidecybersecurity.com/sites/insidecybersecurity.com/files/documents/2018/nov/cs2018_0459.pdf.

[220] The specific technologies that qualify as "emerging and foundational technologies" are to be identified by an interagency process led by the Department of Commerce. See P.L. 115-232, Title XVII, §1702(c). For more information on FIRRMA, see CRS In Focus IF10952, *CFIUS Reform Under FIRRMA*, by James K. Jackson and Cathleen D. Cimino-Isaacs. Some entities, including the National Security Commission on Artificial Intelligence, have argued that the U.S. government should consider additional measures of technology protection, such as "heavier scrutiny of the potential end use and end user of specific items." See National Security Commission on Artificial Intelligence, *Interim Report*, November 2019, p. 42, at https://drive.google.com/file/d/153OrxnuGEjsUvlxWsFYauslwNeCEkvUb/view.

[221] Office of the Secretary of Defense, "Memorandum on the Establishment of the Protecting Critical Technology Task Force."

[222] C. Todd Lopez, "Task Force Curbs Technology Theft to Keep Joint Force Strong," DOD News, November 26, 2019, at https://www.defense.gov/Explore/News/Article/Article/2027555/task-force-curbs-technology-theft-to-keep-joint-force-strong/.

[223] See, for example, Daniel Kliman, Ben FitzGerald, Kristine Lee, and Joshua Fitt, *Forging an Alliance Innovation Base*, Center for a New American Security, March 2020, at https://s3.amazonaws.com/files.cnas.org/documents/CNAS-Report-Alliance-Innovation-Base-Final.pdf?mtime=20200329174909.

[224] Daniel R. Coats, "Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community," delivered before the U.S. Senate Committee on Armed Services, March 6, 2018.

[225] Samuel J. Brannen, Christian S. Haig, Katherine Schmidt, and Kathleen H. Hicks, *Twin Pillars: Upholding National Security and National Innovation in Emerging Technologies Governance*, Center for Strategic and International (continued...)

Studies, January 2020, at https://csis-prod.s3.amazonaws.com/s3fs-public/publication/200123_Brannen_TwinPillars_WEB_FINAL.pdf?eljUpAKOjVauOujYfnvuSGDK0xvsQGZF.

Similarly, Section 9414 of the FY2021 NDAA directs the Director of the National Institute of Standards and Technology to oversee a study that assesses China's role in international standards setting organizations and provides recommendations for mitigating China's influence and strengthening U.S. participation in these organizations.

Oversight[226]

As Congress conducts oversight of emerging military technologies, it may be challenged in its ability to independently evaluate and assess complex, disparate technical disciplines. In 1972, Congress established the Office of Technology Assessment (OTA) to provide expert "assessments, background papers, technical memoranda, case studies, and workshop proceedings" that were to inform congressional decisionmaking and legislative activities.[227] Congress eliminated funding for OTA in 1995 "amid broader efforts to reduce the size of government.[228] Since then, Congress has continued to debate the need for OTA or a similar technology assessment organization.[229]

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226 For a full discussion of issues surrounding congressional oversight of technology, see CRS Report R46327, *The Office of Technology Assessment: History, Authorities, Issues, and Options*, by John F. Sargent Jr..

227 Ibid.

228 Ibid.

229 For an overview of OTA/technology assessment-related legislation in the 107th-116th Congresses, see Appendix C in CRS Report R46327, *The Office of Technology Assessment: History, Authorities, Issues, and Options*, by John F. Sargent Jr..