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The Implications of Fifth-Generation Aircraft for Transatlantic Airpower

A Primer

Secretary Deborah Lee James and Dr. Daniel Gouré

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Cover: F-35A Lightning II fighter jets from the 388th Fighter Wing at Hill Air Force Base, Utah, fly in formation over the Utah Test and Training Range. *(U.S. Air Force photo/R. Nial Bradshaw)*

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FOREWORD

Great-power competitors—like Russia and China—are engaged in multipronged approaches to undermine the West through economic, political, and military means, thereby hoping to gain competitive advantage that could prove decisive in future conflicts. The application of anti-access/aerial denial (A2/AD) strategies has proven particularly challenging for Western airpower, especially the use of sophisticated air defense, cyber, and long-range-fires systems. Stated another way, NATO can no longer assume, or take for granted, that it will control the skies in the event of a great-power conflict.

Enter the transformational capabilities of fifth-generation aircraft.

The Atlantic Council's report—*The Implications of Fifth-Generation Aircraft for Transatlantic Airpower*—makes a compelling case that the next major battle will be won through the ability to integrate a wide range of sensors, computers, databases, and networks. The name of the game will be successful acquisition, exploitation, and movement of information, coupled with lethal firepower. The ability of fifth-generation aircraft to operate as highly survivable and agile sensor platforms—and to act as quarterbacks and force multipliers for fourth-generation aircraft—will be a key part of the winning strategy.

As the former secretary of the US Air Force, I am keenly aware that competitors are not sitting idly by as NATO fields these new capabilities. Rather, they are seeking to develop their own fifth-generation capabilities, as well as to invest in cyber, space, hypersonics, artificial intelligence, and electronic-warfare techniques to counter or interfere with NATO's capabilities. For this reason, it is imperative that NATO take concrete steps to solidify its position through increased development and procurements, joint and allied training, focus on command-and-control systems, and the creation of a common communications architecture.

NATO's airpower has been—and must remain—a centerpiece for the Alliance's defense strategy and war-waging strength. This report contains valuable insights and recommendations for all who wish to reach this goal in the decades to come.

—Deborah Lee James
23rd Secretary of the US Air Force
Board Member and Distinguished Fellow,
Atlantic Council

INTRODUCTION

Modern warfare is undergoing a transformation as broad and complex as that which occurred in the first half of the twentieth century. To the three classic domains of warfare—land, sea, and air—space and cyber have been added. Modern military operations seek to employ capabilities in multiple domains in an orchestrated manner designed to create overmatch. Military systems in all domains are evolving to be longer range, more precise, and highly lethal. The ability to integrate a wide range of sensors, computers, databases, and networks has resulted in the competition for military advantage shifting toward a fight to acquire, exploit, and move information. NATO faces an ever more lethal and disruptive battlefield, with forces combining across domains and operations conducted at increasing speed and reach, and with unprecedented situational awareness.[1]

Great-power competitors are engaged in a multi-faceted campaign to undermine the West's political, social, and military advantages and, to that end, are creating unique capabilities and forces that could prove decisive in future conflicts. One area where their efforts are proving particularly challenging is the development of so-called anti-access/area denial (A2/AD) capabilities. Competitors have focused, in particular, on degrading the Alliance's long-standing dominance of the air domain by deploying extremely sophisticated layered air defenses. In addition, the survival of NATO forces in all domains is under the growing threat posed by adversaries' long-range-fire systems directed by a proliferated array of sensors and targeting systems. There is a consensus among experts in air warfare that the systems and forces that provided the West with the decisive operational advantage of air dominance in the conflicts of the past thirty years are no longer able to achieve that same level of advantage.[2]

The development of fifth-generation aircraft with low-observable features, commonly referred to as "stealthiness," and an array of advanced sensors is intended not only to counter advanced air defenses, thereby restoring the West's erstwhile advantage in the air, but to extend the power of platforms and forces operating in that domain. The ability of fifth-generation aircraft, most notably the F-35 Joint Strike Fighter, to operate as a highly survivable and agile sensor platform is of nearly incalculable advantage to all networked land, air, and sea forces.

Fifth-generation aircraft are only now entering service in significant numbers. Yet, they are already changing the way Western militaries think about airpower and its relationship to the operations of joint and combined forces. Based on the evolving threat, advances in relevant technologies and the growing body of knowledge gained from operating fifth-generation aircraft, NATO countries are already planning for the development of even more advanced sixth-generation aircraft.

1 "Summary of the National Defense Strategy of the United States: Sharpening the American Military's Competitive Edge," US Department of Defense, 2018, https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

2 Keir Giles and Mathieu Boulegue, "Russia's A2/AD Capabilities: Real and Imagined," *Parameters*, Spring/Summer 2019, https://ssi.armywarcollege.edu/pubs/parameters/Issues/SpringSummer_2019/5_Giles.pdf.

WHAT FIFTH-GENERATION AIRPOWER BRINGS TO THE GAME

Today, the central challenge confronting transatlantic airpower is to overcome the threat posed by Russia's increasingly lethal layered air defenses, in order to be able to accomplish critical missions from the outset of hostilities. Russian land- and sea-based air defenses are intended to present attacking aircraft with multiple challenges ranging from sophisticated, long-range and high-speed anti-aircraft systems such as the S-400—capable of tracking and engaging dozens of targets simultaneously—to medium- and short-range, vehicle-mounted systems such as the Pantsir, which employ both missiles and radar-directed cannon to provide tactical defense of mobile forces and fixed sites.[3] The Russian Navy also operates large squadrons of ships armed with advanced anti-aircraft missiles in the Baltic and Black Seas. The Russian military deploys these air defenses in a manner that creates overlapping and interlocking rings of sensors and weapons that provide multiple opportunities to detect, track, and engage adversary aircraft.

NATO will also have to contend with the Russian Air Force, which consists almost entirely of fourth-generation aircraft, some of which are considered the equal of those flown by the Alliance.[4] Russia is believed to have begun production of its own fifth-generation stealth fighter, the SU-57, although there are doubts that it will be deployed in significant numbers.[5]

There is a general consensus that fourth-generation aircraft have decreasing survivability in the face of advanced, integrated air-defense networks. Efforts to sustain the ability of older aircraft to penetrate increasing lethal defenses will require larger force packages and the extensive use of scarce support assets, such as airborne jammers.[6] Given that NATO air forces will also be fighting outnumbered, with their infrastructure under continuous attack from long-range-fire systems, this is a losing proposition.

Fifth-generation aircraft offer NATO proven means of countering Russia's massive investment in layered air defenses, thereby restoring deterrence. In the event of conflict, fifth-generation forces will be able to penetrate and degrade hostile air defenses and deliver decisive effects (kinetic, electronic, and cyber) against enemy forces, infrastructure, and networks, thereby helping to defend Alliance territory and deny Russian forces their objectives. The same capabilities that enable fifth-generation platforms to evade, degrade, and defeat hostile air defenses are also of inestimable value in supporting and even enhancing the activities of legacy aircraft as well as forces in other domains.

The term "fifth-generation" is generally associated with aircraft design features such as aerodynamic shaping and specialized radar-wave-absorbing coatings that reduce the range at which hostile sensors can detect, track, and engage them. Other aircraft emissions that can be detected—for example, heat from the engine or electronic signals from aircraft avionics—have also been cloaked or limited. The F-35 is able to employ its all-aspect stealth to enter defended airspace with a reduced risk of being detected by hostile radars that would readily find and target non-stealthy fourth-generation aircraft. This capability alone has the effect of creating gaps in an integrated air defense that the F-35 can further exploit. The ability to avoid detection and targeting by air defenses gives fifth-generation aircraft the chance to get in the first shot against those defenses.

In addition to aerodynamic shaping and specialized coatings, fifth-generation platforms employ self-protection systems and radar-jamming capabilities that can be applied directly against air-defense nodes. Fifth-generation aircraft possess integrated avionics, which can fuse information collected by the aircraft's multi-spectral sensors and off-board data to provide pilots with an accurate, real-time operating picture

3 "The SAM Factory: Russia's Air-Defense Capabilities," *Jane's 360*, https://www.janes.com/images/assets/717/84717/The_SAM_factory_Russian_air-defence_capabilities.pdf.

4 Tom O'Connor, "How Does Russia's Air Force Compare to America's?" *Newsweek*, April 18, 2018, https://www.newsweek.com/how-does-russia-air-force-compare-us-904377.

5 Stefano D'Urso, "Sukhoi Begins Serial Production Of The Su-57, Meanwhile Let's See What We Know About Russia's 5th Generation Stealth Jet," *Aviationist*, August 1, 2019, https://theaviationist.com/2019/08/01/sukhoi-begins-production-of-the-su-57-meanwhile-lets-see-what-we-know-about-russias-5th-generation-stealth-jet/.

6 Lt. Gen. David A. Deptula, USAF (Ret.), Maj. Gen. Lawrence A. Stutzriem, USAF (Ret.), and Heather R. Penney, "Ensuring the Common Defense: The Case for Fifth Generation Airpower," *Mitchell Institute Policy Papers* 20 (2019), http://www.mitchellaerospacepower.org/single-post/2019/04/18/Ensuring-the-Common-Defense-The-Case-for-Fifth-Generation-Airpower.

that can be used to exploit emerging gaps and seams in enemy defenses. Today, F-35s are able to share information between themselves using the low-probability-of-intercept Multifunction Advanced Data Link (MADL), and with fourth-generation aircraft using the "Link 16" tactical data-link network.

Embedded sensors and specialized software allow the F-35 to detect, characterize, and localize enemy emitters, creating an electronic map of the battlefield.[7] The F-35's advanced active electronically scanned array (AESA) radar can be used simultaneously as a sensor and as a signal generator for jamming hostile radars. The Electro-Optical Targeting System (EOTS) provides operators with several multi-spectral imaging options.[8] Unlike radar, EOTS is a passive system, hence undetectable.

The electronic warfare (EW)/jamming capabilities of the F-35, is highly integrated, enabling the aircraft to simultaneously conduct both offensive and defensive electronic missions.[9] Its powerful array of electronic-warfare systems allow this aircraft to take on missions that previously could only be performed by dedicated electronic-warfare platforms. The F-35's stealthiness allows it to approach close enough to the target to employ low-power jamming.

The F-35 can carry different amounts and combinations of munitions, depending on the particular mission it is performing. When operating in stealth mode, fifth-generation aircraft carry air-to-air and air-to-ground munitions internally.[10] The F-22 can carry six radar-guided AIM-120 medium-range air-to-air missiles or two thousand-pound GBU-32 Joint Direct Attack Munitions and two AIM-120Cs. The F-35 can deploy with four AIM-120Cs or two AIM-120Cs and two two-thousand-pound GBU-31 Joint Direct Attack Munitions. Equally important, when stealthiness is not a prime consideration, the F-35 can carry up to twenty-two thousand pounds of ordnance in internal storage and external hard points, including up to twelve AIM-120Cs, or two AIM-120Cs and six GBU-31s. The introduction of the Small Diameter Bomb will allow the F-35 to carry eight bombs internally, while engaging targets at ranges of up to forty kilometers.[11] Most legacy aircraft are forced to make significant performance trade-offs when optimizing for a given mission, such as targeting pods, additional EW equipment, or external fuel tanks. This is not the case with the F-35, which was designed to operate with a common configuration—except for weapons loadouts—that allows it to take on different missions without sacrificing performance.

Only a few years ago, attacking a modern surface-to-air system required a force package of twenty or thirty legacy aircraft. Many of these aircraft do not directly deliver ordnance on target but instead are required to conduct ancillary missions such as intelligence, surveillance, and reconnaissance (ISR) or EW. The combination of stealthiness, advanced integrated avionics, electronic-warfare capabilities, and expansive weapons suites allow air planners to employ small numbers of fifth-generation aircraft to accomplish the same mission. In addition, the sophisticated sensor suites deployed on fifth-generation aircraft allow them to take on missions currently performed by specialized electronic-warfare and intelligence aircraft.

The combination of the F-22 and F-35 is particularly well suited to seizing control of the air and then exploiting the opportunities this presents. The F-22, intended as an air-superiority fighter, can clear contested airspace—allowing the F-35, designed to operate deep in hostile environments, to penetrate and degrade layered air defenses, as well as attack time-critical targets. Together, they create the battlefield conditions that enable fourth-generation platforms and their large magazines to be most effectively employed.

The value of fifth-generation stealth platforms in combat has been repeatedly demonstrated in exercises and wargames. At the US Air Force's 2017 Red Flag exercises, F-35s operating in an early configuration reportedly achieved a kill ratio against aggressors as high as twenty to one.[12] In the 2019 Red Flag, F-35s equipped with the latest software upgrade were equally successful in multiple engagements against superior numbers

7 Tyler Rogoway, "Could the F-35 Become the Biggest Intelligence Collection System Ever Devised?" *War Zone*, July 6, 2016, https://www.thedrive.com/the-war-zone/4291/could-the-f-35-become-the-biggest-electronic-intelligence-collection-system-ever-devised.

8 Tami Eschel, "Lockheed Martin Prepares to Enhance F-35 Targeting Options," https://defense-update.com/20190917_aeots.html

9 Loren Thompson, "The F-35 Isn't Just 'Stealthy': Here's How Electronic Warfare System Gives it an Edge," *Forbes*, May 13, 2019, https://www.forbes.com/sites/lorenthompson/2019/05/13/how-a-super-agile-electronic-warfare-system-makes-f-35-the-most-invincible-combat-aircraft-ever/#599f02ae4382.

10 "About the F-35," Lockheed Martin, last accessed September 3, 2019, https://www.f35.com/about/carrytheload/weaponry.

11 Kris Osborn, "A 'New' F-35 Is Coming: The Stealth Fighter Will Get Even More Deadly," *National Interest*, April 2, 2019, https://nationalinterest.org/blog/buzz/new-f-35-coming-stealth-fighter-will-get-even-more-deadly-50282.

12 Tom Demerly, "'Red Flag Confirmed F-35 Dominance with a 20:1 Kill Ratio' U.S. Air Force Says," *Aviationist*, February 28, 2017, https://theaviationist.com/2017/02/28/red-flag-confirmed-f-35-dominance-with-a-201-kill-ratio-u-s-air-force-says/.

Two US Air Force F-35A Lightning IIs from the 388th Fighter Squadron and three F-15C Eagles from the 493rd Fighter Squadron fly in formation during a training sortie over the United Kingdom, April 27, 2017. The F-35As first arrived at Royal Air Force Lakenheath, England, April 15, from Hill Air Force Base, Utah, marking the aircraft's first flying training deployment to Europe. *(U.S. Air Force photo by Tech. Sgt. Roidan Carlson*

of fourth-generation aircraft.[13] In the air-to-ground role, fifth-generation aircraft have demonstrated the ability to apply stealth, maneuvers, electronic warfare, and smart weapons to penetrate and degrade enemy air defenses and strike a range of fixed and mobile targets.

The ability of fifth-generation aircraft to gather, exploit, and move information cannot be underestimated. It is leading to a radical change in combat tactics and force structure. A new operational architecture is being created, one in which fifth-generation platforms are nodes on a network that spans multiple domains. Some observers have called this the "Combat Cloud."[14] Continuous information sharing across a distributed network allows advanced aircraft to change missions at a moment's notice, and allows entire force packages to reconfigure themselves in the air so long as changes to weapons loadouts are not required.

In many future great-power scenarios, the most powerful role played by fifth-generation systems is as sensor/information nodes in a robust network that includes not only other fifth-generation platforms, but legacy aircraft, information collectors in other domains, and weapons systems operated by other services. The US Missile Defense Agency and the US Army have both conducted experiments in which the F-35 acted as a forward sensor, passing data to ground-based air- and missile-defense interceptors.[15] The US Army and Navy are looking to employ the F-35 to provide targeting information for their new long-range strike systems. The US Navy has demonstrated the ability to link the F-35 with the Aegis air and missile defense system, thereby extending the effective engagement range of the Standard missile system family. The US Air Force and Missile Defense Agency teamed up to demonstrate the ability of an F-35 to detect a long-range missile launch with its on-board sensors and share the information through a high-altitude U-2 to the air defense commander on the ground. By employing stealthy fifth-generation aircraft as forward-deployed sensors, the range and effectiveness of long-range air-defense and precision-strike systems can be substantially increased.

Countering integrated air defenses and reasserting dominance of the air domain depends on creating the necessary networks and protocols to exploit the power of fifth-generation aircraft as information nodes. Fifth-generation aircraft must be able to share information with one another, as well as with legacy platforms. A new Alliance-wide battle-management schema must be created, one that has as its central function the exploitation of information to achieve tactical advantage and operational overmatch.

13 James Kitfield, "Red Flag 2019: First Great Power Air War Test In Years," *Breaking Defense*, March 6, 2019, https://breakingdefense.com/2019/03/red-flag-2019-first-great-power-air-war-test-in-years/.

14 Lt. Gen. David A. Deptula, USAF (Ret.), "Evolving Technologies and Warfare in the 21st Century: Introducing the 'Combat Cloud,'" *Mitchell Institute Policy Paper* (2016), http://www.mitchellaerospacepower.org/single-post/2018/08/20/Evolving-Technologies-and-Warfare-in-the-21st-Century-Introducing-the-%E2%80%9CCombat-Cloud%E2%80%9D.

15 Daniel Goure, "Lockheed Martin's F-35: How the Joint Strike Fighter is Becoming a Key Missile Defense Sensor," *National Interest*, January 29, 2018, https://nationalinterest.org/blog/the-buzz/lockheed-martins-f-35-how-the-joint-strike-fighter-becoming-24259.

THE POWER GAINED BY INTEGRATING FOURTH- AND FIFTH-GENERATION PLATFORMS

Fifth-generation aircraft are only now entering service in significant numbers. While they will constitute a growing fraction of NATO Allies' overall air order of battle, it will be decades before they eclipse the numbers of fourth-generation and legacy aircraft that will remain in service. The effectiveness of these older aircraft is increasingly challenged by Russia's deployment of sophisticated, layered air defenses, and its introduction of advanced fighters. Fortunately, the integration of fourth- and fifth-generation aircraft presents the option to not only extend the utility of the former, but to leverage the advantages of the latter.

The F-35 is particularly well suited to supporting NATO air operations. It has the ability to enter contested airspace from the opening minutes of a conflict, engage critical targets, and simultaneously take in massive amounts of electronic information that can be shared with other fifth-generation aircraft and, in many cases, fourth-generation platforms. These older aircraft are then able to exploit the rich operating picture provided by the F-35s to more effectively conduct air superiority and strike missions at reduced risk.

The most obvious way that fifth-generation aircraft can support the operations of fourth-generation systems is by degrading integrated air defenses, creating conditions in the battlespace suitable for the operations of non-stealthy aircraft. The suppression of enemy air defenses is a necessary precondition for the establishment of air superiority and the application of air power against both fixed and mobile targets. Because of its ability to get inside hostile air defenses, blowing corridors through which fourth-generation aircraft can move and conduct electronic and cyberattacks, fifth-generation aircraft can create conditions suitable for other platforms to conduct both close air support and battlefield interdiction missions. With its sophisticated sensor suite, the F-35 today can create a real-time picture of the battlespace that follow-on, non-stealthy aircraft can then use to avoid threats.

Fifth-generation aircraft can also serve as a force multiplier for fourth-generation formations. Their ability to disaggregate and degrade hostile air-defense forces creates opportunities for these older platforms to inflict massive casualties on hostile forces. Mixed fourth- and fifth-generation formations can take advantage of the unique attributes of both. Fourth-generation platforms have kinematic and payload advantages that complement the stealthiness and information advantages of fifth-generation platforms.

Ongoing exercises confirm the value of operating mixed formations. In 2017, as part of the US Air Force's Weapons Systems Evaluation Program at Eglin, Florida, four F-15s and four F-22s conducted multiple engagements against a much larger formation of simulated "red air" fighters. The final result of that mission was a kill ratio of forty-one to one in favor of the mixed-generation force.[16] Stealthy fighters can either use their own weapons to actively engage hostile aircraft or act as forward sensors or command-and-control nodes for the more heavily armed F-15s, allowing them to attack aerial targets from a position of relative safety behind the screen provided by the F-22s or F-35s.

Perhaps the most important contribution that fifth-generation platforms can make to the performance of fourth-generation aircraft is by providing forward-deployed intelligence, surveillance, and reconnaissance (ISR). Non-stealthy aircraft generally have an advantage in payload capacity over fifth-generation platforms—certainly in the opening days of a future great power conflict. What they lack are the advanced electronic suites and the ability to operate unobserved in contested airspace. Employing their sophisticated suite of sensors, fifth-generation aircraft can pass high-quality, near-real-time targeting information to fourth-generation platforms operating at a distance from high-threat air defenses. These older platforms can then employ their large payload to greater effect, responding rapidly to changes in the battlespace operating picture.

16 David Cenciotti, "Combined Force of 4 F-15s and 4 F-22s achieves 41-1 kill ratio against 14 'Red Air' fighters at WSEP," *Aviationist*, April 4, 2017, https://theaviationist.com/2017/04/04/flight-of-4-f-15s-and-4-f-22s-achieves-41-1-kill-ratio-against-14-red-air-fighters-at-wsep/.

Because the F-35 can share information with both fourth- and fifth-generation platforms, they can serve as the "quarterback" in complex air operations. Recent Red Flag exercises have repeatedly demonstrated how effective F-35s can be in support of fourth-generation aircraft operated by NATO air forces. In one exercise, US Air Force F-35s conducted sorties in support of British Typhoons to take out "high value targets."[17] The F-35s employed the tactical data-link network, Link 16, to pass the Typhoons information on the changing operating picture, thereby allowing these fourth-generation aircraft to plan safe routes to their targets.

The synergy between fifth- and fourth-generation aircraft is likely to become more robust with the introduction of new technologies such as hypersonic missiles. Hypersonic weapons will permit older aircraft to remain viable in the face of advanced integrated air defenses, provided the launching aircraft has a high-fidelity, near-real-time operating picture. The short time-of-flight of airborne hypersonic weapons will allow fourth-generation aircraft to take advantage of the first-look, first-shot opportunities provided by forward-operating F-35s.

Connectivity is a key to enhancing the interoperability between fourth- and fifth-generation aircraft.[18] For fourth-generation platforms to fully benefit from the F-35's ISR capabilities, a more robust communications capability is required. Currently, the F-35 can communicate with fourth-generation aircraft over Link 16. F-22s, can receive, but not transmit, Link 16 communications. However, Link 16 is bandwidth limited. As a consequence, much of the data gathered by the F-35's sensors cannot be transmitted over this system. In addition, there is a considerable risk that Link 16 transmissions can be intercepted or, at a minimum, used by hostile forces to target fifth-generation aircraft. The US Air Force is working on a special program, called TACLink 16, to remediate this problem, allowing the F-22 to use Link 16 to communicate with both F-35s and fourth-generation aircraft.[19]

As data links improve, NATO air forces will need to revisit their communication architectures and information security protocols in order to allow all friendly forces to be able to share the operating picture generated by fifth-generation aircraft. There is the inevitable danger of information overload as sensors' capabilities to collect data continue to grow and the capacity of networks to process more information increases.

In addition to the challenge of integrating fourth- and fifth-generation aircraft, planners need to develop the command-and-control systems to bring multi-domain capabilities to the air campaign. Aircraft of all generations must not only be able to share information among themselves, but must be able to draw information from sensors in other domains, as well as provide it to joint and coalition forces. Instead of the current, extremely complex and cumbersome system of centrally planning air operations, future commanders will rely on the initiative of each strike package, and even individual aircraft exploiting the massive flow of information available on the network.

The integration of fourth- and fifth-generation aircraft will challenge long-standing approaches to command and control and force design. Existing air force command-and-control principles and organizational structures are not designed to facilitate technical or tactical interoperability. Nor are they well suited to taking advantage of the massive amounts of information generated by fifth-generation aircraft. Airpower experts regularly describe the future command-and-control environment as a cloud with force distributed throughout the battlespace, and decision-making decentralized to clusters of platforms, or even individual aircraft.[20]

Rather than being organized around squadrons, groups, and wings of the same type of aircraft, the mixed fourth- and fifth-generation air force should be based on clusters of capabilities that allow for the unique advantages of each platform or generation to provide support and enhancement to the others. Strike packages must be designed for maximum flexibility in order to take advantage of real-time information flows.

17 Brian W. Everstine, "The F-22 and the F-35 Are Struggling to Talk to Each Other…And to the Rest of USAF," *Air Force Magazine*, March 2018, http://www.airforcemag.com/MagazineArchive/Pages/2018/March%202018/The-F-22-and-the-F-35-Are-Struggling-to-Talk-to-Each-Other---And-to-the-Rest-of-USAF.aspx.

18 Ibid.

19 Kris Osborn, "How the Air Force is Getting the Stealth F-22 Raptor Ready for War," *National Interest*, February 7, 2019, https://nationalinterest.org/blog/buzz/how-air-force-getting-stealth-f-22-raptor-ready-war-43857.

20 Maj. Luke J. Harris and Col. Max M. Marosko III, USAF, "Building a Fifth Generation Coalition: Advancing Allied F-35 Interoperability," *Mitchell Forum* 24 (2019), http://www.mitchellaerospacepower.org/single-post/2019/03/06/Building-a-Fifth-Generation-Coalition-Advancing-Allied-F-35-Interoperability.

FIFTH-GENERATION AIRCRAFT AND JOINT FORCES

While the mechanical facets of combat aviation are still important, the ability to gather information, process the data into actionable information, and act in a cooperative fashion with other assets in a given region will stand as an increasingly vital capability. While fifth-generation aircraft are often best recognized for their stealthy designs, it is their ability to engage in this combat-cloud construct that provides the most value. It is all about harnessing information to understand the battlespace and determine how to best secure desired effects, collaborate with other services and coalition systems in the region, and minimize the projection of unnecessary vulnerability.

> "The power of the F-35 as a forward-deployed sensor platform will allow it to also support future air and missile defense operations."

The power of the F-35 as a forward-deployed sensor platform will allow it to also support future air and missile defense operations. Using the F-35s powerful radar and electro-optical sensors, defensive interceptors can be launched on remote, meaning while the incoming target is still over the horizon. As a result, it is possible to engage aircraft and missiles earlier in their flight trajectories and at longer ranges.[21] In addition, for some threats, the F-35 itself could act as a forward operating defense, employing air-to-air missiles or directed energy weapons to strike ballistic and cruise missiles early in their launch phase.

The US Department of Defense has already explored the use of fifth-generation aircraft as forward sensors for both missile-defense operations and long-range strikes. In 2014, the Missile Defense Agency (MDA) conducted an experiment employing the F-35's distributed-aperture system, a set of electro-optical and infrared sensors, to develop a three-dimensional moving picture of a ballistic missile's trajectory.[22] In 2016, the US Navy successfully demonstrated that the F-35 could serve as a forward-deployed sensor for the Aegis Ballistic Missile Defense System.[23]

The US Army concept for multi-domain operations has made countering integrated air defenses a priority. The key to penetrating and degrading the layers of air defense rests with a combination of space-based sensors, penetrating fifth-generation aircraft, and long-range precision fires. The US Navy and Marine Corps view fifth-generation aircraft as playing a vital role in supporting the concepts of distributed operations and expanded long-range fires.

In a similar fashion, fifth-generation aircraft could play a central role in providing NATO land and sea forces with the real-time ISR and operating picture of the battlespace necessary to conduct major combat operations at speed and distance. To maximize the value to joint forces from the presence of fifth-generation aircraft, NATO militaries will need to invest in additional long-range fires and battle-management systems that can make use of the massive amounts of real-time data generated by these aircraft.

21 Goure, "Lockheed Martin's F-35: How the Joint Strike Fighter is Becoming a Key Missile Defense Sensor."

22 Patrick Tucker, "Newly Revealed Experiment Shows How F-35 Could Help Intercept ICBMs," *Defense One*, December 6, 2017, https://www.defenseone.com/technology/2017/12/newly-revealed-experiment-shows-how-f-35-could-help-intercept-icbms/144365/?oref=d-dontmiss.

23 Dave Majumdar, "Game Changer: Combining Lockheed Martin's F-35 and AEGIS Missile Defense," *National Interest*, September 13, 2016, https://nationalinterest.org/blog/the-buzz/game-changer-combining-lockheed-martins-f-35-aegis-missle-17695.

FIFTH-GENERATION AIRCRAFT: CHANGING THE FACE OF AIR WARFARE

Militaries all over the world are confronting the reality that the era of uncontested airspace is ending. NATO faces an even more serious challenge. For more than a decade, the Russian military has been investing in a multi-layered air defense designed to neutralize the Alliance's erstwhile dominance in the air. Today, NATO air forces, consisting largely of fourth-generation and legacy aircraft, face the nearly insurmountable problem of having to survive in a highly lethal air-defense environment, while attempting to strike critical targets.

The introduction of fifth-generation aircraft coupled to integrated information networks holds out the promise of restoring the advantages NATO airpower once provided. With their combination of stealth, advanced sensors, sophisticated electronics, and robust communications systems, fifth-generation aircraft—particularly the F-35—provide the capacity not only to directly engage advanced ground and air targets, but to provide critical ISR and command-and-control support to fourth-generation forces.

The decision by a number of NATO countries and other US allies to acquire the F-35 is extremely important. The F-35 will prove to be the cornerstone for Allied air forces' interoperability.[24] The ability of the aircraft to share data will create unprecedented opportunities for cooperation across a range of missions. In addition, the data collected by the F-35s' sensors can be employed by NATO ground and naval forces to improve the effectiveness of the Alliance's air defenses. To achieve a new level of interoperability, NATO will have to develop new protocols for sharing information.

At present, the number of fifth-generation platforms available globally is on the order of six hundred aircraft, consisting of one hundred and eighty-seven F-22s and more than four hundred F-35s in all three variants. Only a fraction of these would be available for a NATO contingency. As long as the number of fifth-generation platforms remains relatively limited, their roles in an air campaign will, of necessity, be highly selective. They must take on the burden of directly engaging the most advanced air-defense threats, both aircraft and surface-to-air missiles.

In addition, early in a conflict involving a great power, fifth-generation aircraft, particularly NATO F-35s, will be called on to provide air support for outnumbered NATO ground and naval forces. If Russian air defenses and sensor networks can be sufficiently degraded, fifth-generation platforms can transition to providing support to fourth-generation platforms that will be called upon to deliver large volumes of fire against advancing enemy conventional forces, their lines of communications, and command-and-control facilities.

One critical mission for NATO fifth-generation aircraft must be to eliminate the threat to Alliance airspace posed by advanced air defenses deployed in Kaliningrad, along the westernmost edge of Russian territory, and aboard naval forces in the Baltic and Black Seas. Unless this threat is significantly degraded in the opening days of a conflict with Russia, all of NATO's air operations will be severely hampered.

Once NATO acquires a larger number of fifth-generation platforms, the opportunity exists to engage in a new kind of air war. NATO air operations can begin to be designed around formations or clusters of platforms, both fifth- and fourth-generation, that exploit the advantages of both in order to maximize access to information, electronic attack, and kinetic firepower. While fifth-generation platforms will conduct selected attacks against high-value and well-defended targets, they could have an even more significant role in orchestrating the activities of other platforms, including those in other domains. Fifth-generation platforms can use their advantages in ISR, electronic warfare, and access to space and cyber to create a flexible, virtual defense behind which non-stealthy fourth-generation platforms can operate with relative security.

Fifth-generation aircraft will enhance NATO's air and missile defenses and enable new, long-range fires. Operating from within an adversary's air-defense network, these aircraft will provide early threat detection and tracking, improving the engagement potential of defensive systems. In addition, nascent investments in long-range fires and intermediate-range missiles require a forward-deployed targeting capability that, at present, only fifth-generation platforms can provide.

24 Harris and Marosko, "Building a Fifth Generation Coalition: Advancing Allied F-35 Interoperability."

Pictured is the first RAF F-35B (Lightning II) aircraft to arrive on British soil. With the British aircraft are 2 USAF F-35B's and two RAF Typhoons. This fifth Generation STOVL multi-role supersonic stealth aircraft will provide the UK with a hugely capable and flexible weapons and sensor platform for decades to come. Designed to operate from established land bases, austere strips and the new Queen Elizabeth Class aircraft carriers, the Lightning will join the Typhoon FGR4 in providing the Combat Air component of UK defense from 2018. *(UK Ministry of Defense photo by Sgt. Peter George)*

The US Army is exploring the possibility of employing the F-35 as a forward-deployed targeting capability for its long-range precision-fires program.[25]

The likely follow-on step after the successful integration of fourth- and fifth-generation aircraft is manned-unmanned teaming.[26] Unmanned platforms can add to the array of sensor capabilities deployed by fifth-generation platforms, creating a wide-area ISR cloud. In addition, as surface-to-air missiles become more sophisticated, longer-range, and, hence, more lethal, the ability to use drones to penetrate these defensive bubbles could prove to be a critical operational advantage. Future NATO air operations could consist of swarms of unmanned aerial vehicles conducting the initial penetration and degradation of hostile air-defense networks, providing critical ISR to enable strikes by fifth-generation platforms and creating a flexible defensive shield for fourth-generation aircraft.

The key to fully exploiting the potential of unmanned systems across the entire NATO air fleet is the creation of a common communications architecture and a secure network that can be used to enhance the situational awareness of all aircraft.[27] Enhancing the fifth-generation aircraft to fully exploit information—not only from their own sensors, but from those aboard other airborne platforms, from space, and from cyber intelligence—will allow them to serve as the "concert master," orchestrating the actions of NATO's air fleets.

25 Kris Osborn, "Army Refines Wargames for Multi-domain Combat," Fox News, August 1, 2019, https://www.foxnews.com/tech/army-refines-wargames-for-multi-domain-combat.

26 Douglas Birkey, Lt. Gen. David Deptula USAF (Ret.), and Maj. Gen. Lawrence Stutzriem, USAF (Ret.), "Manned-Unmanned Aircraft Teaming: Taking Combat Airpower to the Next Level," *Mitchell Institute Policy Paper* 24 (2018), http://docs.wixstatic.com/ugd/a2dd91_65dcf7607f144e729dfb1d873e1f0163.pdf.

27 Lt. Col. Carlos Presa and Captain Willian A. Perkins, "Air Warfare Communication in a Networked Environment; An Interdisciplinary Approach," Joint Airpower Appreciation Centre, July 2017, japcc.org/wp-content/uploads/JAPCC_AWCNE_screen.pdf.

This will reduce, or even eliminate, the current reliance on large, but increasingly vulnerable, airborne command-and-control platforms for management of the air war.

> "NATO must expect Russia and other competitors to continue to invest in a wide range of capabilities designed to challenge NATO's efforts to enhance its airpower."

Fifth-generation aircraft must be continually upgraded in order to stay ahead of the threat. NATO must expect Russia and other competitors to continue to invest in a wide range of capabilities designed to challenge NATO's efforts to enhance its airpower. In addition to new, more capable radars, it is likely that the next several decades will see the deployment of advanced airborne and land-based multi-spectral sensors, more capable and jam-resistant interceptors, sophisticated electronic-warfare systems, new cyber tools, and even hypersonic weapons.

The F-22 is receiving software upgrades that enhance the performance of its sensor suite and allow it to carry advanced weapons such as the AIM-X.[28] It is also being upgraded with a version of Link 16. The F-35 has a program called Continuous Capability Development and Delivery that will routinely add new software, enhancing avionic and missions systems and the ability to carry new weapons.[29] The current Block 4 upgrade to the F-35 will add some fifty-three new capabilities over the next five years. By exploiting an open systems architecture, the F-35 program allows for a more timely and cost-effective insertion of new capabilities than is possible with fourth-generation fleets.

It is already clear that the evolution to sixth-generation platforms will depend on advances in sensors, networks, and command and battle-management capabilities. Sixth-generation aircraft will require enhanced stealth characteristics to include sophisticated signature management. Nevertheless, stealthiness is only a basic admissions ticket to the future struggle between offense and defense for advantage in the air domain. Most experts predict that sixth-generation platforms will have to be faster and longer-range than fifth-generation systems in order to counter advanced air defenses.[30] In the future, the F-35 will carry an array of new weapons including counter-missile missiles, directed energy weapons, mini-drones, and hypersonic weapons. Sixth-generation platforms will need to be even better. Investments in multi-domain sensor fusion and agile battle-management systems will be more important. So will connectivity, the ability to communicate and share information with the full array of NATO aerial assets, as well as platforms and systems in all the other domains.

The deployment of fifth-generation technology will not end the challenge posed by advanced air defenses. Russia and China are continuing to work on increasingly sophisticated sensors and lethal interceptors. They will both soon deploy their own fifth-generation aircraft armed with longer-range, more maneuverable air-to-air missiles. Countering more advanced threats and ensuring NATO air superiority for the long term requires investments in a host of capabilities, including airframe materials, high-efficiency and low-signature engines, multi-spectral sensors, electro-magnetic weapons, artificial intelligence, and secure communications.

28 Charlie Gao, "Raptor Forever: How the Stealth F-22 Will Kill America's Enemies for Decades," *National Interest*, March 18, 2019, https://nationalinterest.org/blog/buzz/raptor-forever-how-stealth-f-22-will-kill-americas-enemies-decades-47917.

29 John A. Tirpak, "Keeping the F-35 Ahead of the Bad Guys," *Air Force Magazine*, March 2019, http://www.airforcemag.com/MagazineArchive/Pages/2019/March%202019/Keeping-the-F-35-Ahead-of-the-Bad-Guys.aspx.

30 John Harper, "What to Expect from Sixth Gen aircraft," *National Defense Magazine*, August 16, 2019 https://www.nationaldefensemagazine.org/articles/2019/9/16/what-to-expect-from-sixth-gen-aircraft

CONCLUSIONS AND RECOMMENDATIONS

NATO airpower has been a centerpiece of the Alliance's deterrence strategy and war-waging strength. This is why adversaries, particular great-power competitors, have invested heavily in capabilities intended to deny Alliance air forces access to critical airspace. Russia's highly lethal, layered air-defense system poses a nearly insurmountable challenge to the current inventory of fourth-generation and legacy aircraft.

Fifth-generation aircraft, particularly the F-22 and F-35, hold the promise of reversing the current offense-defense balance in favor of the former. The critical attributes of fifth-generation platforms—stealthiness, and advanced situational awareness—allow them to create opportunities to penetrate and degrade existing air defenses. In addition, the development of sophisticated communications networks, notably the F-35's Multifunctional Advanced Data Link, allow these advanced aircraft to share a common operating picture, thereby allowing changes in tactics and targets in near-real time.

Investments in fifth-generation aircraft and robust information networks are vital to ensuring the continued viability of fourth-generation aircraft. By creating gaps in opposing air defenses, fifth-generation aircraft can assist fourth-generation platforms in operating in contested airspace. Full integration of fifth- and fourth-generation fleets will allow NATO air commanders to leverage the stealthiness and information advantage of the former and the large payloads of the latter. As the capabilities of networks continue to evolve, fifth-generation platforms also will have the ability to support themselves and fourth-generation aircraft with resources drawn from the other warfare domains.

It is important that NATO take advantage of this decade by increasing it's investments in fifth-generation platforms, developing secure networks to link aircraft and provide joint and combined forces with access to F-35 data, and conducting operational exercises with fourth-generation aircraft. These exercises should be multi-domain, pulling in cyber and space effects, in particular. This will require NATO countries to meet or exceed the 2-percent commitment, as well as prioritize these expenditures within their defense budgets.

NATO air forces are just beginning to appreciate the advantages that fifth-generation aircraft provide. Experiments and war games are already suggesting ways in which air combat must change to take advantage of the unique capabilities fifth-generation aircraft provide. As fifth-generation platforms become a larger fraction of NATO's overall aircraft inventory, the options for changing both tactics and operational concepts will only grow.

There are a number of concrete steps that members of the Alliance must take in order to fully take advantage of fifth-generation capabilities and restore NATO's advantages in the air.

- **Meet NATO's 2 percent of GDP for defense commitment, devoting more resources to modernization.** Currently, only eight member states have achieved this target level of defense spending, although many have increased their defense budgets. In addition, a number of NATO members spend a dangerously low fraction of their defense budget on procurement even though their equipment tends to be old and even obsolescent. Building a modern air force with the appropriate networks is an expensive proposition but absolutely essential for an era of great power competition. Failing to modernize with fifth generation aircraft will result in fielding air forces unable to survive in modern high-intensity combat and in aircraft maintenance costs rising to an unacceptable level.

- **Prioritize and accelerate procurement of fifth-generation platforms and communications capabilities that link fifth- and fourth-generation aircraft.** Given the current state of progress in developing and procuring fifth-generation aircraft, the majority of NATO air forces will still consist of fourth generation platforms in 2040. This will be inadequate to meet even near-term mission requirements. It is vital that procurement of fifth-generation platforms be accelerated. It is equally important that the advantages available from fourth-fifth generation teaming be fully exploited by the deployment of assured communications between both. Moving and exploiting the information fifth-generation aircraft can provide all Coalition air forces should be a major focus of NATO investments in command and control.

- **Expand NATO exercises and Red Team efforts.** The introduction of fifth-generation aircraft will require NATO air forces to learn to fight in fundamentally different ways. The best way to develop new tactics and techniques is through a rigorous program of exercises at all levels. It is particularly important that exercises employ a mix of fourth and fifth-generation platforms. In addition, NATO should conduct Red Team efforts to

An F-22 Raptor from the Hawaii Air National Guard conducts training over the Pacific near the Hawaiian island of Oahu, March 22, 2012. The Raptors are assigned to the 199th Fighter Squadron, HIANG, and the 19th FS, 15th Wing, Joint Base Pearl Harbor-Hickam. *(U.S. Air Force photo/Staff Sgt Mike Meares)*

develop a predictive model of possible adversary responses to the deployment of fifth-generation aircraft. The introduction of stealthy aircraft and hypersonic weapons will create a new environment with shorter decision cycles. Military and political leaders need to practice making decisions in a compressed timeline with uncertain information.

- **Invest in research-and-development (R&D) on critical technologies to support sixth-generation capabilities.** Work on basic technologies such as materials, engines and avionics is already well underway. But sixth-generation capabilities must go beyond what will be available with fifth-generation aircraft. It is important to focus R&D efforts on developing "trusted" networks to enable the collection, exploitation and movement of data. NATO needs to focus more attention on sixth-generation supporting technologies such as space-based sensing, cyber defenses, cloud computing, artificial intelligence, and machine learning.

- **Develop NATO command-and-control systems to bring multi-domain capabilities to joint and coalition operations.** The focus of such efforts should be on creating common communications architecture and secure networks that can be used to share data and enhance the situational awareness among all aircraft and with forces in other domains. This will allow all forces to exploit the advantages of forward-operating fifth-generation aircraft operating as undetectable sensor platforms. In addition, a new operational architecture for Alliance forces needs to be created--one in which fifth-generation platforms are nodes on a network that spans multiple domains and all NATO Allies. Continuous information sharing across a distributed network will allow advanced aircraft to change missions at a moment's notice, and permit entire force packages to reconfigure themselves in the air. This same architecture must allow fifth-generation aircraft to act as advanced ISR platforms for land and sea-based forces.

GLOSSARY

Active Electronically Scanned Array Radar: An airborne radar that consists of an array of antennas which form a beam of radio waves that can be aimed in different directions without physically moving the antennas themselves.

AIM-9X: A US-built, short-range, infrared, guided air-to-air missile.
https://www.nationaldefensemagazine.org/articles/2019/9/16/what-to-expect-from-sixth-gen-aircraft

Anti-Access/Area Denial (A2/AD): The mix of offensive and defensive systems area-denial tactics intended to deny an adversary the ability to traverse or occupy a particular part of the land, air, sea, or space domains.

Link 16: A military-tactical data network used by NATO that permits military aircraft, as well as ships and ground forces, to communicate and exchange tactical information in near-real time.

F-15: A US-built, fourth-generation, twin-engine, multirole fighter.

F-22: A fifth-generation, stealthy, single-seat, twin-engine, high-performance fighter flown by the United States Air Force. It is primarily an air-superiority aircraft but has some electronic and ground-attack capabilities.

F-35: A fifth-generation, single-seat, single-engine, all-weather, multirole fighter, designed for both ground-attack and air-superiority missions. There are three variants of the F-35: the A model operated from land, the short-takeoff/vertical-takeoff B model, and the aircraft-carrier-based C model.

Hypersonics: Missiles, aircraft and weapons that can fly at speeds in excess of Mach 5 or 3800 miles per hour.

Multifunction Advanced Data Link: A high-speed, low-probability-of-intercept, directional-communications and data-transmission system for stealth aircraft.

Pantsir: A family of Russian self-propelled, medium-range surface-to-air missile systems with a phased-array radar designed to protect fixed installations, other air-defense sites, and mobile forces.

Red Flag: A two-week, advanced aerial-combat training exercise held several times a year by the United States Air Force, in which the other services and allied countries can participate.

S-400: A Russian advanced, long-range, mobile air-defense system capable of intercepting aircraft, unmanned aerial vehicles, and cruise and ballistic missiles at both low and high altitudes.

SU-57: Russia’s first stealthy aircraft. The SU-57 is a single-sea, twin-engine multirole fighter.

ABOUT THE AUTHORS

Deborah Lee James is former secretary of the United States Air Force. She was the 23rd secretary of the Air Force and was responsible for the affairs of the Department of the Air Force, including the organizing, training, equipping and providing for the welfare of its nearly 660,000 active-duty, Guard, Reserve and civilian Airmen and their families. She also oversaw the Air Force's annual budget of more than $139 billion. Ms. James has 30 years of senior homeland and national security experience in the federal government and the private sector. For nearly a decade, Ms. James held a variety of positions with SAIC to include senior vice president and director of Homeland Security. From 2000 to 2001, she was executive vice president and chief operating officer at Business Executives for National Security, and from 1998 to 2000 she was vice president of International Operations and Marketing at United Technologies. During the Clinton Administration Ms. James served in the Pentagon as the assistant secretary of Defense for Reserve Affairs. Prior to her Senate confirmation in 1993, she served as an assistant to the assistant secretary of Defense for Legislative Affairs. From 1983 to 1993, she worked as a professional staff member on the House Armed Services Committee, where she served as a senior adviser to the Military Personnel and Compensation Subcommittee, the NATO Burden Sharing Panel, and the Chairman's Member Services team. Ms. James earned a Bachelor of Arts degree in comparative area studies from Duke University and a master's degree in international affairs from Columbia University School of International and Public Affairs.

Dr. Daniel Gouré is senior vice president with the Lexington Institute, a nonprofit public-policy research organization headquartered in Arlington, Virginia. He is involved in a wide range of issues as part of the institute's national security program. Dr. Gouré has held senior positions in both the private sector and the US Government. Most recently, he was a member of the 2001 Department of Defense Transition Team. Dr. Gouré spent two years in the US Government as the director of the Office of Strategic Competitiveness in the Office of the Secretary of Defense. He also served as a senior analyst on national security and defense issues with the Center for Naval Analyses, Science Applications International Corporation, SRS Technologies, R&D Associates and System Planning Corporation. Prior to joining the Lexington Institute, Dr. Gouré was the deputy director, International Security Program at the Center for Strategic and International Studies. He directed analyses of emerging security issues with a special emphasis on US military capabilities in the next century. Dr. Gouré has consulted for the Departments of State, Defense, and Energy. He has taught or lectured at the Johns Hopkins University, the Foreign Service Institute, the National War College, the Naval War College, the Air War College, and the Inter-American Defense College. From 2001 to 2007, Dr. Gouré was an adjunct professor in graduate programs at the Center for Peace and Security Studies at Georgetown University, and an adjunct professor at National Defense University from 2002-2009 — teaching a Homeland Security course at both. He has been published extensively in over two dozen journals and periodicals. He is also an NBC national security military analyst. Dr. Gouré holds master's and PhD degrees in international relations and Russian Studies from Johns Hopkins University and a BA in Government and History from Pomona College.

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1030 15th Street, NW, 12th Floor,
Washington, DC 20005

(202) 463-7226, www.AtlanticCouncil.org