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Science and Technology and the Geopolitical Landscape

Major Adam Desy, USMC

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Science and Technology and the Geopolitical Landscape

Major Adam Desy, USMC

Airpower has become predominant, both as a deterrent to war, and-in the eventuality of war-as the devastating force to destroy an enemy's potential and fatally undermine his will to wage war.

— Gen Omar N. Bradley

INTRODUCTION

A geopolitical shift and renewed focus on strategic competition have highlighted a number of developments that challenge the conventional nature of certain doctrinal concepts. The rapid advancement of technologies has provided state and non-state actors alike low cost innovative ways to gain situational awareness, employ effective prohibitive interference and ultimately gain a competitive advantage against perceived threats. Uncertainty and arms proliferation combined with the rapid advancement of autonomous weapon systems will continue to drive security challenges as governments and large bureaucratic organizations seek creative ways to counter and adapt. Consequently, the term "war" has taken a new form that crosses multiple spaces and technological spheres.

In this context, current and emerging threats in the aerospace domain will continue to evolve and further challenge assumptions on the way airpower capabilities are employed. In order to accurately identify and address such challenges, current doctrinal concepts need to be revised. More specifically and as this paper will argue; the conventional definition and doctrinal underpinnings of air superiority are out of date and need to be amended. The argument will be validated through a conceptual discussion and analyses of the current world order synchronized with the pace of technological advancement that have undermined traditional wisdom and to a certain degree changed the character of war. The essay will be informed by qualitative data and two relevant case studies; the Nagorno-Karabakh and Russia-Ukraine conflicts. It will culminate with

suggested operational concepts meant to drive cognitive thought amongst the aerospace defense community.

AIR SUPERIORITY DEFINED

Described in Joint Publication 3-01, air superiority is a degree of control of the air domain that fosters operations without the threat of prohibitive interference; specifically from kinetic capabilities.[1] From World War I to recent operations in Iraq and Afghanistan, capabilities have evolved to enhance battlefield awareness which have generated new methods of employment and means to achieve command and control (C2). Conceptually, it is important to understand that the current operating environment is multi-domain in nature, consists of many systems and actors and therefore is inherently complex. Innovation thrives throughout the world and has to a certain degree pulled the great powers to increased levels of strategic competition. With this considered, a new definition of air superiority must account for variables associated with the changed character of war that incorporate all aspects of the aerospace domain.

Many of the advanced air forces throughout the world have invested in military and commercial space based capabilities that have improved air component effectiveness, lethality and reach.[2] Such capabilities complement kinetic and non-kinetic weapon systems, are modular in nature and have forced military planners to rethink what air superiority really means in the 21st century. As such, a recommended definition should state; aerospace superiority is the total control of all ways, ends and means that mitigate

[1] "Countering Air and Missile Threats" *Joint Publication 3-01*. (21 April 2017) I-4, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_01.pdf
[2] Author is a military aviator with over 10 years of flight experience.

the threat of prohibitive interference from the surface to a specified earth orbit. Furthermore, the definition should be broken down into three subcomponents that integrate the physical, electromagnetic and directed energy spectrums.

STRATEGIC COMPETITION AND THE GEOPOLITICAL LANDSCAPE

Since World War II, the international rules based order largely enforced by the West was characterized by long periods of relative stability. A degree of instability has returned as great powers such as Russia and China look for ways to expand as they compete for influence, international market share and hegemonic status. The dynamics of such relationships have shaped geopolitics over the last century and continue to drive the worldwide friction that exists today. From space exploration to the creation of the internet, a natural competitive landscape gave rise to rapid levels of disruptive technological innovation that provided significant benefits to advanced economies and militaries alike.

The United States (US) continues to be the dominant actor on the world stage and is routinely challenged by state and non-state actors. Over the last two decades, conflict in the Middle East commanded significant attention, political capital and resources from the West. The US, combined with coalition partners and allies have recently withdrawn forces from the region to focus on strategic competition.[3] As such, the security environment today is comparatively more complex with the prevalence of enhanced weapon systems, violent extremist activities and more nuclear actors. Additionally, new

[3] Joseph R. Biden, President USA, "Interim National Security Strategic Guidance", *The White House Washington,* (March 2021) https://www.whitehouse.gov/wp-content/uploads/2021/03/NSC-1v2.pdf

technologies have given rise to unconventional tactics that cross multiple domains and challenge archaic international laws without due regard to traditional borders.

Strategic competition is now a top priority communicated through national security strategies that drive the levels of friction between the liberal democracies of the West and the authoritarian regimes throughout the world.[4] The worldwide pandemic that began in 2019 generated an environment amenable to innovation and technological advancement that have completely upended industries, morphed societies and forced militaries to reconsider traditional solutions to security challenges.[5] Disruptive technologies such as artificial intelligence (AI) combined with automation, machine learning and biotechnology will continue to influence security strategies of the future as these technologies continue to evolve and be integrated into the military spheres of the advanced economies. With the aforementioned factors related to strategic competition combined with a shift in the geopolitical landscape; it is evident that there has been a change to the methods to resolve diplomatic strife that cross the threshold of violence.

To dominate the aerospace domain today, numerous types of aircraft equipped with enhanced beyond visual range weapons systems combined with robust electronic warfare suites are required.[6] Furthermore, the recent employment of loitering munitions and hypersonic missiles integrated with operations in the information environment is noteworthy.[7] Modern warfighters must have the ability to adapt to fluid conditions and

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[4] Joseph R. Biden, President USA, "Interim National Security Strategic Guidance", *The White House Washington,* (March 2021) https://www.whitehouse.gov/wp-content/uploads/2021/03/NSC-1v2.pdf
[5] Wendy Phillips, Jenks K. Roehrich, Dharm Kapletia, "Responding to information asymmetry in crisis situations: innovation in the time of the COVID-19 pandemic". Public Management Review (2021), pages 1-24. https://www-tandfonline-com.cfc.idm.oclc.org/doi/full/10.1080/14719037.2021.1960737
[6] Author is a military aviator with over 10 years of flight experience.
[7] Kelsey D. Atherton "Everything to know about Switchblades, the attack drones the US is giving to Ukraine." Task & Purpose, (24 Mar 2022) https://taskandpurpose.com/analysis/switchblade-attack-drone-ukraine/

rapidly synthesize data as adversarial state and non-state actors leverage these capabilities to spin the narrative to induce confusion in the information environment. Of increasing importance and integrated in the air domain; great powers have openly displayed the intent to allocate significant resources to further develop and weaponize scramjet technology.[8] Originally labelled as the X-43A Flight Research Program- it is a highly complex engine design that has taken decades to develop and is necessary to achieve the potential energy for hypersonic missiles.[9][10]

In a multi-domain environment, a ground force commander (GFC) can no longer ignore the complexities of the domains above and must work to understand and integrate allocated aerospace capabilities to be effective on the modern battlefield. The GFC must also maintain a mindset and requisite situational awareness to shift the main effort to the air component when the common operational picture dictates. With that said, cognitive abilities combined with competence and experience must be prioritized in talent management strategies and further applied to a holistic understanding of maneuver warfare and combined arms. A revised definition will help component commanders eliminate biases and stay ahead of the adversary's decision cycle in a fluid and highly complex operating environment.

[8] Curtis Peebles. *"Road to Mach 10; Lessons Learned from the X-43A Flight Research Program"*, American Institute of Aeronautics and Astronautics, (2008). 170-175.
[9] "Science & Technology Trends 2020-2040: Exploring the S&T Edge" *NATO Science and Technology Organization,* (March 2020) https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf
[10] Curtis Peebles. *"Road to Mach 10; Lessons Learned from the X-43A Flight Research Program"*, American Institute of Aeronautics and Astronautics, (2008). 170-175.

AIR OPERATIONS BY NON-STATE ACTORS

Non-state actors such as violent extremist organizations play an important role in strategic competition through destabilization efforts often exploited by state actors. Often constrained by resources and access, they find creative ways over time to gain a strategic foothold. Whether through the use of improvised explosive devices (IED) or the use of social media to gain influence to sow divide, these low cost means can be a force multiplier for the party involved. Additionally, they have found unique ways to challenge conventional air force tactics through the employment of commercial off the shelf (COTS) drones armed with kinetic munitions. A similar concept of employment with far less capability and accuracy than to armed unmanned aerial systems (UAS) such as the MQ-9 Reaper.

COTS drones used by non-state militants is on the rise throughout the globe. These capabilities generally operate in the low altitude flight regime (200'-3000'), are remotely operated and have ranges that allow for significant standoff from the controller.[1112] More importantly, should the threat have the ability to employ swarm like formations, conventional doctrinal concepts will be further challenged.[13] Air component planners will have to work through the complexities of such a scenario and develop systematic capabilities that are agile, resilient and flexible that at a minimum neutralize such a threat systems center of gravity. No longer is the establishment of combat air

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[11] John E. Peters & Al., "Unmanned Aircraft Systems for Logistics Applications" *RAND Corporation*, (2011), https://www.rand.org/pubs/monographs/MG978.html

[12] Trevor Hughes. "Cheap drones take center stage in Ukraine war, raising concerns about misuse in the United States" *USA Today* (2 May 2022) https://www.usatoday.com/story/news/nation/2022/04/29/cheap-drones-find-new-uses-ukraine-war-raising-u-s-concerns/9554693002/?gnt-cfr=1

[13] Dan Parsons. "Army to Test its Biggest Interactive Drone Swarm Ever Over Utah", *The Warzone.* (22 Apr 2022). https://www.thedrive.com/the-war-zone/army-to-test-its-biggest-interactive-drone-swarm-ever-over-utah

patrols over a defined area with conventional fighter platforms enough to assume control of the skies. In this context, a wider imagination and breadth of understanding is required beyond the physical plane to conceptualize and deny use of the air from adversaries.

THE RISE OF INTEGRATED MEGA CITIES

In advanced and emerging economies, cities have rapidly evolved, have grown in population and continue to be studied throughout the armed forces. Large multinational technology corporations such as Google and Microsoft seek to capitalize through investment in concepts such as "smart cities" to increase their bottom line and speed up the pace of commerce and virtual interaction.[14] Conceptually, this will add layers of complexity and depth to current and future defense strategies as malign actors devise ways to exploit the seams and gaps in such an operating environment. It is common knowledge that air assets rely on data links, cyber and spatial systems to be relevant in today's air domain. In other words, commercial airplanes fly pieces of automated hardware with integrated software to gain airborne situational awareness, navigate with a pilot as a systems operator to provide inputs to the in-flight systems and controls.[15] On a smaller scale, advanced UAS concepts have been developed to perform a variety of commercial functions throughout the "mega" city such as package delivery and transportation of people.[16] Additionally and in line with distributed operations, it is now

[14] "Science & Technology Trends 2020-2040: Exploring the S&T Edge" *NATO Science and Technology Organization,* (March 2020) https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf
[15] Author is a military aviator with over 10 years of flight experience.
[16] "Science & Technology Trends 2020-2040: Exploring the S&T Edge" *NATO Science and Technology Organization,* (March 2020) https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf

common for a UAS operator to control from a terminal in country X and employ aircraft in country Y.[17]

With the aforementioned trends, it is evident that a focus on low intensity conflict in urban terrain should continue to be a priority for defense forces to analyze and war game. Specifically, operators may have to consider and plan for a persistent high civilian population density, a congested electromagnetic spectrum combined with routine air vessel traffic. There is no doubt that war is kinetic, however a focus to compete and maneuver in the electromagnetic spectrum should be prioritized. To truly deny the adversary access to the skies, planners will have to think beyond a traditional ground based air defense system and adopt an unconventional mindset to rethink air superiority in the "mega city" across the spectrum of conflict.

THE FOURTH INDUSTRIAL REVOLUTION

Electronic attack and protection are important variables to the air superiority discussion. As such, if a military does not have the ability to control and effectively protect against frequency and wavelength interference, control of the air has not been achieved.[18] The United States and allies have made it clear that a focus over the next decade is strategic competition amongst the great powers. More importantly, access to key technologies and control of associated raw materials will be critical to effectively source advanced capabilities.[19] From three dimensional printing, quantum computing

[17] Author has experience with UAS.
[18] "Countering Air and Missile Threats" *Joint Publication 3-01*. (21 April 2017) https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_01.pdf
[19] Joseph R, Biden President USA. "Interim National Security Strategic Guidance", *The White House Washington*, (March 2021) https://www.whitehouse.gov/wp-content/uploads/2021/03/NSC-1v2.pdf

and artificial intelligence- advanced hardware and software compatibility efforts are underway to enable systematic integration and interoperability amongst services, allies and partners.[20] Led by Australia, one such example includes the development of the Loyal Wingman; an unmanned platform that flies in support of a manned fighter such as the F-35.[21]

Another important capability that relies on elements of the electromagnetic spectrum and continues to be developed for many commercial and military purposes are unmanned aerial systems (UAS). In many ways a force multiplier, they provide commanders with a number of flexible options with little to no risk to human life. They also provide economic advantages to the effect that they are a low cost option for smaller militaries and non- state actors to compete in certain dimensions of the air domain when conventional militaries presume to have air superiority. To elaborate, a military may have the ability to deny access to fighter aircraft in a particular airspace, however if they do not account for a UAS capability- air superiority in its purest form has not been achieved.

With advanced data links and access to commercial space systems, COTS UAS have the ability to conduct formations and maneuvers once considered to deny the laws of gravity.[22] Quad copter like designs that are predominantly battery powered, operate with a low audible signature and have given rise to a new era of transportation and logistics concepts.[23] Many Western companies have realized the shift and have allocated

[20] Royal Australian Air Force. Future Air and Space Capability, "Loyal Wingman" Accessed on 8 February 2022 https://www.airforce.gov.au/our-mission/loyal-wingman
[21] Ibid.
[22] Dan Parsons. "Army to Test its Biggest Interactive Drone Swarm Ever Over Utah", *The Warzone.* (22 Apr 2022). https://www.thedrive.com/the-war-zone/army-to-test-its-biggest-interactive-drone-swarm-ever-over-utah
[23] John E. Peters & Al., "Unmanned Aircraft Systems for Logistics Applications" *RAND Corporation*, (2011), https://www.rand.org/pubs/monographs/MG978.html

resources and capital to assess feasibility of support.[24] Large corporations such as Amazon and FedEx continue to seek alternative energy sources and the use of UAS assets for package delivery to meet emissions requirements mandated by many western governments.[25] With reliance on data and cloudlike systems to manage inventory, commerce has the capacity to move at a pace where the consumer has the ability to order an item online and have it delivered on the same day.[26] Such concepts have been acknowledged by defense professionals and highlight the demand for modernization by aerospace forces to remain relevant across the principles of war.

FIRES, AERIAL WARFARE AND THE ELECTROMAGNETIC SPECTRUM

The operators of today must envision and rethink how winning conditions are shaped in modern warfare. How will the rapid pace of technological advancement influence battlefield tactics and applicable operating principles? There is no doubt that cognitive ability is necessary to be able to synthesize perspectives and synchronize effects of systems on the battlefield. Simply put, commanders at all levels must have the requisite experience and truly understand all domains, in order to make decisions consistent with the speed of relevance that contribute to the success of published objectives in a campaign plan. Advanced weapon systems concepts consist of hardware and software components that process large amounts of data, broadcast real time

[24] John E. Peters & Al., "Unmanned Aircraft Systems for Logistics Applications" *RAND Corporation*, (2011), https://www.rand.org/pubs/monographs/MG978.html
[25] Camila Domonoske "From Amazon to FedEx, The Delivery Truck is Going Electric". *National Public Radio,* (17 March 2021) https://www.npr.org/2021/03/17/976152350/from-amazon-to-fedex-the-delivery-truck-is-going-electric
[26] Amazon. "Amazon same day delivery" accessed on 1 May 2022 https://www.amazon.com/b/ref=glow_cls?ie=UTF8&node=21382124011

information and in many ways inform the desired effect with a human still in the loop.[27] While the human remains the most important element, defense systems and capabilities must be weighted correctly in design in order to maximize operational effects. In other words, concepts such as a systems of systems approaches must be considered to prioritize tasks and speed up the operator's decision cycle.

The use of weaponized UAV's has become mainstream and must be accounted for at the tactical and operational levels. State actors routinely fund loitering munitions programs while non-state actors procure COTS, modify them to achieve a desired effect. One such example was when the Islamic State of Iraq and Syria (ISIS) installed a mechanism on a UAS to carry and employ a handheld grenade.[28] They filmed one of their creations drop a munition on a Syrian ammunition depot and aired it on a social media propaganda stream.[29] This low cost tactic achieved a psychological and economic effect on the Syrian regime and ignited conversations across militaries on the true meaning of air superiority.

As a result, new tactics, techniques and procedures (TTP) have emerged with the employment of numerous miniature drones geared to saturate adversary air defense assets.[30] Coined as swarm tactics, the concept requires an air platform for launch and then

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[27] "Science & Technology Trends 2020-2040: Exploring the S&T Edge" *NATO Science and Technology Organization,* (March 2020) https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf

[28] Don Rassler. "The Islamic State and Drones, Supply, Scale, and Future Threats". *Combatting Terrorism Center at West Point* (July 2018) https://ctc.usma.edu/wp-content/uploads/2018/07/Islamic-State-and-Drones-Release-Version.pdf 4

[29] Ibid 20.

[30] Dan Parsons. "Army to Test its Biggest Interactive Drone Swarm Ever Over Utah", *The Warzone*. (22 Apr 2022). https://www.thedrive.com/the-war-zone/army-to-test-its-biggest-interactive-drone-swarm-ever-over-utah

they adopt a certain degree of autonomy.[31] Interconnected throughout command and control nodes, they are difficult to target kinetically and require advanced defense capabilities to counter.[32]

Elements of the electromagnetic spectrum vital to maintain air superiority are now highly integrated with operational principles and technologies to enhance decision making ability. Data and analytics are now mainstream and accelerate the speed and accuracy of requirements to achieve information dominance. Technologies that fall under the "Big Data and Advanced Analytics" umbrella include elements of artificial intelligence, human performance and factors engineering.[33] In this context, it is evident that force design and doctrinal operating principles are being challenged at all levels**.** The United States Marine Corps' (USMC) Force Modernization strategy; Force Design 2030 is an effective model that successfully addresses the pace of change with relevant and viable investments in emerging concepts and divestments in antiquated assets.[34]

2020 NAGORNO-KARABAKH WAR CASE STUDY

The Nagorno-Karabakh War; fought in 2020 provides valuable insight into the use of loitering munitions to achieve a swift and decisive victory. The territorial conflict between Azerbaijan and Armenia goes back to the 1900s and was amplified following the

[31] Dan Parsons. "Army to Test its Biggest Interactive Drone Swarm Ever Over Utah", *The Warzone*. (22 Apr 2022). https://www.thedrive.com/the-war-zone/army-to-test-its-biggest-interactive-drone-swarm-ever-over-utah
[32] Ibid.
[33] "Science & Technology Trends 2020-2040: Exploring the S&T Edge" *NATO Science and Technology Organization,* (March 2020) https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf
[34] General David H. Berger. "Force Design 2030" *Headquarters Marine Corps,* (March 2020) https://www.hqmc.marines.mil/Portals/142/Docs/CMC38%20Force%20Design%202030%20Report%20Phase%20I%20and%20II.pdf?ver=2020-03-26-121328-460

break-up of the Soviet Union in 1990.[35] Border disputes combined with a mutual disdain for one another that were often seen through the lens of political warfare.[36] From Turkish support, Azerbaijan was able to mature to a certain degree and advance economically.[37] Armenia relations with Russia weakened over time which had an impact on the Collective Security Treaty Organization; grounded from the origins of the Soviet Union.[38] As such, friction between both countries continued to rise, diplomacy faltered and military conflict ensued.

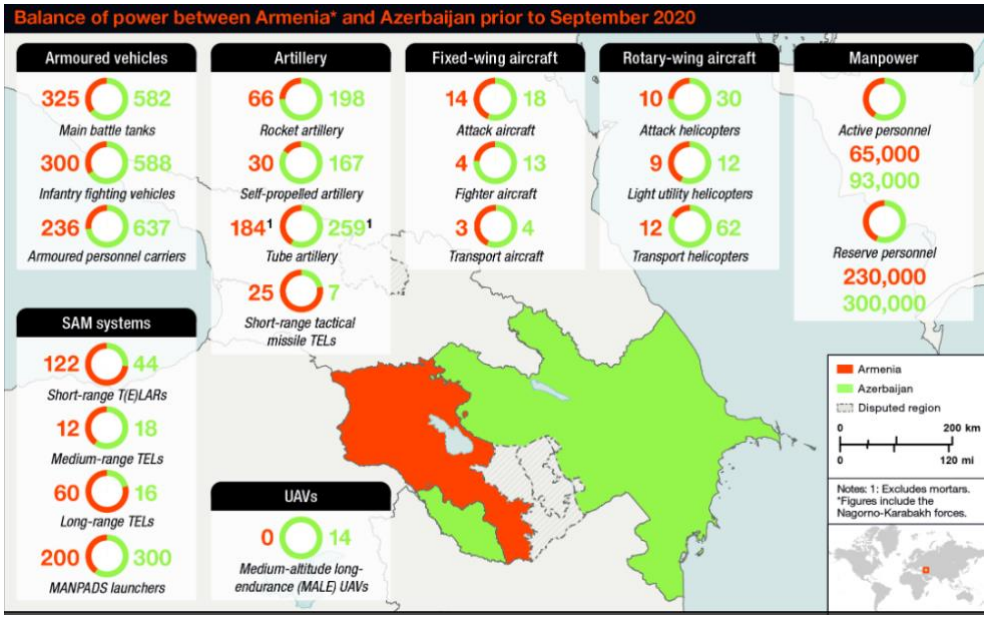

Figure 1.1 – Balance of power between Armenia and Azerbaijan

Source: Unmanned strategy: The fight for Nagorno-Karabakh, Janes.

Figure 1.1 demonstrates that the force ratio and balance of power clearly favored Azerbaijan.[39] However, it was not conventional military might that enabled a decisive

[35] "Unmanned strategy: The fight for Nagorno-Karabakh", https://customer-janes-com.cfc.idm.oclc.org/DefenceWeekly/DisplayFile/FG_3863602?edition=2021
[36] Ibid.
[37] Ibid.
[38] Ibid.
[39] "Unmanned strategy: The fight for Nagorno-Karabakh", accessed on 26 April 2022 https://customer-janes-com.cfc.idm.oclc.org/DefenceWeekly/DisplayFile/FG_3863602?edition=2021

victory. Tempo was gained through the propagation of misinformation combined with the application of unconventional air assets.[40] The Medium-Altitude-long-endurance (MALE) UAS was the force multiplier that largely contributed to the swift Azeri victory.[41] Specifically, the Bayraktar TB2 UAV; an unmanned kinetic system that incorporates advanced technologies such as artificial intelligence to navigate, select and subsequently prosecute a target.[42] A combined approach of the application of non-traditional airpower combined with the control of the narrative through a mainstream medium such as YouTube proved to be an important observation in the evolved ways, ends and means to achieve a particular end state.

The Azeri's used surprise to their advantage as well as unconventional capabilities that leveraged political ties to acquire advanced airborne weapons systems; such as loitering munitions.[43] Additionally, an important geopolitical factor was the acknowledged rivalry between Russia and Turkey. Russia, who loosely supported Armenia through security ties aimed to deescalate the situation.[44] In the end, Azerbaijan effectively secured loitering munitions capabilities from Turkey that were the key to success to counter the volume of Russian military equipment employed by Armenia.[45]

This particular conflict is an empirical example that highlights the importance of low cost emerging technologies in the air domain combined with the use of digital

[40] Azerbaijan Propaganda Video published on YouTube 27 Sep 2020, accessed on 1 May 2022 https://www.youtube.com/watch?v=bSh5tm2Hmn0&t=77s
[41] "Unmanned strategy: The fight for Nagorno-Karabakh", accessed on 26 April 2022 https://customer-janes-com.cfc.idm.oclc.org/DefenceWeekly/DisplayFile/FG_3863602?edition=2021
[42] Ibid.
[43] Ibid.
[44] Agnieszka Miarka. "The 2020 Autumn War in Nagorno-Karabakh: Course and Implications for the Strategic Balance of Power in the South Caucasus Region", *Asian Affairs,* (2021) 52:4, 826-851. https://doi-org.cfc.idm.oclc.org/10.1080/03068374.2021.1993050
[45] Ibid.

mediums that achieved the element of surprise on the battlefield and had a significant psychological impact on Armenian fighters.[46]

2022 RUSSIA-UKRAINE WAR CASE STUDY

Another recent example that proves the complexity and changing character of the air domain is the conflict between Russia and Ukraine. On 24 February 2022, the Kremlin mounted a full scale invasion of Ukraine that included the bombardment of urban centers, a massive disinformation campaign and rapid control of the skies. Ukraine swiftly mobilized and worked to defend their homeland with all available means.

They leveraged the use of UAS to provide battlefield situation awareness that ultimately informed maneuver and targeting.[47] Russia, assessed to be numerically superior, had early vulnerabilities exposed with the employment of stinger missiles and javelin rockets.[48] In other words, an effective decentralized C2 structure characterized by small distributed Ukrainian strike cells were deployed with Javelin anti-armor systems and switchblade drones to shorten the kill chain, increase agility and rapid maneuver.[49] Such friction induced by the Ukrainian forces further challenge the traditional character of war and have allowed Western military professionals to rethink doctrinal definitions, force modernization and employment combined with investment and divestment strategies.

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[46] Azerbaijan Propaganda Video published on YouTube 27 Sep 2020, accessed on 1 May 2022 https://www.youtube.com/watch?v=bSh5tm2Hmn0&t=77s

[47] Karoun Demirijan and Dan Lamothe, "Pentagon: Russia has fully withdrawn from Kyiv, Chernihiv" *The Washington Post,* (6 April 2022) https://www.washingtonpost.com/national-security/2022/04/06/pentagon-russia-withdraws-kyiv-chernihiv/

[48] Ibid.

[49] Ibid.

Did Russia perceive to have air superiority? Russia had the ability to deter NATO from direct participation in the defense of Ukraine. With that said, Russia still suffered air component losses, did not have full control of the air due to Ukraine's ability to employ man portable surface to air missiles.[50] In this context, Ukraine dealt Russia an operational and economic loss propagated in the information environment. An important example of successful integration of air and information capabilities to place elements of the Russian military in a combined arms dilemma.

The TTP's observed further prove that multi-dimension maneuver warfare is an important method of operational employment that challenges traditional air warfare theories. The Ukrainians clearly understand economy of force and how to layer a defense as they found ways to challenge adversary units that clearly have mass and force ratio to their advantage. Dispersion and drawing Russian fighters into large cities has also to some degree enabled a desired effect. On April 6, the Pentagon reported that Russia withdrew the majority of forces from Kiev to change their operational approach due to heavy losses sustained in the urban environment.[51]

Similar to the Nagorno-Karabakh conflict, an important capability employed by Ukraine has been loitering munitions. Predominantly supplied by the United States, these precision standoff munitions can be employed from up to 40 km at a speed of 70 mph.[52][53] Such innovative technologies applied to combined arms fire support plans

[50] Jonathan Beale. "Ukraine's Battle for Control of its Skies", BBC News (15 April 2022) https://www.bbc.com/news/world-europe-61106245
[51] Karoun Demirijan and Dan Lamothe, "Pentagon: Russia has fully withdrawn from Kyiv, Chernihiv" *The Washington Post*, (6 April 2022) https://www.washingtonpost.com/national-security/2022/04/06/pentagon-russia-withdraws-kyiv-chernihiv/
[52] AeroVironment accessed on 25 April 2022 https://www.avinc.com/tms/switchblade-600
[53] Kelsey D. Atherton "Everything to know about Switchblades, the attack drones the US is giving to Ukraine, *Task & Purpose,* (24 Mar 2022) https://taskandpurpose.com/analysis/switchblade-attack-drone-ukraine/

enables an underequipped force to achieve strategic effects with limited air power capabilities. From an economic perspective, they are evidently cheaper to operate and acquire than the cost basis of an advanced fighter program with associated munitions and maintenance programs. Both case studies have effectively challenged the conventional approach to air superiority; such as no fly zone enforcement through persistent fighter presence.

ALL DOMAIN AEROSPACE DEFENSE TECHNOLOGIES AND PATHWAYS TO INNOVATION

New doctrinal definitions under the air superiority umbrella will generate innovate pathways to capabilities required to compete and win in today's geopolitical context. It will stimulate horizontal and vertical thought across defense organizations in order to generate flexibility across the spectrum of conflict and competition. Operational concepts that incorporate human-machine teaming, agile acquisitions and materials science must be further developed and refined to meet the challenges associated with economic competition that bleed into the threshold of violence. In an era of rapid technological advancement, it is evident that there is a paradigm shift in society that has forced large companies and military organizations to rethink processes and policies required to achieve desirable end states and further redefine what success looks like. In this context, the use of big data and advanced analytics must be common practice to be relevant in the current operating environment.

Many defense industry professionals have acknowledged the changes and have shifted business practices to reflect. For example, Lockheed Martin has managed to

recruit and retain talent as well as foster a dynamic work environment to remain at the cutting edge of technology.[54] A workplace design that integrates functions and practices in a collaborative and interoperable fashion should be adopted by all military professionals and organizations. Furthermore, a focus on collective air defense with allies and partners characterized by compatibility and interoperability will be vital to achieve 21st century multi-domain air dominance, gain a strategic competitive advantage to ultimately achieve effective deterrence.

Additionally, militaries must plan for assumptions that normalize a technology enabled battlefield and place significant thought into force design that reward skills and knowledge in the use and development of cutting edge hardware and software. As discussed, the air domain will continue to play an important role as new technologies are developed to achieve a particular effect. With the increased attention on hypersonic missiles and precision strike capabilities, industry and military professionals alike should challenge conventional wisdom and encourage innovative approaches throughout their organizations.

A MODERN APPROACH TO AIR SUPERIORITY - A FUSED OPERATIONAL CONCEPT

Based on the detailed research that outlines how the nature of the air domain has changed, what is a potential solution? A new definition to influence the way to think about operations in, through and around the aerospace domain is an important start. Furthermore, hardware and software programs must be part of the discussion to ensure

[54] Lockheed Martin, "Center for Innovation, The Lighthouse" accessed on 1 May 2022 https://www.lockheedmartin.com/en-us/capabilities/research-labs/center-for-innovation.html

the West is able to maintain the advantage and keep up with the pace of change. Simply put by General Dunford, the 19th Chairman of the Joint Chiefs of Staff; "Military decision-making must exceed the speed of War".[55]

A variety of systems now have the ability to find and fix targets through integrated recognition software.[56] In this context, the next decade will likely give light to highly automated additive manufacturing processes and enhanced levels of human-machine teaming that will continue to inform the evolution of most dimensions on the battlefield.[57]

In many of the world's most credible universities, significant research and development in fields that include augmented reality, robotics, human machine teaming and advanced biotechnologies is well underway.[58] Militaries and governments have remained abreast to this trend and have allocated material and human capital to keep up. One important societal trend that has gained interest from the defense community is the video game industry. Programs such as Microsoft Kinect displays a human-technology interactive concept developed to enable movement while gaming and ultimately remain competitive in a rapidly evolving industry.[59] Such examples have inherent military applications through human to machine interactions which continue to be studied. With

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[55] General Joseph Dunford. "Speed of Military Decision-Making Must Exceed the Speed of War Joint Chiefs of Staff, accessed on 28 April 2022 https://www.jcs.mil/Media/News/News-Display/Article/1067479/dunford-speed-of-military-decision-making-must-exceed-speed-of-war/

[56] Dos Reis, Douglas Henke, Daniel Welfer, Marco Antonio De Souza Leite Cuadros, and Daniel Fernando Tello Gamarra. "Mobile Robot Navigation Using an Object Recognition Software with RGBD Images and the YOLO Algorithm." *Applied Artificial Intelligence* 33, no. 14 (December 2019): 1290–1305. https://web-s-ebscohost-com.cfc.idm.oclc.org/ehost/detail/detail?vid=1&sid=54f04012-d376-4f1b-aae6-f15f42dc4982%40redis&bdata=JnNpdGU9ZWhvc3QtbGl2ZSZzY29wZT1zaXRl#AN=139805938&db=a9h

[57] "Science & Technology Trends 2020-2040: Exploring the S&T Edge" *NATO Science and Technology Organization,* (March 2020) https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf

[58] Ibid.

[59] Ibid.

that said, will air superiority design of the future incorporate console operators linked to multi-role UAS platforms connected to a number of content delivery networks and nodes throughout the world?

Organizations such as the United States Air Force have recognized the trend and have maneuvered to adapt and shift focus. Recruitment efforts that cater to technology enthusiasts, video gamers and drone racers have rapidly become the norm.[60] At the strategic level, partnerships with the private sector are now encouraged through efforts such as the Defense Innovation Unit (DIU) and AFWERX.[61][62] Disruptive technologies such as directed energy weapons are also important and have attracted the attention of most US and allied forces.[63] One concept recently tested and touches the air domain are airborne lasers capable to counter kinetic munitions.[64] Will this concept prove to challenge the notion of mass in peer conflict?

It is clear that a revised approach to air warfare doctrinal concepts and definitions is required to meet the uncertainties of the current and future security environments. In line with integration and interoperability, a fused operational concept should be developed to meet the rigors and complexities associated with the aforementioned recommended definition of air superiority. Through the adoption of a mindset that describes everything as a sensor- a predominant focus should be on software centric systems that are modular and easily modified as battlefield conditions change. Lastly,

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[60] United States Air Force, "How an Air Force Recruiting commercial became a popular VR game" accessed on 1 May 2022 https://www.af.mil/News/Article-Display/Article/2849185/how-an-air-force-recruiting-commercial-became-a-popular-vr-game/
[61] AFWERX accessed on 24 April 2022 https://www.afwerx.af.mil/.
[62] Defense Innovation Unit accessed on 23 April 2022 https://www.diu.mil/.
[63] Ibid.
[64] Henry "Trey". Obering III. "Directed Energy Weapons are Real… And Disruptive". *Prims 8-3* National Defense University Press, (January 2020) 36-46 https://ndupress.ndu.edu/Media/News/News-Article-View/Article/2404322/5-key-technologies-and-the-revolution-of-small-smart-and-cheap-in-the-future-of/

those whom have not started efforts to force modernize and have not recognized the application of advanced technologies such as artificial intelligence and machine learning will be left behind and rendered irrelevant.

CONCLUSION

To conclude, in a rapidly changing world, militaries need to restructure and modernize to meet the battlefield challenges of the future. More specifically, anti-air warfare strategies that predominantly rely on the application of kinetic force to address force ratio problem sets are no longer viable in the era of renewed strategic competition. Defense technology and procurement streams must develop and refine systems to provide accurate feedback loops to speed up decision cycles to ultimately outpace adversaries.

In the end, the current doctrinal definition of air superiority is outdated and no longer relevant. It must be revised to coincide with Western air component modernization efforts and stimulate cognitive thought informed by numerous perspectives to generate all domain defense professionals. While forecasting the future is difficult, it is important to note; "Air power is, above all, a psychological weapon – and only short-sighted soldiers, too battle-minded, underrate the importance of psychological factors in war".[65]

[65] B.H. Lidell Hart "AZ Quotes" accessed on 25 April 2022. https://www.azquotes.com/quotes/topics/air-power.html

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