

**THE UNITED STATES AIR FORCE AND ARTIFICIAL
INTELLIGENCE:
Moving Forward by Learning from Past Technology
Implementation**

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Abstract: Artificial Intelligence (AI) has re-emerged as a buzzword across the world in recent years. The potential benefits from AI span across society, from finance to medical care, and agriculture to transportation. One of the most potentially significant areas of AI implementation is in the world's militaries. There are incredible benefits for those forces who can adopt AI and the significant risks for those forces who fail to adapt. This paper examines historical examples that may inform how the United States Air Force (USAF) may best adopt AI. This paper examines the historical roots of radar development through World War II and the advent of stealth technology through the F-117A as well as examines studies on how the Department of Defense has adopted commercial-off-the-shelf technology and software in the past. The paper then examines areas of symmetry between these past technologies and AI to determine effective technology adoption methods. Finally, this paper offers several functional recommendations to ensure the effective and efficient adoption of AI in the future.

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Artificial Intelligence (AI) is a key emerging technology to the future of United States (US) National Security. In an era of rapidly expanding technological breakthroughs, a recent study says AI might be the most far-reaching.² US policy makers recognize the importance of AI, and in just the last two years, released the Presidential Executive Order 13859 on Maintaining American Leadership in AI,³ used specific language discussing AI in the 2019 National Defense Authorization Act,⁴ and issued the 2018 Department of Defense Artificial Intelligence Strategy.⁵ The US is not alone in this pursuit, nor necessarily guaranteed their place at its front. In the forward to a recent AI policy recommendation paper, former US Deputy Secretary of Defense Robert Work notes, “China, Russia, members of the European Union, Japan, and South Korea all are increasing AI research, development, and training. China, in particular, sees advances in AI as a key means to surpass the United States in both economic and military power. China has stated its intent to be the world leader in AI by 2030 and is making major investments to achieve that goal.”⁶ There are numerous recommendations already written for the US government on how to best prepare for the potential AI revolution. This paper builds on existing recommendations, using analysis from different historical examples, to focus many previous government-wide recommendations directly to the United States Air Force (USAF).

To begin, we must first try to define what is meant by AI. The hype surrounding AI today clouds the discussion to the point where meaningful conversations can be lost before they even begin. On the most capable side of AI many people immediately start thinking in terms of Hollywood portrayed science fiction like Skynet from *The Terminator*,⁷ the machines from *The Matrix*,⁸ or Matthew Broderick almost starting World War III in *WarGames*.⁹ Conversely, on the least capable side of AI, it seems that everyone wants to capitalize on the hype, all the way down to an advertisement a colleague recently shared about her “AI-enabled litter-box.”¹⁰ It seems self-evident that we are not discussing the same thing when comparing a computer intelligence that enslaves the whole human race with a smart litter box, but with everyone claiming AI, how are we to know the difference and have an informed discussion?

² Martijn Rasser, Megan Lamberth, Ainikki Riikonen, Chelsea Guo, Michael Horowitz, and Paul Scharre, *The American AI Century: A Blueprint for Action*, (Washington D.C., Center for a New American Security, 2019), 2, <https://www.cnas.org/publications/reports/the-american-ai-century-a-blueprint-for-action>.

³ “Executive Order 13859 of February 11, 2019, Maintaining American Leadership in Artificial Intelligence,” *Federal Register*, Volume 84, Issue 31 (2019), <https://www.govinfo.gov/content/pkg/DCPD-201900073/pdf/DCPD-201900073.pdf>.

⁴ *John S. McCain National Defense Authorization Act for Fiscal Year 2019*, Public Law 115-232, *U.S. Statutes at Large* 132 (2018).

⁵ Department of Defense, *Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity* (Washington D.C., 2019).

<https://media.defense.gov/2019/Feb/12/2002088963/-1/-1/1/SUMMARY-OF-DOD-AI-STRATEGY.PDF.me>

⁶ Martijn Rasser, Megan Lamberth, Ainikki Riikonen, Chelsea Guo, Michael Horowitz, and Paul Scharre, *The American AI Century: A Blueprint for Action*, (Washington D.C., Center for a New American Security, 2019), 2, <https://www.cnas.org/publications/reports/the-american-ai-century-a-blueprint-for-action>.

⁷ *The Terminator*, directed by James Cameron (1984; Santa Monica, CA: Cinema '84, Metro-Goldwyn-Mayer, 2003), DVD.

⁸ *The Matrix*, directed by Lana Wachowski and Lilly Wachowski (1999; Los Angeles, CA: Warner Bros., 2003), DVD.

⁹ *WarGames*, directed by John Badham (1983; Los Angeles, CA: United Artist, Metro-Goldwyn-Mayer, 1998), DVD.

¹⁰ Kim Lyons, “This AI kitty litter box will analyze your cat’s poops for some reason,” *The Verge*, Vox Media, 7 January 2020, <https://www.theverge.com/2020/1/7/21054690/ai-smart-kitty-litter-box-cats-poop-pee-ces-health>.

The National Artificial Intelligence R&D Strategic Plan: 2019 Update explains AI by saying, “Artificial intelligence enables computers and other automated systems to perform tasks that have historically required human cognition and what we typically consider human decision-making abilities.”¹¹ The 2019 National Defense Authorization Act uses the following points as definition while also directing the Secretary of Defense to provide an official Department definition of AI within one year:

- (1) Any artificial system that performs tasks under varying and unpredictable circumstances without significant human oversight, or that can learn from experience and improve performance when exposed to data sets.
- (2) An artificial system developed in computer software, physical hardware, or other context that solves tasks requiring human-like perception, cognition, planning, learning, communication, or physical action.
- (3) An artificial system designed to think or act like a human, including cognitive architectures and neural networks.
- (4) A set of techniques, including machine learning, that is designed to approximate a cognitive task.
- (5) An artificial system designed to act rationally, including an intelligent software agent or embodied robot that achieves goals using perception, planning, reasoning, learning, communicating, decision making, and acting.¹²

This definition is a useful place to start; however, we must make further distinctions. The first is the difference between General AI and Narrow AI, sometimes referred to as strong and weak AI respectively. General AI describes a computer intelligence that surpasses human intelligence across the breadth of human capability, including complex decision making and a level of critical thinking.¹³ While general AI is often the image that comes to mind when describing AI, most experts agree that it is still several decades in the future, if it is even possible.^{14, 15} All current AI effects fall into the category of narrow AI, where programs are designed to solve a

¹¹ Executive Office of the President, National Science and Technology Council, Select Committee on Artificial Intelligence, *The National Artificial Intelligence Research and Development Strategic Plan: 2019 Update*, (Washington D.C., 2019), 1, <https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf>.

¹² *John S. McCain National Defense Authorization Act for Fiscal Year 2019*, Public Law 115-232, *U.S. Statutes at Large* 132 (2018): 1697-1698.

¹³ U.S. Library of Congress, Congressional Research Service, *Artificial Intelligence and National Security*, by Kelley Saylor, R45178 (2019), 2, <https://crsreports.congress.gov/product/pdf/R/R45178/5>.

¹⁴ U.S. Library of Congress, Congressional Research Service, *Artificial Intelligence and National Security*, by Kelley Saylor, R45178 (2019), 2, <https://crsreports.congress.gov/product/pdf/R/R45178/5>.

¹⁵ Katja Grace, John Salvatier, Allan Dafoe, Baobao Zhang, and Owain Evans, “When Will AI Exceed Human Performance? Evidence from AI Experts,” *Journal of Artificial Intelligence Research*, Volume 62 (2018): 731

specific problem. This includes everything from navigation, to image recognition, language translation, game playing, and self-driving cars.¹⁶

Under the umbrella of Narrow AI, there are multiple approaches and techniques with names often used interchangeably with AI that further cloud the issue. These techniques include everything from Deep Neural Nets and Machine Learning (ML), to big data, and autonomy.¹⁷ It is essential to understand that all of these additional terms describe the “how” of Narrow AI. In other words, to harness Narrow AI, you might build an algorithm that utilizes multiple neural nets to accomplish image recognition.¹⁸ Even the idea of Narrow AI is incredibly challenging to define as it seems to change continuously. Each time science breaches a new AI barrier, what was before unachievable then seems commonplace, and therefore no longer worthy of bearing the “AI” moniker. This increasing capability subsequently creates a new concept of AI.¹⁹ Thus, in a very real way, the accepted definition of AI is continually changing, presenting an even more difficult task of clarifying the idea. The focus of this paper is on the current and future application of Narrow AI, including all the tools and techniques that fall within that concept.

While there is a great deal of confusion about defining what AI is, there is agreement among experts or politicians that AI has the potential to be revolutionary. China released a strategy document in 2017, before any official US AI strategy, with a stated goal to attain the global AI lead by 2030.²⁰ The same year Vladimir Putin declared Russia’s AI goal by famously saying, “[W]hoever becomes the leader in this field will rule the world.”²¹ Two years later the United States followed with President Trump issuing an Executive Order on the American position in AI, saying, “Continued American leadership in AI is of paramount importance to maintaining the economic and national security of the United States and to shaping the global evolution of AI in a manner consistent with our Nation’s values, policies, and priorities.”²² AI is definitively a critical technology for future national security.

It is easy to see why AI is being put forward as such an opportunity for militaries around the world. Military success has always been as much about information and decision making as

¹⁶ U.S. Library of Congress, Congressional Research Service, *Artificial Intelligence and National Security*, by Kelley Saylor, R45178 (2019), 2, <https://crsreports.congress.gov/product/pdf/R/R45178/5>.

¹⁷ Executive Office of the President, National Science and Technology Council, Select Committee on Artificial Intelligence, *The National Artificial Intelligence Research and Development Strategic Plan: 2019 Update*, (Washington D.C., 2019), 54, <https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf>.

¹⁸ Executive Office of the President, National Science and Technology Council, Select Committee on Artificial Intelligence, *The National Artificial Intelligence Research and Development Strategic Plan: 2019 Update*, (Washington D.C., 2019), 54, <https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf>.

¹⁹ Executive Office of the President, National Science and Technology Council, Committee on Technology National Science Technology Council, Subcommittee on Machine Learning Artificial Intelligence, *Preparing for the Future of Artificial Intelligence*, (Washington D.C., 2016), 7, https://obamawhitehouse.archives.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/preparing_for_the_future_of_ai.pdf.

²⁰ U.S. Library of Congress, Congressional Research Service, *Artificial Intelligence and National Security*, by Kelley Saylor, R45178 (2019), 1, <https://crsreports.congress.gov/product/pdf/R/R45178/5>.

²¹ U.S. Library of Congress, Congressional Research Service, *Artificial Intelligence and National Security*, by Kelley Saylor, R45178 (2019), 1, <https://crsreports.congress.gov/product/pdf/R/R45178/5>.

²² “Executive Order 13859 of February 11, 2019, Maintaining American Leadership in Artificial Intelligence,” *Federal Registrar*, Volume 84, Issue 31 (2019): 1, <https://www.govinfo.gov/content/pkg/DCPD-201900073/pdf/DCPD-201900073.pdf>.

about soldiers and technology. Col John Boyd’s famous “OODA Loop” has been at the core of military tactical doctrine for over a generation. He summarizes what military leaders have long known, that if you can Observe, Orient, Decide, and Act faster than your enemy, you can defeat them.²³ Today’s Air Force is overwhelmed by data, with millions of hours of video from remotely piloted aircraft needing to be analyzed. AI is now enabling the USAF to process information through a computer vision program called Project Maven. The immediate goal is to make analysts up to three times more effective than they are currently.²⁴ The next step in AI development could very well enable human to machine level decision making, speeding decision making to a level no unaided human can manage. The advantages are apparent even to non-military personnel: if one force is processing information and making decisions orders of magnitude faster than the other force, there would be no way to contend against them. Decision making in a large-scale conflict is only one of the areas where AI might be a threat.

The following table shows just how many areas AI might have potentially significant consequences if the USAF does not maintain a competitive advantage in adoption and employment. The areas of peer competitor competition and virtual/cyber conflict present the highest threat. Facing an opponent with equal capabilities or in the cyber domain who is equipped with more advanced AI technology would quickly tip the already then balance. Hybrid warfare and conflict in mega-cities do not present as much of a threat, as more of the conflict will remain in the traditional sense. The trend toward more technology means those areas will move toward high threat as cities and homes become more interconnected and dependent on technology. Failed states and state instability do not present a threat currently, as they are not dependent on AI or related technology. As the world develops technologically, even failed states may present high threat if highly developed and equipped with AI technology.

Table 1. Threat if out-paced in AI adoption

	N/A	Low	Medium	High
Environments	Present	5-10 Years	25 Years	
Peer Competitor				
Hybrid Warfare				
Failing/Failed State				
Virtual/Cyber				
Mega City				
State Instability				

²³ Frans Osinga, *Science, Strategy and War: The strategic Theory of John Boyd* (New York, NY: Routledge, 2007), 1-3.

²⁴ Cheryl Pellerin, *Project Maven to Deploy Computer Algorithms to War Zone by Year’s End*, (Washington D.C., DOD News, 2017), 2, <https://defense.gov/Explore/News/Article/Article/1254719/project-maven-to-deploy-computer-algorithms-to-war-zone-by-years-end>.

There have been multiple studies about how best to posture the United States for the AI revolution. This paper will attempt to do the same for the US Air Force (USAF) as a subset. This paper will offer recommendations to the Air Force for earning and maintaining a dominant place in the future concerning AI. To accomplish this, this paper examines how the past technologies were integrated, focusing on points that parallel AI growth adoption, in order to develop recommendations for how to adopt AI in the future. First, it will examine the development and adoption of stealth, then radar technology, and finally, the Air Force's adoption of commercial off the shelf, or COTS technology, with a particular focus on the microchip and software.

ARTIFICIAL INTELLIGENCE

The first discussion of learning machines began in the 1940s with Alan Turing clarifying the debate in 1950, although the term Artificial Intelligence only appeared in 1956.²⁵ After initial interest, it became apparent that computer technology had not developed enough to make significant progress. In the late 1990s, Narrow AI efforts increased and culminated in 1997 with the success of IBM's chess-playing program, Deep Blue, against world champion Garry Kasparov.²⁶ In the last decade new machine learning algorithms, enabled by rapidly increasing computational power and dataset sizes are fueling the ongoing AI revolution.²⁷ The increased AI capabilities allowed DeepMind's Go-playing computer, AlphaGo, to defeat the world champion Go player in 2016, ten years before experts predicted AI would beat humans at such a complex game.²⁸ Additionally, AI image recognition went from a 26 percent error rate in 2011 to a 3.5 percent error rate in 2015, better than the human standard error rate measure of 5 percent.²⁹

²⁵ Executive Office of the President, National Science and Technology Council, Committee on Technology National Science Technology Council, Subcommittee on Machine Learning Artificial Intelligence, *Preparing for the Future of Artificial Intelligence*, (Washington D.C., 2016), 5, https://obamawhitehouse.archives.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/preparing_for_the_future_of_ai.pdf.

²⁶ Executive Office of the President, National Science and Technology Council, Committee on Technology National Science Technology Council, Subcommittee on Machine Learning Artificial Intelligence, *Preparing for the Future of Artificial Intelligence*, (Washington D.C., 2016), 5-6, https://obamawhitehouse.archives.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/preparing_for_the_future_of_ai.pdf.

²⁷ Peter Stone, Rodney Brooks, Erik Brynjolfsson, Ryan Calo, Oren Etzioni, Greg Hager, Julia Hirschberg, Shivaram Kalyanakrishnan, Ece Kamar, Sarit Kraus, Kevin Leyton-Brown, David Parkes, William Press, AnnaLee Saxenian, Julie Shah, Milind Tambe, and Astro Teller, "Artificial Intelligence and Life in 2030," *One Hundred Year Study on Artificial Intelligence: Report of the 2015-2016 Study Panel*, (Stanford CA, Stanford University, 2016), 14, <http://ai100.stanford.edu/2016-report>.

²⁸ U.S. Library of Congress, Congressional Research Service, *Artificial Intelligence and National Security*, by Daniel Hoadley and Nathan Lucas, R45178 (2016), 28, <https://crsreports.congress.gov/product/pdf/R/R45178/3>.

²⁹ Executive Office of the President, National Science and Technology Council, Committee on Technology National Science Technology Council, Subcommittee on Machine Learning Artificial Intelligence, *Preparing for the Future of Artificial Intelligence*, (Washington D.C., 2016), 6, https://obamawhitehouse.archives.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/preparing_for_the_future_of_ai.pdf.

An important aspect to understand about AI is that it is driven primarily by software. While this distinction may not seem important, it marks a unique difference to most prior technologies. AI programs can be developed and then relatively easily exported and implemented with over the counter hardware, making exclusive use of AI a near impossibility. Compounding this problem is the research community's mentality that AI should be free for all. "This facet of AI is compounded by a culture of openness in the AI community that leads to research being widely published, and trained AI models being available to download for free online."³⁰ Two key examples of this are TensorFlow and PyTorch; Google and Facebook's respective free to all Machine Learning frameworks.

The nature of AI programs as software and the standard of open discovery and sharing have pushed AI into all aspects of society. Now even commercial companies, without the inherent technology base and funding to develop their own AI, can utilize pre-built algorithms or use shared computing and pre-built programs to build their own specific applications. This is a significant deviation from the nature of almost every technology that the Air Force has harnessed in the past creating a considerable challenge for the USAF to capitalize on moving forward.

Nations are recognizing the dramatic potential of AI and of being a first-mover in the field. In 2017 Canada invested \$100 million toward training AI graduates, South Korea announced \$863 million per year investment for five years, and China announced a plan to earn \$59 billion in AI economic activity by 2030.³¹ The US pursued AI as well, with an approximate investment in AI R&D of \$1.1 billion in 2015 and \$1.2 billion in 2016.³² The Department of Defense (DOD) established the Joint Artificial Intelligence Center (JAIC) in 2018 to oversee future AI development. Their approximate budget for 2020 is \$208 million, notably only about half what the Pentagon projected the center to need.³³ The Defense Advanced Research Projects Agency (DARPA) recently announced "AI Next," a five-year \$2 billion plan to research advanced AI technologies.³⁴

These numbers are small in comparison with what the commercial sector is spending. 2016 estimates are that top US and Chinese tech companies (Alibaba, Alphabet, Apple, Amazon, Baidu, Facebook, Microsoft, Tencent) invested between \$20-\$30 billion on AI. Simultaneously,

³⁰ Michael Horowitz, Gregory Allen, Elsa Kania, and Paul Scharre, *Strategic Competition in an Era of Artificial Intelligence*, (Washington D.C., Center for a New American Security, 2018), 7,

<https://www.cnas.org/publications/reports/strategic-competition-in-an-era-of-artificial-intelligence>.

³¹ Ben Scott, Stefan Heumann, and Philippe Lorenz, *Artificial Intelligence and Foreign Policy*, (Berlin, Stiftung Neue Verantwortung, 2018), 15, <https://ssrn.com/abstract=3103961>.

³² Executive Office of the President, National Science and Technology Council, Committee on Technology National Science Technology Council, Subcommittee on Machine Learning Artificial Intelligence, *Preparing for the Future of Artificial Intelligence*, (Washington D.C., 2016), 25,

https://obamawhitehouse.archives.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/preparing_for_the_future_of_ai.pdf.

³³ Martijn Rasser, Megan Lamberth, Ainikki Riikonen, Chelsea Guo, Michael Horowitz, and Paul Scharre, *The American AI Century: A Blueprint for Action*, (Washington D.C., Center for a New American Security, 2019), 39, <https://www.cnas.org/publications/reports/the-american-ai-century-a-blueprint-for-action>.

³⁴ Martijn Rasser, Megan Lamberth, Ainikki Riikonen, Chelsea Guo, Michael Horowitz, and Paul Scharre, *The American AI Century: A Blueprint for Action*, (Washington D.C., Center for a New American Security, 2019), 39, <https://www.cnas.org/publications/reports/the-american-ai-century-a-blueprint-for-action>.

global startup investment in AI exceeded \$5 billion.³⁵ With this clear attempt by countries and corporations to be AI technology leaders, how can the USAF gain and maintain technical and functional superiority in the realm of AI technology? The USAF has had distinct advantages or been early adoptors in many prior technological advancements. Review of some of these technology adoptions will provide insight into what USAF needs to do to become AI leaders.

RADAR

“RADAR, like most of the major technological advances during the twentieth century, did not result from a sudden and inspired line of thought pushed to the point of fulfillment by one inventor. As with the other great innovations, the basic idea preceded the invention by several decades, and it was only when certain special means had been developed that its realization became practicable. Again, as with the other great inventions of this century, once the background work was complete development proceeded independently in several nations simultaneously.”³⁶

The history of radar, which stands for Radio Detection and Ranging, is fascinating both from a technological aspect and strategically considering how critical it became during World War II. The first recorded use of radio waves for detection was in 1904, by the German scientist, Christian Hülsmeyer.³⁷ The technology was not significantly pursued publicly again until eighteen years later, when multiple people in several companies began seriously advancing the technology. Notably, two of those people were American, including one from the United States Naval Research Laboratory (NRL), an organization that would later fall under the Department of Defense — demonstrating early US investment in research and development (R&D).

Around 1930, Bell Telephone Company and the US Naval Research Laboratory both noted similar fluctuations in radio signals from aircraft beyond visual sight range and “as a result, made a proposal for equipment that could be constructed for the detection of both aircraft and ships. This did not find favour by the Navy Department and was dropped.”³⁸ The scientists from the NRL subsequently left the Navy in frustration. They filed patents on their work in 1934, which were later sent to multiple foreign countries bolstering those countries’ initial radar R&D.³⁹ While these discoveries in detection were happening, there were simultaneous discoveries in determining range, the other half of the required components for functioning radar.

³⁵ Ben Scott, Stefan Heumann, and Philippe Lorenz, *Artificial Intelligence and Foreign Policy*, (Berlin, Stiftung Neue Verantwortung, 2018), 15-16, <https://ssrn.com/abstract=3103961>.

³⁶ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 55.

³⁷ Brian Kendal, "An Overview of the Development and Introduction of Ground Radar to 1945," *The Journal of Navigation*, Volume 56, Issue 3 (2003): 344.

³⁸ Brian Kendal, "An Overview of the Development and Introduction of Ground Radar to 1945," *The Journal of Navigation*, Volume 56, Issue 3 (2003): 344.

³⁹ Alexander Rose, "Radar and Air Defense in the 1930s," *Twentieth Century British History*, Volume 9, Issue 2 (1998): 234.

It is important to note the broader situation influencing the development of radar. During the critical initial stages of development, Britain was facing the issue of increasing rearmament from Germany, especially of the fighter and bomber force, a direct threat to Britain's home island. Additionally, scientific development was aided by Britain's R&D structure at the time. Britain's scientific research belonged in three closely tied agencies, one of which was the Department of Industrial and Scientific Research (DISR). DISR began in 1917 in response to Germany's superior technology development in WWI. This situation is strikingly similar to the US' creation of DARPA in response to Sputnik's launch by the USSR.

Through the 1930s, the Germans worked on two different methods of using radio waves to help aircraft accurately bomb targets. These two systems, the *X-Grerät* and the *Knickebein*, were not actual uses of radar, they were directed radio beams that aircraft used with blind receivers tuned to specific frequencies.⁴⁰ On 4 November 1939, the British received information on these German radio beams through an unknown German turncoat who provided the "Oslo Report."⁴¹ The importance of these systems lay primarily in their ability to provide guidance out to 260 miles, the distance required to reach London from the closest point in Germany or German-controlled Norway. The prevailing scientific thought in Britain was that the frequency in use could not be received greater than 180 miles away.⁴² Discovering that the British homeland was at risk of precision bombing from Germany was shocking. With this intelligence, the race was on to improve radar detection and navigation and deny its use to the enemy.

Both Britain and Germany began WWII with radar equipment in the inventory. Germany had radars from two companies, Gema and Telefunken, which built the *Freya* and the *Würzburg* respectively. The *Freya* had a range of 75 miles, 360 degree coverage, and was mobile but it could not measure the altitude of approaching targets. The *Würzburg* only had a range of 25 miles, but could pinpoint incoming aircraft accurately and was highly sought after by German anti-aircraft gunners. The radar allowed them to target incoming aircraft without first finding them visually. In contrast, the British system, the *Chain Home*, had a range of 120 miles but a limited 120 degree field of view; its size also precluded any mobility. Both countries were working on small radars to install in aircraft. Germany was set to begin testing an airborne radar for a transport aircraft while Britain was about to field a system for patrol aircraft and a system for fighter aircraft.⁴³

As bombing began in earnest over Germany, the need for radar support increased. After early warning radar information led to the loss of 14 of 24 British bombers during a daytime raid, all bombing missions moved to night raids.⁴⁴ Without sufficient *Würzburg* radars to guide anti-aircraft guns, the Germans instituted a night fighter squadron to combat the British bombers. The current radars were insufficient to support night fighter operations as they were either not accurate enough to keep the incoming bombers and defending fighters separate or did not have sufficient detection range. Night fighter command worked with Telefunken to develop the Giant *Würzburg*. This new system was both more accurate and doubled the range of the previous system. A similar increase in size worked for the *Freya*, with the result being the *Mammut* radar

⁴⁰ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner's Sons, 1978), 21-23.

⁴¹ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner's Sons, 1978), 23-24.

⁴² Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner's Sons, 1978), 26-28.

⁴³ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner's Sons, 1978), 60-61.

⁴⁴ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner's Sons, 1978), 61-62.

built by a third German company, I. G. Farben.⁴⁵ While these improvements in ground-based early warning radar were ongoing, Telefunken also produced the *Lichtenstein*, an airborne radar for night fighters. Interestingly, while both were new technology, the pilots had already become used to the ground-based radar control and often refused to fly with the airborne-radar equipped aircraft due to a slight loss in handling. They eventually overcame the hesitancy as one officer, Captain Ludwig Becker, persisted in using the new radar.⁴⁶ “As Becker’s score of kills steadily mounted, the device began to gain acceptance elsewhere.”⁴⁷

With hints from the 1939 Oslo Report, the British assigned a scientist, Dr. R. V. Jones, to the Air Ministry Directorate of Intelligence to investigate the German systems.⁴⁸ Additionally, the British sent an envoy to America to trade all radar secrets “in exchange for help on technical and production assistance.”⁴⁹ By early 1941, British leadership was still not convinced the Germans had any radar at all.⁵⁰ After receiving photographic evidence of the *Würzburg*, the British staged a daring raid against it for parts and technical manuals in February 1942. With this information work on counter-measures began in earnest. By April 1942, the British deployed “Moonshine,” an airborne anti-radar spoofing device that simulated a large force of incoming aircraft. However, the technique was only suitable against the *Freya*.⁵¹

Simultaneously, research was ongoing in both countries on a second and highly effective method of countering radar. Dropping large numbers of small metal strips, what we today refer to as “chaff,” then referred to as “Window” by the British and *Düppel* by the Germans, created a large return effectively hiding aircraft the radar operators were trying to find. In a remarkably similar response, both countries chose not to further pursue this technology because of how bad it would be for themselves if the enemy found out.⁵² As it turns out, chaff was already in use in the other theatre of the war. Japan developed *Giman-shi* (deceiving paper) and had already deployed it effectively against US Navy gunners at Guadalcanal.⁵³ The British never received this information, and it was not until July 1943 that British aircraft finally deployed Window. One of the reasons determined to make the use of Window acceptable, was that American radar research had finally caught up. The American SCR.720 radar developed a method of finding and dismissing the radar returns from Window, effectively negating the issues it caused to friendly forces.⁵⁴ Britain eventually used Window during a mass raid on Hamburg, a highly defended military target. The force included 791 bombers and Window proved incredibly successful. Typical losses for a Hamburg raid were 6 percent; on this occasion, the British lost only twelve aircraft, or 1.5%, saving an estimated thirty-five aircraft.⁵⁵

⁴⁵ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 65-69.

⁴⁶ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 69-70.

⁴⁷ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 70.

⁴⁸ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 23.

⁴⁹ Brian Kendal, “An Overview of the Development and Introduction of Ground Radar to 1945,” *The Journal of Navigation*, Volume 56, Issue 3 (2003): 350.

⁵⁰ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 77.

⁵¹ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 88-89.

⁵² Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 115-120.

⁵³ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 142.

⁵⁴ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 128.

⁵⁵ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 151-158.

New tactics and jamming techniques continued to develop throughout the war. The apex of this development came in support of the Allied invasion of Normandy. A comprehensive deception plan was developed and employed to cover the invasion force. The British systematically destroyed prominent German radar sites leading up to the invasion. On the night of the invasion, a fleet of eighteen ships, four with specially modified Moonshine jammers and fourteen with tethered radar reflective balloons, nicknamed “Filbert,” were dispatched. Accompanying these two false armadas were bomber squadrons using a mix of Window and airborne jammers. Once at the decoy landing locations, they deployed a smokescreen and broadcast noises similar to ships dropping anchor. Covering the real invasion force were two hundred ship-borne radar jammers. The culmination of these efforts was to prevent any airborne response to the invasion force and sow such confusion that the Germans did not commit their heavy forces to Normandy until the afternoon, thinking it was another feint.⁵⁶

This brief initial history of radar development, use, and exploitation provides several clear signposts for comparison with the present-day development of AI. First, the United States initially ignored the early stages of radar entirely. This not only caused the US to fall behind in R&D but alienated both key leading scientists in the field and a leading commercial company, directly leading to early US patented technology being used by foreign (even hostile) countries prior to the US further developing that same technology. Second, partnership across international lines developed both the US and Britain’s technology beyond where it could have been achieved by working in isolation. Without early British assistance the US might not have caught up with technology development and therefore, never provided Britain with the solution to Window. Third, radar technology was developed both for stand-alone defensive systems, monitoring incoming aircraft, as well as airborne radar improving the capability of pilots to find and locate enemy aircraft. This demonstrates a dual path of technology first in unique, stand-alone systems and second in integrating new technology into known platforms. Lastly, initial development of radar technology highlighted both risk areas and defeat potential. Simultaneous research into developing counter radar technology and protection from those efforts began as soon as radars came into service and was critical to the war effort.

Applying these lessons to current AI development demonstrates both where the USAF is currently succeeding and where significant improvement needs to be made. The spending discussed previously shows that the USAF is not “passing” on AI technology, however, it is already behind from a funding perspective. The challenge the USAF faces is not alienating the private sector as happened with radar research. The primary companies funding AI research are not typically defense contract companies. DARPA’s “AI Next” program will undoubtedly draw atypical industry partners but is unlikely to draw the AI powerhouses whose R&D funding already exceeds DOD. While DARPA’s initiative of leveraging the DOD tech base in the correct direction is a positive step, the lack of ability to directly connect to a USAF program of record means that there is a high potential for this research to get lost, reminiscent of the Department of the Navy’s choice not to pursue radar in the 1930s. We will see the same issue in the stealth discussion, a DARPA program, even a successful one, does not guarantee an official USAF program of record. The USAF must choose to embrace AI, so it is prepared to adopt developing AI technology.

⁵⁶ Alfred Price, *Instruments of Darkness* (New York, NY: Charles Scribner’s Sons, 1978), 205-211.

Britain had the advantage of close ties between the scientific section and the policymakers or future policy makers. In addition, the known and impending threat of Germany with no other technological potential to combat airborne bombing drove a need for radar technology. The USAF faces the opposite critical issue today: unchallenged success. The USAF's success over the past several decades in the Middle East has developed an entire generation that views the current force structure and tactics as the penultimate use of air power. While AI programs will very likely improve the existing capabilities and tactics of air power, they will also enable new and unique opportunities for executing air combat. Without an open mind to new methods of executing airpower, potentially at the exclusion of current aircraft, techniques, or personnel, the USAF may fail to innovate, instead only incrementally improving what it already has.

A second and equally important lesson is the benefit of interaction with other countries. The positives of leveraging foreign technology capability should not be missed. This is especially true in light of the open source mentality mentioned previously. Other countries will be using developments from the US AI community. Sharing openly with our closest allies ensures both the US and their allies are at the leading edge of AI technology, as well as continuing to develop goodwill among allies with whom we share what will likely be released soon anyway. This will also help ensure interoperability between the international systems of the the US and its allies. Recent conflicts demonstrate how likely it is that multiple countries will be allied with the US in any future conflict. Developing shared, or at least similar, systems best prepares both countries for future conflict. Because there is so much commercial and open source research into AI, it is unlikely secrets will be lost by sharing with allies. As long as the critical pieces of technology development are sufficiently protected, like training datasets or actual equipment, there is very little risk.

The development of radar happened near simultaneously as ground-based early warning and ground control, as well as for installation directly onto aircraft for airborne use, providing another lesson. The USAF must ensure AI is used both to improve current technology, like improving aircraft within embedded radar, and find the right new ideas, like developing an early warning station. Project Maven which was mentioned above is an excellent example of using AI to improve current equipment and tactics. The USAF must continue to pursue this type of improvement wherever possible. The first place to look is where commercial companies are already developing systems that could easily be applied. This may be in aircraft maintenance or scheduling where partnering with a commercial airline or shipping company could benefit both. At the same time, bringing AI into certain combat systems might immediately provide solutions to ongoing struggles. Overcoming radar jamming and detecting radar tracking both have high potential to benefit from AI due to the large amount of information and speed at which it must be processed. The USAF must be forceful in ensuring defense contractors take potential AI benefits seriously. This could be accomplished by specifically requiring aspects of projects require AI execution or by setting requirements only met through use of AI. Additionally, open system architecture must be available so multiple users can develop software and AI programs that can be quickly and efficiently adopted to fielded aircraft. Leaving everything to primary defense contractors significantly limits the potential talent pool and ideas that can be implemented.

Lastly, the example of how quickly radar technology was countered in multiple and unique ways highlights the potential risks of AI. The USAF needs to take AI defense seriously, and to

“harden” any developing AI systems, as well as planning defense against enemy AI capabilities. One of the highest risks currently is corruption of the dataset used to train AI algorithms. The corruption might happen accidentally, or it might be malicious, with an enemy state or player intentionally adding images to force the program to learn incorrectly. Followed very closely is unknown bias that can develop in programs learning from a dataset. This unknown bias might be due to an incomplete dataset, one that has not been properly built, or one that was intentionally tampered with. Because the creators of specific algorithms are often not aware of how AI programs are making decisions there is a real danger of the programs developing unknown bias. Additionally, because the datasets required to train AI algorithms are so large, it is extremely difficult to continually monitor the validity of the dataset. Finally, images that appear as nonsense to humans can effectively trick computer recognition programs into high-probability false reports. These are just a few of the known potential pitfalls of AI. The USAF must take the risks seriously and develop systems that are protected from subversion. Managing correctly protected and sorted datasets needs to be of utmost importance for military AI algorithms and is a good start. However, talking about the latest issues that are accidentally discovered is not enough. The USAF must dedicate a skilled “red team,” a group who understands AI and has the primary responsibility of finding means of exploitation against our own systems. The traditional level of testing and validation will be insufficient with a technology so different from anything seen to date.

Lastly, the USAF must look toward defending against offensive use of AI as well. This will be an order of magnitude more difficult as it involves correctly predicting how adversaries are likely to use AI technology and then seeking to counter those efforts. It is especially important to note that appropriately preparing defensively against AI must be more than just looking at protecting datasets and advancing electronic warfare. AI algorithms have the potential to affect so much more, and in ways that people are just now beginning to discuss. Deepfakes, AI produced video that mimic a real person to the point that it is indistinguishable from a real video, are a huge potential threat. While this is certainly an issue at the higher levels of government, it cannot be ignored by the USAF.

STEALTH

Stealth technology is one element of a larger field that attempts to allow aircraft to avoid radar detection. This field includes multiple approaches, including chaff, tactics, electronic attack, radar absorbent materials (RAM), and aircraft shape, as was discussed previously in the radar section. Most people associate stealth with the initial release of the F-117 Nighthawk by Lockheed, but the attempt to avoid detection began as soon as ground detection radars came into service, as early as WWII.⁵⁷ It was quickly apparent that reductions in the radar cross-section (RCS) were incredibly difficult and had minimal returns. Following the now well-established radar range equation, scientists at the time soon discovered that to reduce the detection range of an

⁵⁷ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 2.

aircraft by a factor of 10, the aircraft RCS would need to be reduced by a factor of 10,000.⁵⁸ By the 1970s, the dominant work in RCS management was almost entirely due to various efforts dealing with RAM and minimal effort was put into a way to manage aircraft shape to make a significant RCS reduction.⁵⁹

Reducing aircraft RCS soon became a significant focus for the USAF. In 1973 Israel fought Syria and Egypt in the Yom-Kippur War. Israel fought using the latest USAF aircraft and tactics and yet lost 108 aircraft in 18 days, mostly to surface to air missiles (SAMs) operated by assessed by then current US intel as “substandard” troops.⁶⁰ This loss shocked the USAF and drove a nearly frantic race to find a way to survive Soviet Union SAMs (the same systems that were so devastating to the Israelis) in a potential Eastern European conflict with Russia. The following year DARPA began a program with a two-fold objective: discover the required RCS for tactical aircraft to avoid detection, and develop the technical methods to achieve that RCS.⁶¹ Interestingly, the initial request went out to only five companies: Northrop, McDonnell Douglas, General Dynamics, Fairchild, and Grumman, not including Lockheed. McDonnell Douglas and Northrop were each awarded contracts of \$100,000 for further study.⁶² Lockheed earned their way into the project after briefing DARPA on the highly classified work previously accomplished on the A-12 and D-21 reconnaissance aircraft designed for the Central Intelligence Agency.⁶³ Lockheed decided to approach the problem by designing to meet RCS first in the design priority, rather than designing to tactical aircraft requirements and then attempting to reduce the RCS. Denys Overholser and his team developed computer programs to predict the radar signature of a given aircraft design. A significant breakthrough came after he discovered a scientific work on radar signal diffraction by the Russian P. I. Ufimtsev published in 1962 that was translated into English in 1972.^{64,65}

With the computer predictions as a baseline, Lockheed received \$25,000 to construct a wooden model with a metal frame of the initial design to verify the accuracy of the models. Tests were conducted in 1975 by both Lockheed and McDonnell Douglas to verify the models⁶⁶ leading to DARPA beginning the project that would come to be known as the Experimental Survivable Testbed (XST).⁶⁷ Three teams competed in the XST competition, with Lockheed and Northrop

⁵⁸ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 4.

⁵⁹ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 5-8.

⁶⁰ “Inside the Skunk Works,” *Popular Science*, Volume 245, Issue 4 (1994): 2.

⁶¹ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 13.

⁶² David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 14.

⁶³ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 15.

⁶⁴ “Inside the Skunk Works,” *Popular Science*, Volume 245, Issue 4 (1994): 2-3.

⁶⁵ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 18-20.

⁶⁶ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 20-21.

⁶⁷ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 20-21.

exceeding expectations and submitting nearly identically performing prototypes. The third team was a partnership between McDonnell Douglas and Teledyne Ryan that did not meet the XST specifications.

Before partnering, McDonnell Douglas was struggling to meet the RCS requirements after focusing on a more universal stealth design. Their prior design, named “Quiet Attack,” sought to remain undetected by reducing signatures in four separate domains: radar, acoustic, infrared, and visual. After pairing with Teledyne Ryan, the joint proposal still underperformed on reduced RCS and planned to make up the difference with Electronic Counter Measures (ECM).⁶⁸ Lockheed and Northrop were both given approximately \$1.5 million to proceed with phase I of the XST program. As phase I concluded, DARPA selected Lockheed for the project and moved into phase II. The work the Northrop team performed was recognized and they were encouraged to continue working on another DARPA project that was just beginning. Their efforts were the baseline for the Tacit Blue program that was the baseline for the B-2 bomber program.⁶⁹

Prior to starting Phase II, DARPA decided to broaden the scope of the project. Unfortunately, the new overall cost estimate was \$36 million. The typical share of the cost in DARPA programs was 34 percent DARPA and 33 percent for both the contractor and the associated service. In this case, Air Force funding was an issue, with many people in leadership reluctant to fund the \$12 million. Internally, the Air Force was struggling to agree on the lightweight fighter program (which would become the F-16, the most prevalent fighter in the USAF inventory), and many did not want to support another technology demonstration.⁷⁰ Eventually, DARPA secured the funding and Phase II began in April of 1976, intending to build an actual aircraft technology demonstrator. The program’s security was also increased to Top Secret and named “Have Blue.” Many of the people who worked on phase I were not briefed and never knew the effort continued.⁷¹

Construction on the two Have Blue aircraft began in 1976. To save cost and time much of the essential equipment for the aircraft were taken directly from existing aircraft: a side stick controller from the F-16, nose wheel steering from the F-5, and General Dynamics engines from the Navy’s T-2C stock.⁷² Have Blue aircraft 1 flew its first flight on 1 Dec 1977,⁷³ four years after the wake-up call of the Yom Kippur War and only three years after DARPA began the program to see if it was even possible to avoid detection by SAMs. The total cost through the end of the Have Blue program was \$54.6 million, with an average of only 66 Lockheed engineers for Phase II.⁷⁴ After the success of the Have Blue program, Lockheed tried to design low-observable ships for

⁶⁸ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 26, 29.

⁶⁹ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 33.

⁷⁰ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 27-28.

⁷¹ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 33-34.

⁷² David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 38-39.

⁷³ “Inside the Skunk Works,” *Popular Science*, Volume 245, Issue 4 (1994): 4.

⁷⁴ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the “Stealth Fighter”* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 45-46.

the Navy. With support from DARPA and after successfully demonstrating similarly spectacular results with submarines, the Navy leadership declined to pursue the capabilities. Ben Rich, who was critical to Lockheed's Have Blue program and later led Skunk Works (Lockheed's technology department responsible for the Have Blue program), speculates that the Navy declined due to an inability to shift culture away from accepted design and manning. He said the Navy thought, the design "looked too different," it did not need enough sailors for a captain to feel like he was leading, and the Navy would not need enough of them to fill required leadership positions. In the end, Rich says the Navy decided it was "too radical a design."⁷⁵

There were still many issues to overcome between proving the scientific theories and fielding a fully functional tactical stealth aircraft, most significantly the passive infra-red targeting system.⁷⁶ After initially planning to purchase 20 aircraft, then increasing to as many as 89 aircraft, the USAF eventually settled on 59 aircraft total.⁷⁷ After a declaration of Limited Initial Operationally Capable in 1983, the F-117A dropped bombs in combat for the first time in Panama in 1989. The F-117As only flew two sorties and no information was gained about the aircraft capabilities as there was no ground radar defense network. In Operation Desert Storm in 1991, the F-117A had the first opportunity to prove the viability of stealth technology in highly contested combat. The F-117 fleet flew 1270 combat sorties and was the only crewed aircraft tasked against highly defended targets in Baghdad. The F-117As flew only 2 percent of the overall strike sorties and yet were used in 40% of the missions against Iraqi strategic targets, all without ever being struck by enemy fire.⁷⁸

There are several useful lessons from the development of stealth to apply to AI development. First, it is important to note that nowhere in the world were there examples of stealth research with this level of success. This is due to several factors: the extremely focused use of the technology and lack of any associated civilian benefit, the perceived lack of a need for the technology (as seen in the Russian response who favored defensive SAMs rather than offensive stealth),⁷⁹ and the highly successful effort by the U.S. to classify the project and maintain secrecy of the existence of a stealth program, much less the details. The stark difference between this situation and the current global race for AI is critical, as it demonstrates the futility of attempting to manage AI development in an isolated classified world. Certainly, some AI programs or elements of programs might be classified, as well as military datasets and other equipment, but development and usage of AI in the commercial sector have already outpaced even the DoD's leading-edge agency DARPA. As discussed previously, DARPA's aggressive AI Next plan will spend less than 10% of what the world's leading companies are spending on AI

⁷⁵ "Inside the Skunk Works," *Popular Science*, Volume 245, Issue 4 (1994): 5-6.

⁷⁶ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the "Stealth Fighter"* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 55.

⁷⁷ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the "Stealth Fighter"* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 131.

⁷⁸ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the "Stealth Fighter"* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 154.

⁷⁹ "Inside the Skunk Works," *Popular Science*, Volume 245, Issue 4 (1994): 11.

development in the near future.^{80,81} The USAF will not maintain an edge in AI adoption by keeping a shroud of secrecy.

Despite the massive difference in development, several corollaries provide lessons for moving forward in AI. David Aronstein and Albert Piccirillo offer several vital lessons from their study of stealth development. First, do not avoid outside areas of expertise: Lockheed was initially left out of the discussion because they were not seen as being involved in fighter design.⁸² The USAF must not limit technology cooperation to traditional defense service corporations. While those traditional companies will no doubt play critical roles in the future, the risk of missing the best team for unique adaptation is too high. The USAF must invite and find ways of engaging with companies not generally associated with the defense industry.

Second, encourage competition and do not let knowledge and skill go to waste: DARPA encouraged Northrop to participate in the second project, enabling future stealth designs.⁸³ In this critical time of technology development and innovation, no expertise should be dismissed. Communication across functional areas, specialties and even service departments is a must. The DARPA program manager effectively transitioned a team into another area of discovery, directly impacting the next generation of stealth. The USAF must develop and protect channels of communication so breakthroughs and innovative design not suited for one task are not lost but shifted to where they will be critical.

Third, personnel is critical: in the development of stealth, the government and industry teams worked well together and all the teams were small groups of highly skilled and motivated people.⁸⁴ The U.S. as a whole understands this and is pushing aggressively to increase the science, technology, engineering, and mathematics (STEM) focus of our future graduates. The USAF must realize and accomplish the same. It must set a high premium on AI knowledge and experience both at the tactical level and in senior leaders. Passing up the next military revolution because USAF leadership does not understand AI and sees the idea as too different from the current paradigm is a failure the USAF cannot afford. Aronstein and Piccirillo summarize a crucial lesson as follows:

Several program participants, representing most of the major organizations that were involved, have attributed much of the success of the early U.S. Air Force low observables effort to the senior leaders who structured the program, supported it, and allowed it to happen in a streamlined way with abbreviated oversight. They allowed much of the

⁸⁰ Martijn Rasser, Megan Lamberth, Ainikki Riikonen, Chelsea Guo, Michael Horowitz, and Paul Scharre, *The American AI Century: A Blueprint for Action*, (Washington D.C., Center for a New American Security, 2019), 39, <https://www.cnas.org/publications/reports/the-american-ai-century-a-blueprint-for-action>.

⁸¹ Ben Scott, Stefan Heumann, and Philippe Lorenz, *Artificial Intelligence and Foreign Policy*, (Berlin, Stiftung Neue Verantwortung, 2018), 15-16, <https://ssrn.com/abstract=3103961>.

⁸² David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the "Stealth Fighter"* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 48.

⁸³ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the "Stealth Fighter"* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 49.

⁸⁴ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the "Stealth Fighter"* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 51.

usual bureaucracy to be cut out and authorized program personnel to accomplish their jobs.⁸⁵

This lesson is undoubtedly the most difficult to apply; after all, they are discussing what was easy and effective to do for a small program. How to accomplish the same effect when AI as a concept is likely to invade not only every operational piece of equipment, but operational control, maintenance, and all support efforts as well? In this instance, the USAF will do best by mimicking what the DoD has already done by creating an AI office. If appropriately placed, staffed, and funded, a USAF AI office might well be vital in applying several of the associated lessons. The office could be critical in coordinating with new commercial companies and leading AI technology firms, assisting in communication across all aspects of the service, be responsible for the appropriate level of oversight for ongoing projects, and be a perfect location for select AI cyber and AI acquisitions specialist personnel to work.

Lastly, as the USAF develops and adopts AI, care must simultaneously be given to counter AI technology and weaknesses in both the underlying technology or execution. While McDonnell Douglas' XST failed to perform in RCS reduction, the application of stealth across all "bands" of visual, acoustic, infra-red, and radar is significant. One of the biggest challenges currently facing USAF stealth aircraft is that potential adversary countries have chosen not to engage them with radar where the USAF technology is still superior. Instead, they are moving to other bands where they can potentially detect stealth aircraft more easily. The only tactical loss of an F-117A in Kosovo in 1999 is an excellent reminder of this. The SAM defense forces had no chance of using radar to detect and target a USAF stealth aircraft traditionally, but in this case, they did not need to. They used a combination of visual observers making phone calls when the aircraft launched from Italy and capitalized on the unfortunate choice to use the same route of flight over and over again from the F-117As to know roughly where the aircraft would be.⁸⁶

COMMERCIAL OFF THE SHELF (COTS) AND SOFTWARE

The focus area of the final analysis is on DOD's prior efforts to adopt commercial computer technology. The primary sources examined are reports from Defense Service Board studies spanning the January 1987 study "Use of Commercial Components in Military Equipment"⁸⁷ to the February 2018 study "Design and Acquisition of Software for Defense Systems."⁸⁸ While all of the studies did not focus on precisely the same technology acquisition, they were essentially iterations of each other referencing DoD usage of the technology available

⁸⁵ David Aronstein and Albert Piccirillo, *Have Blue and the F-117A: Evolution of the "Stealth Fighter"* (Reston, VA, American Institute of Aeronautics and Astronautics, Inc., 1997), 173.

⁸⁶ Zord Gabor Laszlo, "Secrets of 1999 F-117 Shootdown Revealed," *Journal of Electronic Defense*, Volume 29, Issue 1 (2006): 26.

⁸⁷ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1987), <https://apps.dtic.mil/dtic/tr/fulltext/u2/a180338.pdf>.

⁸⁸ Department of Defense, Office of the Under Secretary of Defense for Research and Engineering, Defense Science Board, *Design and Acquisition of Software for Defense Systems* (Washington D.C., 2018), <https://apps.dtic.mil/dtic/tr/fulltext/u2/1048883.pdf>.

at their time-period and before. What is striking is how similar the findings and recommendations were from each of the studies while spanning over thirty years of technology development.

Throughout the DOD's history of computer technology use, the services have repeatedly trended toward a lack of trust in commercial capability and an over-specification of requirements for needed purposes.^{89,90,91} Each of the studies reviewed highlighted how commercial technology was moving at a pace that was outstripping the DoD. One study even specifies that "Defense-funded research and development once drove commercial technology, but commercial technology now leads DOD in many key areas."⁹² This assessment shows the striking similarities between the past and today's balance between DOD and commercial AI technology. So, what are the successes and failures and how can we learn from them?

From the earliest study, which deals with the acquisition of microprocessors in the late 1980s, there were several issues highlighted. First, DOD standards were more restrictive than the current acceptable commercial standard. This developed initially when there was no industry standard. As the technology developed, military applications led the way, creating an acceptable standard with numerous criteria. As the commercial industry grew and the baseline equipment increased in both efficiency and reliability, the specific technology did not always follow the previously defined military specifications. Rather than being willing to accept the civilian standard, the military increasingly held to the already defined MIL-SPEC or, often, even increased the requirements.⁹³ Notably, these additional requirements often did not make the product more capable than the commercial counterpart. This made dealing with the DOD extremely cumbersome for commercial companies who needed to create separate items for military and commercial sales that had essentially the same function. This trend continues to this day and is one of the reasons many companies find it challenging to work with the USAF and choose to avoid military contracts.⁹⁴ Over and over again, we find that the USAF is paying more for a product that is not as functional as the civilian counterpart. One of the reasons for DOD requirements is to maintain US control of product production. While there are certainly issues with product

⁸⁹ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1987), 38, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a180338.pdf>.

⁹⁰ Department of Defense, Office of the Under Secretary of Defense for Acquisition & Technology, Defense Science Board Task Force, *Acquiring Defense Software Commercially* (Washington D.C., 1994), 30, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a286411.pdf>.

⁹¹ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Defense Science Board Task Force on Integrating Commercial Systems into the DOD, Effectively and Efficiently, *Buying Commercial: Gaining the Cost/Schedule Benefits for Defense Systems* (Washington D.C., 2009), 18, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a494760.pdf>.

⁹² Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Defense Science Board Task Force on Integrating Commercial Systems into the DOD, Effectively and Efficiently, *Buying Commercial: Gaining the Cost/Schedule Benefits for Defense Systems* (Washington D.C., 2009), 2, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a494760.pdf>.

⁹³ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1987), 20, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a180338.pdf>.

⁹⁴ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1989), 9, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a274729.pdf>.

pipeline security, there are many areas where the risk is more than acceptable. Additionally, as was found in the past, even with very significant restrictions and oversight, many of the US companies purchased products that are created outside the US and only assembled in the States.⁹⁵

Historically the USAF has also found itself weak in the knowledge base of emerging technology. This might seem counter-intuitive, however, it was highlighted over and over again in the DSB studies.^{96,97,98} This is not to say that the USAF has not been leading in the usage of technology, only that the right people did not have sufficient knowledge and experience. The Air Force excels at executing with advanced technology but often struggles with either cost or time (or both) in the development and acquisition of those technologies. This lack of knowledge particularly applies to the acquisition and sustainment world, where USAF Airmen are coordinating multi-million dollar contracts without fully understanding what the real requirements can and should be and how to properly work with the private companies that hold the actual design and build expertise with advanced technologies. In the past, this has often led to time and cost overruns⁹⁹ and, ultimately, to the DoD paying more and getting less than private companies.¹⁰⁰

This insufficiency of knowledge also drives a lack of ability to set appropriate requirements for the future.¹⁰¹ This is both a scientific knowledge base and a cultural challenge. The USAF must have a cadre of AI educated personnel in the acquisition career field to adequately work with commercial companies on contracts. The USAF also needs AI trained personnel in the future capabilities and Program Offices to know where platforms should look to develop and what areas will be no longer useful to pursue due to advances in that area or bordering areas in AI.

⁹⁵ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1989), 6, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a274729.pdf>.

⁹⁶ Department of Defense, Office of the Under Secretary of Defense for Acquisition & Technology, Defense Science Board Task Force, *Acquiring Defense Software Commercially* (Washington D.C., 1994), i, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a286411.pdf>.

⁹⁷ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Defense Science Board Task Force on Integrating Commercial Systems into the DOD, Effectively and Efficiently, *Buying Commercial: Gaining the Cost/Schedule Benefits for Defense Systems* (Washington D.C., 2009), xix, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a494760.pdf>.

⁹⁸ Department of Defense, Office of the Under Secretary of Defense for Research and Engineering, Defense Science Board, *Design and Acquisition of Software for Defense Systems* (Washington D.C., 2018), 26, <https://apps.dtic.mil/dtic/tr/fulltext/u2/1048883.pdf>.

⁹⁹ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1987), 32, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a180338.pdf>.

¹⁰⁰ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1989), 1, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a274729.pdf>.

¹⁰¹ Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology, Defense Science Board Task Force, *Acquiring Defense Software Commercially* (Washington D.C., 1994), 17, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a286411.pdf>.

Additionally, the USAF needs critical tactical thinkers and supporting strategic thinkers to find the best areas to use AI in the future. These ideas should not be limited to just making what the USAF has better; they should strive for real innovation, using AI in a completely separate way or paired with a system to achieve strategic goals in a new and unique way. The 2009 DSB study recommended that the DOD have “relevant competence and experience, across both technical domain and project management.”¹⁰² Then in 2018, the DSB study recommended the services “develop workforce competency and a deep familiarity of current software development techniques.”¹⁰³ Clearly this is an issue the USAF has faced previously and has yet to overcome. It will not only take educated personnel but a culture change as well.

That these lessons need to be driven by a full culture change is apparent through the years of the studies, which is likely why after so many recommendations, it still has not happened. In 1989, the DSB recommended that the DOD needs a fundamental cultural change “to receive the potential benefits of higher quality, reduced total costs, greater access to advanced technology, a broader industrial base, and greater customer satisfaction -- as represented by recent trends in the civilian sector.”¹⁰⁴ The 1994 study cites stove pipe culture as the reason recommendations are not accepted.¹⁰⁵ Again the 2009 study calls for a culture change toward buying and modifying COTS to gain speed and lower costs and risks.¹⁰⁶ Finally, the 2018 study says the defense contractor base has not kept up with proven commercial sector software development due to DOD culture.¹⁰⁷ Over and over the recommendation to change and adapt is provided and yet not achieved. Thankfully up to this point it has only cost time and money. If the USAF is unable to adapt to AI, the consequences could be far worse. In three of the studies, top-down engagement

¹⁰² Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Defense Science Board Task Force on Integrating Commercial Systems into the DOD, Effectively and Efficiently, *Buying Commercial: Gaining the Cost/Schedule Benefits for Defense Systems* (Washington D.C., 2009), xix, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a494760.pdf>.

¹⁰³ Department of Defense, Office of the Under Secretary of Defense for Research and Engineering, Defense Science Board, *Design and Acquisition of Software for Defense Systems* (Washington D.C., 2018), 26, <https://apps.dtic.mil/dtic/tr/fulltext/u2/1048883.pdf>.

¹⁰⁴ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1989), 3, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a274729.pdf>.

¹⁰⁵ Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology, Defense Science Board Task Force, *Acquiring Defense Software Commercially* (Washington D.C., 1994), 6, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a286411.pdf>.

¹⁰⁶ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Defense Science Board Task Force on Integrating Commercial Systems into the DOD, Effectively and Efficiently, *Buying Commercial: Gaining the Cost/Schedule Benefits for Defense Systems* (Washington D.C., 2009), xxii, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a494760.pdf>.

¹⁰⁷ Department of Defense, Office of the Under Secretary of Defense for Research and Engineering, Defense Science Board, *Design and Acquisition of Software for Defense Systems* (Washington D.C., 2018), 2, <https://apps.dtic.mil/dtic/tr/fulltext/u2/1048883.pdf>.

from high-level leadership is the recommendation to correct the DoD lack of ability to shift to COTS equipment.^{108,109,110} Culture change toward adopting AI must start at the top as well.

RECOMMENDATIONS

The most critical finding across all three case studies is that an external driving force is essential to the effective and efficient application of emerging technologies. In the case of Radar, it was the looming threat and then the ongoing action of WWII that drove technical implementation. For stealth, it was the fear inspired by the Israeli's losses in the Yom-Kippur War, causing the American Air Force to doubt its equipment and tactics against even a less trained adversary. As for thoroughly and efficiently adopting COTS technology and software, over and over again, the DOD falls behind the commercial sector because there is no driving need galvanizing execution. Unfortunately, without an external motivator that unifies action, this trend is incredibly challenging to overcome.

To meet this challenge, the USAF must pursue multiple avenues. First, the USAF must prioritize AI adoption from the top down. The 2019 report to Congress from the National Security Commission on Artificial Intelligence (NSCAI) makes this same point. It cites the Soviet Union as the existential threat that pushed nuclear weapon technology in the Cold War and then stealth and GPS in the 1970s.¹¹¹ This should be done both with current leadership making AI adoption an ongoing critical interest item as well as creating a USAF office to drive and assist AI adoption across all elements of the service. The Air Force made initial steps, but it is not enough. The 2019 USAF AI Annex to the DOD AI strategy document places a priority on effectively and efficiently adopting AI across the service. However, it is not enough, nor is the mindset inherent in the text sufficient to fully adopt AI to the degree required. In the closing it says, "(f)or those of us in the military sphere, AI is akin to the development of stealth aircraft and precision guided munitions."¹¹² As discussed throughout this paper, stealth technology, while significant, was an isolated technology that was evolutionary, enabling a substantial increase in well-established USAF doctrine. AI, on the other hand, has the potential to be revolutionary across multiple domains, both for the USAF and its adversaries. Without a specific external impetus, the USAF

¹⁰⁸ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1989), 11, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a274729.pdf>.

¹⁰⁹ Department of Defense, Office of the Under Secretary of Defense for Acquisition and Technology, Defense Science Board Task Force, *Acquiring Defense Software Commercially* (Washington D.C., 1994), 9, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a286411.pdf>.

¹¹⁰ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Defense Science Board Task Force on Integrating Commercial Systems into the DOD, Effectively and Efficiently, *Buying Commercial: Gaining the Cost/Schedule Benefits for Defense Systems* (Washington D.C., 2009), xxii, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a494760.pdf>.

¹¹¹ National Security Commission on Artificial Intelligence, *National Security Commission on Artificial Intelligence Interim Report*, Prepared in response to the 2019 National Defense Authorization Act, 2019, 29, https://permanent.fdlp.gov/gpo128602/NSCAI_Interim_Report_for_Congress_201911.pdf.

¹¹² Department of Defense, Department of the Air Force, *The United States Air Force Artificial Intelligence Annex to the Department of Defense Artificial Intelligence Strategy*, Washington D.C., 2019, 6, <https://www.af.mil/Portals/1/documents/5/USAF-AI-Annex-to-DoD-AI-Strategy.pdf>.

must internalize the importance of AI development and employment as if there were an existential driving force. If it does not, the same trap seen over and over in prior adoption of technology will develop and the USAF will fall behind. The NSCAI expresses the same concern, agreeing that there is a clear acknowledgment of the importance of AI for national security, “however, it is not clear that these top-level beliefs and strategic priorities have been fully embraced by departments and agencies. There must be broad organizational understanding of how AI can address core national security challenges and what is needed to achieve an AI advantage.”¹¹³

The office needs not only the appropriate level of rank and official leadership oversight, but also an allocated budget that supports the importance of the AI effort with the ability to allocate those funds to any organization or project moving toward a definite AI adoption goal. This mirrors the top three recommendations from the 2002 DSB study,¹¹⁴ the conclusions of the 2009 DSB study,¹¹⁵ and the implementation plan from the 1990 DSB study.¹¹⁶ Additionally, the office must be staffed with people who are trained in AI.

The second recommendation made clear in these case studies is the importance of the right people. As was pointed out above in the examination of COTS adoption and seen in the amazing development done by the small number of engineers at Lockheed working on Have Blue. Three of the primary documents with future AI recommendations (NSCAI, the Center for a New American Security study *The American AI Century: A Blueprint for Action*, and the USAF AI annex to the DOD AI Strategy), all make recruiting and training AI personnel one of their primary findings.^{117,118,119} The USAF should approach this in multiple ways, first by creating a career field for AI trained personnel, or at least creating a subset of the cyber career field. This reinforces the importance of AI in the top-down approach and develops USAF personnel. Additionally the USAF could provide bonuses similar to other career fields for extended service.

¹¹³ National Security Commission on Artificial Intelligence, *National Security Commission on Artificial Intelligence Interim Report*, Prepared in response to the 2019 National Defense Authorization Act, 2019, 31, https://permanent.fdlp.gov/gpo128602/NSCAI_Interim_Report_for_Congress_201911.pdf.

¹¹⁴ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, Defense Science Board Task Force, *The Impact of e-Business on DOD Acquisition Processes* (Washington D.C., 2002), 50-53, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a406686.pdf>.

¹¹⁵ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Defense Science Board Task Force on Integrating Commercial Systems into the DOD, Effectively and Efficiently, *Buying Commercial: Gaining the Cost/Schedule Benefits for Defense Systems* (Washington D.C., 2009), 23-24, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a494760.pdf>.

¹¹⁶ Department of Defense, Office of the Under Secretary of Defense for Acquisition, Defense Science Board, *Use of Commercial Components in Military Equipment* (Washington D.C., 1989), 11-12, <https://apps.dtic.mil/dtic/tr/fulltext/u2/a274729.pdf>.

¹¹⁷ National Security Commission on Artificial Intelligence, *National Security Commission on Artificial Intelligence Interim Report*, Prepared in response to the 2019 National Defense Authorization Act, 2019, 35, https://permanent.fdlp.gov/gpo128602/NSCAI_Interim_Report_for_Congress_201911.pdf.

¹¹⁸ Martijn Rasser, Megan Lamberth, Ainikki Riikonen, Chelsea Guo, Michael Horowitz, and Paul Scharre, *The American AI Century: A Blueprint for Action*, (Washington D.C., Center for a New American Security, 2019), 13, <https://www.cnas.org/publications/reports/the-american-ai-century-a-blueprint-for-action>.

¹¹⁹ Department of Defense, Department of the Air Force, *The United States Air Force Artificial Intelligence Annex to the Department of Defense Artificial Intelligence Strategy*, Washington D.C., 2019, 5, <https://www.af.mil/Portals/1/documents/5/USAF-AI-Annex-to-DoD-AI-Strategy.pdf>.

The second way to gain the right personnel is by establishing strong relationships with commercial companies that are strong in AI development. A USAF AI office would be uniquely situated to develop close partnerships with companies not normally associated with the DOD. There is a widening gap between the military and the technology sector, personal relationships and direct office ties will help to close the gap. The USAF must look to companies already deploying AI in ways that are directly transferrable to current operations. This may be in maintenance or flight scheduling process from a commercial airline company or air-carrier or it may be assisting base security or travel coordination. Starting by working with less strict security requirements will not only make the USAF more efficient across the board, it will strengthen the bonds between non-traditional commercial companies and will help introduce AI to USAF personnel. This will build trust across multiple avenues towards greater AI development cooperation. The USAF must also ensure AI development in the companies and programs currently operational.

The Air Force must emulate the development of radar technologies by both improving known systems and making a focused effort to find areas where AI can create or enhance entirely new equipment, or tactical and operational lines of effort. Radar was designed into aircraft to enhance their performance, but it was first and foremost designed as an entirely new element, ground based detection and control. The lesson the USAF must take is to purposefully seek entirely new and unique ways that AI may enable tactical, operational, or strategic advantage. First, AI can and should be used to dramatically improve known platforms and capabilities. Upgrade programs on current aircraft must advance to include AI. However, if that is where USAF adoption ends it will potentially lose the greatest advantage developing technologies provide.

The USAF needs to develop a sense of AI potential in tactical officers and encourage innovative thinking for the future. This may be the most difficult process of all, as it will undoubtedly cause movement away from traditional USAF equipment and tactics in some areas. The slow and painful adoption of remotely piloted aircraft demonstrates just how difficult this process might be. If not successful, enemy countries will likely have adapted AI to defending against our current tactics and the USAF will be left behind. This process must also immediately include creative defense and ways to counter adversary AI as well.

AI will be a defining technology of the next generation, shaping militaries around the world. The USAF is perfectly situated to take advantage of the benefits and maintain its place of preeminence in the world, as long as it makes the commitment to apply the technology and gain the benefits. Action must be taken, following the steps laid out in this paper will help ensure those actions are the correct ones for the future.

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