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At the Vanguard

European Contributions to NATO's Future
Combat Airpower



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Preface

Combat airpower constitutes an important line of effort in bolstering NATO's deterrence and defense in a range of potential scenarios against a near-peer competitor. In this report we assess the evolving capability and readiness of European air forces to contribute to a high-intensity theater conflict and identify specific issues that allied forces could address to position themselves as central contributors to NATO's deterrent posture at the vanguard of any foreseeable combat air campaign. Drawing from interviews, an expert roundtable, and relevant literature, we conclude that trend lines lead in the right direction. Acquisitions of new combat aircraft—if accompanied by investment such as enhanced radars, advanced and long-range munitions, and secure communications links—will enhance deterrence and defense. Continued attention to increasingly sophisticated training and exercises will also be needed to maximize the value of fifth-generation aircraft, of which European nations will possess several hundred by the mid-2020s. And with additional budgetary and policy attention to increasing readiness, European allies have the opportunity to significantly enhance combat airpower over the coming decade.

The research reported here was completed in May 2020 and underwent security review with the sponsor and the Defense Office of Prepublication and Security Review before public release. Human Subject Protections (HSP) protocols were used in this study in accordance with the appropriate statutes and Department of Defense (DoD) regulations governing HSP. Additionally, the views of the sources rendered anonymous by HSP are solely their own, and do not represent

the official policy or position of DoD, the U.S. Government or any other official agency.

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Summary

Russia's 2014 aggression against Ukraine, Moscow's subsequent efforts to destabilize and divide Western allies, and its continued military modernization prompted a marked shift in NATO's security posture. For much of the post–Cold War period, the NATO Alliance focused predominantly on cooperative security and crisis management operations—two of NATO's three core tasks—in and around Europe, as well as in Afghanistan and later Libya. In the months and years following the Ukraine crisis, leaders across the Alliance acknowledged the need to strengthen NATO's deterrence and collective defense, the third core task, vis-à-vis Russia.¹ At the 2016 Warsaw Summit, heads of state and government declared that “the greatest responsibility of the Alliance is to protect and defend our territory and our populations against attack. And so renewed emphasis has been placed on deterrence and collective defense.”²

Combat airpower constitutes an important line of effort in bolstering NATO's deterrence and ensuring capabilities are in place to defend allies in a range of high-intensity scenarios against a near-peer competitor.³ Russia's political and military leaders and planners, mean-

¹ NATO, *Strategic Concept for the Defense and Security of the Members of the North Atlantic Treaty Organization, Adopted by Heads of State and Government at the NATO Summit in Lisbon*, Brussels: North Atlantic Treaty Organization, November 19–20, 2010, p. 1.

² NATO, “Warsaw Summit Communiqué,” July 9, 2016, cited in “Joint Air Power Following the 2016 Warsaw Summit: Urgent Priorities,” NATO Joint Air Power Competence Centre (JAPCC), 2018, p. 1.

³ See JAPCC, 2018.

while, have observed the development of NATO's post-Cold War airpower capabilities and remain keenly aware of its potential to achieve devastating strategic and operational effects, including in the early stages of a conflict.

While NATO has traditionally relied heavily on U.S. airpower, ongoing modernization among a number of European air forces,⁴ including through the introduction of fifth-generation aircraft, could offer an essential contribution to transatlantic security, enhance deterrence, and provide commanders much-needed combat power and flexibility in the event a major conflict ensues. In July 2018, NATO developed and released its Joint Air Power Strategy (JAPS), which describes the value of allied air forces and offers a broad pathway forward for their development across the Alliance's core tasks, with an amplified emphasis on collective defense.

The question of this research effort was, "What is the evolving capability and readiness of European air forces to perform select combat air missions in a high-intensity theater conflict?" Relatedly, the project explored how an increase in capability could affect adversary planning and the challenges and opportunities that European air forces could address to position themselves as central contributors—that is, at the vanguard—to NATO's deterrent posture and any foreseeable combat air campaign.

While NATO airpower could be applied to a broad range of allied operations, we focus specifically on maximalist conditions: high-intensity operations that would require rapid and large-scale application of airpower, conducted in the European theater. Our analysis is based on an Article 5 declaration and full contributions from all

⁴ In using the terms *airpower* and *air forces* in this report, we are referring to capabilities residing in multiple services. Unless referring to a single service (e.g., the United Kingdom Royal Air Force), these terms are used to denote the domain, not a particular service. Combat aircraft residing within naval aviation are considered in this report, though principally as they relate to contributions to joint missions such as countering integrated air defense systems (IADS), not maritime-dominant missions such as protecting naval task forces or conducting anti-submarine warfare. We did not review multinational training in regard to naval aviation. Additionally, this report focuses on the European dimension of NATO's airpower and as such does not consider Canada, although many of this report's observations would most likely apply.

members. We do not assess political will or Alliance cohesion, a matter addressed elsewhere, but rather focus on a review of capabilities.⁵

Findings

First, Russian political and military leadership remains concerned about NATO's relative advantage in the air domain—a dynamic that will likely intensify over the next five years as large numbers of fifth-generation fighters enter NATO inventories. Russia enjoys a relative advantage in rapidly deployable ground forces in regions close to Russian borders, notably the Baltic states and Poland. However, Russian strategy documents, statements, and actions indicate particular concern about the depth and speed provided by NATO's advanced platforms and munitions, which could serve to blunt Russia's ground advantage. Furthermore, observations of Western targeting practices over the past two decades have raised Russian concerns about the vulnerability of Russian ground forces, military bases, and critical infrastructure, as well as political leadership, to NATO's combat air capabilities. Although the perceived extent of NATO's relative airpower advantage is unclear, Russian defense analysts evaluating the combat potential of Western military aircraft have historically considered qualities such as firepower, mobility, survivability, and command and control, as well as a platform type's contributions to units and larger formations. These are all areas where the increase in capability resulting from NATO's modernization efforts will become more pronounced in the next five years. Extensive Russian investment in integrated air defense systems (IADS) underscores the significance with which Russia views the air domain a central dimension of its military planning.

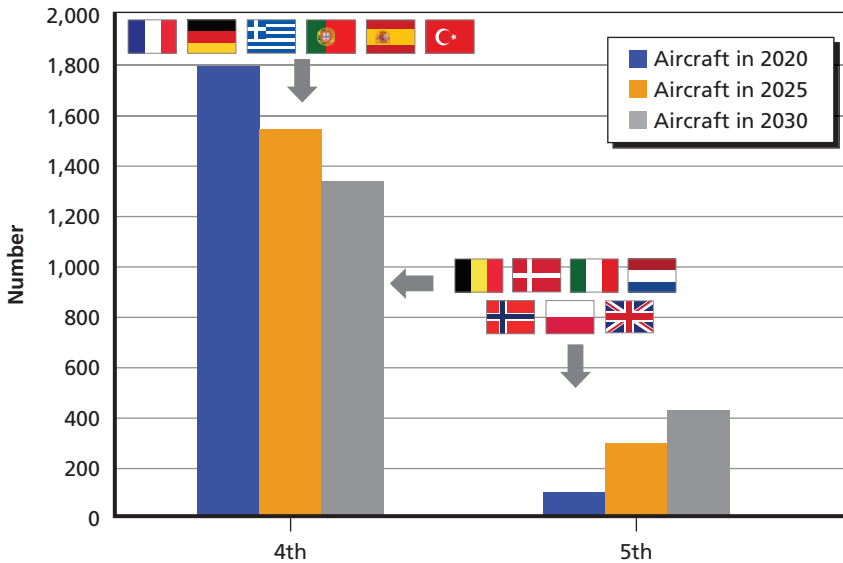
⁵ See, for example, Anika Binnendijk and Miranda Priebe, *An Attack Against Them All? Drivers of Decisions to Contribute to NATO Collective Defense*, Santa Monica, Calif.: RAND Corporation, RR-2964-OSD, 2019; and Michael J. McNerney, Ben Connable, S. Rebecca Zimmerman, Natasha Lander, Marek N. Posard, Jasen J. Castillo, Dan Madden, Ilana Blum, Aaron Frank, Benjamin J. Fernandes, In Hyo Seol, Christopher Paul, and Andrew Parasiliti, *National Will to Fight: Why Some States Keep Fighting and Others Don't*, Santa Monica, Calif.: RAND Corporation, RR-2477-A, 2018.

Second, European air forces currently possess fleets with relatively limited capabilities for conducting the most-demanding missions expected in a high-intensity conflict and of most concern to Russia. Currently, the European allies considered in this report maintain about 1,900 combat aircraft, fewer than 100 of which are fifth generation. European air forces made substantive contributions to previous allied and coalition air operations across the spectrum of combat air missions, but typically in less contested operating environments. During the opening phases of a conflict with Russia, vulnerability to advanced ground-based threats would constrain the roles of most fourth-generation and so-called fourth-generation-plus platforms. While limited in a highly contested environment, these aircraft could still perform defensive counter-air missions over national airspace or other strategically significant locations, long-range (outside of advanced IADS range) missile strikes with precision-guided munitions (PGM), and electronic warfare (EW) attacks. As long as an extensive IADS threat persisted, more advanced platforms such as the Rafale or Eurofighter could theoretically perform strike missions inside the threat zone in conjunction with fifth-generation platforms, although this approach could yield unacceptable attrition. If the threat posed by adversary air defenses were reduced, fourth-generation aircraft could begin to conduct a broader range of traditional roles such as offensive counter-air or close air support to ground forces. Another complication likely to stress NATO planners—particularly in light of the demise of the Intermediate-Range Nuclear Forces Treaty—will be the need to reserve enough sorties for protection of national airspace, air bases, and other sensitive sites from cruise and ballistic missile attack.

Third, European acquisition of fifth-generation fighters will improve NATO's capacity for operations in a high-intensity conflict with Russia, though new capabilities are needed above and beyond the platform itself. By 2025, the seven F-35-acquiring European allies will, in aggregate, possess more than 200 F-35s stationed in Europe.⁶ This will exceed the number of U.S. fifth-generation aircraft

⁶ We assume that Turkey will not acquire F-35s.

Figure S.1
Projected Fourth-Fifth Generation Mix of Aircraft Among European Allies



SOURCE: RAND analysis based on IHS Jane's, the International Institute for Strategic Studies (*The Military Balance 2019*), interviews, and open source reporting.

stationed in the European theater by a wide margin.⁷ By 2030, the total number of fifth-generation fighters in these air forces will exceed 300 and is likely to approach 400 aircraft, which would account for 30 percent of combat aircraft among the nations considered in Figure S.1.

In the opening days of a notional conflict, the F-35's stealth and sensor fusion will enable unprecedented situational awareness and the potential to acquire and service targets at rapid tempos. This will be impactful across the range of combat air missions, including for suppression of enemy air defenses (SEAD) in the early hours and days of a campaign and conducting counter-land operations to delay, damage, and destroy enemy maneuver forces. These missions could be accomplished by the F-35 directly or with the F-35 performing a combat

⁷ Currently, the United States plans to station two F-35 squadrons at Royal Air Force (RAF) Lakenheath beginning in 2021. Christopher Dennis, "Construction of First Permanent US F-35 Campus in Europe Begins at Lakenheath," *Stars and Stripes*, July 15, 2019.

intelligence, surveillance, and reconnaissance (ISR) role and securely passing targeting data to other air and joint platforms.⁸

As capable as they are, fifth-generation fighters operate as part of a broader system of platforms and capabilities. Some nations are acquiring world-class fourth-generation-plus aircraft, though others have yet to commit to recapitalizing their fleets in the 2020s. Uncertainties remain as to which nations will invest in active electronically scanned array (AESA) radar technology, advanced and long-range munitions, and secure communication links, among other important capabilities. The degree to which European air forces acquire these technologies will directly impact their ability to contribute to the range of combat air missions expected in a high-intensity conflict. At the same time, reliance on the F-35 for combat ISR functions previously performed by longer-range, ISR-dedicated standoff aerial systems (e.g., RC-135W River Joint, E-8 Sentinel, and E-3 Sentry) raises the question of capacity and prioritization alongside other demands such as SEAD, counterland operations, and air defense.⁹

Fourth, a high degree of interoperability and integration between European fifth-generation fighters and NATO's other air and joint forces is required to maximize the Alliance's combat potential. As both Western and Russian analysts have observed, the combat potential of an individual aircraft is, in part, a function of its ability to work effectively within a broader formation. Fifth-generation platforms have the potential to serve as a force multiplier across a combined force, improving the performance of other platforms by enhancing their situational awareness. Fourth-generation fighters—many able to wield greater firepower than their stealthier fifth-generation counterparts and still projected to account for about 70 percent of NATO's

⁸ For one of the more extensive public accountings of how the F-35 is transforming operational concepts, see Justin Bronk, *Maximum Value from the F-35: Harnessing Transformational Fifth-Generation Capabilities for the UK Military*, Whitehall Report 1-16, Royal United Services Institute, February 2016. See also Justin Bronk, *The Future of NATO Airpower: Whitehall Papers*, Vol. 94, No. 1, January 28, 2020b.

⁹ This report focuses on combat air capabilities. For more on the evolution and future direction of air command and control, ISR and early warning, and EW-dedicated systems, see, for example, Justin Bronk, "The Future of Air C2 and AEW: E-3 Sentry, Threat Technologies, and Future Replacement Options," RUSI Occasional Papers, June 2017.

inventory by 2030—will still constitute an important element of air-power. It is reasonable to assume that the Russian military would seek to disrupt this synergy during a conflict, particularly in light of recent Russian investments in EW capabilities.

Already, allies have undertaken initial steps to establish common tactics, techniques, and procedures (TTP) for incorporating fifth-generation assets into combined operations through targeted exercises as well as preliminary synthetic training systems that link fourth- and fifth-generation aircraft. Recent training and exercises have emphasized operations in contested environments and prioritized missions such as SEAD, a skill set new to most European air forces. Important progress has been made, though it has been limited by policy and technological constraints to real-time information sharing among platforms and between allies.

Over the coming years, the need to familiarize aircrew across the Alliance with combined operations integrating fifth-generation aircraft will increase as the F-35 comes online. Major European air forces without fifth-generation capabilities, such as France, have ample opportunity to participate as full partners by joining in the development of emerging operational concepts. Additionally, air forces require clear policy guidance for fifth-generation interoperability and information sharing, secure and reliable communications links, and additional resources for combined training in denied and degraded environments.

Fifth, even as many allied governments pursue procurement of advanced combat platforms, all European air forces still struggle to maintain high levels of readiness. To be operationally relevant during a theater conflict, NATO's air forces must maintain a sufficient number of available aircraft, munitions, and aircrew. Currently, most European air forces maintain around half of their existing fleets or less at mission-capable status, with some allies falling below that mark. For many fourth-generation fleets, rising maintenance costs from platform age, operational wear and tear resulting from a high operational tempo, and challenges associated with spare parts pipelines serve as significant constraints to aircraft availability. Early challenges within the F-35 program—in particular, implementing an envisioned global spare parts pooling concept and overcoming malfunctions of the autonomic logistics information system (ALIS)—could limit the benefits from

European investments in the platform if left unaddressed. European investments in PGMs, including standoff weapons, deepen the allied arsenal and, if sufficient in quantity, would allow for a more sustained contribution to a collective defense operation should the need arise. Finally, insufficient airspace for exercises and the number of pilots and skilled maintainers represent limiting factors for most allied air forces.

Recommendations

Over the coming decade, European air forces will be increasingly capable of playing a significant role at the outset of a high-intensity collective defense operation. In particular, current and planned acquisitions of fifth-generation aircraft and their use within combat ISR, SEAD, and counter-land roles could fundamentally change the way that NATO conducts air operations, improving survivability and lethality and enabling greater European involvement across some of the most-demanding mission sets. Drawing from these findings, the following recommendations are designed to inform European investments, the implementation of JAPS, and other forms of multinational collaboration that make the most of emerging technology.

1. **Prioritize investments that enable fourth-generation aircraft and other platforms to complement the F-35's unique capabilities.** In order for the F-35 to maximize its impact across a conflict, the following investments should be made by allies to improve the survivability, firepower, and connectivity of existing platforms:
 - Upgrade fourth-generation aircraft radars. In particular, an AESA radar system for Eurofighter Typhoon fleets would enhance survivability during a high-intensity conflict.
 - Continue to stockpile munitions, including new options such as the Joint Strike Missile and recently developed or expected anti-radiation missiles. Using mechanisms such as the NATO Air-to-Ground project (known as A2G-PGM) as well as collaboration with European industry, allies should continue to expand their PGM arsenals with particular attention to anti-armor weapons and air-to-ground missiles with ranges between 100 km and 1,000 km, including anti-radiation mis-

siles that provide fourth-generation aircraft a SEAD and strike capability from standoff ranges.

- Ensure that fourth-generation aircraft, as well as ground and maritime systems, can receive targeting information from the F-35 in a timely and secure manner. Since NATO communications are a likely focus of Russian electronic attack, they must be robust and sufficiently redundant in the context of jamming and other interference.
2. **Prepare fifth-generation fleets across NATO to undertake operations within the range of Russia's most sophisticated air defenses.** Maximizing the impact of European F-35 purchases for collective defense will require that fleets are capable of contributing to challenging missions in the initial phases of an air operation. To enable this contribution, NATO air forces should initiate the following:
 - Include the SEAD mission in training and exercises beyond the initial training program at Luke Air Force Base in the United States. This will necessitate trainer aircraft that closely simulate the capabilities of the F-35 as well as realistic threat emitters and electronic jammers, among other features.
 - Develop operational concepts for locating, tracking, engaging, and destroying moving armored formations in contested environments, and ensure training and exercises provide adequate opportunities to rehearse blunting large-scale ground offensives.
 - Hone international cross-maintenance practices to facilitate distributed operations and reduce predictability with flexible aircraft servicing that enables forward refueling and rearming.
 3. **Institute routine combined training and exercises for multinational formations, including with the F-35.** The introduction of fifth-generation aircraft alters existing NATO concepts of operation and creates the need for closer synergy among aircrew. To improve operational cohesion over the coming decade, NATO air forces should institute the following:
 - Train on a regular basis as often as practicable—ideally quarterly or even monthly—in combined multinational formations that include fifth- and fourth-generation systems. Initiatives can draw from the experiences of the long-standing

multinational F-16 training program, Nordic Cross-Border Training arrangement, and recent UK-hosted Point Blank exercises.

- Identify options for linked synthetic training among NATO air forces, potentially expanding on the 2018 Spartan Alliance simulator exercise.
- Establish a NATO Air Warfare Center to facilitate regular and financially sustainable multinational air training, perhaps taking advantage of relatively large airspace and existing facilities available in Italy or Spain.
- Leverage multinational advanced training events, such as U.S. Red Flag, to permit all members of the European F-35 user group to practice high-intensity combat air operations.
- Initiate a robust personnel exchange program across allied F-35 users in order to rapidly standardize TTPs based on maturing fifth-generation operational concepts.
- Ensure that the French air force, which does not participate in the European–NATO Joint Jet Pilot Training Program, has ample opportunity to participate in combined training.

4. **Commit to a greater level of public objectives and transparency for combat aircraft availability.** Data on the mission-capable rates of European air platforms are not generally publicized. Public agreement by NATO leaders on standard availability objectives could provide renewed political and budgetary focus on efficient and adequately funded maintenance and sustainment. The recent U.S. nadir of an average overall 70-percent mission-capable rate might offer a reasonable NATO-wide objective. This report identifies the following actions to improve availability levels:

- Invest in measures to improve current limiting factors such as spare parts shortages and lengthy maintenance timelines within both the F-35 program and fourth-generation fleets.
- Continue to address malfunctions within the F-35 ALIS logistics system.
- Continue to develop a predictable and transparent system for spare parts allocation across the F-35 global spares pool.

5. **Update national and F-35 program policies and procedures to allow U.S. and European air forces to enhance collaboration for training and operations.** At present, unclear and sometimes unnecessary restrictions on information sharing and planning stifle cooperation among air staffs and reduce their ability to adequately prepare for high-end multinational operations. In particular, senior-level attention will be needed to
 - release an updated F-35 interoperability policy that identifies guidelines on information sharing within the consortium in a way that balances legitimate security needs without unduly restricting multinational cooperation
 - facilitate collaboration among U.S., European, and NATO planners to synchronize TTPs and concepts of operation, perhaps through the establishment of standing liaisons at the squadron and/or group levels.

Implications

Recent and anticipated investments in combat air capabilities and increased emphasis on training and preparation for high-intensity missions are likely to improve European contributions to a notional collective defense scenario over the coming decade. These developments could also enhance deterrence—an objective at the forefront of NATO’s agenda since 2014—by making it more likely that Europeans would be able to impose extensive military costs on Russia in response to aggression against a NATO member. One common scenario considers a calculation by the Russian government that Russia could leverage a regional imbalance in ground forces to occupy some slice of NATO territory, employ air defenses to stave off allied air forces, present a *fait accompli* similar to that seen in Crimea, and politically divide NATO by calling for negotiations.¹⁰ The ability of European fifth-generation fighters to penetrate Russian air defenses

¹⁰ David A. Shlapak and Michael Johnson, *Reinforcing Deterrence on NATO’s Eastern Flank: Wargaming the Defense of the Baltics*, Santa Monica, Calif.: RAND Corporation, RR-1253-A, 2016.

and make significant combat contributions from the opening hours of a response—at the vanguard—would most likely challenge the logic behind this scenario, improving deterrence by increasing the Russian risks associated with this approach. This RAND report, premised on the validity of that assumption, concludes that in the air domain at least, trend lines in platform modernization lead in the right direction. But increased investments in key supporting areas are called for in order to fully realize the Alliance's combat air potential.

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Abbreviations

A2/AD	anti-access/area denial
A2G-PGM	NATO Air-to-Ground project
AESA	active electronically scanned array
AI	air interdiction
ALIS	autonomic logistics information system
AMRAAM	advanced medium-range air-to-air missile
ASRAAM	advanced short-range air-to-air missile
AWR	air weapons range
BDM	battle decisive munitions
BMD	ballistic missile defense
BVRAAM	beyond visual range air-to-air missile
C2	command and control
CAS	closer air support
COF	correlation of forces
COFM	correlation of forces and methods
COMAO	Composite Air Operation
CONOPS	concept of operations

DCA	defensive counter-air
ECR	electronic combat and reconnaissance
EDA	European Defense Agency
EEAW	EPAF Expeditionary Air Wing
eFP	enhanced Forward Presence
ENJJPT	Euro-NATO Joint Jet Pilot Training
EPAF	European Participating Air Forces
ER	extended range
EW	electronic warfare
FMS	Foreign Military Sales
GAM	Global Asset Management
GBAD	ground-based air defenses
GSS	Global Support Solution
IADS	integrated air defense systems
ICBM	intercontinental ballistic missile
IFTS	International Flight Training School
IIR	imaging infrared-guided
IR	infrared-guided
ISR	intelligence, surveillance, and reconnaissance
JAPCC	Joint Air Power Competence Centre
JAPS	Joint Air Power Strategy
JDAM	Joint Direct Attack Munition
JPO	F-35 Joint Program Office
JSF	Joint Strike Fighter

JTE	Joint Threat Emitter
LNPI	Lead Nation Procurement Initiative
LOAL	lock-on-after-launch
MADL	Multifunction Advanced Data Link
MFTS	Military Flying Training System
MOU	memorandum of understanding
MRO&U	maintenance, repair, overhaul, and upgrade
NASAMS	Norwegian Advanced Surface-to-Air Missile System
NATO	North Atlantic Treaty Organization
NRF	NATO Response Force
NRI	NATO Readiness Initiative
NSPA	NATO Support and Procurement Agency
O&M	operations and maintenance
OCA	offensive counter-air
OT&E	operational training and evaluation
PESA	passive electronically scanned radar
PGM	precision-guided munitions
QRA	Quick Reaction Alert
RAF	Royal Air Force
RDAF	Royal Danish Air Force
RNLAF	Royal Netherlands Air Force
RUSI	Royal United Services Institute
SACEUR	Supreme Allied Commander Europe
SAM	surface-to-air missile

SDB	small diameter bomb
SDSR	Strategic Defense and Security Reviews
SEAD	suppression of enemy air defenses
STOVL	short take-off and vertical landing
TLP	Tactical Leadership Program
TSP	theater security package
TTP	tactics, techniques, and procedures
UAV	unmanned aerial vehicle
USAFE	U.S. Air Forces in Europe
VJTF	Very High Readiness Joint Task Force

Introduction

Russia's 2014 aggression against Ukraine, subsequent efforts to destabilize and divide Western allies, and continued military modernization prompted a marked shift in NATO's security posture. For much of the post-Cold War period, the Alliance focused predominantly on cooperative security and crisis management operations—two of NATO's three core tasks—in and around Europe, as well as in Afghanistan and later Libya. In the months and years following the Ukraine crisis, leaders across the Alliance acknowledged the need to strengthen NATO's third core task, deterrence and collective defense, vis-à-vis Russia.¹ At the 2016 Warsaw Summit, heads of state and government declared that “the greatest responsibility of the Alliance is to protect and defend our territory and our populations against attack. And so renewed emphasis has been placed on deterrence and collective defense.”²

To address this changing strategic landscape, NATO adopted a range of initiatives and actions to enhance posture and improve combat readiness for collective defense. Although allies initially focused on land-centric adaptations such as strengthening U.S. Army presence in Europe and positioning NATO's enhanced Forward Presence (eFP) battlegroups in Poland and the Baltic states, other domains—air, maritime, cyber, and space—are now receiving equal attention as part of the

¹ NATO, *Strategic Concept*, 2010, p. 1.

² NATO, “Warsaw Summit Communiqué,” July 9, 2016.

Alliance's effort to develop an increasingly credible joint and enabled deterrent posture.³

For NATO, combat airpower constitutes an important line of effort in bolstering deterrence and ensuring capabilities are in place to defend allies across a range of high-intensity scenarios against a near-peer competitor.⁴ Russian political and military leaders and planners, meanwhile, have continued to observe the development of NATO's post-Cold War airpower capabilities and remain keenly aware of its potential to achieve devastating strategic and operational effects, including in the early stages of a conflict.

While NATO has traditionally relied heavily on U.S. airpower, ongoing modernization among a number of European air forces, including through the introduction of fifth-generation aircraft, could offer an essential contribution to transatlantic defense, enhance deterrence, and provide commanders much-needed combat power and flexibility in the event a conflict ensues.⁵ In July 2018, NATO developed and released its Joint Air Power Strategy (JAPS), which describes the value of allied air forces and offers a broad pathway forward for their development across NATO's core tasks, with an amplified emphasis on collective defense.

³ For more on the maritime dimension, see Magnus Nordenman, *The New Battle for the Atlantic: Emerging Naval Competition with Russia in the Far North*, Annapolis, Md.: Naval Institute Press, 2019; and Chapter 2 of Gene Germanovich, J. D. Williams, Stacie L. Pettyjohn, David A. Shlapak, Anthony Adler, and Bradley Martin, *NATO's Amphibious Forces: Command and Control of a Multibrigade Alliance Task Force*, Santa Monica, Calif.: RAND Corporation, RR-2928-USMC, 2019. Cyberspace and space have been declared by NATO as operational domains in 2016 and 2019, respectively.

⁴ See Joint Air Power Competence Centre (JAPCC), "Joint Air Power Following the 2016 Warsaw Summit: Urgent Priorities," 2018.

⁵ In using the terms *airpower* and *air forces* in this report, we are referring to capabilities residing in multiple services. Unless referring to a single service (e.g., the United Kingdom Royal Air Force), these terms are used to denote the domain, not a particular service. Combat aircraft residing within naval aviation are considered in this report, though principally as they relate to contributions to joint missions such as countering integrated air defense systems (IADS), not maritime-dominant missions such as protecting naval task forces or conducting anti-submarine warfare. We did not review multinational training in regard to naval aviation. Additionally, this report focuses on the European dimension of NATO's airpower and as such does not consider Canada, although many of this report's observations would most likely apply.

In light of these developments, and recent unpublished RAND research on Russian air defense planning highlighting the need to examine European combat air capabilities, this report examines European allies' combat air capabilities in the context of NATO's collective defense in the 2020s.

This chapter summarizes the project's research approach and how RAND reviewed Europe's current combat air capabilities, projected their evolution, and arrived at a series of issues that might be addressed to strengthen deterrence and collective defense in relation to Russian leadership and armed forces that have come to respect NATO's airpower.

Research Question and Approach

This research project assessed the evolving capability and readiness of European air forces to contribute to a high-intensity theater conflict. Relatedly, the study sought to identify specific issues that European air forces could address to position themselves as central contributors to NATO's deterrent posture and at the vanguard of any foreseeable combat air campaign. To consider the implications of recent and projected developments for a potential adversary, we examined Russian perspectives on evolving NATO combat airpower to extrapolate mission areas of likely significance to Russian decisionmakers and planners.

While NATO airpower could be applied to a broad range of allied operations, this study focuses specifically on maximalist conditions: high-intensity operations that would require rapid and large-scale application of airpower, conducted in the European theater. The analysis is based on an Article 5 declaration and full contributions from all members. It does not assess political will or Alliance cohesion, a matter addressed elsewhere, but rather focuses on a review of capabilities.⁶ This report relies on the best available data as of February 2020.

⁶ See, for example, Binnendijk and Priebe, 2019; and McNerney et al., 2018.

Understanding Russian Perspectives

If deterrence is to be enhanced, a potential adversary needs to understand and respect NATO capabilities. In this regard, Russia's outlook on NATO's combat air capabilities may provide new opportunities to strengthen defense and deterrence. NATO's relative advantage in the air domain has long been a source of concern to the Russian leadership, prompting extensive Russian investments in air defense systems, among others. This study drew from an analysis of Russian strategic literature, senior leader statements, and recent operations to extrapolate which NATO combat air capabilities and missions may be of greatest concern to Russian planners in the context of a notional conflict with NATO.

Selecting Airpower Roles for Examination

This report considers the combat air contributions that non-U.S. NATO members could make to a NATO collective defense operation, now and over the coming decade. Specifically, we assess the capability of select European air forces to contribute to NATO operations in a high-intensity theater conflict.

To scope our analysis, we addressed potential European contributions to two of the four airpower roles identified in NATO doctrine and the JAPS: counter-air and attack. These two airpower roles were selected based on our review of the emphasis placed on these roles by Russian planners and decisionmakers, as well as project scoping discussions that revealed these issues to be of interest to the U.S. Department of Defense. While the remaining roles of intelligence, surveillance, and reconnaissance (ISR) and air mobility represent critical dimensions of an overall response, this project focuses on those roles that require contact with adversary forces and form the core of a nation's airpower capability.⁷

⁷ The four airpower roles are not necessarily mutually exclusive. For example, many fighter aircraft—in particular, fifth-generation systems—have an organic ISR capability. While recognizing the importance of specific advanced early warning, ISR, and electronic warfare (EW) systems, this review focuses on forces and platforms designated as fighters. For more on air command and control and early-warning-dedicated systems, see, for example, Bronk, 2017. European nations do not possess bombers.

According to NATO doctrine, counter-air seeks to establish control of the air to “shape the operational area wherein friendly operations can proceed at the optimum place and time without prohibitive air interference.”⁸ JAPS acknowledges the new challenges that allied forces face from near-peer state adversaries in establishing control of the air.⁹ Efforts to establish such control may be achieved through offensive counter-air operations, which can include surface attack operations, air-to-air missions, and suppression of enemy air defenses (SEAD), as well as through air defense operations.¹⁰ For the latter category, this study, while recognizing the importance of ground-based air defense, focuses on air-based contributions to air defense.

NATO describes the second air role addressed in this study—attack—as lying “at the heart of air power’s capacity to create influence by changing behaviors or the course of events.”¹¹ Strategic attacks may seek to “weaken the adversary’s ability or will to engage in conflict or continue an action” by engaging targets that would disrupt leadership functions, threaten war-sustaining resources, or undermine adversary strategy.¹² Counter-land attack operations may threaten ground targets such as adversary’s fielded forces, supply lines, or supporting infrastructure. Such missions may take place at a distance from friendly forces (air interdiction) or in close proximity, requiring careful coordination to avoid fratricide (close air support).¹³

⁸ NATO, *Allied Joint Doctrine for Air and Space Operations*, AJP-3.3, Edition B, Version 1, April 2016.

⁹ NATO, *NATO’s Joint Air Power Strategy*, Belgium, last updated June 27, 2018.

¹⁰ NATO, AJP-3.3, April 2016.

¹¹ NATO, AJP-3.3, 2016.

¹² “A key advantage of air power, over many other military forces, is the ability to strike directly at the heart of the adversary, disrupting critical leadership functions, war-sustaining resources and strategy, while avoiding the need to sequentially fight through layers of surface forces to get there” (NATO AJP-3.3, 2016). Note that this study does not consider employment of nuclear weapons.

¹³ NATO, AJP-3.3, 2016. Airpower contributions to counter-maritime operations are also addressed in NATO doctrine, but were excluded from this study.

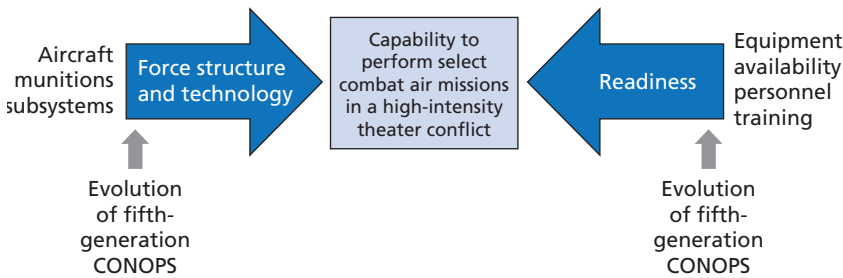
We do not consider nuclear-related mission sets because of the limited information on this topic in the public domain, although fighters capable of performing a dual-capable aircraft role are included in the inventory considered.

Assessing European Capabilities

We conducted documentary research, interviews, and roundtable discussions with subject matter experts from the United States and select European air forces and NATO commands.¹⁴ Insights garnered through these techniques were synthesized and incorporated into a framework based on two overarching factors for assessing European combat airpower. Figure 1.1 illustrates how the two factors influence combat air capabilities.

The first, force structure and technology, centers on a review of fighter aircraft and munitions inventories belonging to operational forces, including key subsystems and add-ons subsequent to original procurements. Our review of this factor incorporated emerging operational concepts being considered by Western air forces as a result of ongoing procurements and expected technologies, particularly fifth-generation aircraft that offer joint forces a potentially unparalleled capa-

Figure 1.1
Factors Reviewed to Assess Combat Air Capabilities



¹⁴ Additionally, RAND organized a workshop in Washington, D.C., to explore plans and developments among European air forces in the context of the new Joint Air Power Strategy. This event included presentations by officials of seven allied governments.

bility to provide real-time situational awareness and take timely action within a highly contested battlespace.

The second factor, readiness, incorporates those elements necessary to successfully operate combat aircraft, including equipment availability, recruitment and career progression of qualified personnel, and provision of training and relevant exercise opportunities. In considering this factor, part of the research effort explored the likely impact of the fifth-generation-enabled operational concepts.

We elected the two overarching factors based on a recognition that introducing high-end technology cannot in itself transform a nation's capabilities without corresponding efforts to ensure readiness. As depicted in Figure 1.2, this report considers capabilities resident in 13 European nations. The 13 nations were selected because each maintains at least two squadrons of fourth- and/or fifth-generation aircraft, advanced munitions, and associated training that would be needed to make a substantial contribution to the airpower roles identified above.

We do not assess the contributions that the remaining NATO nations could make, nor do we consider basing, access, or supporting

Figure 1.2
European Nations Reviewed



^aThese nations' militaries possess a naval aviation capability that includes fixed-wing fighter aircraft.

capabilities. Combat air missions fundamentally depend on supporting (e.g., mobility, ISR) and joint (e.g., space and cyberspace) capabilities that, while critical, remain beyond the scope of this effort. We also limit our analysis to NATO members commitments, notwithstanding that key partners could contribute to an Alliance operation.¹⁵

Limitations and Assumptions

This report does not provide a definitive assessment of requirements for individual European air forces or NATO as a whole—this would necessitate extensive modeling and simulation and access to classified technical information.¹⁶ Instead, we offer a broader review of combat air capabilities through the limited but instructive prisms of force structure and technology and readiness. In regard to the latter, we attempted to capture key dynamics and limiting factors to combat air readiness on the whole but did not attempt to analyze what would be relatively sensitive data needed to arrive at a quantitative measurement of readiness to perform individual mission sets.

We make two major assumptions that merit explicit mention here. The first is that fifth-generation capabilities—for this study, chiefly the F-35 program—will continue to mature and anticipated technologies will be developed without substantial, mission-critical, and/or unmanageable delays. Second, we assume Europe's acquisition and development of this capability—if managed carefully—will contribute to deterrent effects in NATO's relationship with Russia. We revisit the implications of this assumption in the concluding chapter.

¹⁵ Sweden and Finland stand out as highly capable militaries with substantial air forces, including the new Gripen E/F fighter to be operated by Sweden and potentially other European nations. For one perspective on the need to integrate Scandinavian defense with NATO, see Carl Bildt, "The End of Scandinavian Non-Alignment," Project Syndicate, October 17, 2018.

¹⁶ An outdated but relevant example of such analysis is Kathleen Harris and Louis H. Wegner, *Tactical Airpower in NATO Contingencies: A Joint Air-Battle*, Santa Monica, Calif.: RAND Corporation, R-1194-PR, 1974.

Report Organization

This report is designed to inform allied government decisionmakers on the prospects, challenges, and opportunities of an evolving European combat airpower capability in relation to NATO's objectives of deterrence and collective defense. It is organized across seven chapters. Chapter Two provides an overview of recent and current NATO airpower developments and relays what national air forces have been tasked to do through their respective levels of ambition. Chapter Three addresses Russia's perspectives on NATO airpower and identifies its concerns about a potential theater-wide conflict. Chapter Four reviews current and projected force structure and technology while Chapter Five and Chapter Six review equipment availability and training, respectively. Other aspects of readiness, also covered in Chapter Five, are recruitment and retention, training and exercises, maintenance and spare parts, and basing infrastructure. Finally, Chapter Seven combines insights from force structure and technology and those about readiness to provide an overall depiction of capability and relays findings and recommendations.

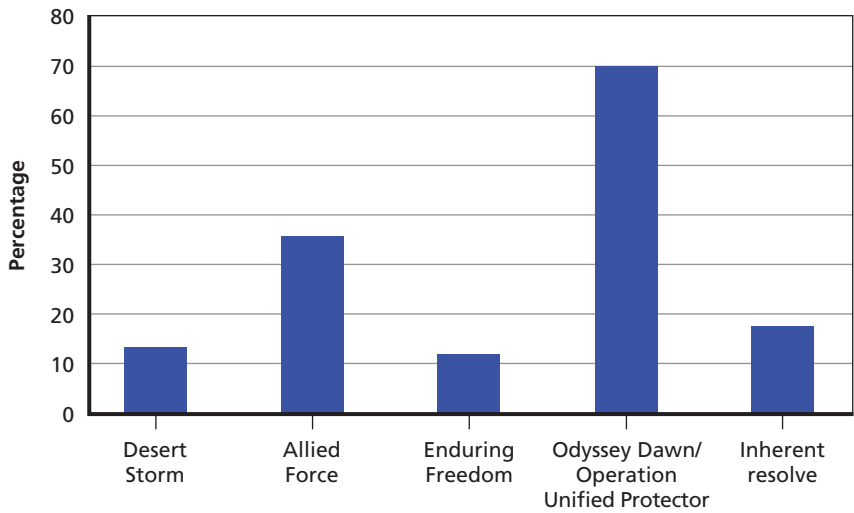
NATO Combat Air: Operations, Strategy, and Ambition

This chapter describes aspects of the post–Cold War evolution of airpower in Europe. It begins by exploring European contributions to two NATO operations fought predominantly in the air: Allied Force (1999) against Serbia and Unified Protector (2011) against Muammar Gaddafi’s Libya. Next, it reviews steps NATO has taken, including within the air domain, to improve its defense and deterrence posture in response to a changing European security environment. The chapter concludes with an overview of the level of ambition and areas of emphasis within each of the European air forces covered by this study.

European Contributions to Combat Air Operations

Combat airpower has played a significant role in allied and coalition operation over the course of the post–Cold War period. In particular, technological advances in precision-guided munitions (PGM), stealth, and standoff weapons, beginning with the 1991 Gulf War, often made airpower a preferred instrument for decisionmakers. Positing that NATO was increasingly “addicted to the air power advantage,” one Norwegian Air Commodore has highlighted the extent to which rapid post–Cold War technological developments made the offense superior to defense in air warfare, offering that the West has gained “new possibilities for strategic attacks against multiple target categories of a nation state (military units, leadership, and critical

Figure 2.1
Percentage of Sorties Flown by Allies and Partners in Select Conflicts



SOURCE: Chart includes data presented in Karl P. Mueller, ed., *Precision and Purpose: Airpower in the Libyan Civil War*, Santa Monica, Calif.: RAND Corporation, RR-676-AF, 2015, p. 4.

infrastructure).”¹ Figure 2.1 identifies the percentage of sorties flown by U.S. allies and partners in select conflicts since the end of the Cold War.

European allies have represented an important part of this progression, contributing to air operations throughout the post–Cold War period. Operations Allied Force and Unified Protector provide useful examples to examine as two NATO operations fought predominantly in the air domain, with participation from a broad range of allied air forces.

Operation Allied Force

In March 1999, NATO initiated a major offensive military campaign in an effort to coerce Serbian leader Slobodan Milosevic into ending ethnic cleansing in Kosovo and removing Serbian forces from the prov-

¹ Frans Osinga, “European Security and the Significance of the F-35,” *Norwegian Airforce Magazine*, published by JAPCC, October 2016.

ince.² While initially envisioned as lasting less than week, the operation took 78 days as Milosevic first responded to the campaign by accelerating violence against ethnic Albanians before ultimately meeting allied demands.³ Allied Force was largely fought as an air war and included significant European contributions, which by one count constituted as many as 60 percent of overall sorties.⁴ Thirteen of the 18 non-U.S. countries then part of NATO contributed aircraft to Allied Force.⁵ Of these, 11—the United Kingdom, France, Germany, Italy, Belgium, Canada, Denmark, the Netherlands, Norway, Spain, and Turkey—contributed to both defensive and offensive combat air operations (see Table 2.1).⁶

As the largest European contributor to the operation, France provided 98 aircraft, of which 76 were combat platforms, representing over 12 percent of the total number of aircraft.⁷ Extensive force modernization efforts following the 1991 Gulf War made the French air force more capable. Investments in precision-guided munitions—in particular, Paveway II and III laser-guided bombs and ASOL air-to-surface missiles—enabled France to take on a more significant role in strike operations than most other allies.⁸ However, a limited number of laser-designating pods, an absence of target recognition systems, and an

² John E. Peters, Stuart Johnson, Nora Bensahel, Timothy Liston, and Traci Williams, *European Contributions to Operation Allied Force: Implications for Transatlantic Cooperation*, Santa Monica, Calif.: RAND Corporation, MR-1391-AF, 2001, p. xiii.

³ Peters et al., 2001, p. xiii.

⁴ Karl P. Mueller, ed., *Precision and Purpose: Airpower in the Libyan Civil War*, Santa Monica, Calif.: RAND Corporation, RR-676-AF, 2015, p. 4. A separate source notes that in Allied Force, the United States contributed 59 percent of allied aircraft and released over 80 percent of expended munitions. See Christian F. Anrig, *The Quest for Relevant Air Power: Continental European Responses to the Air Power Challenges of the Post-Cold War Era*, Maxwell AFB, Ala.: Air University Press, 2011, p. 36.

⁵ Benjamin S. Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Assessment*, Santa Monica, Calif.: RAND Corporation, MR-1365-AF, 2001, p. 20.

⁶ Lambeth, 2001, p. 20.

⁷ Etienne de Durand, "French Air Power," in *European Air Power: Challenges and Opportunities*, ed. John Andreas Olsen, Dulles, Va.: Potomac Books, 2014, p. 18. Number includes support aircraft.

⁸ Peters et al., 2001, p. 20.

Table 2.1
Combat Sorties of Select European Air Forces During Allied Force

		France	Germany	Italy	Netherlands	UK
Counter-air	Defensive counter-air (combat air patrol)	458	0	362	656	148
	SEAD	0	414	170	0	4
Attack	Air interdiction	821	0	90	319	415
	Close air support	396	0	358	110	686

SOURCE: Adapted from John E. Peters, Stuart Johnson, Nora Bensahel, Timothy Liston, and Traci Williams, *European Contributions to Operation Allied Force: Implications for Transatlantic Cooperation*, Santa Monica, Calif.: RAND Corporation, MR-1391-AF, 2001, table 2.2, p. 20.

absence of SEAD capabilities on Mirage 2000s presented operational constraints.⁹ For French authorities, the conflict reportedly reinforced the need for a cruise missile inventory, which appeared to have given the British government a greater role in pre-conflict strategic planning.¹⁰

The United Kingdom, the second-largest European contributor to the campaign, deployed 45 fixed-wing aircraft and flew 1,008 strike missions.¹¹ The UK dropped Paveway II and III laser-guided bombs and fired a small number of ALARM anti-radiation missiles.¹² From the maritime domain, the British submarine HMS *Splendid* launched Tomahawk cruise missiles for the first time in British history.¹³

Over the course of the conflict, Serbian forces fired 800 SA-3 surface-to-air missiles (SAMs).¹⁴ SA-2s, SA-3s, and SA-6s were supported by 100 acquisition and tracking radars, as well as a civilian and

⁹ De Durand, 2014, p. 18.

¹⁰ De Durand, 2014, p. 18; Christian F. Anrig, “Air and Space Warfare,” in *The Handbook of European Defence Policies and Armed Forces*, ed. H. Meijer and M. Wyss, Oxford: Oxford University Press, 2018, p. 585.

¹¹ Peters et al., 2001, p. 23.

¹² Peters et al., 2001, p. 23.

¹³ Lambeth, 2001, p. 20.

¹⁴ Anrig, 2018, p. 580.

military visual observer network.¹⁵ Serbia preserved its air defense systems by shutting them off and frequently moving them to complicate NATO's targeting: Many systems survived the war intact.¹⁶ Because the SAM threat persisted throughout the operation, a near-constant SEAD operation comprised approximately 35 percent of NATO's sorties flown.¹⁷ Of Europe's air forces, Germany and Italy were the only two fully capable of undertaking SEAD operations, although the Royal Air Force (RAF) did fire four ALARM anti-radiation missiles.¹⁸ Ten German and six Italian Tornado electronic combat and reconnaissance (ECRs) performed the European SEAD role, firing HARM missiles against Serbian SAMs.¹⁹ German Tornados employed 236 HARMs (out of a total of 743), the only munitions that German fighter pilots have fired in a combat setting since World War II.²⁰ Germany conducted a SEAD- and reconnaissance-only role during the conflict. Italy, the third-largest European contributor of aircraft, also provided Tornado IDS and AMX fighters for defensive combat air sorties.²¹

European F-16 fighters also contributed to the operation. A Dutch Royal Netherlands Air Force pilot downed a Serb MiG-29, the solitary European air-to-air kill during the 1990s.²² Danish F-16s performed defensive combat air patrol missions over the Adriatic Sea and later participated in the bombing of Serbian installations.²³ Danish air-power scholars note that while the traditional NATO perspective had previously "focused on exercising and training for operations within the borders of allied countries," NATO's air campaigns in the Balkans

¹⁵ Lambeth, 2001, p. 18.

¹⁶ Peters et al., 2001, pp. 32-33.

¹⁷ Lambeth, 2001, p. 65.

¹⁸ Mueller, 2015, p. 270.

¹⁹ Anrig, 2018, p. 580; Peters et al., 2001, p. 22.

²⁰ Anrig, 2018, p. 580.

²¹ Peters et al., 2001, p. 22.

²² Mueller, 2015, p. 270.

²³ Henrik Roboe Dam, "Danish Air Power," in *European Air Power: Challenges and Opportunities*, ed. John Andreas Olsen, Dulles, Va.: Potomac Books 2014, p. 157.

“opened new prospects for Danish air power that entailed deployable forces and offensive operations.”²⁴ Turkey contributed 18 F-16 fighter jets.²⁵ Portugal also made available several F-16 fighters, although these were limited to combat air patrol missions.²⁶ In addition to these European F-16 contributions, Spanish F/A-18s flew sorties from Aviano Air Base in Italy.

The conflict saw a marked increase in the use of PGM compared with previous campaigns: About 35 percent of munitions were precision, predominantly from the U.S. arsenal.²⁷ This represented an increase from the Gulf War, when only 7.5 percent of munitions were precision-guided.²⁸ Aside from the British and French, the Netherlands contributed the only European aircraft capable of autonomously employing laser-guided bombs.²⁹ Ultimately the Dutch fired slightly more PGMs than the RAF during the course of the operation.³⁰ In the absence of GPS-guided munitions, the Dutch borrowed three laser designator pods from the United States during the conflict, allowing one F-16 to provide “buddy-lasing” for another F-16 carrying the missile.³¹

Although this report focuses on capabilities, it is notable that political considerations across the Alliance influenced the nature of missions that air forces undertook. Because NATO sought to maximize allied participation to increase the diplomatic legitimacy of the mission, the operation included a disproportionate number of combat air patrol missions, a form of defensive combat air.³² Most pilots were

²⁴ Dam, 2014, p. 157.

²⁵ Müge Kinacıoğlu and Aylin G. Gürzel, “Turkey’s Contribution to NATO’s Role in Post–Cold War Security Governance: The Use of Force and Security Identity Formation,” *Global Governance*, Vol. 19, No. 4, 2013.

²⁶ Jane’s, “Portugal Air Force,” World Air Forces database, November 19, 2019.

²⁷ Anrig, 2018, p. 579.

²⁸ Anrig, 2018, p. 578.

²⁹ Mueller, 2015, p. 270.

³⁰ Mueller, 2015, p. 270.

³¹ Anrig, 2011, p. 256.

³² Lambeth, 2001.

required to fly at a medium altitude to reduce risk. Additionally, political debates on targeting decisions created operational friction: as the largest European contributor, France frequently used its veto power to preclude attacks on targets with a high potential for collateral damage, as well as on SAM sites and an airfield in Montenegro.³³

For several allied air forces, the conflict prompted a keen interest in increasing investments in munitions. Based on their experience in Allied Force, the RAF established a requirement for an all-weather strike capability, leading to the British acquisition of anti-armor Maverick missiles as well as enhanced Paveway laser-guided bombs with additional GPS guidance.³⁴ Across the Alliance, SEAD capabilities and PGM were viewed as two of the critical shortfalls, in addition to European support capabilities such as aerial refueling and ISR. These gaps were highlighted three years later at the 2002 Prague Summit, at which allies made political commitments to increase PGM stockpiles and improve capabilities for SEAD, among other desired airpower enhancements.³⁵

Operation Unified Protector

The 2011 intervention in Libya highlighted both the potential strengths and limitations of modern European airpower. For the first time since the Suez crisis, British and French forces led a military operation in the Maghreb, joined by a small contingent of NATO and non-NATO partners. The intervention represented a new model in which the United States deliberately sought to “lead from behind,” undertaking only 27 percent of the overall sorties.³⁶ The United States played the most significant combat role at the outset of the Odyssey Dawn coalition

³³ Anrig, 2018, p. 580.

³⁴ Benjamin S. Lambeth, *The Unseen War: Allied Air Power and the Takedown of Saddam Hussein*, Annapolis, Md.: Naval Institute Press, 2013.

³⁵ Deficiencies were noted across “chemical, biological, radiological, and nuclear defense; intelligence, surveillance, and target acquisition; air-to-ground surveillance; command, control, and communications; strategic air and sea lift; air-to-air refueling; and deployable combat support and combat service support units.” NATO, *Prague Summit Declaration*, Czech Republic, November 21, 2002.

³⁶ Mueller, 2015, p. 4.

campaign, with a concept of operations that began with aggressive counter-air missions, including SEAD and electronic warfare activities, with secondary strikes focused on missile and radar warning sites, neutralization of remaining regime aircraft, and close air support.³⁷ As the operation shifted to NATO auspices under Unified Protector, European aircraft generated the majority of combat sorties, with the United States continuing in a SEAD role and providing critical enablers such as logistics support, ISR, refueling, and airlift.³⁸ The United States retained a SEAD role due to limited capacity among its allies; for example, in the absence of SEAD capabilities in the French air force, Mirages and Rafales focused on tasks such as air interdiction by flying at medium altitude to attack Libyan ground forces in March 2011.³⁹

The conflict demonstrated the successful employment of European cruise missiles. In mid-March, the RAF flew four Tornado GR4s on a 3,000-mile round trip to conduct deep strikes on key Libyan installations, achieving eight direct hits with Storm Shadow cruise missiles.⁴⁰ The Ministry of Defense confirmed that the United Kingdom expended a combined total of around 80 Storm Shadow and Tomahawk land attack missiles between March and late-October 2011.⁴¹ A similar mission the following month employed 12 Storm Shadows against Libyan command-and-control facilities and air defense infrastructure.⁴² The French air force deployed its AASM "Hammer" bomb to successfully strike a Libyan SA-3 in the early days of the conflict.⁴³ Both the

³⁷ Mueller, 2015, p. 121.

³⁸ Mueller, 2015, p. 150.

³⁹ Anrig, 2018. The Spectra electronic warfare system reportedly allowed the Rafale to operate within the threat range of Libyan single-digit SAMs. See Sebastien Roblin, "Sorry, France: This Fighter Jet Is No F-35 Stealth Fighter," *The National Interest*, October 24, 2019.

⁴⁰ "Storm Shadow Conventionally Armed Stand Off Missile (CASOM)," *Think Defence*, undated. This strike included missiles fired from naval platforms.

⁴¹ Craig Hoyle, "UK Details Cruise Missile Use in Libya Campaign," *Fight Global*, October 24, 2012.

⁴² Mike Markowitz and John D. Gresham, "Storm Shadow at War," *Defense Media Network*, May 17, 2012.

⁴³ Elie Tenenbaum, "A French Way of SEAD?" *Ultima Ratio*, May 20, 2013.

air force and navy fired SCALP cruise missiles—the French variant of Storm Shadow—for the first time with a salvo of seven cruise missiles into Al-Joufra air base, 250 km inside the Libyan border.⁴⁴ The Italian air force also employed its Storm Shadow for the first time, reportedly firing between 20 and 30 missiles from Tornado IDS aircraft during the course of the campaign, with a 97-percent success rate.⁴⁵

In addition to extensive operations by the French and British, the F-16-operating nations of Norway, Denmark, and Belgium undertook hundreds of sorties, delivering kinetic effects despite a limited number of combat aircraft.⁴⁶ The Royal Norwegian Air Force, accounting for over 3,100 flying hours, conducted 615 sorties over the course of operations Odyssey Dawn and Unified Protector.⁴⁷ The Royal Danish Air Force also made significant contributions, flying 600 sorties, of which all but two involved offensive missions.⁴⁸ Table 2.2 highlights the numbers and type of munitions released by six European allies during the course of the Libya campaign.

Over the course of the conflict, the United States and its allies expended a total of 7,642 bombs and missiles, including 3,544 laser-guided bombs, 2,844 satellite-guided weapons, and 1,150 direct-fire PGM.⁴⁹ By April 2011, news of the rapid depletion of European PGM arsenals made international headlines.⁵⁰ Most allies had to purchase ammunition from the United States and non-coalition nations to

⁴⁴ Mueller, 2015, p. 195.

⁴⁵ Markowitz and Gresham, 2012.

⁴⁶ Robert M. Gates, “Remarks by Secretary Gates at the Security and Defense Agency,” speech, Brussels, Belgium, U.S. Department of Defense, June 10, 2011.

⁴⁷ Mueller, 2015, p. 284.

⁴⁸ Mueller, 2015, p. 278.

⁴⁹ Mueller, 2015, p. 4. (Information drawn from International Commission of Inquiry on Libya, *Report of the International Commission of Inquiry on Libya—Advance Unedited Version*, New York: United Nations Human Rights Council, A/HRC/19/68, March 2, 2012, p. 206.)

⁵⁰ Karen DeYoung and Greg Jaffe, “NATO Runs Short on Some Munitions in Libya,” *Washington Post*, April 15, 2011; Steven Erlanger, “Libya’s Dark Lesson for NATO,” *New York Times*, September 3, 2011; David Alexander, “NATO Deal Leaves U.S. Still Commanding Libya Airstrikes,” Reuters, March 25, 2011.

Table 2.2
Select European Munitions Released During Operations Odyssey Dawn and Unified Protector

	France	UK	Denmark	Norway	Belgium	Italy
Munitions released	1600 [including naval]	[unknown]	923	588	473	704
Bombs	GBU-12	Enhanced Paveway II	GBU-12	GBU-31 (V)1/B	GBU-10	GBU-16
	GBU-24	Enhanced Paveway IV	GBU-24	GBU-31 (V)3/B	GBU-12	GBU-32
	GBU-49		GBU-31		GBU-24	
			GBU-49		GBU-31 (V)1/B	
					GBU-38	
Air-to-ground missiles	SCALP	Brimstone				Storm Shadow
	AASM	Storm Shadow				
	ACM					AGM-88B HARM

SOURCE: Information drawn from Karl P. Mueller, ed., *Precision and Purpose: Airpower in the Libyan Civil War*, Santa Monica, Calif.: RAND Corporation, RR-676-AF, 2015 (annex and throughout text) and supplemented with media reporting where necessary.

NOTE: Includes only nations that dropped munitions and excludes naval aviation.

satisfy their immediate operational requirements.⁵¹ Despite American willingness to replenish European stocks, U.S. air-launched munitions were incompatible with several of the coalition’s strike aircraft.⁵² For the RAF, the Brimstone’s ability to hit targets on the move with nearly 99-percent accuracy made it a weapon of choice, so effectively used that the UK inventory reportedly ran down to single digits.⁵³ Although

⁵¹ Michael Clarke, *Accidental Heroes: Britain, France, and the Libya Operation*, London: Royal United Services Institute, September 2011, p. 6; Erlanger, 2011.

⁵² Jason R. Greenleaf, “The Air War in Libya,” *Air & Space Power Journal*, March–April 2013.

⁵³ Mueller, 2015, pp. 168, 176. The RAF also used the dual-mode Brimstone variant, which incorporates a semi-active laser (SAL) seeker. See Center for Strategic and International Studies, “Brimstone,” Missile Threat database, last modified July 18, 2019a.

the French dropped 1,000 bombs and 600 missiles by early September, France reportedly maintained an adequate supply of munitions throughout the duration of the seven-month operation.⁵⁴

As had been the case in 1999, the 2011 intervention exposed several shortcomings in NATO's capacity to stage sustainable combat air operations. In addition to munitions, operations underscored the extent to which European air forces continued to rely on the United States for critical enablers. Neither the Italian nor the German air forces, the two sole air forces with SEAD capabilities, provided their Tornado ECRs in the opening days of the conflict.⁵⁵ The coalition was thus once again largely reliant on the United States for SEAD, as well as air-to-air refueling, throughout the operation. As in Allied Force, domestic political constraints played a role in determining contributions: Turkey, the Netherlands, and Spain limited their air participation to surveillance and DCA missions, while Germany provided no contributions.⁵⁶

The substantive contributions of allied air forces during operations in Libya demonstrated European combat air skills and capabilities. However, constraints imposed on military operations owing to incompatibility among allied combat platforms and air-launched munitions also underscored that the consequences of underinvestment were no longer hypothetical.

Insights from Operations Allied Force and Unified Protector

The 1999 Kosovo and 2011 Libya conflicts provide context on European contributions to NATO air operations. Neither operation was at the scale or intensity that a conflict with a near-peer adversary would likely entail, and neither reflects changes that have taken place in European militaries over the course of the past decade. However, the operations highlight some of the traditional relative strengths of allied air forces, as well as considerations that might arise in a larger allied operation.

⁵⁴ Mueller, 2015, p. 197.

⁵⁵ Anrig, 2018, p. 587. The Italian air force flew Four Tornado ECRs configured for a SEAD role in its first operational sorties on March 20, 2011. See Mueller, 2015, p. 220.

⁵⁶ Mueller, 2015, p. 268; Kinacioglu and Gürzel, 2013.

In both cases, the French air force provided the largest contributions of combat air capabilities, followed closely by the RAF, with both air forces performing a range of air-to-air and air-to-ground missions. Italy offered basing during both conflicts and in both cases represented the third-largest contributor of combat aircraft. Each of these campaigns also saw operationally meaningful contributions by smaller air forces. For Kosovo, Dutch entrepreneurship in borrowing laser designator pods from the U.S. Air Force allowed its aircraft to employ PGM and conduct air interdiction mission almost on par with the RAF. In Libya, intensive air-to-ground sorties by the Danish, Norwegian, and Belgian F-16s made them a core element of the broader allied response. Table 2.3 compares systems from each conflict.

Over the course of the dozen years between the two conflicts, most European air forces had acquired PGM and, by 2011, a number were willing to employ them to valuable effect. The air forces of the United Kingdom, France, and Italy demonstrated their long-range strike capabilities through the deployment of conventional cruise missiles against targets inside Libyan borders. However, after each conflict, NATO highlighted PGM as enduring shortfalls in summit-level declarations.

Both adversaries—the Serbian and the Libyan militaries—were able to employ air defenses against NATO using older Russian-made SAMs. In both cases, SEAD operations were a critical dimension of the response—Germany and Italy conducted SEAD throughout the operation in 1999, while the United States conducted the majority of SEAD missions in 2011. During both conflicts, the French air force accepted operational risk in the face of adversary air defenses.

Multinational interoperability presented challenges during both conflicts. Issues such as incompatible data links, procedures for intelligence sharing, and the inherent difficulty of employing tactical formations with platforms and pilots from multiple nations taxed air planners and required extensive workarounds. Yet the case of the Dutch employing U.S. air designator pods also reveals that NATO air forces can and do innovate to make the most out of available capabilities. This is enabled by a foundation of routine multinational training and exercises and the maintenance of common, or at least compatible, doc-

Table 2.3
Allied Combat Aircraft in Kosovo and Libya

Nation	1999	2011
France	12 Jaguar	4 Mirage F1CT/R
	3 Mirage IV-P	17 Mirage 2000
	6 Mirage F1CR	13 Rafale B/C
	16 Mirage 2000 (C/D)	
UK	16 Harrier GR-7	20 Tornado GR4
	1 Canberra PR-9	8 Typhoon F2
	12 Tornado	
Italy	22 Tornado (4 ECR)	5 Tornado IDS
	6 AMX	4 F-16
	4 F-104 ASA	4 AMX Ghibli
Germany	14 Tornado ECR/IDS	
Denmark	9 F-16	6 F-16
Norway	6 F-16	6 F-16
Belgium	12 F-16	6 F-16
Netherlands	18 F-16	6 F-16
Spain	6 EF-18	
Turkey	18 F-16s	6 F-16s

SOURCES: Information drawn from John E. Peters, Stuart Johnson, Nora Bensahel, Timothy Liston, and Traci Williams, *European Contributions to Operation Allied Force: Implications for Transatlantic Cooperation*, Santa Monica, Calif.: RAND Corporation, MR-1391-AF, 2001; and Karl P. Mueller, ed., *Precision and Purpose: Airpower in the Libyan Civil War*, Santa Monica, Calif.: RAND Corporation, RR-676-AF, 2015 (annex and throughout text) supplemented with media reporting where necessary.

trine and tactics, techniques, and procedures (TTPs), a point addressed more extensively in Chapter Six.

Finally, although this report focuses on military capabilities rather than political decisionmaking, it was notable that European contributions to both conflicts were significantly influenced by political considerations. For Kosovo, the NATO Alliance was able to achieve consensus about the Allied Force mission, but disagreements about targeting slowed decisionmaking and left some U.S. policymakers

wary of offering allies an operational veto in subsequent conflicts. In Libya, Spanish and Dutch political caveats limited these nations to a less relevant role. The Italian government was initially reluctant to participate in SEAD operations, and Germany declined to participate entirely.

Reorienting to a New Security Environment

The first NATO summit after Russia's 2014 intervention in eastern Ukraine highlighted the beginning of the Alliance's reorientation toward collective defense. The Wales Summit Declaration explicitly acknowledged the security challenges posed by Russia, a shift from the 2010 Strategic Concept, which did not categorize Russia as a threat.⁵⁷ To address this new security environment, NATO agreed to a series of measures to reinforce its eastern presence, including adopting a Readiness Action Plan and reinvigorating the NATO Response Force (NRF) by establishing a multinational, brigade-sized Very High Readiness Joint Task Force (VJTF) with approximately 5,000 on-call ground troops with support from air, maritime, and special forces.⁵⁸

Additionally, the 2014 Wales Summit emphasized increased defense spending across the Alliance, with a resultant increase of European allied defense budgets from \$272 billion in 2014 to \$313 billion by 2018.⁵⁹ The summit also included a more specific emphasis on investments in modernization and acquisition of military equipment. In the 2014 Wales Summit Defense Investment Pledge, allies agreed to the goal of dedicating 20 percent of their defense budgets on major equipment expenditures inclusive of research and development. A group of allies led by Denmark also announced the start of a multi-

⁵⁷ Jeffrey A. Larsen, "The Wales Summit and NATO's Deterrence Capabilities: An Assessment," NATO, November 2014.

⁵⁸ Mariusz Fryc, "From Wales to Warsaw and Beyond: NATO's Strategic Adaptation to the Russian Resurgence on Europe's Eastern Flank," *Connections*, Vol. 15, No. 4, 2016; and NATO, "NATO Response Force (NRF) Fact Sheet," 2018.

⁵⁹ Paul Shinkman, "NATO's Increases in Defense Spending Have Little to Do with Trump," *U.S. News and World Report*, April 3, 2019.

national joint procurement initiative for air-to-ground PGM, which we discuss in Chapter Five.⁶⁰

Within the air domain, Russia's aggression against Ukraine prompted an enhancement of the NATO air policing missions over the Baltic states, Poland, and Romania.⁶¹ The Baltic Air Policing mission, in which allied air forces provide air policing of Baltic airspace on a rotational basis, has taken place since the Baltic states' accession to NATO in 2004, as these frontline nations do not possess combat aircraft. At the height of Russia's operations in Ukraine during 2014 and 2015, the number of NATO fighter jets routinely dedicated to the Baltic Air Policing mission temporarily rose from four to 16.⁶² As of September 2019, eight combat aircraft from NATO air forces are dedicated to the mission in six-month rotations.⁶³ Since 2014, observers have noted an uptick in Russian incursions into Baltic airspace as aircraft fly "with transponders switched off or failures to file flight plans," often as they transit from mainland Russia to Kaliningrad.⁶⁴ NATO aircraft conducting air policing in the Black Sea region have also had to scramble frequently: During a four-month deployment in 2018, RAF fighters scrambled eight times in response to 20 Russian aircraft flying near Romanian airspace.⁶⁵ Since 2008, allied air forces have also flown periodic air surveillance and training over Iceland; and in September 2019, Italy deployed its F-35s for the Iceland Air Policing mission.⁶⁶

⁶⁰ Paul McCleary, "NATO Stocks Up on Bombs, Giving Smaller States More Punch," *Breaking Defense*, November 8, 2018.

⁶¹ NATO, "Allies Enhance NATO Air-Policing Duties in Baltic States, Poland, Romania," April 29, 2014.

⁶² Agence France-Presse, "NATO Halves Baltic Air Policing Mission," *Defense News*, August 4, 2015.

⁶³ Ed Adamczyk, "NATO Announces Change in Baltic Air Policing Duties," United Press International, September 6, 2019b.

⁶⁴ Jarsoslaw Adamowski and Martin Banks, "Without a NATO-wide Effort, the Skies Along the Northeastern Flank Could Be in Peril," *Defense News*, June 16, 2019.

⁶⁵ NATO, "Belgium, Canada, and Germany Take Up NATO Air Policing Duties," August 31, 2018.

⁶⁶ Gareth Jennings, "Italy Deploys F-35 on First NATO Mission," *Jane's Defence Weekly*, September 26, 2019b.

The 2016 Warsaw Summit outlined further steps to improve NATO's deterrent posture. Although the VJTF offered a useful mechanism to focus allies on readiness, NATO military leadership concluded that its operational utility in a collective defense scenario would be constrained by its size, inability to deploy in sufficient time, and vulnerability to adversary forces.⁶⁷ To bolster ground presence on the Alliance's northeastern flank and signal political resolve, NATO established four rotational battalion-strength battlegroups in Estonia, Latvia, Lithuania, and Poland, among other adaptations. Although the majority of NATO's defense and deterrence enhancements from 2014 to 2016 were focused on land forces, General Frank Gorenc, former chief of the U.S. Air Forces in Europe (USAFE), observed in 2016 that the United States and allies were nonetheless "carefully putting in the air perspective and the air proponentcy" to establish a ready and responsive joint posture that included a robust air component.⁶⁸

In the wake of the Warsaw Summit, a report by NATO's JAPCC identified airpower as a critical component for what some allies perceive as a deterrence gap stemming from a limited number of forward-postured ground forces on NATO's eastern flank. The study underscored the idea that airpower can mitigate this gap by offering options for an immediate allied response to a sudden Russian ground offensive.⁶⁹ If the Russian government doubts that its armed forces can successfully undertake such an operation, deterrence could be strengthened.⁷⁰ A subsequent RAND study similarly noted the potential role of NATO combat aircraft in destroying Russian ground maneuver and artillery systems during a Baltic scenario, highlighting an imbalance in globally available combat aircraft: While NATO countries maintained 5,457 combat-capable aircraft worldwide in 2017 (of which

⁶⁷ Sam Jones, *NATO Rapid Unit Not Fit for Eastern Europe Deployment, Say Generals*, Washington, D.C.: Atlantic Council, May 15, 2016, as cited in Bryan Frederick, Matthew Povlock, Stephen Watts, Miranda Priebe, and Edward Geist, *Assessing Russian Reactions to U.S. and NATO Posture Enhancements*, Santa Monica, Calif.: RAND Corporation, RR-1879-AF, 2017.

⁶⁸ John A. Tirpak, "Bears Watching," *Air Force Magazine*, September 2016.

⁶⁹ Shlapak and Johnson, 2016.

⁷⁰ JAPCC, 2018, p. 36.

2,529 were non-U.S.), Russia maintained a total of 1,251.⁷¹ In order to maximize the deterrent effect of NATO's relative advantage in combat air capabilities, JAPCC's report recommended that NATO air forces work to

- improve readiness, deployability, and sustainability
- maintain the ability to rapidly gain air superiority in an anti-access/area denial (A2/AD) environment
- maximize their ability to operate with limited U.S. participation.⁷²

The JAPS, released in June 2018, largely reflects the JAPCC study's insights on the critical role of airpower to NATO's defense and deterrence. The strategy highlights the advantages provided by the speed of airpower, allowing it "exploit time and control tempo."⁷³ The document further highlights the "unrivalled reach that permits airpower to employ its capabilities at distance, including deep into enemy territory, and isolated locations" that would make NATO combat airpower pivotal to any rapid response to aggression in NATO's east.⁷⁴

Consistent with existing NATO doctrine, the JAPS document identifies four airpower roles: counter-air, attack, air mobility, and contribution to joint ISR. Of these, it asserts that joint airpower's "decisive influence can be exercised through its attack role, which can be executed on very short notice. Attack has the capacity to generate effects from the

⁷¹ Scott Boston, Michael Johnson, Nathan Beauchamp-Mustafaga, and Yvonne K. Crane, *Assessing the Conventional Force Imbalance in Europe: Implications for Countering Russian Local Superiority*, Santa Monica, Calif.: RAND Corporation, RR-2402, 2018. Calculations were drawn from 2017 figures from the International Institute for Strategic Studies (IISS) and included all fourth-generation or newer combat-capable aircraft for all sides. NATO figures incorporate all allied air forces, not the more limited scope included in this study. For a review of Russian perceptions of correlations of forces, see Clint Reach, Vikram Kilambi, Mark Cozad, *Russian Assessments and Applications of the Correlation of Forces and Means*, Santa Monica, Calif.: RAND Corporation, RR-4235, 2020.

⁷² JAPCC, 2018, p. 36.

⁷³ NATO, *NATO's Joint Air Power Strategy*, 2018.

⁷⁴ NATO, *NATO's Joint Air Power Strategy*, 2018.

tactical to the strategic level through the threat or the use of force.”⁷⁵ The strategy also addresses the counter-air role, applied in an effort to achieve “a desired degree of control of the air . . . and enabling the freedom of maneuver of air and surface-based forces in all domains . . . by opposing the adversary’s air power.”⁷⁶ It is more circumspect about NATO’s ability to establish control of the air. For the first time since the Cold War, it notes, “the Alliance has to be able to conduct operations against any peer-state actor. As a result, the future operating environment may be one in which air superiority can neither be assured at the onset of operations nor, once obtained, be an enduring condition.”⁷⁷ The strategy offers a broad doctrinal overview of the Alliance’s vision for the application of airpower in the current security environment, although the more concrete details required for planning and force development are unlikely to be available for public consumption.

NATO leaders have also sought to further improve readiness and deployability to ensure that the Alliance would be able to employ “the right forces in the right places at the right time” across domains.⁷⁸ In their NATO Readiness Initiative (NRI) announced at the 2018 Brussels Summit, the allies agreed that, from within their overall pool of forces, they would “offer an additional 30 major naval combatants, 30 heavy or medium maneuver battalions, and 30 kinetic air squadrons, with enabling forces, at 30 days’ readiness or less.”⁷⁹

Overall, NATO has undertaken important steps to improve its defense and deterrence posture in response to Russia’s aggressive actions and continued military modernization. Increasingly, combat airpower is viewed as a critical dimension to this response. Although gaps and shortfalls persist, a major institutional shift has allowed the Alliance to begin to address security threats not seen since the end of the Cold War.

⁷⁵ NATO, *NATO’s Joint Air Power Strategy*, 2018.

⁷⁶ NATO, *NATO’s Joint Air Power Strategy*, 2018.

⁷⁷ NATO, *NATO’s Joint Air Power Strategy*, 2018.

⁷⁸ Rose Gottemoeller, “Speech at the Conference ‘Resourcing a Coherent and Credible Alliance,’” L’École Militaire, Paris, France, October 16, 2018.

⁷⁹ NATO, *Brussels Summit Declaration*, Belgium, July 11, 2018.

National Levels of Ambition and Areas of Emphasis

The ambitions and emphases of national air forces vary across the Alliance. This section, drawing from a review of national budgets, doctrine, and recent operational history, offers three broad categories in which to consider the European air forces reviewed. These groupings, as depicted in Figure 2.2, are not necessarily determinative of an ally’s potential combat air contributions—as recent NATO air operations have shown, sometimes larger allies have on occasion opted out for political reasons, while smaller air forces have punched above their weight. Rather, this section offers an overview of the general characteristics of each of the air forces addressed in this report, to provide context and background for subsequent discussions of allied force structure, technology, maintenance, training, and exercising in the air domain.

Allies with Unique Capability, Capacity, and Experience: France and the United Kingdom

Given the quality and quantity of aircraft in their armed forces, the two European nations that contributed most significantly to NATO air

Figure 2.2
Groups of Allies Considered



^aNations that maintain a naval aviation capability.

operations discussed in this chapter—France and the United Kingdom—are in a category of their own. France's strategic ambition has manifested in its air force investments and operations, potentially making it, in the eyes of some analysts, the NATO ally with the greatest will and capability to contribute significantly and aggressively to NATO collective security threats.⁸⁰ The United Kingdom, long one of the closest allies of the United States, has recently invested in a more ambitious role for the RAF and would also be counted on as a primary European contributor to any collective defense mission.

For France, the concept of strategic autonomy is central to its approach to airpower. France's 2017 Strategic Review of Defense and National Security, which explicitly acknowledges that "the threat of a major conflict is once again a possibility," emphasized the need for strategic autonomy or "the capability to decide and act alone to defend its interests."⁸¹ Also in 2017, the French air force unveiled a new strategic "Flight Plan" to ensure it was powerful in its capabilities, audacious in its innovation, agile within a new environment, and connected, both to partners and to French society.⁸²

The French air force seeks to independently perform the four airpower missions noted in JAPS and highlights its multirole fighter aircraft fleet as able to accomplish an extensive range of operations. France prioritizes its air force's role in nuclear deterrence through the nuclear-capable Rafale, armed with the ASMP-A missile.⁸³ Much of France's armed forces are built around this deterrence capability: As one analyst notes, "France's quick reaction force is defined upon the rigor, reactivity 24/7, safety and ability to penetrate a theater first, far away and in depth."⁸⁴ Indeed, the 2017 Strategic Review, as well as its predecessors

⁸⁰ Michael Shurkin and Peter A. Wilson, "France Is Replacing the UK as America's Top Ally in Europe," *The RAND Blog*, March 30, 2015.

⁸¹ Republic of France, *Defense and National Security National Strategic Review*, 2017.

⁸² Christina Mackenzie, "French Air Force Deputy Talks Strategy, Brexit, and Future Fighter Jets," *Defense News*, June 16, 2019.

⁸³ Republic of France, 2017; Corentin Brustlein, "Entry Operations and the Future of Strategic Autonomy," French Institute of International Relations (IFRI), December 2017.

⁸⁴ Murielle Delaporte, "French Quick Reaction Force Key to Syrian Missile Strikes," *Breaking Defense*, May 2, 2018.

in 2013 and 2008, identify France's ambition to possess capabilities for first entry in the air, land, and maritime domains.⁸⁵ Analysts note that French debates on defense policy, strategy, and budgets increasingly refer to first entry as a crucial factor, and one that is "central to its defense policy and singular among Western countries."⁸⁶ France does not possess a dedicated SEAD capability and instead relies on a combination of self-protection through the Rafale's SPECTRA jamming and decoy system as well as the aircraft's ground attack capabilities, which in their current configuration would most likely be insufficient against an advanced IADS threat.⁸⁷

Most recently, in 2019, the French government has committed to maintaining 20 Rafales, with accompanying strategic lift and maintenance crews, on a 48-hour notice for operations anywhere in the world.⁸⁸ If realized, this level of ambition would be an important addition to the collective responsiveness of European airpower, albeit designed for a much broader range of tasks than collective defense in Europe.

The RAF represents a core element of the United Kingdom's fighting force. One scholar has noted that airpower likely dominates any British contribution to future state-to-state conflicts.⁸⁹ British ambition in the air domain covers a range of missions, including air defense of the United Kingdom and its South Atlantic territories, a credible and capable combat air presence to contribute to conventional deterrence and containment, an expeditionary combat air contribution to enduring land operations, strategic and tactical airlift, and other airpower capabilities such as ISR.⁹⁰ UK air and space power doctrine is

⁸⁵ Brustlein, 2017, p 10.

⁸⁶ Brustlein, 2017, p 10.

⁸⁷ Brustlein, 2017, p. 39. For more system-level information on current IADS, see Justin Bronk, "Modern Russian and Chinese Integrated Air Defence Systems: The Nature of the Threat, Growth Trajectory and Western Options," RUSI Occasional Papers, January 2020a.

⁸⁸ Interview with European airpower expert, January 2020, Washington, D.C.

⁸⁹ Peter Gray, "British Air Power," in *European Air Power: Challenges and Opportunities*, ed. John Andreas Olsen, Dulles, Va.: Potomac Books, 2014, p 119.

⁹⁰ Jane's "United Kingdom: Air Force," World Air Forces database, March 1, 2019.

closely aligned with NATO and envisages British contributions across JAPS's four air roles.⁹¹

British Strategic Defense and Security Reviews (SDSR) over the past decade have offered divergent guidance, first cutting spending and then ultimately improving reinvestment in the RAF. Reflecting the budgetary constraints of the 2008 financial crisis, the 2010 SDSR reduced British military ambition and slashed British armed forces' overall conventional military capability by a third.⁹² Due in part to changes in the international security environment, the 2015 SDSR emphasized investments in modernization, particularly in the air domain, around the concept of a more capable "Joint Force 2025."⁹³ In 2016, the UK air command's budget increased by 11 percent with the objective of creating two F-35 and seven Typhoon squadrons and a mandate to stockpile PGM, including Storm Shadow and Brimstone.⁹⁴ The 2015 SDSR also increased the number of planned personnel for the RAF in the wake of the 2010 SDSR cuts. Implementation of the 2015 SDSR ambitions will yield a more robust combat force for the RAF, though shortfalls in enablers such as aerial command-and-control and capacity to conduct ISR may limit British air autonomy. As one British analyst has written, "the United Kingdom, particularly in air power terms, is most likely to participate in any future conflict as part of a coalition, or as a member of an alliance."⁹⁵ Within this capacity, the RAF would be anticipated to contribute extensively of any NATO collective defense operation.

Allies with Medium-Sized Air Forces

The next subset of air forces is postured for contributions to NATO or coalition air operations, with more limitations in capability, capacity, and/or readiness than France and the United Kingdom. While some of

⁹¹ Delaporte, 2018.

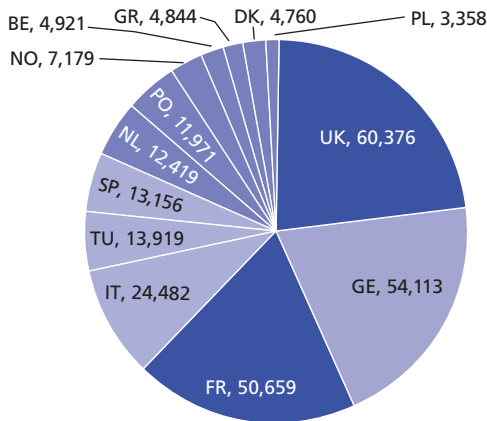
⁹² IISS, *The Military Balance 2019*, Washington, D.C.: International Institute for Strategic Studies, February 2019, p. 82.

⁹³ IISS, 2019, p. 82.

⁹⁴ Commons Select Committee, "SDSR 2015 and the RAF Inquiry Launched," Parliament of the United Kingdom, April 12, 2017.

⁹⁵ Gray, 2014, p. 131.

Figure 2.3
Select European Defense Budgets in 2019 U.S. Dollars



SOURCE: Based on data from NATO, "Defence Expenditure of NATO Countries (2013–2019) Communiqué," NATO Public Diplomacy Division, November 29, 2019, table 2. Figures represent NATO estimates and prices and exchange rates as of November 2019. Darkest shade indicates large air forces with unique capability and capacity; medium shade indicates medium-sized air forces; and the lighter shade indicates European Participating Air Forces (EPAF) nations.

the F-16 nations could also be categorized as medium, we defer discussion of these to the subsequent section.

Although the German military budget is the second largest in Europe, it lies far below the 2 percent of GDP threshold sought by NATO allies. Politically, German military ambition might best be understood through the lens of the country's post–World War II orientation, which includes one pacifist theme ("never again war") and another multinational ("never alone"). The German Luftwaffe, accordingly, has tended to contribute to nonkinetic missions in support of multinational operations, including ISR and transport, as well as SEAD, its primary kinetic focus. In this vein, Germany has made a commitment to NATO to provide an airborne electronic jamming capability by the mid-2020s.⁹⁶ Germany's 2010 military reorientation does

⁹⁶ Gareth Jennings, "Germany Sets Out 'Challenging' Airborne Electronic Attack Timeline for NATO," *Jane's Defence Weekly*, November 13, 2019c. This is an ambitious timeline according to German military officials.

cite an ambitious set of contributions to multilateral operations for the Luftwaffe covering the full spectrum of force, including “up to two flying task forces for airstrike, including close air support, flying air defense, tactical reconnaissance, suppression of enemy air defenses, and unmanned surveillance and reconnaissance in up to two operational areas . . . for a limited time” as well as a range of support contributions.⁹⁷ However, budget constraints have limited the realization of German defense aspirations: In 2015, a defense policy spokesman for the Social Democratic Party warned that Germany was “currently unable to meet the commitments we have made to NATO.”⁹⁸ Similarly, in 2018, Germany’s parliamentary commissioner for the armed forces stated that “while foreign missions with small contingents went well, the Bundeswehr as a whole cannot currently be used in the collective defense.”⁹⁹

The Italian air force reflects the strategic priorities set out in Italy’s 2015 White Book: Euro-Atlantic defense, Euro-Mediterranean interests, the Sahel, Horn of Africa, and the Persian Gulf. Italy’s strategic focus is largely to NATO’s south. Within this area, the Italian military strives to lead “high intensity, full-spectrum crisis management missions.”¹⁰⁰ Largely mirroring the airpower roles identified in NATO doctrine, the Italian air force’s four core priorities are “persistent ISR/situational awareness, precision engagement, IAMD [integrated air and missile defense], and efficient air mobility.”¹⁰¹ In the midst of transition, the Italian air force seeks to “achieve a balanced, flexible, agile, and expeditionary mix of capabilities in a resource-constrained

⁹⁷ Mey Holger, “German Air Power: Ready to Participate in Joint and Combined Operations,” in *European Air Power: Challenges and Opportunities*, ed. John Andreas Olsen, Dulles, Va.: Potomac Books, 2014, p. 48.

⁹⁸ Atlantic Council, “Infographic: Transformation of NATO Forces After Wales Summit,” June 11, 2015.

⁹⁹ Kyle Rempfer, “German Military Too Small to Aid ‘Collective Defense,’ Official Says,” *Military Times*, January 25, 2018.

¹⁰⁰ Daniel Keohane, “The Defense Policies of Italy and Poland: A Comparison,” *Center for Security Studies (CSS) Analyses in Security Policy*, No. 219, December 2017.

¹⁰¹ “RAND Workshop on NATO Air Power and Collective Defense,” PowerPoint presentation, June 2019.

and complex environment.”¹⁰² The overall Italian defense budget has, however, dropped by 26 percent between 2012 and 2015—while it has since increased, it has not yet returned to 2012 levels.¹⁰³ Adding to Italy’s defense challenges is a relatively outsized personnel account, which as of 2018 comprised 65 percent of the budget (as compared with France and Germany at 47 percent and the United Kingdom at 34 percent). Despite these challenges, Italy has actively participated in NATO’s reorientation toward collective defense, regularly contributing to Baltic Air Policing missions, more recently contributing F-35s for Icelandic Air Policing, and serving as the lead nation for the VJTF.¹⁰⁴ The Italian air force envisions itself as representing an international training hub, with recent national investments in training facilities and curricula made in part with the intent of expanding and modernizing this role.

Spain’s 2003 Strategic Defense Review sets the Spanish air force’s ambition of contributing two combat aircraft squadrons, with support elements, in two different theaters as well as support elements to a third theater.¹⁰⁵ The service’s priorities include defense of national airspace and projection of force in support of international peace and humanitarian operations, and its fleet is capable of performing air defense and moderate air-to-ground attack missions.¹⁰⁶ Like Italy, the Spanish military experienced severe budget cuts—nearly 30 percent between 2012 and 2016—with spending just now returning to 2012 levels.¹⁰⁷ The Spanish air force reportedly fared the worst among the nation’s military services.¹⁰⁸ Spain considers itself a leader within NATO in the area of combat air training, hosting the NATO Tactical Leadership Program in Albacete. As

¹⁰² “RAND Workshop on NATO Air Power and Collective Defense,” 2019.

¹⁰³ NATO, “Defence Expenditure of NATO Countries (2012–2019),” NATO Public Diplomacy Division, June 25, 2019, table 2.

¹⁰⁴ Keohane, 2017.

¹⁰⁵ Jane’s, “Spain: Air Force,” World Air Forces database, October 14, 2019.

¹⁰⁶ Jane’s, “Spain: Air Force,” October 14, 2019.

¹⁰⁷ NATO, “Defence Expenditure of NATO Countries (2012–2019),” June 25, 2019.

¹⁰⁸ NATO Air Power Roundtable, RAND Corporation, Arlington, Virginia, June 11, 2019.

discussed in Chapter Six, Spain and Italy may be attractive candidates as hosts to a more robust allied air training apparatus.

Poland's military ambition is viewed through the lens of the perceived security threat posed by neighboring Russia. The Polish air force maintains a relatively new F-16 fleet, allowing it to conduct a range of attack and air defense missions.¹⁰⁹ However, the geographic proximity of Poland to Russian IADS and current absence of Polish SEAD capability would leave Warsaw most likely unable to control nearly half of its national airspace during a conflict with Russia.¹¹⁰ The 2017 Polish Defense Concept thus prioritized the purchase of fifth-generation combat aircraft and long-range precision weapons for the Polish air force as a "crucial element of our deterrence force."¹¹¹ Poland's decision to invest \$6.5 billion in acquiring an F-35 fleet to replace its aging Soviet platforms indicates the depth of its commitment to airpower as a primary pillar of national defense and is likely to transform the capabilities of the Polish air force across airpower roles.¹¹² That said, prior difficulties transitioning from Soviet and Russian systems to the F-16, and to a degree mindset, might be indicative of some the challenges to come in Poland's rapid push to modernize; sufficient resourcing and integration with NATO can serve as mitigating factors in this regard.

The air force of Greece seeks to be a credible regional force with the ability to maintain air superiority over Greek airspace, support joint national joint operations, and support multinational operations abroad.¹¹³ Ongoing tensions with neighbor and NATO ally Turkey over the Aegean Sea have at times resulted in intense intercepts and even dogfights—in 2016, the Greek military claimed 1,671 Turkish violations of its airspace.¹¹⁴ Although the service experienced budget

¹⁰⁹ Jane's, "Poland: Air Force," World Air Forces database, September 13, 2019.

¹¹⁰ Jane's, "Poland: Air Force," September 13, 2019.

¹¹¹ Republic of Poland, *The Defense Concept of the Republic of Poland*, Ministry of National Defense, 2017.

¹¹² Sebastien Roblin, "The F-35 Will Transform the Polish Air Force—But They May Need Backup," *The National Interest*, September 15, 2019.

¹¹³ Jane's, "Greece: Air Force," World Air Forces database, March 27, 2019.

¹¹⁴ Ben Brimelow, "A 'Secret War' Between Turkey and Greece Just Turned Deadly After a Long History of Dogfights over the Aegean Sea," *Business Insider*, April 14, 2018.

constraints during a nearly decade-long economic crisis, the Greek government decided in 2018 to invest in an upgrade of about half of its F-16 fleet, providing it with advanced radars, datalinks, and electronic warfare capabilities.¹¹⁵ As of 2019, Greece was also engaged in discussion with the F-35 program about a potential purchase.¹¹⁶

Finally, the Turkish air force represents an ambitious and capable potential military contributor with a historically close relationship to the U.S. Air Force, though hampered by set of relatively unique constraints. Reflecting national security priorities beyond its traditional competition with Greece, Turkish airpower has most recently focused on countering the terrorist-designated Kurdistan Workers Party, and recent air operations have sought to strengthen Turkey's border areas against Iraqi, Syrian, and Turkish Kurdish militants.¹¹⁷ With extensive investments in modernizing its large F-16 fighter fleet as well as its PGM stockpile over the past two decades, the Turkish air force is prepared to conduct the full range of combat air missions, including SEAD under less than the most-demanding conditions.¹¹⁸

But recent political and diplomatic crises have had an adverse impact on the Turkish air force. In 2017, Turkish president Recep Erdogan initiated widespread political purges of the military after an attempted coup. These proved particularly devastating to the Turkish air force, leaving the service with leadership gaps as well as a significant shortage of experienced combat pilots.¹¹⁹ Recent strengthening of Turkish-Russian military relations has also had a deep impact. Originally a partner in the Joint Strike Fighter program and committed to

¹¹⁵ Gareth Jennings, "LM Contracted to Upgrade Greek F-16s," *Jane's Defence Weekly*, December 21, 2018.

¹¹⁶ Dario Leone, "Everyone Gets an F-35 as Pentagon Eyes New European Buyers," *The National Interest*, July 14, 2019.

¹¹⁷ Jane's, "Turkey: Air Force," World Air Forces database, August 14, 2019.

¹¹⁸ Christian F. Anrig, "Turkish Air Power," in *European Air Power: Challenges and Opportunities*, ed. John Andreas Olsen, Dulles, Va.: Potomac Books, 2014, p. 65.

¹¹⁹ Stephen J. Flanagan, F. Stephen Larrabee, Anika Binnendijk, Katherine Costello, Shira Efron, James Hoobler, Magdalena Kirchner, Jeffrey Martini, Alireza Nader, and Peter A. Wilson, *Turkey's Nationalist Course: Implications for the U.S.-Turkish Strategic Partnership and the U.S. Army*, Santa Monica, Calif.: RAND Corporation, RR-2589-A, 2020, p. 183.

purchasing 116 F-35s, Turkey, had the sale been finalized, would have operated the second-largest fleet of NATO fighter-bombers, second only to the United States.¹²⁰ Unfortunately, security and political concerns surrounding Turkey's purchase of Russian-made S-400 SAMs ended Ankara's participation in the Joint Strike Fighter (JSF) program, with no firm plan for an alternative.¹²¹ At a strategic level, Turkey's drift toward Russia and singular focus on Kurdish threats makes allies wary of its commitment to collective defense. Thus, while Turkey has the potential and ambition to be a regional airpower heavyweight, political conflicts and uncertainties may limit its role in a collective defense scenario.

European Participating Air Forces Nations

Smaller European air forces with fourth-generation combat fleets predominantly composed of F-16 fighter jets could also make significant contributions to NATO operations but rely heavily on a coalition structure. For these air forces, the primary mission is defense of national or regional airspace, with varying ambitions to support formations in multinational peace and stability operations.¹²² For five of these air forces, close collaboration has facilitated greater ambitions by capitalizing on efficiencies in purchasing, updating, and sustaining platforms as well as training aircrew. The air forces of Belgium, Denmark, the Netherlands, Norway, and more recently Portugal are closely connected through the European Participating Air Forces (EPAF) consortium. In the mid-1970s, the Danish, Dutch, Belgian, and Norwegian air forces elected the F-16 aircraft as a then-unprecedented example of multinational cooperation in procurement; they later identified and executed a common midlife update of the fleets in the 1990s.¹²³ These air forces have leveraged common training and equipment to make effective con-

¹²⁰ Anrig, 2014, p. 64.

¹²¹ Turkey is reportedly exploring further collaboration with the Russian military industry through procurement of Russian Su-35 or Su-57 platforms. See Jane's, "Turkey: Air Force," August 14, 2019.

¹²² Jane's, "Belgium: Air Force," World Air Forces database, March 29, 2019.

¹²³ Mueller, ed., 2015, p. 269.

tributions in support of NATO operations. A mixed formation of Dutch and Belgian F-16s carried out 11.6 percent of NATO missions during Allied Force, while a combined detachment of 18 Dutch, Danish, and Norwegian F-16s leveraged common logistics and support.¹²⁴ In 2004, the four original EPAF nations and Portugal signed a memorandum of understanding (MOU) to establish the EPAF Expeditionary Air Wing (EEAW). The collective approach embraced by these air forces extends to core national defense responsibilities: as of 2017, the Belgians and Dutch share Quick Reaction Alert (QRA) responsibilities over their combined airspace as well as Luxembourg's.¹²⁵

Currently, the four EPAF nations transitioning to an F-35 airframe are in varying stages of modernization. New capabilities will strengthen each air force's ability to conduct air defense, attack, and SEAD sorties in high-intensity conditions. However, the number of platforms that each country believes it is able to contribute to international missions may be reduced, at least temporarily. Table 2.4 identifies the current levels of ambition of each of the four air forces, as well as available details on how these ambitions may change during and after the transition.

Conclusion

European combat airpower represents an important military dimension of NATO's reorientation to once again address the potential for Article 5 threats to member states. In the past, European air forces made tangible, operationally significant contributions to NATO campaigns, albeit with a range of limiting factors. Institutionally, NATO's recent updates to policy and doctrine have sought to enhance the Alliance's posture and capabilities in order to improve deterrence and, if necessary, ensure collective defense. Within the air domain this has included a new strategy, the JAPS, that underscores the central role of

¹²⁴ JAPCC, "Regional Fighter Partnership—Options for Cooperation and Cost Sharing," March 2012.

¹²⁵ Jane's, "Netherlands: Air Force," World Air Forces database, October 9, 2019.

Table 2.4
Levels of Ambition for European Participating Air Forces Transitioning to the F-35

	Belgium	Denmark	Netherlands	Norway
Current ambition	6x F-16 for high-intensity operations indefinitely 4x F-16 for low-intensity operations for up to four months annually 2x F-16 for QRA	Three simultaneous contributions of air assets at short notice and/or ability to maintain some missions for an extended period of time	8x F-16 for limited period of time 4x F-16 for extended period of time 2 F-16 QRA	12x F-16 for limited period of time 2x F-16 for QRA
During F-35 transition	Undefined	Limited international operations	4x aircraft for limited period of time	Limited international operations
After F-35 transition	Unknown	No attrition reserve; number of airframes may be insufficient for required national defense tasks	4x aircraft for extended period of time	

SOURCES: Jane’s World Air Forces database 2018–2019, “Belgium: Air Force,” “Denmark: Air Force,” “Netherlands: Air Force,” and “Norway: Air Force.”

airpower to address current and evolving threats. Individually, many European air forces are modernizing their airpower capabilities as they recover from fiscal challenges imposed by the 2008 economic crisis to address evolving threats. Subsequent chapters consider Russian perceptions of NATO airpower and explore recent developments in the force structure and readiness of European air forces.

Russian Perceptions of NATO Airpower

In order to understand the contributions of NATO's combat air capabilities to deterrence, it is important to consider how they may be perceived by a potential adversary. Drawing from an analysis of Russian official strategy documents, military science journals, senior leader statements, and recent operations, this chapter reviews Russian perceptions of NATO airpower through the lens of current and historic themes in Russian military analysis. Our observations suggest several NATO combat air capabilities, missions, and qualitative features that the Russian military likely identifies as central to NATO's airpower and that thus may be of greatest concern to Russian planners in the context of a notional conflict with NATO. These insights offer important context for discussions in subsequent chapters of current trends in the force structure, technology, and readiness of European allied air forces. The analysis in this chapter is derived from open source information and documents, including Russian sources previously translated by RAND.¹

Before analyzing Russian perceptions of NATO airpower, it will be helpful to compare Russian terms used for air operations with common Western terms. Since the Russian literature does not always use common terminology, Table 3.1 provides a summary of key Western terms along with some of the terms used throughout the Russian literature.

¹ Much of this chapter benefits substantially from research conducted for RAND by Clint Reach, Jim Williams, Vikram Kilambi, and Mark Cozad. See *Russian Assessments and Applications of the Correlation of Forces and Means*, Santa Monica, Calif.: RAND Corporation, RR-4235-OSD, 2020.

Table 3.1
Comparison of Key NATO and Russian Air Operations Terms

NATO Terms	Representative Russian Terms
Strategic attack	Attack on critical rear area targets, Deep Strike
Offensive counter-air (OCA)—suppression of enemy air defense (SEAD)	Suppression of air defensive
Counter surface force operations—air interdiction (AI)	Attacks on supply lines
Counter surface force operations—closer air support (CAS)	Attack on fielded forces, direct air support
Defensive counter-air (DCA)—passive and active defense	Air defense

SOURCES: NATO, *Allied Joint Doctrine for the Conduct of Operations*, AJP-3, Edition C, Version 1, NATO Standardization Office, February 2019a; NATO, *Allied Joint Doctrine for Air and Space Operations*, AJP-3.3, Edition B, Version 1, NATO Standardization Office, April 2016. Various Russian documents, 2019.

NOTE: This report also refers to anti-armor missions that may be carried out by means of AI or CAS. We also refer to DCA as air defense and for the purposes of this report are focused primarily on active defense using fighter aircraft.

The Besieged Fortress Mentality: Historical Influences on Russian Geopolitical Thinking

Repeated attacks and varying levels of success in protecting the homeland lie at the core of Russia’s defensive ethos. The nature, consequences, and frequency of military conflicts in the region are almost unprecedented, host to some of the largest armies, biggest battles, and worst losses of life in history. Perhaps best described in *Russia: The Story of War*, “near-constant warfare and invasions since the medieval period [have] reinforced Russia’s self-image not only as a besieged Orthodox bastion of exceptional strength, but as a great power destined to be the savior of humanity.”² At the same time, Russia has a long history of internal tension and uncertainty, with short periods of radical transformations, followed by periods of conservatism and stagnation.³

² Stephen Blank, “Threats to and from Russia: An Assessment,” *Journal of Slavic Military Studies*, Vol. 21, No. 3, August 29, 2008.

³ Guerman Diligensky and Sergei Chugrov, *The “West” in Russian Mentality*, Institute of World Economy and International Relations, Moscow, 2000, p. 10.

As a result, war—a constant amid turnover and ambiguity—saturated Russian culture and has become the country’s enduring common denominator. The belief that no other nation has faced such persistent challenges to its existence for centuries, particularly from the West, forms the basis of Russia’s “besieged fortress mentality,” a trepidation that predates militarized airpower.⁴

Russia’s historical encounters with Western airpower, particularly in World War II and the Cold War, hardened this way of thinking. According to a recent RAND study, Russian military strategists were particularly influenced by the major losses sustained during the 1941 Luftwaffe Operation Barbarossa, in which German aircraft penetrated up to 600 km inside the Soviet Union, as well as similar strikes two years later. The use of military airpower to strike military assets and critical infrastructure within the country’s interior, and the inefficacy of Soviet air defenses in preventing the attacks, highlighted an enduring sense of vulnerability.⁵ The growth of Soviet national air defense organizations and investment in building its capabilities in the postwar period further suggests Moscow internalized that air operations are an important component of the Western way of war.

Most sources suggest that deep strikes in the homeland or air attacks on fielded forces were at the forefront of Soviet concerns throughout the Cold War.⁶ Soviet leadership and military analysts considered NATO’s development of long-range precision strike capabilities, ability to deploy combat air forces in large numbers along multiple lines of attack, introduction of stealth fighter aircraft, and advancement of low-altitude variant cruise missiles among the most lethal emerging threats.⁷ Meanwhile, other Soviet analysts took notice of NATO air exercises, which demonstrated the allies’ increasing

⁴ David Brooks, “The Siege Mentality Problem,” *New York Times*, November 13, 2017; Gordon Corera, “Russia and the West: A Century of Subversion and Suspicion,” BBC News, March 25, 2017; Diligensky and Chugrov, 2000; Blank 2008.

⁵ Stratfor, “The Geopolitics of Russia: Permanent Struggle,” April 15, 2012.

⁶ Dima Adamsky, “The Soviet PVO Innovation: Strategic Considerations and Non-Strategic Drivers,” Office of Net Assessment, March 2017, p. 15.

⁷ Yu N. Baluevskii, ed., trans., RAND Corporation, *The General Staff of the Russian Military: Past and Present*, Akademicheskii Proekt, 2006, p. 321.

ability to evade enemy air defenses at low altitudes.⁸ The priority given to each mission area tended to vary based on organizational imperatives, but deep strike seemed most concerning to the majority of Soviet analysts.

Today, persistent concerns about domestic vulnerability to air strikes continue to represent a central dimension of pervasive Russian narratives around existential external threats. Russian leaders often cite concerns that reflect the besieged fortress mentality in their public remarks.⁹ Russia's latest military doctrine also serves as a reminder that the specter of Western encirclement of the Russian homeland is a prevailing apprehension. For example, Russia's overarching doctrinal publication identifies "a buildup of NATO military potential and its empowerment with global functions . . . in violation of international law" and "the expansion of NATO's military infrastructure to the Russian borders" atop the list of military threats to Russia.¹⁰ These concerns illustrate Moscow's resistance to NATO's enlargement in the early 2000s, as well as its current emphasis on combat air capabilities.¹¹ Likewise, Russia's 2015 National Security Strategy explicitly denounces the allies for "exerting a negative influence on the realization of Russian

⁸ A. R. Davydov and V. N. Gusak, trans., RAND Corporation, "Tactics of the SAM Troops: Past Experience and Lessons for the Future," *Military Thought*, No. 5, 2015, p. 52.

⁹ For example, in 2015, Russian Minister of Defense Sergey Shoigu observed "a consistent expansion of NATO. In a relatively short time, it has almost doubled with 12 members. Currently, Montenegro, Bosnia and Herzegovina, Georgia, and Ukraine are actively preparing to join the block, while Finland, Sweden, Serbia, and Moldova are being involved in its sphere of influence." In 2019, Chief of the General Staff of the Armed Forces, General Valerii Gerasimov, echoed Shoigu's sentiment before the Academy of Military Sciences, stating, "Today, Washington is continuing along a path of expanding its system of military presence near the borders of Russia and of destroying the system of treaty relations on issues of limiting and destroying arms, which are leading toward the disruption of strategic stability." See Sergey Shoigu, Defense Minister of the Russian Federation, RAND trans., speech before Russia's Defense Chiefs at the Russian Defense Ministry Collegium, December 11, 2015; and Valerii Gerasimov, trans., RAND Corporation, "Vectors in the Development of Military Strategy," speech, Annual Meeting of the Academy of Military Sciences, March 4, 2019.

¹⁰ Russian Federation, trans., *The Military Doctrine of the Russian Federation*, press release, December 25, 2014.

¹¹ Blank, 2008.

national interests.”¹² It also warns of U.S. threats to regional stability and Russian geopolitical influence posed by “practical implementation of the ‘global strike’ concept and deployment of strategic non-nuclear precision systems.”¹³

Impressions of NATO’s Combat Air Tactics and Capabilities, 1991–Present

Since the collapse of the Soviet Union, Russian military scholars and practitioners have continued to closely observe Western air campaigns. Russian political and military leaders believe Western airpower poses an especially distressing threat. Several sources discuss Western combat air tactics and capabilities employed in the First Gulf War (1991), the conflict in the former republic of Yugoslavia (1999), the U.S. War in Iraq (2003), and the intervention in Libya (2011). These are among the most frequently cited cases. In addition, some analysts highlight NATO air exercises and member nations’ investments in next-generation strike platforms and munitions as evidence of a growing threat. There are three recurrent themes in Russian analysis of Western campaigns and activities:

1. emergent and refined capabilities, specifically the advent of PGM and the Alliance’s increased use of EW in the air domain
2. the combination of depth and speed enabled by developments in NATO forces’ long-range strike capabilities and combat platforms
3. a distinct pattern in Western target prioritization.

A brief review of Russian operations during this period also reveals several indications that the Kremlin has taken concrete steps to prepare its air and air defense forces to counter or mitigate threats posed by these capabilities in a notional conflict with the West. The few examples of

¹² Russian Federation, trans., *Russian National Security Strategy*, Moscow, December 2015.

¹³ Russian Federation, *Russian National Security Strategy*, 2015.

Russian leaders' statements presented in this section are not exhaustive but do demonstrate that Russia's views of Western airpower are relatively consistent from the lower-level analyst to the highest level of Russian leadership, including President Vladimir Putin.

Emergent and Refined Capabilities

Over the past two decades, Russian analysis of NATO air operations repeatedly raised concerns about Western technological developments and their combat implications.¹⁴ In the air domain, Russian leadership and military planners remain fixed on the advent of PGM and the Alliance's increased use of EW to support offensive air operations. From the Russian perspective, not only do these capabilities highlight key aspects of Western airpower independently but, when deployed in combination (which Russia refers to as reconnaissance-strike concepts), they threaten to degrade Russia's combat potential, particularly that of its air defenses.

NATO's use of short- and long-range PGM frequently appears in Russian military writings and statements.¹⁵ For example, an analysis of air operations in the 1999 conflict in Kosovo observed that "NATO precision guided anti-radiation missiles destroyed practically any source of radio-frequency emissions."¹⁶ A decade later, another Russian analyst accurately identified the increased use of PGM by NATO forces as a standard practice: "Within the framework of using airborne strike assets in conflict, there is a growing trend toward increasing the share of PGM within the whole of ammunition employed in operations."¹⁷

¹⁴ For example, see V. N. Dybov and Yu.D. Podornykh, "Necessary Conditions for Attaining Superiority in Aerospace," *Military Thought*, undated.

¹⁵ For example, see A.V. Kartapolov, trans., RAND Corporation, "Lessons of Military Conflicts and the Perspectives of the Development of the Forms and Methods of Their Conduct: Direct and Indirect Action in Modern International Conflicts," *Journal of the Academy of Military Sciences*, Vol. 51, No. 2, 2015; P. A. Kul'nev and V. I. Orlanskii, "Principal Changes in the Nature of Armed Struggle in the First Third of the 21st Century," *Vestnik Akademii Voenykh Nauk Vestnik of the Academy of Military Science*, No. 1, 2015.

¹⁶ A. V. Usikov, et al., *Military Art in Local Wars and Armed Conflicts*, Moscow: Military Publishing House, 2009, p. 577.

¹⁷ Usikov, 2009.

And, during the Libya operation, Chief of the General Staff Nikolai Makarov observed that “as before, the leading role is assigned to high-precision weapons,” including Tomahawk cruise missiles and other precision-guided munitions.¹⁸

In part, this trend reflects Moscow’s fear that “the speed, accuracy, and quantity of non-nuclear strategic precision-guided weapons can achieve strategic effects on par with nuclear weapons.”¹⁹ In February 2017, Defense Minister Sergey Shoigu stressed this explicitly: “It is to be noted that future role of nuclear weapons in deterring a potential aggressor will decrease. Primarily, it will be decreased due to development of high-precision weapons.”²⁰ This is likely among the primary reasons Russia reserves the right to launch a nuclear response to a non-nuclear attack that threatens the existence of the state.²¹ Shoigu continued that to counter adversarial precision threats, “the impact potential of our high-precision weapons will increase by four times to 2021,” which “will ensure the security of Russian borders.”²²

Russia’s intervention in Syria offers a tangible example of its efforts to implement reconnaissance-strike concepts similar to those used by the West.²³ In addition to employing combat aircraft within close range of targets, Russia has recently introduced long-range PGM (e.g., Iskander, Kalbr, and KH-101) to the theater. While several reports claim Russia employed these weapons sparingly from 2015 to 2017, Moscow has since used precision-guided bombs and missiles in

¹⁸ N. E. Makarov, trans., “The Nature of Future War and Problems of Force Structure and Employment of the Armed Forces in Modern Conditions,” *Vestnik of the Academy of Military Sciences*, No. 2, 2010.

¹⁹ U.S. Defense Intelligence Agency (DIA), *Russia: Military Power*, Washington, D.C.: U.S. Department of Defense, 2017, pp. 14–15.

²⁰ Middle East Media Research Institute, “Russian Defense Minister Shoigu: ‘The Attempts of the U.S.-Led West to Impede the Establishment of a New, Fair World Order Are Leading to Growing Chaos . . . Russia’s Strategic Partner Is China,’” Special Dispatch No. 6812, March 3, 2017.

²¹ DIA, 2017, p. 22.

²² Middle East Media Research Institute, 2017.

²³ Anton Lavrov, *The Russian Air Campaign in Syria: A Preliminary Analysis*, Washington, D.C.: Center for Naval Analyses, June 2018.

several high-profile strikes and in retaliation for attacks on key forward-deployed Russian assets.²⁴

Similarly, Russia's observation of NATO air forces' increased reliance on EW is linked to what some analysts call "new-generation war."²⁵ Initial observations emerged in Russian analysis shortly after the First Gulf War. One article described "the novelty" of Western operations in Iraq in terms of how "radio-electronic suppression was used as a special weapon that was equivalent in its effectiveness to a strike by fires" to disrupt command and control of ground forces and weapon systems.²⁶ A similar observation described the new "U.S. way of war" to involve "employment of electronic warfare to blind ground forces against an incoming air assault, and disrupt the mobilization and deployment of ground troops and weapon systems."²⁷ Today, Russian military experts continue to emphasize the need to prepare for widescale disruption of the electromagnetic spectrum at the outset of a modern conflict.²⁸

Russian analysts accurately discerned a trend in Western integration of EW in modern air campaigns as early as the 1990s. However, it

²⁴ Douglas Barrie and Howard Gethin, "Russian Weapons in the Syrian Conflict: A Review," NATO Defense College, May 2018; Matthew Bodner, "Russia Shows Early Success, New Capabilities in Syria," interview with a former member of the General Staff, Lt Gen Yevgeny Buzhinsky, *Defense News*, October 18, 2015; Joseph Threvithick, "American General Says 'Adversaries' Are Jamming AC-130 Gunships in Syria," *The Drive*, April 25, 2018; Dave Majumdar, "The Rise of Russia's Military," *The National Interest*, July–August 2018; Andrew Radin, Lynn E. Davis, Edward Geist, Eugeniu Han, Dara Massicot, Matthew Povlock, Clint Reach, Scott Boston, Samuel Charap, William Mackenzie, Katya Migacheva, Trevor Johnston, and Austin Long, *The Future of the Russian Military: Russia's Ground Combat Capabilities and Implications for U.S.-Russia Competition*, Santa Monica, Calif.: RAND Corporation, RR-3099-A, 2019; Dima Adamsky, "Moscow's Syria Campaign: Russian Lessons for the Art of Strategy," IFRI Russia/NIS Center, No. 109, 2018, p. 16; and Andrew E. Kramer and Anne Barnard, "Russia Asserts Its Military Might in Syria," *New York Times*, August 19, 2016.

²⁵ This roughly equates to the U.S. concept of "modern warfare." See S. G. Chekinov and S. A. Bogdanov, trans., RAND Corporation, "The Nature and Content of a New-Generation War," *Military Thought*, No. 10, 2013.

²⁶ I. N. Vorobyov, trans., RAND Corporation, "Lessons from the War in the Persian Gulf," *Military Thought*, No. 5, 1992.

²⁷ Vorobyov, 1992.

²⁸ Chekinov and Bogdanov, 2013.

was not until 2008 that the Kremlin indicated real interest in modernizing its own EW capabilities, reflecting a newfound appreciation for the severity of its limitations in the air domain. That year, losses sustained during Russia's five-day war with Georgia revealed to Russian commanders the linear relationship between EW supremacy and air superiority. While Russian ground forces were relatively effective, its air forces were unable to suppress Georgian air defense systems, which resulted in the loss of several Russian combat aircraft.²⁹ In response, President Putin ordered at least 70 percent of Russia's EW equipment to be upgraded by 2020 as part of the country's broader military modernization effort.³⁰ According to Deputy Defense Minister Yuriy Borisov, that figure could be closer to 80 or 90 percent at the current rate of investment.³¹

Both to test and to demonstrate return on its investments, Russia used the conflicts in eastern Ukraine and Syria as opportunities to engage in extensive EW activities. In the former, Russia deployed both airborne and ground systems to conduct electromagnetic reconnaissance and jamming against enemy satellite, cellular, and radio communication systems, along with GPS spoofing and electromagnetic attacks against Ukrainian unmanned aerial vehicles (UAVs).³² In April 2018, several reports claimed Russia had been particularly successful at using EW technology to interfere with coalition-led air operations in Syria.³³

²⁹ While there are no official figures, Russia reported that it lost three Su-25 strike aircraft and one Tu-22 long-range bomber in the attack. At the time, Georgia claimed it shot down up to 21 Russian aircraft. Another source estimated Russian losses included one Tu-22M2 long-range bomber, one Su-24M Fencer fighter-bomber, one Su-24MR Fencer E reconnaissance plane, and four Su-25 attack aircraft. See Vladimir Isachenkov, trans., "War Reveals Russia's Military Might and Weakness," *Aviation*, August 18, 2008; Mikhail Barabanov, "The August War Between Russia and Georgia," Center for Analysis of Strategies and Technologies, *Moscow Defense Brief*, Vol. 3, No. 13, 2009.

³⁰ Timothy L. Thomas, *Russia Military Strategy: Impacting 21st Century Reform and Geopolitics*, Fort Leavenworth, Kans.: Foreign Military Studies Office, 2015, pp. 151–153.

³¹ "Defense Ministry: Proportion of Modern Electronic Warfare Systems in Troops Could Reach 90 Percent," *RIA Novosti (RIA News)*, September 24, 2015, as cited in Thomas, 2015, p. 152.

³² Liam Collins, "Russia Gives Lessons in Electronic Warfare," Association of the United States Army, July 26, 2018.

³³ Stratfor, "In Syria, the Russian Military Found the Ultimate Testing Ground," October 23, 2017.

For example, Russia reportedly deployed the Krasukha-4, which is designed to obstruct radars of enemy attack, reconnaissance, and unmanned aircraft.³⁴ The “truck-mounted radio emitter is capable of jamming not only radar signals, but also control channels for drones, making planes ‘blind and deaf,’” with a range of 300 km.³⁵ Other related capabilities deployed include the Moscow-1 and Richag-AV radar and sonar jamming system, which scan the battlefield’s airspace and transfer data to various Russian EW systems charged with neutralizing enemy air threats.³⁶ In a press conference that spring, U.S. Special Operations Commander, General Raymond Thomas, said Syria has become “the most aggressive EW environment on the planet.”³⁷

These episodes present stark indicators that Russia—learning both from two decades of analysis on NATO air campaigns and its own combat experiences—believes EW bears formidable influence over its potential to counter a key aspect of Western air superiority. This analysis indicates that Russia seems likely to expect the West to depend on precision weapons and an extensive use of electronic warfare to accomplish strikes on Russia.

Combining Depth with Speed

Russia’s long-standing quest for strategic depth, once provided by Warsaw Pact territory, no longer stands as an effective defense against an attack on the Russian heartland. The advent of intercontinental ballistic missiles (ICBM) during the Cold War introduced the real prospect of Western strikes on the Russian homeland, in a way virtually immune to even the most sophisticated defense measures.³⁸ Conven-

³⁴ Anna Varfolomeeva, “Signaling Strength: Russia’s Real Syria Success Is Electronic Warfare Against the U.S.,” *The Defense Post*, May 1, 2018; “Advanced System to Guard Russia from Hi-Tech Surveillance, Drone Attacks,” *Russia Today*, November 18, 2013.

³⁵ Courtney Kube, “Russia Has Figured Out How to Jam U.S. Drones in Syria, Officials Say,” *NBC News*, April 10, 2018; Varfolomeeva, 2018.

³⁶ Kube, 2018.

³⁷ Threvithick, 2018.

³⁸ Linton Brooks, Francis J. Gavin, and Alexei Arbatov, “Challenges of the Nuclear Era: The Russian Perspective,” February 2018; Congressional Research Service, “ICBM: Early Developments,” Washington, D.C., May 26, 1997.

tional bombers and other systems took longer to reach their targets, assuming they could penetrate air defenses. Today, Russian analysts and military leaders alike have come to view the increased speed of modern combat aircraft and weapons and their proximity to Russia, combined with existing and enhanced long-range strike capabilities, as a serious threat.

During NATO operations in Iraq (1991) and Kosovo (1999), Russia witnessed how the strategic scope and depth of the battlefield increased with the employment of long-range precision munitions, launched primarily from air- and sea-based platforms.³⁹ This represented a radical departure from previous operations, where strikes were conducted almost exclusively within the immediate airspace above enemy air defense and ground combat forces.⁴⁰ Russia observed how NATO forces struck targets throughout the adversary's entire territory from the outset of military operations, regardless of whether there was immediate, calculated tactical value.⁴¹ In many ways, these observations evoked deep-seated fears associated with the German strikes on Russia's interior in World War II. After witnessing the onset of the U.S. War in Iraq (2003), some Russian analysts no longer considered Western capabilities to execute airstrikes with strategic depth an aberration or a nascent competency. This "trend is associated with an increase in the range of precision-guided weapons and the possibility of their effective use for striking at targets deep in the rear of the opposing side."⁴² More recently, Russian commentators have cited a growing concern with how emerging Western capabilities and force postures have made deep strikes

³⁹ Vladimir Pyriev, Vladimir Dvorkin, and trans., Natalia Bubnova, "The U.S./NATO Program and Strategic Stability," in *Missile Defense: Confrontation and Cooperation*, ed. Alexei Arbatov and Vladimir Dvorkin, Moscow: Carnegie Moscow Center, 2013; Yevgeny Miasnikov, trans., "Counterforce Potential of Precision-Guided Munitions," in *Nuclear Proliferation: New Technologies, Weapons, Treaties*, ed. Alexei Arbatov and Vladimir Dvorkin, Moscow: Carnegie Moscow Center, 2009; Brooks, Gavin, and Arbatov, 2018.

⁴⁰ V. A. Vakhrushev, trans., RAND Corporation, "Local Wars and Armed Conflicts: Their Nature and Impact on Military Art," *Military Thought*, No. 4, 1999.

⁴¹ Vakhrushev, 1999.

⁴² O. V. Orekhov and S. G. Chekinov, trans., RAND Corporation, "Typical Characteristics of Armed Conflict over the Past Decade," *Military Thought*, No. 10, 2004.

possible in much shorter time frames.⁴³ Various sources also describe Russia's concern with more advanced and high-speed weapons.⁴⁴

Statements from Russian political leaders are less common on the specifics of the use of airpower. Nonetheless, they often reinforce the views of Russian military leaders and analysts on this issue. Beginning in 2013, General Valeri Gerasimov, the current Chief of the General Staff, gave several speeches and published several writings that discuss modern warfare. While most Western analysis has focused on the less traditional aspects of Gerasimov's thinking, he still covers key aspects of conventional military operations in his statements. For instance, in a 2013 speech before the Academy of Military Sciences, he observed the "destruction of enemy infrastructure is executed throughout the full depth of his territory."⁴⁵ In his 2019 presidential address to the Federal Assembly, Putin also commented on the threat posed by NATO aircraft in the Baltics and medium-range missile launchers in Romania and Poland, emphasizing how each has decreased the West's strike and flight time to Moscow. Putin stated,

Russia does not intend to deploy such missiles in Europe first. If they really are built and delivered to the European continent, and the United States has plans for this, at least we have not heard otherwise, it will dramatically exacerbate the international security situation, and create a serious threat to Russia, because some of these missiles can reach Moscow in just 10–12 minutes. This is a very serious threat to us. In this case, we will be forced, I would

⁴³ "This trend is associated with an increase in the range of precision-guided weapons and the possibility of their effective use for striking at targets deep in the rear of the opposing side. Thus, on the one hand, the scale of war is expanding to a global level, which is due to the intercontinental reach of the means of destruction, the extensive use of space systems (reconnaissance, communications, navigation, control), and the transfer of the main events of military operations to the aerospace sphere. On the other hand, the objectives of war are achieved by executing a number of tasks at the local level, for example targeted, selective strikes with high-precision weapons on the most important enemy targets." See Orekhov and Chekinov, 2004.

⁴⁴ Michael Peck, "Russia Says It Can Shoot Down Hypersonic Missiles," *The National Interest*, May 22, 2019.

⁴⁵ V. V. Gerasimov, trans., RAND Corporation, "The Primary Trends in the Development of Forms and Methods of Employing the Armed Forces and the Current Tasks of Military Tasks in Improving Them," Academy of Military Sciences, *Vestnik*, No. 1, 2014.

like to emphasize this, we will be forced to respond with mirror or asymmetric actions.⁴⁶

Separately and more recently, Russian leaders have continued to acknowledge that emerging weapons technology can strike with ever-decreasing warning time.⁴⁷

Russian announcements and efforts to build advanced systems to defend against Western weapons indicate that Moscow harbors real concerns over NATO's ability to conduct rapid deep strikes. Between 2008 and 2015, the Russian military received more than 350 new combat aircraft and about 1,000 helicopters, as well as hundreds of air defense systems. Russian leaders regularly claim to have advanced systems capable of shooting down modern cruise missiles and fighter aircraft.⁴⁸

Originally developed to deter against an attack on its homeland by a major military power, presumably the United States or NATO, the S-400 is an advanced air defense system with no Western counterpart. Russia's demonstration in Syria is an important example, as it provides a potential preview of how Russia would likely establish air defenses of fixed sites in future conflicts. The buildup of its IADS in Syria involved the S-200, S-300, and S-400, along with several short-range air defense systems, including the Pantsir-1 and Buk missile systems. The deployment of these systems, though seemingly disparate, was designed to culminate in a fully functional IADS that some Western analysts claim was designed to threaten U.S. and coalition aircraft rather than to defend Russian bases and forces.⁴⁹

⁴⁶ Vladimir Putin, Presidential Address to the Federal Assembly, speech, Moscow, Russia, February 20, 2019.

⁴⁷ Michael T. Klare, *An "Arms Race in Speed": Hypersonic Weapons and the Changing Calculus of Battle*, Arms Control Association, June 2019.

⁴⁸ Mark Episkopos, "Introducing Russia's S-500: Can It Take Out an F-22 or F-35?" *The National Interest*, May 18, 2019.

⁴⁹ "This deployable and road mobile IADS solely aims to threaten US and coalition aircraft and deter further involvement or escalation of coalition operations. There is no credible fixed wing, rotary wing, or ballistic missile threat to Russian forces in Syria from ISIS [the Islamic State] or any other potential adversary that would require a modern IADS." See Chris Harmer and Kathleen Weinberger, *Russia Advances Its IADS in Syria*, Institute for the Study of War, October 16, 2016.

President Putin has also made numerous public statements about the importance of air defense and related preparations for conflict. For example, during a 2015 speech to military chiefs, Putin stated that “we have already taken additional measures to provide security to Russian service members and air bases. They are reinforced through new air units and means of air defense. All actions by strike aircraft are conducted under fighter cover. My order is to act harshly. Any targets threatening the Russian group or our infrastructure on the ground should be destroyed immediately.”⁵⁰ Defense Minister Sergey Shoigu made similar statements highlighting the creation of the aerospace forces in 2015.⁵¹

In sum, Russian writing, pronouncements, and actions make clear that Russia likely fears a mixed force of modern aircraft capable of striking deep and doing so with greater speed than was possible in the past.

Target Prioritization and Non-Contact War

Russian military officials and analysts have underscored a Western preference for precision strikes against high-value targets, generally defined as prompt global strikes, in order to avoid a more traditional ground fight.⁵² Three years after NATO operations in Kosovo, V. N. Tsygichko, who worked on strategic operations modeling for the Soviet General Staff, discussed a conflict scenario for a regional-level combat model in which a NATO-like force elected to “conduct strikes against vitally important infrastructure targets” that bring the enemy “to the brink of economic and humanitarian catastrophe.”⁵³ Just prior to the withdrawal of U.S. forces from Iraq in 2011, General Nikolai Makarov, then Chief of the General Staff, commented that destruction of critical infrastructure had become “a key component of armed

⁵⁰ Vladimir Putin, President of the Russian Federation, trans., speech before Russia's Defense Chiefs at the Russian Defense Ministry Collegium, December 11, 2015.

⁵¹ Shoigu, 2015.

⁵² Pavel Felgenhauer, “Instant Global Deception: What Is Prompt Global Strike, with Which Our Military Scares the Authorities, Pulling the Country into an Unbearable Arms Race,” *Novaya Gazeta*, October 14, 2017.

⁵³ V. N. Tsygichko, trans., “On the Category of Correlation of Forces in Potential Military Conflicts,” *Military Thought*, No. 3, 2002.

combat” because of the disruption it brings to a number of vital elements of state command and control in wartime. In 2004, an analyst observed that “the scale of war is expanding to a global level . . . on the other hand, the objectives of war are achieved by executing a number of tasks at the local level, for example targeted, selective strikes with high-precision weapons on the most important enemy targets.”⁵⁴ In the case of Libya, Russian sources underscored coalition strikes against high-value political targets, such as the residences of the Libyan leader and mass media facilities.⁵⁵

Statements from senior Russian leaders confirm a belief that the West will prioritize targets critical to an adversary. General Valeri Gerasimov commented on how the nature of modern armed conflict includes reducing the military-economic potential of the country by attacking and destroying both military and civilian infrastructure.⁵⁶ Naturally, more subordinate military leaders in Russia share similar views: two years later the commander of the Western Military District, A. V. Kartapolov, stated that a defining feature of modern warfare is the “delivery of precision-guided, electronic, and information strikes against the most important targets and critical infrastructure [of the enemy].”⁵⁷

Conclusions drawn at the top echelons of the Russian military and government regarding NATO activities and military modernization have a direct influence on future Russian force structure, acquisition, planning, and training. In 2015, Shoigu described how modern Russian air operations are now following the pattern of Western air operations:

On September 20, we launched a special operation in Syria involving long-range strategic and army aviation. . . . For the first time, mass scale strikes with high precision-air and sea-based cruise

⁵⁴ Orekhov and Chekinov, 2004.

⁵⁵ Andrei Goncharov, trans., RAND Corporation, “The War Will Be in All Domains,” *Aerospace Defense*, No. 6, 2015.

⁵⁶ Gerasimov, 2014.

⁵⁷ Kartapolov, 2015.

missiles were delivered at a range of up to 1,500 km. Combat aviation performed some 4,000 combat flights and destroyed over 8,000 terrorist military infrastructure facilities.⁵⁸

This shift in Russian approach began over a decade earlier when, in 2003, then Minister of Defense Sergei Ivanov wrote that warfare in the twenty-first century would be conducted in large part from the aerospace and maritime domains: "While ground warfare was still relevant, it was seen as a secondary element of war to consolidate gains made by air and sea-based strikes that crippled the enemy's ability to counter." Ivanov went further: "Increased range would give the adversary the ability to strike not only troops and military targets but also the country's economy completely, with its infrastructure, civilian population, and practically the whole territory."⁵⁹

The themes described above suggest that Russia likely expects the West to begin operations with a fully coordinated, multi-axis air assault on the Russian homeland, targeting critical infrastructure and key government and military command-and-control centers. Russia would likely expect these attacks to be synchronized with repeated attacks on Russian IADS designed to create gaps in coverage and approach lanes for both advanced and legacy weapons and platforms. Here Russia will likely carefully study the force mix of modern and legacy fighter aircraft and their associated payloads to determine its own procurement and planning priorities.

Following deep strikes in Russian territory and SEAD, Russia would expect the West to also conduct air interdiction of key lines of communication and resupply. This expected shift creates a planning challenge for Russia because it cannot simply defend critical infrastructure but must also account for its potentially more vulnerable, and clearly more dispersed, supply lines. Russia would also have to plan for means to defend its fielded forces since any NATO counterattack

⁵⁸ Shoigu, 2015.

⁵⁹ Russian Federation, *Priority Tasks for the Development of the Armed Forces of the Russian Federation*, Ministry of Defense, Moscow: Voenform, 2003.

would be expected to eventually include ground operations, supported by airpower, intended to repulse conventional Russian ground forces.

Correlation of Forces and Means (COFM) and Air Defense Analysis

Throughout the Cold War, the Soviet Union used a method called correlation of forces (COF). COF was an analytical concept for measuring the state of competition between the Warsaw Pact and NATO using quantitative political, economic, and military indicators.⁶⁰ Since the end of the Cold War, Russian COF assessments have received scant attention from the United States. A recent RAND report bridges the gap that emerged in the early 1990s in this area of Russian military science, referring to the modern approach as correlation of forces and means (COFM). This research finds that “COFM in modern Russian political and military parlance is a description of military superiority of one side over another.”⁶¹ Today, Russian military planners appear to continue to rely on combat potential values to calculate COFM in operational planning. There is, however, intense debate among Russian practitioners about the shortcomings of various COFM techniques and their overall utility for operational planning.⁶²

Some insights about Russian perceptions of airpower are available from studying COFM, as well as its more recent critiques within Russian military literature. For example, during the Cold War there was a clear focus on superiority in ground forces personnel and armor.⁶³ Both Western and Soviet forces ran comparative calculations

⁶⁰ Reach, Kilambi, and Cozad, 2020, p. 1.

⁶¹ Reach, Kilambi, and Cozad, 2019, p. 1.

⁶² See, for example, Vladimir Dmitrievich Stepanov, trans., RAND Corporation, “Military Potentialometry—New Science or Old Fallacies?” Academy of Military Sciences, *Vestnik*, No. 4, 2014.

⁶³ Soviet General Staff calculations suggested a requirement of a 6:1 advantage in tanks in a war in Europe, for example.

of COFM in the immediate post-Cold War era. Representatives from the Center for Operational-Strategic Studies of the General Staff were invited to join scientists and representatives of NATO, the United States, the United Kingdom, France, Germany, and Italy in unofficial discussions in 1992 centered on reducing military conflict in Europe.⁶⁴ One of the products from this meeting was an agreed-on model for assessing weapons, military equipment, and model generic combat formations. Consideration of the air domain yielded results like those shown in Figure 3.1. The blue bars indicate the relative value of a platform to Russian planners while the orange denotes the UK perspective. The F-15E is used here as the baseline by which to measure the combat potential of three other systems.

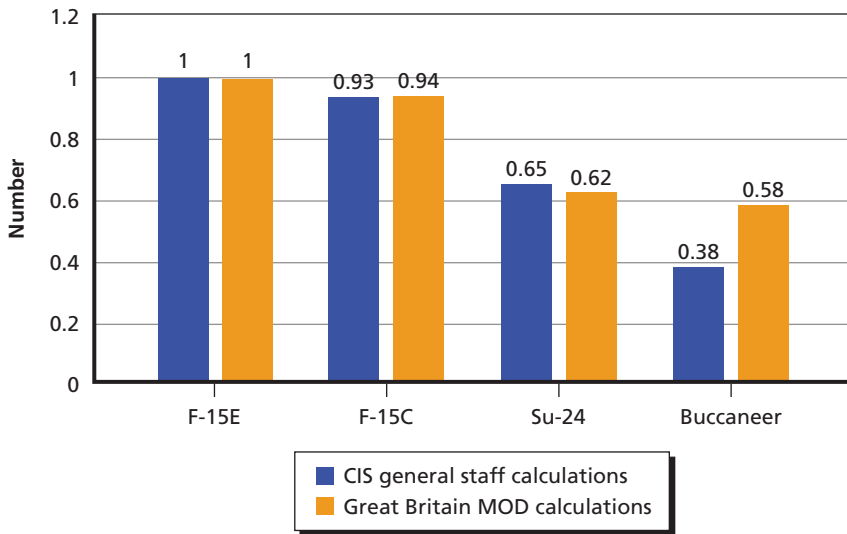
Post-Cold War Russian observations of the U.S. way of war have shifted the emphasis to war waged predominantly from the air and sea, “supported by a large number of long-range precision munitions, a highly capable C4ISR system, and air-based electronic warfare capability.”⁶⁵ Since COFM analysis still carries weight in Russian planning, it follows that the type of air and sea platforms and their specific capabilities, the performance specifications of specific weapons (including cruise and ballistic missiles), and how they interact could be significant factors for Russian planners and analysts.

Soviet and Russian approaches to COFM calculations over the years have attempted to quantify combat potential through different formulations designed to assign values to platform subsystems/capabili-

⁶⁴ Sergey Alekseevich Bogdanov and Lev Zakharov, trans., RAND Corporation, “On the Development of Unified Approaches to Evaluation of Combat Potentials of Arms,” *Military Thought*, No. 8, 1991.

⁶⁵ “Even despite the possession of such an arsenal, however, the changing nature of warfare and a threat environment that is different from that of the Cold War did have an impact on Russian thinking on COFM in a broad sense of the term beyond operational planning. Decisions that were made on the force structure of the Russian armed forces were in part derived from the idea that large clashes of frontal ground forces was a thing of the past, which is how the Russian military was oriented to fight up to 2008. The underlying assumptions of the 2008 reforms of the Russian military, while quite controversial within Russian defense circles, were that the armed forces needed to be able to fight and defend against modern wars that involved fewer, ready ground forces and greater reliance on long-range precision strike.” See Reach, Kilambi, and Cozad, 2020, pp. 11, 78.

Figure 3.1
Comparison of COFM Calculations for Combat Aviation Platforms



SOURCE: Adapted from Sergey Bogdanov and Lev Zakharov, trans., RAND Corporation, "On the Development of Unified Approaches to Evaluation of Combat Potentials of Arms," *Military Thought*, No. 8, 1991.

ties. Four qualitative features of military equipment or weapon systems of particular focus in Russian military journals, in particular, are

- firepower
- survivability
- maneuverability
- command-and-control capability.⁶⁶

In order to establish a common unit of combat potential, analysts apply coefficients to weight each of the four key components,

⁶⁶ For an example of this approach, consider the following: A weapons platform represents a "complex system that consists of a functionally connected aggregate of subsystems: firepower/strike, C2 [command and control], mobility, protection/survivability." Bogdanov and Zakharov, 1991. Later articles offered different and often much more complex formulations.

indicating their relative significance to the overall combat potential of a weapon systems. The effectiveness of a given qualitative feature may be determined by the value of another. For example, as one Russian military scholar notes, "Regardless of the firepower of the strike aircraft systems, without ensuring a high level of survivability when overcoming the zonal and target air defense of the enemy, the completion of the mission will be impossible because of the complete destruction of the combat detachment aircraft systems when approaching the target."⁶⁷ While the list of subsystems and capabilities varies among authors and critiques, it is reasonable to consider widely accepted components of combat potential such as firepower (or strike), survivability (or protection), maneuverability (or mobility), and command and control.

Russian military analysis has focused on finding common benchmarks for the importance of not only weapons and platforms but also combat formations. Articles have reinforced the importance of calculating the combined capabilities of an air formation since the combined formation capabilities may be greater than the sum of the individual parts.⁶⁸ A 2009 article defines this capability as follows:

A combat formation as opposed to an individual weapon or piece of military equipment is a complex combat system that contains a determined amount of similar-type and different-type weapons and military equipment, a subsystem of combat C2 [command and control] and material-logistics support. The presence of these subsystems gives the combat formation a new synergistic quality that increases the combat capability of the combat formation in comparison with a simple collection of weapons and military equipment.⁶⁹

⁶⁷ Stepanov, 2014.

⁶⁸ Bogdanov and Zakharov, 1991; A. S. Bonin, trans., RAND Corporation, "Primary Provisions of the Methodological Approaches to Assessing Combat Potentials and Combat Capabilities of Air Formations," *Military Thought*, No. 1, 2008.

⁶⁹ Aleksandr Ivanovich Buravlev, Sambu Rabdanovich Tsyrendorzhiev, and Vladimir Sergeevich Brezgin, "Fundamentals of the Methodological Approach to the Evaluation of the Combat Potential of Military Weapons and Equipment and Combat Formations" *Arms and Economics Journal*, Vol. 3, No. 7, 2009.

These considerations provide insights on how Russian military authorities might view the emergence of new NATO air platforms that operate collectively as well as individually.

Conclusion

Overall, this chapter suggests that Russia is likely to be most concerned about emerging capabilities that would improve NATO's ability to suppress or destroy air defense or to penetrate deep into Russian territory. Russian analysis and public statements regarding the Western use of airpower reveal several recurring themes. First, Russian planners and military leaders may fully expect the United States and NATO to use a high percentage of precision-guided munitions in an initial attack.⁷⁰ They may expect that such an attack will prioritize strikes on targets inside Russian territory that include a mix of military and civilian targets considered vital for Russian resilience.⁷¹ Additionally, Russians would most likely anticipate that any Western air strikes would include attacks on Russian air defense systems—the air defense literature regularly makes the case that large numbers of platforms and weapons have the potential of overwhelming Russian air defenses.

Based on their analysis of previous NATO campaigns, Russians may perceive a high likelihood that Western air forces would also conduct air interdiction strikes against targets that allow resupply of front-line forces as well as frontline forces themselves, including armored formations. Furthermore, Russian activity in Syria to defend bases and

⁷⁰ Well-known Russian military theorists Sergei Chekinov and Sergei Bogdanov, who work within the Center for Military-Strategic Studies of the General Staff, wrote in 2015 that “there was a high probability that future wars would include the use of long-range precision munitions to destroy both troop groupings as well as the economic potential of the enemy.” See Chekinov and Bogdanov, 2013.

⁷¹ “It may be assumed, with a large measure of probability, that defeating the enemy's main forces and destroying the economic potential of the country attacked, and also overrunning its territory are the principal objectives of a new-generation war fought in a network-centric environment. The full range of military, economic, political, diplomatic, and its measures, blended with effective psychological information activities, may be used to achieve these objectives.” Chekinov and Bogdanov, 2013.

numerous public statements and analysis of emerging Russian capabilities (such as the Iskander and anticipated S-500) also demonstrates intent to attack NATO air operations at or close to their source.⁷² This implies a need for NATO to plan for its own defensive counter-air as part of a notional overall air campaign against Russia.

Our review of Russian correlation of forces and air defense analysis also indicates that Russian planners will likely carefully review both the quantity and quality of platforms and weapons possessed by NATO, as well as how they are grouped in formations. The available data place a heavy emphasis on the importance of the quality of NATO platforms and weapons, especially precision deep-strike weapons such as cruise missiles. Russian literature on the combat potential of weapon systems suggests that Russian analysts may consider at least four qualitative features when assessing NATO platforms: survivability (or protection), firepower (or strike), maneuverability (or mobility), and command and control. NATO's planned modernization of combat aircraft is likely to have an impact on Russian thinking about these areas, including in regard to long-range firepower and the targeting and situational awareness aspects of command and control. Collectively, Russian analysis may also consider how a given NATO platform contributes to a military formation more broadly. For example, if a formation includes a mix of legacy capabilities paired with an advanced platform such as the F-35, Russian estimates will likely give the overall formation greater weight. While not an exhaustive review and based solely on publicly available materials, this examination provides a contextual foundation for subsequent discussions about the force structure, technology, and readiness of NATO air forces.

⁷² Nikolai Novichkov, "Syria Is a Proving Ground for Russian Weapons," *Aviation Week*, November 16, 2019; Mark Episkopos, "Russia's F-35 Killer: Report Claims S-500 Air Defense System Was 'Tested' in Syria," *The National Interest*, November 11, 2019.

Current and Emerging Force Structure and Technology

Defense budget cuts following the Cold War and again in the aftermath of the 2008 Great Recession forced European militaries, including air forces, to undertake dramatic reductions in force structure. The number of combat aircraft in European inventories fell considerably, and fewer modern aircraft were procured than initially anticipated.¹ European nations accepted that, in the extremely low probability event of a major war, the United States would need to assume the dominant role.² Aggregate European capabilities, at nearly 2,000 fourth-generation combat aircraft,³ nonetheless remain sizable in relation to most foreseeable security challenges, and in many cases air forces have undertaken key upgrades and recapitalization projects to enhance capabilities and are benefiting from some of the most advanced technologies in the world.⁴

¹ For an overview of the evolution of European air forces, see John Andreas Olsen, ed., *European Air Power: Challenges and Opportunities*, Dulles, Va.: Potomac Books, 2014. To illustrate, in 2008, the French air force planned to have 230 Rafales by 2020, but there are currently 100 in the inventory.

² NATO's 2010 Strategic Concept identified collective defense as a core task, but the document assessed that "the Euro-Atlantic area is at peace and the threat of a conventional attack against NATO territory is low." NATO, *Strategic Concept*, 2010, p. 11.

³ Had this study included Sweden, Finland, and NATO nations with one combat aircraft squadron, the number would be over 2,000.

⁴ Unless otherwise stated, we use the term *European* to denote the NATO air forces considered in this analysis.

This chapter surveys airpower capabilities in Europe, with a focus on combat aircraft and the emerging mix of fourth- and fifth-generation force structure and technology in the region. After reviewing extant and emerging capabilities, we highlight how the introduction of fifth-generation aircraft offers the potential to serve as a force multiplier for joint forces in the context of collective defense against a near-peer adversary such as Russia.

Force Structure and Technology (2020–2030)

This review of force structure and technology compares existing and projected combat aircraft inventories for the coming decade, orienting around capabilities available in 2020, reflected or assumed in defense plans for 2025, and envisioned for 2030. We identified this ten-year window as the time period for analysis primarily since this is when nations in the F-35 program will acquire the majority of their inventories while others, notably France, are projected to undertake modernization initiatives that, while not providing fifth-generation-equivalent capabilities, are nevertheless critical to collective defense.⁵ An additional motivation for focusing on the 2020 to 2030 time period centers on a number of key budgetary decisions facing European governments in the early 2020s, many of which will be addressed in Chapter Five and Chapter Six in our discussion of readiness.

Capabilities Other Than Combat Aircraft

This study focuses on combat aircraft, but European militaries possess a number of other forces capable of delivering effects in the air domain that warrant brief mention. Other capabilities include ground-based air defenses (GBAD) and, to a lesser extent, naval cruise missiles for

⁵ Development of sixth-generation capabilities, through programs such as Franco-German-led Future Combat Air System and a similar UK-led effort, will remain in research and development during the 2020s and may not be available until 2040 or later. See Sebastian Sprenger, "European Leaders Unveil Model of Next-Gen Fighter Aircraft at Paris Air Show," *Defense News*, June 17, 2019b.

land attack.⁶ These forces function in concert with combat aircraft as part of a wider airpower and joint toolkit and constitute an important factor in Russian planning to defeat NATO's air defenses, prepare for strategic attack on key nodes, and protect against long-range strike from ground formations and supply lines.

For air defense, European air forces and in some cases armies maintain GBAD capabilities for protection against suspicious or hostile aircraft, cruise missiles, and increasingly drones.⁷ Prominent systems include the Patriot (with PAC-2/3 missiles) and SAMP/T (with Aster 30 missiles). The Norwegian Advanced Surface-to-Air Missile System (NASAMS), widely exported and designed to fire the AIM-120 advanced medium-range air-to-air missile (AMRAAM), represents arguably the most sophisticated platform to counter short- and medium-range threats from the ground.⁸ In its own employment concept, Norway uses NASAMS to protect the lower half of its layered defense while F-16s, and soon F-35s, are responsible for the upper half. The third version of NASAMS is in development. According to IHS Jane's,

This upgrade will, among other things, enable launchers to be placed a greater distance from the fire control centers and thus make the air defence system more flexible. In addition, NASAMS III will ultimately be upgraded with extended range missiles, possibly

⁶ European nations do not possess long-range bombers and are unlikely to develop long-range ground-launched cruise missiles, the other primary means of delivering airpower, because of their perceptions of how introducing such a capability could alter strategic stability. See Douglas Barrie, "Ground-Launched Cruise Missiles, Europe and the End of the INF Treaty?" *Military Balance Blog*, February 15, 2019.

⁷ Systems that counter cruise missiles may also provide limited protection against ballistic missiles, though ballistic missile defense (BMD) continues to be a major challenge for NATO. The Alliance's BMD mission is focused on defending against the relatively limited Iranian threat, not Russia. For more on this issue, see for example, Ian Williams, *"Achilles' Heel: Adding Resilience to NATO's Fragile Missile Shield"*, Washington, D.C.: Center for Strategic and International Studies, August 5, 2019.

⁸ A possible indication of how the system is held in high regard, reports indicate that the United States uses NASAMS to protect its national capital region. Charlie Gao, "America's Capitol Is Defended by This Missile (From Norway)," *The National Interest*, May 5, 2018.

the AMRAAM-Extended Range (ER). Furthermore, a new long-range missile will be procured in the long term to operate alongside the NASAMS.⁹

For strategic attack and other forms of strike, NATO's naval cruise missiles offer a standoff capability of significant concern to Russian planners, but this dynamic relates primarily to U.S. Navy forces. While several European navies possess this capability, their quantity of naval combatants and munitions would most likely translate to a marginal contribution during a sustained high-intensity conflict. The April 2018 trilateral operation (U.S., UK, and France) to carry out strikes in retribution for the Syrian's regime's use of chemical weapons may be representative in this regard. According to news reports, the United States employed 57 naval cruise missiles in a land attack role, the French fired three, and the United Kingdom did not employ long-range naval fires.¹⁰ Although naval cruise missiles offer an important standoff capability, NATO's European members will continue to rely on combat aircraft as the mainstay of their airpower.

Fourth-Generation Aircraft

Technology

Fourth-generation fighter aircraft emerged at scale in the late 1970s.¹¹ Modern fourth-generation aircraft, with longer ranges, heavier payloads, and more advanced avionics than their predecessors, are increasingly capable of serving in both air-to-air and air-to-ground missions.

The F-16 has been a foundational airpower capability for some of Europe's more advanced militaries, including Belgium, Denmark, Greece, the Netherlands, Norway, Portugal, Turkey, and, well after the

⁹ Jane's, "Norway: Air Force," World Air Forces database, December 5, 2019.

¹⁰ Aaron Mehta and Tara Copp, "Coalition Launched 105 Weapons Against Syria, with None Intercepted, DoD Says," *Military Times*, April 14, 2018.

¹¹ Key characteristics commonly associated with this generation include the Doppler radar, fly-by-wire technology for operating without manual controls, digital avionics, enhanced maneuverability and speed, and varying levels of stealth and sensor fusion. Alessandro Marone and Michele Nones, eds., *Europe and the Future Combat Air System*, Instituto Affari Internazionali, March 2019, p. 15.

end of the Cold War, Poland. Indeed, multinational cooperation on this aircraft goes back to its very origins when the United States and four European nations established the F-16 Multinational Fighter Program consortium, a then-unprecedented effort to jointly manufacture, sustain, and operate a fighter aircraft in support of gaining efficiencies through scale, facilitating European technological maturation, and supporting NATO's interoperability for decades to come.¹² The European F-16 Mid-Life Upgrade program likewise ensured commonality in avionics, radar, cockpit, and other components and made it possible for the F-16AM/BM variants to employ beyond visual range missiles and execute precision strikes, including at night and in adverse weather.¹³ The F-16C/D has similar capabilities.

Other U.S.-made fourth-generation aircraft found in European fleets include the F/A-18 Hornet and the AV-8B Harrier, which is capable of short take-off and vertical landing (STOVL). The F/A-18 Hornet was operated by the Spanish air force and the AV-8B Harrier by the Spanish and Italian navies (and, previously, the UK Royal Navy) from aboard aircraft carriers and big-deck amphibious ships. Fourth-generation aircraft developed by individual European nations or multinational consortiums include the Mirage 2000, Tornado (with the ECR variant designed for SEAD missions), and Gripen-A/B/C/D, as well as the more recent Eurofighter Typhoon, Rafale, and Gripen-E.¹⁴ Finally, Poland plans to maintain the Russian-made MiG-29 in a DCA role until it introduces the F-35 later this decade.

Over approximately the past 20 to 25 years, industry has introduced key technologies that contribute to what some commentators term "fourth-generation-plus" capabilities that, when integrated onto

¹² U.S. Air Force, "F-16 Fighting Falcon," fact sheet, September 23, 2015; "Lockheed Martin F-16 Fighting Falcon," *Jane's All the World's Aircraft*, May 15, 2019.

¹³ F-16A/Bs received the AM/BM designation following the Mid-Life Upgrade. For a more complete breakdown of the Mid-Life Upgrade, see "History/The Beginning: Reason for the Mid Life Update," F-16.net, undated.

¹⁴ While none of the nations examined in this study possess the Gripen, the recently developed Gripen-E may be competitive on the international market as a platform comparable to the F/A-18E/F Super Hornet, Rafale, and Eurofighter. See, for example, Gerard O'Dwyer, "Industry Bids Are in for Finland's \$13 Billion Fighter Race," *Defense News*, February 1, 2019.

a fourth-generation aircraft, provide advantages for operations in demanding environments. One technology that stands out as highly relevant to the scenarios envisioned by both U.S. and Russian strategists is the active electronically scanned array (AESA) radar. An AESA radar can “detect, track and identify greater numbers of targets much faster and at much longer ranges” than a passive electronically scanned radar (PESA).¹⁵ The resultant situational awareness and ability to defeat multiple threats at the same time makes an AESA capability essential for aspects of high-intensity operations—for example, to intercept cruise missiles. The French decision to procure AESA is informed by the opportunity to provide a 50 percent increase in detection range, including of low-observable targets, and maximize the value of new weapon systems such as the Meteor beyond visual range missile.¹⁶

Aside from the newest increments of France's Rafales, none of the European air forces examined possess fourth-generation aircraft with AESA radars at this time, although reports indicate that both Greece and Turkey have contracted for the capability to be installed on a portion of their F-16 fleets.¹⁷ The fourth-generation-plus aircraft with perhaps the most noticeable gap in this regard is the Typhoon, which is scheduled to operate in the air forces of Italy, Germany, Spain, and the United Kingdom until the late 2030s or beyond.¹⁸ Indeed, these four partner nations invested one billion euros to develop the Captor-E AESA radar, which first flew on a Typhoon in 2007, but none of these nations has placed an order.¹⁹ The United Kingdom and Italy are at least acquiring the F-35, which leaves Germany and Spain with the prospect of a PESA-only fleet lagging behind fellow NATO air forces

¹⁵ Dave Majumdar, “America's F-16 Fighters Are Getting a New Radar (and Russia Is Partly to Blame),” *The National Interest*, June 7, 2017.

¹⁶ Jane's, “France: Air Force,” World Air Forces database, October 31, 2019.

¹⁷ Jane's, “Air Force: Turkey,” Sentinel Security Assessment—Eastern Mediterranean,” October 31, 2019; and Jennings, 2018.

¹⁸ An additional complication is that only Tranche 3 fleets have the requisite cooling and electrical power to retrofit an AESA radar. Additional modifications would need to be made for older versions. “Eurofighter TYPHOON—Moving to Electronically Scanned Radar,” Monch Publishing Group, December 5, 2018.

¹⁹ Giovanni de Briganti, “Eurofighter Looks to Future Improvements but AESA Radar Lags,” *Defense-Aerospace.com*, June 20, 2019.

and less able to contribute to allied operations against a near-peer adversary. For example, this means German and Spanish aircraft will be less effective at detecting and destroying Russian cruise missiles in the air defense role or while performing offensive counter-air missions.

Another aspect of fourth-generation technology to consider is the extent of air-to-ground capabilities resident in NATO air forces. Under the banner of Project Centurion, the UK Royal Air Force has upgraded its Tranche 2 and 3 Typhoon fleets to be suitable for land attack missions with add-ons that include a laser designation capability, the latest-generation Litening III targeting pod, and the integration of new munitions, including the Storm Shadow cruise missile for deep strike. Spain, on the other hand, has dedicated its Typhoons to an air defense role, relying on its F/A-18 fleet for strike, including with the Taurus KEPD 350 long-range cruise missile. Leaving the Typhoons in a specialty air defense role may present certain advantages, including budgetary, but provides less flexibility for high-intensity conflict. Germany falls somewhere in between: according to IHS Jane's, the first Luftwaffe Eurofighter squadron became multirole-capable (with an air-to-ground capability) in 2017, while the timeline for the remaining three squadrons will depend on resource availability.²⁰

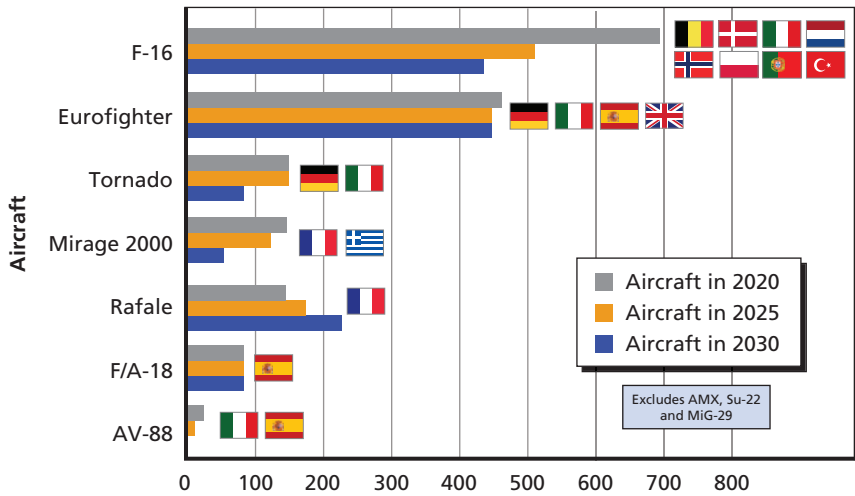
Current and Projected Quantity in Europe

Figure 4.1 provides a breakdown of major combat aircraft systems operated by European allies today, as well as the quantity we project for 2025 and 2030. Quantities shown include aircraft that could be made operationally available in the event of a conflict and exclude systems designed and used exclusively for training. We exclude third-generation aircraft that remain in the Turkish and Greek air forces and also omit Italy's AMX and Poland's Su-22 fleet being retired in 2019 and 2020, respectively.

The 13 European nations examined currently possess 1,700 fourth-generation aircraft, a number that will decrease to 1,500-plus and 1,300-plus by 2025 and 2030, respectively, as F-16s and other systems are phased out and fifth-generation capabilities come online. Important modernization initiatives are underway or expected,

²⁰ Jane's, "Germany: Air Force," World Air Forces database, July 18, 2019.

Figure 4.1
Projected Quantity of Fourth-Generation Aircraft Among European Allies



SOURCE: RAND analysis based on IHS Jane's, *The Military Balance*, interviews, and open source reporting.

including continued procurement of the newest Rafales. The overall number of Typhoons may not change significantly, but less capable Tranche 1s and 2s will gradually be replaced by newer Tranche 3s, though in the case of the United Kingdom, this modernization may not keep up and could result in reduction of overall inventory.²¹ Box 4.1 contains the assumptions that informed our projections for 2025 and 2030.

Outstanding concerns include timelines associated with Germany's aging Tornados,²² including the SEAD-capable ECR variant, and Spain's ability to maintain an F/A-18 fleet suitable for high-intensity operations as well as its plans for replacing the aging AV-8B. Another

²¹ Correspondence with airpower expert, March 2020.

²² Germany has an ongoing fighter competition; depending on the aircraft selected and resources available for air force procurements, the timeline for phasing out Tornados could be accelerated. The F-35 has been eliminated from the competition. Additional Typhoons or the F/A-18E/F Super Hornet remain in contention. Sebastian Sprenger, "Germany Officially Knocks F-35 Out of Competition to Replace Tornado," *Defense News*, January 31, 2019a.

Box 4.1: Assumptions for Calculating Quantity of Fourth-Generation Aircraft

1. Eurofighter-operating nations will gradually phase out Tranche 1 aircraft for newer Tranche 3s (and eventually 4s) and/or upgrade Tranche 2s, though the United Kingdom's overall inventory will decrease by 10 percent.
2. France will continue to operate its legacy Mirage 2000C/5F and older models of the 2000D aircraft until 2025, at which point a steady increase in new Rafales will be introduced into the fleet by 2030. France will not procure additional Rafale M aircraft for its carriers but will upgrade its 40 maritime systems to the highest standard, including with the AESA radar.
3. Italy will maintain its Tornado aircraft through 2025 while Germany will continue with service life extension-type initiatives to keep its fleet operational through 2030.
4. As their F-35s reach final operational capability (FOC) in the mid-2020s, the Netherlands and Norway will phase out F-16s in the mid-2020s while Belgium and Denmark will do so toward the end of the decade.
5. Poland will continue to operate its F-16s beyond 2030, using the F-35 as a replacement for its MiG-29s.
6. Turkey and Portugal will maintain their F-16 fleets through 2030, and Greece will do the same for the majority of its F-16 fleet.
7. Spain will maintain its AV-8Bs while Italy transitions to the F-35B for its maritime STOVL capability.
8. Spain will maintain its F/A-18 fleet through 2030 with service life extension-type initiatives.

area of high interest to the development of NATO's joint airpower capabilities concerns plans for Turkey's indigenous aircraft industry and Ankara's consideration of the Russian-made Su-35 aircraft as a follow-on to its controversial purchase of the S-400 air defense system.²³

Fifth-Generation Aircraft

Technology

Fifth-generation aircraft—for Europe, only the F-35²⁴—distinguish themselves through a range of features that enable operations in highly contested environments against near-peer adversaries possessing a web of integrated air defenses that would almost assuredly overwhelm fourth-generation platforms. Low observability, or stealth, gained through the airframe's unique shaping and specialized material coatings make it more difficult for opposing radars to detect, track, and engage the aircraft. Minimizing the aircraft's signature also relies on technologies that mask the heat and electronics emissions from subsystems, such as the engine and avionics components.

Stealth is coupled with enhanced maneuverability and an array of self-protection and radar-jamming capabilities that enable the aircraft to penetrate air defenses with a lower likelihood of detection, complete a mission, and survive for a period of time in the opponent's weapons engagement zone.²⁵ These capability enhancements, though, tell only part of the story. The revolution inherent in fifth-generation technology, particularly in the case of the F-35, stems equally as much from advances in computers, sensor suites, and data links.²⁶

Onboard sensors and specialized software allow an individual F-35 to combine many sources of information to detect, characterize,

²³ Burak Ege Bekdil, "Turkey, Russia in Negotiations for Potential Su-35 Jet Deal," *Defense News*, October 28, 2019.

²⁴ The so-called fourth-generation-plus systems such as the newest increments of the Rafale, F/A-18E/F, and Gripen-E could be considered as incorporating aspects of fifth-generation capabilities.

²⁵ Deborah Lee James and Daniel Goure, *The Implications of Fifth-Generation Aircraft for Transatlantic Airpower: A Primer*, Washington, D.C.: Atlantic Council, October 2019, p. 3; and Marrone and Nones, 2019, p. 19.

²⁶ The other Western fifth-generation aircraft, the F-22, is currently fielded only by the United States. Its comparative advantage over the F-35 is in air-to-air engagements, while the F-35 provides unique ISR capabilities.

and localize enemy emitters and aggregate results into an electronic map of the battlefield on a near-instantaneous basis.²⁷ Sharing data among a flight of F-35s through the Multifunction Advanced Data Link (MADL), a low probability of intercept communications link that enables the aircraft to pass data securely, offers the potential to provide an individual pilot with “a far greater situational awareness than a commander in a CAOC [combined air operations center] relying on inputs from various dedicated ISR assets” operating outside the range of enemy air defenses.²⁸ This ISR functionality enables targeting at unprecedented speed and scale, although, critically, the F-35 does not necessarily need to be the shooter. The F-35’s design includes the NATO-standard Link 16 system to transmit data to fourth-generation aircraft, naval systems, or ground forces, which in turn can fire on targets from standoff ranges, though this approach could be susceptible to electronic interference.

Current and Projected Quantity in Europe

As depicted in Figure 4.2, we show that the seven F-35-acquiring European nations will receive between 350 and 450 fifth-generation aircraft, all F-35s, by the end of this decade. This figure includes aircraft that will be based in the United States for training, as well as testing and experimentation. Based on current inventories and our understanding of future plans, each F-35 nation will maintain anywhere from two to approximately ten aircraft for these purposes, and because of geographic proximity, they would remain unavailable during a conflict in the European theater. We therefore project between 300 and 400 F-35s in Europe by the end of 2030.

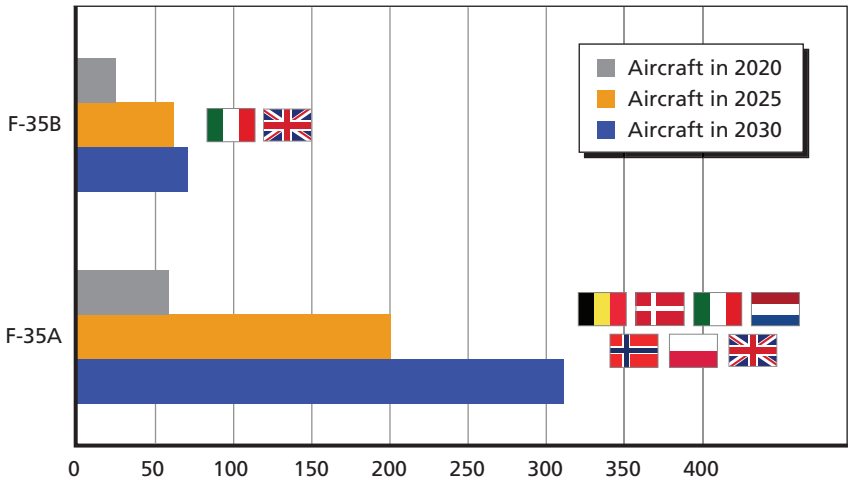
Of our assumptions listed in Box 4.2, the most aggressive may be the United Kingdom’s acquisition of 90 F-35A aircraft by 2030. If the Royal Air Force sees a reduction in the quantity of aircraft procured, or the acquisition takes until the early- to mid-2030s to complete, our lower-bound projection of 350 would be the most likely number of F-35s in European inventories by 2030.

An additional consideration for military planning centers on the quantity of F-35Bs that comprise the total: between 20 and 40 percent,

²⁷ Lee James and Goure, 2019, p. 4.

²⁸ Bronk, 2016, p. 3.

Figure 4.2
Projected F-35 Quantities Among European Allies by Variant



SOURCE: RAND analysis based on IHS Jane's, *The Military Balance*, interviews, and open source reporting.

Box 4.2: Assumptions for Calculating Quantity of Fifth-Generation Aircraft

1. Belgium, Denmark, Italy, the Netherlands, and Norway will procure the number of aircraft stated in their defense plans and do so on or close to currently projected schedules.
2. Poland will proceed with a recently announced purchase of 32 aircraft and acquire these by 2030.
3. The United Kingdom will procure its initial 48 F-35Bs per its defense plan and in line with the projected FOC of 2025. The UK government will then select the F-35A for an additional 90 aircraft with an initial operational capability (IOC) in 2025 and FOC in 2030.
4. Turkey will no longer participate in the F-35 program.
5. No other European nations will acquire the F-35.

depending on the year examined. STOVL functionality and the ability to operate from ships requires inherent system trade-offs: While the F-35B can operate on carriers and use shorter runways, it has a smaller weapons bay and less fuel capacity than the F-35A, limiting its range without aerial refueling. More broadly, in a conflict, F-35Bs will to one extent or another also be required for defense of the aircraft carriers and amphibious ships from which they operate, meaning potentially fewer sorties available for strategic attack and counter-land operations.²⁹

Notwithstanding the caveats about training aircraft in the United States and the dual-purpose nature of the F-35B variant, European forces will possess a sizable capacity of fifth-generation aircraft. Indeed, Italy, the Netherlands, Norway, and the United Kingdom already maintain an inventory of approximately 90 F-35s, a majority of which reside in squadrons that are or will soon be operational. Given Russian concerns about this capability, even a limited quantity may offer an important contribution to deterrence as European nations increasingly demonstrate capabilities, although readiness, as explored in the next two chapters, will influence the extent of any such effect.

Munitions

European air forces generally possess highly capable munitions, though with some capability gaps in select national inventories and, as detailed in Chapter Five, variation in terms of quantity of available stockpiles needed for a major conflict.³⁰

Current Air-to-Air Missiles

Europe's air forces maintain an array of short-range, beyond visual range, and standoff range (generally at least 100 km) air-to-air missiles.

With the exception of France, European air forces possess the active radar-guided Air Intercept Missile-120 AMRAAM, or AIM-120, the most ubiquitous beyond visual range weapon of its kind in Western

²⁹ Based on discussions with U.S. and NATO airpower experts, we would expect that the counter-IADS mission at the beginning of a conflict, because of its importance to a notional campaign, would involve a large proportion of F-35s in the theater. As operations progressed, the F-35B would likely be needed in support of maritime roles.

³⁰ Unless otherwise mentioned, all information in this section is derived from Jane's and IISS, *The Military Balance 2019*.

inventories and compatible with nearly every fourth-generation aircraft and the F-35.³¹ Most nations have upgraded to the AIM-120C-7, which incorporates a significant redesign with a new antenna, receiver, and hardware and software changes to counter emerging threats.³² The French-made *Missile d'Interception de Combat et d'Autodéfense* (MICA) provides a similar capability for Mirage-2000s and Rafales while the Meteor beyond visual range air-to-air missile (BVRAAM) does the same for the UK Royal Air Force.

For short-range air-to-air employment, the infrared-guided (IR) AIM-9 Sidewinder I and imaging infrared-guided (IIR) AIM-9X Sidewinder II are widely operated in Europe, fitting most fourth-generation aircraft and, in the case of AIM-9X, the F-35. Most nations have acquired the AIM-9X Block 2, which incorporates lock-on-after-launch (LOAL) technology and a data link that enables engagement beyond visual range. Similar options include the French-made R550 Magic-2, AIM-132 advanced short-range air-to-air missile (ASRAAM) operated by the United Kingdom; and the more widely proliferated IRIS-T. The MICA also functions within visual range. Table 4.1 provides an overview of current air-to-air munitions by nation.

Current Air-to-Surface Missiles

The AGM-64 Maverick is a widely proliferated PGM for close air support and air interdiction missions, with most air forces operating an AGM-64D or newer versions capable of operations in night and adverse weather. The French AASM and UK's Brimstone II offer similar capabilities.³³ The United Kingdom and Netherlands possess

³¹ The AIM-120-C and later versions fit on the F-35. As mentioned previously, the AMRAAM also functions in an air defense role as part of NASAMS, with an extended range (ER) version in development.

³² To our knowledge, Belgium and the United Kingdom are the only European nations to have acquired the newer AIM-120D with a potentially longer range. Turkey and Spain also maintain the AIM-7 Sparrow, a predecessor to the AMRAAM categorized as having a semi-active radar homing capability lacking a fire-and-forget capability.

³³ Center for Strategic and International Studies, "Brimstone," 2019. The dual-mode Brimstone incorporates a semi-active laser seeker reportedly more capable in missions with fast-moving and maneuvering targets. The French AS-30L is an older, short-range, laser-guided missile.

Table 4.1
Air-to-Air Missiles in Current European Inventories

Missile	Type	Origin	BEL	DEU	DNK	ESP	FRA	GBR	GRC	ITA	NLD	NOR	POL	PRT	TUR
AIM-120A/B AMRAAM	Active radar	USA	X	X	X	X			X	X	X	X			X
AIM-120C/D AMRAAM	Active radar	USA	X		X	X		X	X				X	X	
AIM-7E/P Sparrow	Semi-active radar	USA				X									X
AIM-9B-S Sidewinder	IR guided	USA	X	X	X	X		X	X	X	X	X	X	X	X
AIM-9X Sidewinder II	IR guided	USA	X		X						X	X	X		X
AIM-132 ASRAAM	IIR guided	GBR						X							
Meteor BVRAAM	Active radar	GBR				X		X							
IRIS-T	IIR guided	DEU		X		X			X	X		X			
MICA IR	IIR guided	FRA				X			X						
MICA RF	Active radar	FRA				X			X						
R550 Magic 2	IR guided	FRA				X			X						
Shafrir	IR guided	TUR													X

SOURCES: International Institute for Strategic Studies, Military Balance +, database, as of November 13, 2019; Jane's, Air-Launched Weapons, database, as of November 13, 2019. Excludes Russian-made legacy systems still operated by Poland. Only Turkey still maintains the AIM-120A and is the only nation without the AIM-120B/C/D other than France. Only Belgium and the United Kingdom have the AIM-120D.

the shorter-range AGM-114 Hellfire, widely used for anti-armor and targeted strikes and inclusive of a fire-and-forget feature in the more recent variants acquired by this pair of air forces.

For ranges that exceed 100 km, counter-land operations capabilities are limited to fewer nations. Derived from the Harpoon anti-ship missile, the AGM-84 SLAM-ER (Turkey) offers a standoff range of up to several hundred kilometers.³⁴ The Apache AP, SCALP-EG, and Storm Shadow (UK, France, Italy, Greece) are a family of closely related cruise missile systems, with the latter two having reported ranges of 400 km.³⁵ This group of cruise missiles was designed in part to degrade or eliminate adversary runways. The Taurus KEPD 350 (Germany, Spain) provides a similar capability and has been cited as a particularly effective munition for targets in deep bunkers and/or under reinforced concrete.³⁶ Finally, as part of the Polish air force's modernization program, Warsaw has acquired the AGM-158B JASSM-ER designed to penetrate sophisticated air defenses and attack targets at ranges of approximately 1,000 km.³⁷

Five nations possess the AGM-88 HARM (Germany, Italy, Spain, Greece, and Turkey), critical for executing SEAD missions. Finally, France has a cruise missile in support of its strategic nuclear mission. Table 4.2 summarizes current air-to-surface missiles in Europe.

Current Bombs

European nations possess modern bombs as well as older versions retrofitted with guidance kits and other upgrades. Table 4.3 details national inventories.

³⁴ Only France, Portugal, and Greece maintain anti-ship missiles in the form of the Harpoon and French-made Exocet.

³⁵ Center for Strategic and International Studies, "APACHE AP/SCALP EG/Storm Shadow/SCALP Naval/Black Shaheen," Missile Threat database, last modified June 15, 2018.

³⁶ Franz-Stefan Grady, "South Korea to Develop Air-Launched Indigenous Long-Range Bunker Buster Cruise Missile," *The Diplomat*, July 12, 2018.

³⁷ Center for Strategic and International Studies, "JASSM and JASSM ER," Missile Threat database, last modified July 18, 2019b.

Table 4.2
Air-to-Surface Missiles in Current European Inventories

Missile	Type	Origin	BEL	DEU	DNK	ESP	FRA	GBR	GRC	ITA	NLD	NOR	POL	PRT	TUR
AASM	Precision guided	FRA					X								
AGM-114K Hellfire	Precision guided	USA						X			X				
AGM-158 JASSM-ER	Cruise	USA											X		
AGM-65A-J Maverick	Precision guided	USA	X		X	X			X		X		X	X	X
AGM-84A Harpoon	Anti-ship	USA												X	
AGM-84K SLAM-ER	Precision guided	USA												X	
AGM-88 HARM	Anti-radiation	USA		X		X			X	X					X
AM39 Exocet	Anti-ship	FRA					X		X						
Apache AP	Cruise	FRA					X								
AS-30L	Laser homing	FRA					X								
ASMP-A	Nuclear cruise	FRA					X								
Brimstone	Active radar homing	GBR						X							
Brimstone II / Dual Mode	Active radar homing	GBR						X							
KEPD 350 Taurus	Land attack Cruise	USA		X		X									
Popeye I	Cruise	ISR													X
SCALP-EG/Storm Shadow	Land attack Cruise	GBR					X	X	X	X					

SOURCES: International Institute for Strategic Studies, Military Balance +, database, as of November 13, 2019; Jane's, Air-Launched Weapons, database, as of November 13, 2019. Excludes Russian-made legacy systems still operated by Poland.

Table 4.3
Bombs in Current European Inventories

Bomb	Type	Origin	BEL	DEU	DNK	ESP	FRA	GBR	GRC	ITA	NLD	NOR	POL	PRT	TUR
AGM-154A/C JSOW	Inertial/satellite guided	FRA							X						X
BPG-2000	Laser guided	USA				X									
Enhanced Paveway II	Laser guided	USA					X			X					
GBU-10/12/16/58 Paveway II	Laser guided	USA	X			X	X	X	X		X				
GBU-22/24/27 Paveway III and Enhanced Paveway III	Laser guided	USA	X	X	X	X	X	X	X	X	X				
GBU-24 Paveway IV	Laser guided	USA						X							
GBU-31/32/38 JDAM	Inertial/satellite guided	USA	X	X	X				X		X			X	
GBU-39 Small Diameter	Precision guided	FRA	X												
GBU-48/49/50 Enhanced Paveway II (EGBU-10/12/16) and DMLGB	Laser guided	FRA		X	X	X			X		X			X	
GBU-54 Laser JDAM	Laser guided	FRA	X	X											
GBU-8B HOBOS	Electro-optically guided	FRA							X						X
MAM-L/C	Laser guided	GBR													X
Paveway I	Laser guided	GBR													X
Paveway II	Laser guided	USA						X							X

SOURCES: International Institute for Strategic Studies, Military Balance +, database, as of November 13, 2019; Jane's, Air-Launched Weapons, database, as of November 13, 2019. GBU-54 Laser JDAM includes standard and dual mode.

Munitions for Fifth-Generation Aircraft

F-35-fitting missiles include the AIM-120C AMRAAM, AIM-9X, and, for the United Kingdom, the AIM-132 ASRAAM. Bombs include the GBU-31/32 JDAM, GBU-12, and several small diameter bombs (SDB). Future munitions for operations on the F-35 include the AGM-154 JSOW, AGM-158 JASSM and JASSM-ER, and Storm Shadow. Several munitions remain in development, with the most notable and promising being the Joint Strike Missile (JSM), a derivative of the Norwegian-made Naval Strike Missile, a low-observable, air-launched precision missile for land and sea targets. The JSM has been tested on F-16s, has an IOC date of 2023, and will be compatible with select fourth-generation aircraft and the F-35. Additionally, a new HARM missile is expected as part of the U.S. Navy's Advanced Anti-Radiation Guided Missile-Extended Range (AARGM-ER) program.³⁸ Italy and Germany have contracts in place for AARGM-ER, and Poland is expected to follow.³⁹

Planned upgrades to enable the F-35 to fire the new SDB II will further enable the aircraft's anti-armor mission. Improved sensors allow the bomb to track and hit targets under variable conditions and at greater distances. Lighter than many other air-dropped bombs, eight SDB II bombs will fit on the inside of an F-35, allowing them to be carried without compromising the aircraft's stealth properties.⁴⁰

One additional consideration that will inform how nations develop operating concepts relates to how the F-35, in its stealthy, long-range mode, carries fewer munitions than most fourth-generation aircraft. For example, while most fourth-generation platforms can carry eight AMRAAM missiles, F-35 internal bays carry four.⁴¹ External ordnance may be added as part of its shorter-range, higher-payload

³⁸ Ryan Pickrell, "The F-35 Stealth Fighter Is Getting a Very Long-Range Missile That Can Blind an Enemy's Air Defenses," *Business Insider*, July 24, 2019.

³⁹ For an excellent overview of this capability, see Jakub Palowski, "AARGM Missile for Italy and Germany. NATO Rebuilds Its Anti-Radiation Capabilities," *Defense24.com*, 2016.

⁴⁰ Kris Osborn, "F-35: Soon to Be the Ultimate Tank-Killer?" *The National Interest*, November 22, 2017.

⁴¹ Kyle Mizokami, "The F-35 Is About to Enter Beast Mode," *Popular Mechanics*, September 19, 2019.

mode but this makes it more likely the aircraft would be detected. Recent work to reduce the size of air-to-air missiles may provide fifth-generation platforms with more firepower when in stealth mode, although it is unclear that similar progress has been made for air-to-surface missiles.⁴² The U.S. Department of Defense has also contracted for F-35 weapons bay modifications to allow the aircraft to carry “aft heavy weaponry,” likely including the AARGM-ER.⁴³ Foreign customers have reportedly supplied about 20 percent of the funding for this modification program.⁴⁴

Implications of Evolving Force Structure and Technology

Figure 4.3 depicts the mix of fourth- and fifth-generation aircraft anticipated among the European allies in 2020, 2025, and 2030. What could this evolving combat air force structure indicate about European capabilities to carry out key missions in a high-intensity conflict? What are some of the anticipated limitations?

The early days of a conflict with Russia would immediately challenge NATO's ability to project power into an A2/AD environment in order to eliminate IADS, limit the ability of ground forces taking Alliance territory, and pave the way for subsequent operations. In this regard, European F-35 acquisition could fundamentally alter allied concepts of operations for collective defense air operations against Russia. Justin Bronk of the Royal United Services Institute (RUSI) artfully describes two concepts of operation for employing the aircraft:

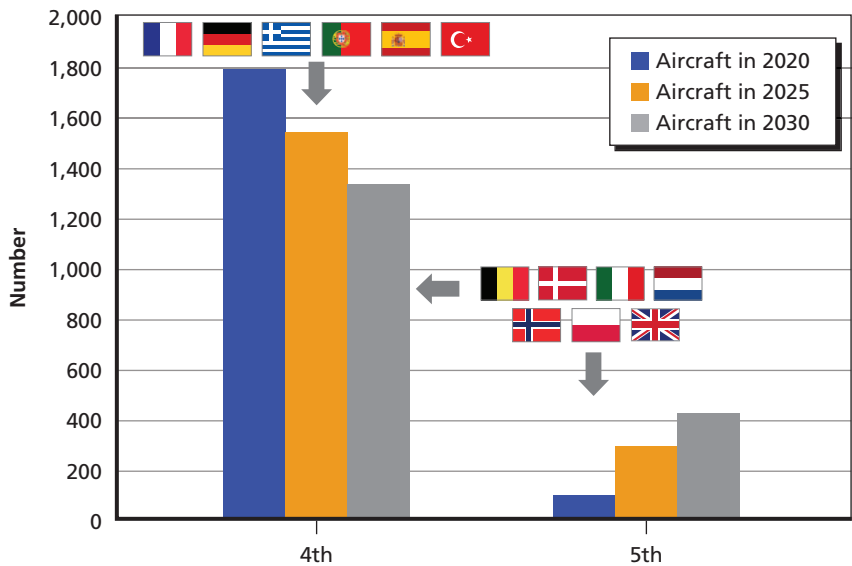
- In the “**alone-and-unafraid** mode,” the F-35 can serve as an “advanced aircraft that will be able to perform the traditional role of a tactical strike fighter more effectively than ever before.” This mode enables operational persistence with limited reliance on links to air operations centers and intelligence collection and

⁴² Mizokami, 2019.

⁴³ Steve Trimble, “F-35 Mod Adds New Missiles to Weapons Bay,” *Aerospace Daily and Defense Report, Aviation Week Network*, July 23, 2019.

⁴⁴ Trimble, 2019.

Figure 4.3
Projected Fourth-Fifth Generation Mix of Aircraft Among European Allies



SOURCE: RAND analysis based on IHS Jane’s, *The Military Balance*, interviews, and open source reporting.

battlespace management aircraft. It would limit the amount of firepower allies can deliver given the small number of F-35s.

- In the “**combat ISR**” mode, a four-ship flight of F-35s connected by MADL generates situational awareness and shares targeting data with legacy platforms that can then fire their payloads from outside the range of the most capable of the enemy’s air defenses. For maximum effectiveness, this mode requires secure, high-bandwidth communication links between the F-35 and other air and joint systems.⁴⁵ This concept of operation has the advantage of increasing the available firepower, assuming the communication links are available.

⁴⁵ Bronk’s full title for the second mode is “combat ISR asset first and strike asset second.” Bronk, 2016, pp. 2–3. The two concepts, of course, are not necessarily mutually exclusive and a commander’s selection will depend on scenario-specific factors as well as alternative concepts of operation informed by the F-35 variant that a given nation elects to acquire: the F-35A conventional takeoff and landing; F-35B STOVL; F-35C carrier variant; or a mixed fleet.

The alone-and-unafraid concept offers an important though evolutionary set of enhancements. Stealth technologies could permit the F-35 to engage in air interdiction and close air support missions within some of the areas covered by Russian air defenses with greater survivability than their fourth-generation counterparts. Within this concept, missions might also include, for example, the delivery of modern anti-armor munitions against advancing adversary tanks.⁴⁶ Reduced reliance on centralized command and control would permit the F-35 to operate in the context of a degraded communications environment expected in a conflict with Russia. However, the platform's ability to fly strategic attack missions deep in adversary territory would likely be constrained by its reduced firepower under stealth as well as refueling requirements that would leave fuel tankers vulnerable to air defense salvos.⁴⁷

Ultimately, the combat ISR functionality holds the promise of a more revolutionary capability by enhancing the combat potential of an air formation as a whole. The F-35's sensor fusion function, allowing it to combine data from onboard and off-board sensors into an integrated picture, provides an unprecedented view of the battlefield. If communication links with sufficient bandwidth are established in a secure manner, targeting information can be passed to fourth-generation aircraft as well as assets belonging to navies and armies.⁴⁸ These links would improve the ability of fourth-generation aircraft to operate from outside the threat of Russian air defense systems with standoff capabilities such as SCALP or Storm Shadow cruise missiles. Highly networked communications could also enhance the survivability of fourth-generation assets, allowing the F-35 aircraft to identify—and if necessary defeat—airborne threats.⁴⁹ To succeed, this concept requires close, dynamic

⁴⁶ David Ochmanek, Peter A. Wilson, Brenna Allen, John Speed Meyers, and Carter C. Price, *U.S. Military Capabilities and Forces for a Dangerous World: Rethinking the U.S. Approach to Force Planning*, Santa Monica, Calif.: RAND Corporation, RR-1782-1-RC, 2017.

⁴⁷ Jerry Hendrix, *Filling the Seams in U.S. Long-Range Penetrating Strike*, Center for a New American Security, September 10, 2018.

⁴⁸ For more on developments on communication links, see Bronk, 2016.

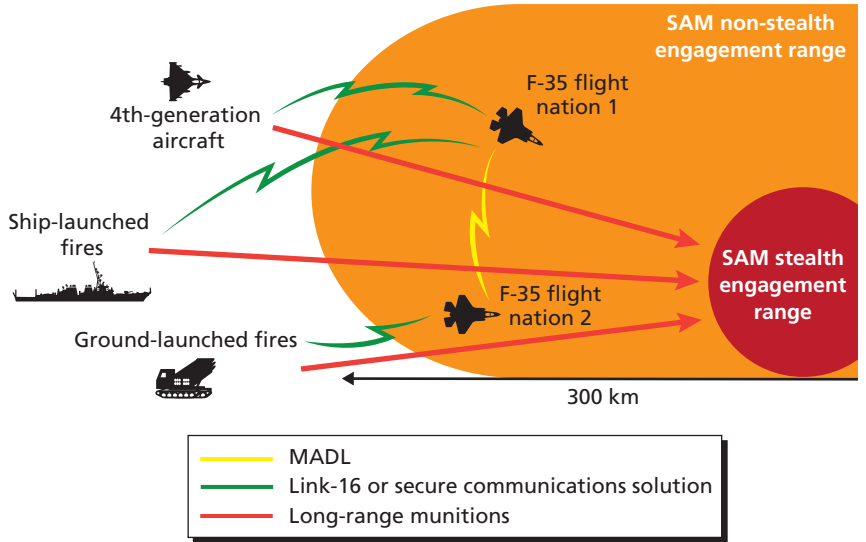
⁴⁹ U.S. Air Force, "Hill AFB Airmen, F-35 a Lethal Combo at Red Flag," press release, 388th Fighter Wing Public Affairs, February 19, 2019.

collaboration across a combat formation, necessitating reliable communications links as well as operator familiarity with combined operations. Figure 4.4 offers a notional concept of operations for the combat ISR role. The concept bears resemblance to Russian fears of highly networked forces massed to execute a debilitating series of strikes early in a campaign.

In light of Russian investments in advanced air defense systems, the SEAD mission stands out as one of the critical elements for the opening hours and days of a campaign. Nations are procuring fifth-generation aircraft such as the F-35 in part to obtain a credible SEAD capability against advanced SAMs at the onset of hostilities.

Fourth-generation aircraft also offer SEAD capabilities for situations short of when the most threatening portion of an adversary’s IADS network remains functional. Several experts highlighted that “not

Figure 4.4
Notional F-35 Combat ISR Concept of Operations



SOURCE: Adapted from Justin Bronk, *Maximum Value from the F-35: Harnessing Transformational Fifth-Generation Capabilities for the UK Military*, Whitehall Report 1-16, Royal United Services Institute, February 2016.

all SEAD is the same.” Based on our research we have disaggregated SEAD into three levels:

- **Level 1 SEAD** occurs in the early hours and days of a campaign in the face of the most advanced integrated air defenses. This mission can be accomplished by fifth-generation aircraft able to survive inside the weapons engagement zone, although fourth-generation and joint assets positioned on the outside will be critical to ensuring enough fires are massed. Other methods in consideration by several air forces include using swarming UAVs for targeting coupled with ground-based fires.
- **Level 2 SEAD** takes place against shorter-range SAMs and long-range SAMs that are not fully integrated as the conflict progresses and the adversary's IADS are degraded. This mission could be accomplished by EW-capable combat aircraft such as the Tornado ECR (and potentially future Typhoons) firing anti-radiation missiles.
- **Level 3 SEAD** applies to isolated SAMs expected on the battlefield after the majority of IADS are destroyed or degraded. This level of SEAD could be performed by fourth-generation-plus aircraft, at least for discreet periods of time within zones of interest. Advanced technologies such as AESA radar could very well be required to offer commanders an acceptable level of risk.

In addition to SEAD, defensive counter-air will be an important mission area for European air forces as they seek to protect populations, infrastructure, and key NATO and national facilities from adversary attacks using theater strike weapons such as air- and ground-launched cruise missiles. Under these circumstances, commanders would need to balance the use of their fleets across missions to ensure survival of bases. Ground-based air defenses such as NASAMS are projected for some nations but not all. And defenses against salvos of ballistic missiles are limited, at least in the near term. For defensive counter-air missions outside the threat range of Russian IADS, the F-35 offers few relative advantages to advanced fourth-generation fighters. The Eurofighter, for example, is highly capable co-air platform that would likely perform

well against comparable Russian aircraft, particularly as the Typhoon begins to carry the Meteor beyond visual air-to-air missile.⁵⁰ In 2020, the U.S. Air Force National Guard will upgrade 22 F-16 fighters with AESA radar, reportedly in order to counter Russian cruise missiles.⁵¹ The bulk of the defensive counter-air mission could be conducted by legacy fighters in conjunction with GBAD systems.

Across combat air missions, a major consideration centers on the degree to which F-35-acquiring nations elect to develop their air forces for the alone-and-unafraid configuration versus the combat ISR mode. To maximize the impact of the overall fleet of aircraft, combined training that integrates fourth- and fifth-generation capabilities will be critical, as well as secure links and stockpiles of long-range precision missiles that can allow fourth-generation platforms to strike from outside the air defense range. Additionally, even with the F-35's low observability, dispersal concepts will need to be developed and resourced.⁵²

Conclusion

This study's focus is on combat aircraft and the missions most likely to be at the center of a collective defense scenario involving Russian aggression. It does not argue that other joint airpower roles are irrelevant or of lesser value. Indeed, mobility, ISR, and specialized aircraft for electronic warfare and C2 also constitute foundational requirements for a major war. Other essential capabilities include space assets and unmanned aerial vehicles. For European allies, to one extent or another, these capabilities represent well-recognized shortfalls: the United

⁵⁰ Dave Mujamdar, "Dogfight to the Death: Russia's Su-35 vs. Eurofighter Typhoon (Who Wins?)" *The National Interest*, September 9, 2019.

⁵¹ Theresa Hitchens, "Air National Guard F-16s First to Fly Fifth-Gen Radar," *Breaking Defense*, January 9, 2020.

⁵² For an overview of distributed operations in contested environments, see Miranda Priebe, Alan J. Vick, Jacob L. Heim, and Meagan L. Smith, *Distributed Operations in a Contested Environment: Implications for USAF Force Presentation*, Santa Monica, Calif.: RAND Corporation, RR-2959-AF, 2019.

States would need to provide a preponderance of capability across the other joint airpower roles.

But that is not a new dilemma. What is new is the promise of fifth-generation technology. The approximately 300 to 400 aircraft positioned in Europe have the potential to change Moscow's COFM calculus and enhance deterrence. Should deterrence fail, European combat air forces will be better positioned to provide leading-edge counter-air and attack capabilities—fighting, that is, at the vanguard.

Available Platforms and Munitions

During a high-intensity theater conflict against Russia, time would be of the essence, and the ability of European aircraft already in theater to rapidly engage in combat would be critical. Fifth-generation platforms capable of operating within the range of an advanced SAM threat would be particularly significant at the vanguard of a response, while a critical mass of fourth-generation aircraft and their superior firepower could hold adversary ground forces, air defenses, and other key targets at risk.¹ Potential cruise missile threats to NATO and national bases and infrastructure would further necessitate aircraft for defensive counter-air missions across NATO airspace.²

This chapter addresses the factors influencing availability of fourth- and fifth-generation aircraft and munitions within European air forces. It identifies ways in which high operational tempos, maintenance requirements, and spare parts shortages can serve as limiting factors on platform availability and addresses emerging sustainment challenges associated with the integration of fifth-generation capabilities into the collective NATO fleet. Noting the depletion of national munitions stockpiles during 2011 operations in Libya, this chapter details steps taken by NATO members to replenish and modernize their stockpiles for future combat requirements. It concludes by considering the implications of platform and munitions availability for European allies' ability to contribute to a NATO collective defense operation.

¹ Bronk, 2016.

² NATO, "Conversation with NATO Secretary General Jens Stoltenberg at the Brussels Forum," interview, last updated August 29, 2019.

Maintaining Existing Fleets

Although several allies are phasing out their fourth-generation fighters over the course of the next decade, many of these aircraft will remain in active inventories and comprise the core of the Alliance's capability into 2025 and beyond. Indeed, by 2030, fifth-generation aircraft will only make up about approximately 30 percent of the total inventory of the 13 European nations examined. In addition, many of these existing platforms suffer from maintenance and sustainment challenges. It will be important for allied governments to ensure combat air fleets are maintained at a level that would allow for prompt and meaningful availability.

The percentage of available combat platforms can be a sensitive question. For the United States Air Force, which publishes high-level readiness figures annually, overall aircraft "mission capable" rates dropped from 77 percent in 2012 to 70 percent in 2019, despite initiatives from senior U.S. defense leaders to halt the slide.³ Table 5.1 identifies the mission-capable rates of select U.S. combat aircraft in fiscal year 2017.

The U.S. Department of Defense distinguishes between "mission capability," which measures the percentage of time that aircraft are safe to fly and able to perform at least one tasked mission, and "full mission capability," which measures the percentage of time for which aircraft are fully capable of accomplishing all tasked missions.⁴ In October 2018, then Secretary of Defense Jim Mattis mandated a minimum of 80-percent mission capability rates for U.S. critical aviation platforms by 2019, a goal that has not yet been attained.⁵

Most European allies do not systematically publicize the availability or mission capability of their combat platforms. In the land

³ Stephen Losey, "Aircraft Mission-Capable Rates Hit New Low in Air Force, Despite Efforts to Improve," *Air Force Times*, July 26, 2019b.

⁴ U.S. Government Accountability Office, *F-35 Aircraft Sustainment: DoD Needs to Address Substantial Supply Chain Challenges*, GAO-19-321, Washington, D.C.: GAO, April 2019, p. 12, figure 4.

⁵ Aaron Mehta, "Mattis Orders Fighter Jet Readiness to Jump to 80 Percent—in One Year," *Air Force Times*, October 9, 2018.

Table 5.1
Mission-Capable Rates of Select U.S. Combat
Aircraft in Fiscal Year 2017

Aircraft	Percent Mission Capable
A-10	74
B-52H	72
F-16C	70
F-22	49
F-35	55

SOURCE: Adapted from Stephen Losey, "Fewer Planes Are Ready to Fly: Air Force Mission-Capable Rates Decline amid Pilot Crisis," *Air Force Times*, March 5, 2019a.

domain, one study suggests that many European militaries would have difficulty making 30–50 percent of their overall ground forces available for deployment within six months and posits a 50-percent unit availability rate for analytical purposes, with equipment shortfalls being a key driver.⁶ In the air domain, several public governmental reports and senior leader statements provide snapshots of the parameters of platform availability across the Alliance. Few of these sources identify mission capability rates, instead addressing aircraft availability in more general terms.

The United Kingdom's RAF maintains one of the higher rates of overall platform availability. Like the United States, the United Kingdom provides public reporting on its aircraft maintenance and sustainment. According to one British Freedom of Information report, about 67 percent of the overall RAF fleet was operational in 2018, with similar availability for its Eurofighter Typhoon inventory.⁷

⁶ Douglas Barrie, Ben Barry, Lucie Béraud-Sudreau, Henry Boyd, Nick Childs, and Bastian Giegerich, *Defending Europe: Scenario-Based Capability Requirements for NATO's European Members*, International Institute for Strategic Studies, April 2019.

⁷ According to Freedom of Information reports, "142 of the RAF's 434 aircraft have been taken off the flight line or are undergoing major maintenance," and "55 of the 156 Typhoon jets are in the RAF's 'sustainment fleet'—and not in its 'forward fleet' ready to be deployed on operations." Ben Glaze, "A Third of RAF Planes Were in Storage or Maintenance as Air Force Celebrated Its Centenary," *The Mirror*, January 3, 2019.

Germany's Luftwaffe has recently improved from what were reportedly among the lowest availability rates in the Alliance. According to a 2018 document provided to the German parliament, an average of only 30 percent of Germany's combat fleet was available for operations or training.⁸ In July 2018, Lt Gen Ingo Gerhartz, the Luftwaffe chief of staff, described his service as "at a low point," with aircraft frequently grounded due to a lack of spare parts or off-site in industry maintenance.⁹ Since that time, prioritization of readiness within Luftwaffe leadership has addressed maintenance delays and spare parts supplies to improve the availability of Germany's Typhoon fleet.¹⁰ Aircraft not scheduled for routine maintenance or upgrades were available at rates that ranged between 62 percent and 70 percent on any given day in August 2019.¹¹ The aging Tornados most likely have lower rates.

As of 2017, the French Ministry of Defense cited a 44-percent overall aircraft availability rate, down from 55 percent in 2000.¹² To address this gap, the French government invested in a new aeronautic maintenance department that has begun centrally coordinating all service contracts across the French air force.¹³

Poland's F-16 fleet lies on the higher end of the European air force availability spectrum. A 2017 Polish parliamentary report suggested

⁸ The parliamentary report cites 39 of Germany's 128 Eurofighter Typhoon jets and 26 of 93 Tornado fighters as available for combat or training. Justin Huggler, "German Air Force Unable to Train Pilots Because of Shortage of Planes," *The Telegraph*, August 5, 2019; and Chase Winter, "Only 4 of Germany's 128 Eurofighter Jets [Are] Combat Ready—Report," *Deutsche Welle*, February 2, 2018.

⁹ Dan Goure, "Germany's Choice for a Tornado Replacement Could Undermine NATO," *Defense News*, July 6, 2018.

¹⁰ German Ministry of Defense, *Bericht zur Materiellen Einsatzbereitschaft der Hauptwaffensysteme der Bundeswehr 2019* [Report on the Material Readiness of the Main Weapon Systems of the Bundeswehr], November 2019.

¹¹ Telephone interview with European airpower expert, December 2019. About a third of the Typhoon fleet is scheduled for maintenance at any given time.

¹² Pierre Tran, "France Creates Office to Improve Military Aircraft Readiness," *Defense News*, December 12, 2017. In December 2017, the French Defense Minister lamented that 56 percent of French military aircraft were unfit to fly at any given moment. Rory Mulholland, "Ground Force: Half of France's Military Planes 'Unfit to Fly,'" *The Telegraph*, December 16, 2017.

¹³ Tran, 2017.

that about 85 percent of the Polish F-16 fleet was combat ready.¹⁴ Poland's newer fleet of 48 F-16C/Ds, received in 2006, had flown about only 15 percent of the aircraft's total lifetime by 2017.¹⁵ However, Polish legacy Soviet MiG-29A and Su-22 airframes have significantly lower availability levels because of long-standing maintenance challenges.¹⁶

Public statements about readiness rates need to be considered with a measure of caution. One U.S. military analyst, writing in 1989, observed that "not mission capable" figures reflect peacetime safety and performance criteria, as well as restrictions on cannibalization of other aircraft that would be ignored during wartime.¹⁷ Thus readiness levels that are at 50 or 60 percent in peacetime might, for a limited time, be as high as 80 percent during wartime.¹⁸ Similarly, some of the European experts engaged during the course of this study observed that even if platforms were technically coded as unavailable for combat and reflected as such in public reporting, air forces such as Germany's Luftwaffe would most likely be able to muster a sizable air contingent in an Article 5 scenario, albeit not necessarily capable of executing the most-demanding mission sets.¹⁹ Still, even if militaries take drastic measures in the initial stages of combat, lower mission-capable levels are an important indicator of overall readiness.

Four factors that contribute to aircraft availability are aging platforms, spare parts, operational tempos, and constrained budgets.

Aging Platforms

Within many European air forces, the increasing strain of maintaining legacy platforms limits aircraft availability. For Italy, the mounting

¹⁴ Jacek Siminski, "Polish Parliamentary National Defense Committee Discusses the Future of the F-16s and Prospects of Acquiring 5th Gen. Jets," *The Aviationist*, March 28, 2017.

¹⁵ Siminski, 2017.

¹⁶ Jane's, "Poland: Air Force," September 13, 2019.

¹⁷ James Garrett, *The Tenuous Balance: Conventional Forces in Central Europe*, New York: Taylor & Francis, 1989.

¹⁸ Garrett, 1989.

¹⁹ Interview with airpower expert, June 2019.

costs and limitations imposed by the availability of an aging and varied fourth-generation fleet represented a major consideration during the F-35 acquisition decision process.²⁰ One 2012 analysis stated that within the Italian fleet, “160 old aircraft, such as the AMX fighter-bombers, the Tornados, and the Harriers, all [would] need to be replaced by 2025–2030, as they will not be able to perform their assigned tasks in a cost-effective way.”²¹ The variety of platforms used by the Italian air force has increased the relative costs of maintenance, upgrades, and repairs as compared with a more homogenous fleet.²² Italy began phasing out its older platforms such as the AMX in 2019 and will proceed with retiring the Tornado and Harrier over the coming five years.²³

Germany's Tornado ECR (21 aircraft in current inventory), which entered service in 1983 and provides the Luftwaffe's SEAD capability, has similarly faced mounting sustainment costs. In April 2019, the German Ministry of Defense estimated that it would take nearly nine billion euros to keep its 93 Tornado jets flying until 2030.²⁴ German officials have noted that the retirement of the UK's Tornado fleet and Italy's plan to phase out its Tornados by 2025 could significantly increase sustainment costs, although discarded platforms might temporarily offer a new source of spare parts.²⁵ While Germany continues to prioritize SEAD in doctrine, the availability of German Tornado ECRs to conduct SEAD is likely to wane over the course of the next

²⁰ In 2007, “the unavoidable and progressive technical and operational obsolescence, the unbearable increase in maintenance costs and the exhaustion of the structural fatigue life . . . dictate the replacement of the current fleet starting from 2014–2015.” F. Giunchi, “L’aeronautica militare e il JSF,” *Rivista Aeronautica*, No. 1/2006, p. 44, as cited in Michael Nones, Giovanni Gasparini, and Alessandro Maronne, “Europe and the F-35 Joint Strike Fighter Program,” Istituto Affari Internazionali, *Quaderini IAI*, No. 16, July 2009.

²¹ Alessandro Marrone, “Italy and the F-35: Rationales and Costs,” *International Journal*, Vol. 68, No. 1, 2012.

²² Marrone, 2012.

²³ Jane's, “Italy: Air Force,” World Air Forces database, June 10, 2019.

²⁴ Reuters, “German Defense Minister Wants Quick Decision on Tornado Replacement,” September 23, 2019.

²⁵ Sebastian Sprenger, “Germany Fears Steeper Tornado Costs After UK Ditches Its Planes,” *Defense News*, April 13, 2018.

decade. Germany is currently assessing options for a new SEAD-capable aircraft, including an ECR-variant Typhoon and EA-18G Growler derivative of the F/A-18E/F Super Hornet.²⁶

Although the several-decades-old F-16 fleets of the Netherlands, Denmark, Norway, and Belgium will continue to operate during the transition to the F-35, governments have expressed concerns about the costs of keeping these platforms operational. In 2012, Dutch analysts forecasting the costs of maintaining the fleet anticipated that “an increasing maintenance workload . . . [and] greater need for repairs will make the aircraft less available for exercises and operational deployment, and operating costs will increase.”²⁷ Of the three F-16 squadrons in the Dutch fleet, 1.8 squadrons worth of aircraft are considered mission capable.²⁸ Norway’s F-16 fleet, with each plane having been flown on average over 10,000 hours, has been the first to begin the phase-out in 2019.²⁹ Norway may keep up to half of its F-16 fleet as a maintenance pool through the aircraft’s projected end of life in 2023 and has experienced two fleet-wide groundings in recent years.³⁰

Finally, the aging of Greece’s Dassault Mirage 2000-5 multirole fighters and F-4E Phantoms over the 2020s will lead to their retirement, with no clear plan for their replacement.³¹ Of Greece’s F-16 fleet, 80 C/D models will receive upgrades. An undetermined number of the remaining models will be modernized in Greece, while others will be sold.³²

²⁶ Gareth Jennings, “Airbus Presses for German Tornado Decision to Meet Electronic Attack Requirements,” *Jane’s Defence Weekly*, November 27, 2019d.

²⁷ Ministry of Defence and Ministry of Economic Affairs, Agriculture, and Innovation, *2010 Annual Report on the Replacement of F-16s Project*, House of Representatives, 2010–2011 Session, 26 488, no. 258, The Hague: Sdu, as cited in Algemene Rekenkamer, *Monitoring the Replacement of the F-16 Fleet*, The Hague: Sdu, 2011, p. 51.

²⁸ Jane’s, “Netherlands: Air Force,” October 9, 2019.

²⁹ Aaron Mehta, “As F-35 Comes Online, Norway to Scrap F-16 Fleet,” *Defense News*, January 27, 2017.

³⁰ Jane’s, “Norway: Air Force,” World Air Forces database, December 5, 2019.

³¹ Jane’s, “Greece: Air Force,” March 27, 2019.

³² Jane’s, “Greece: Air Force,” March 27, 2019.

Spare Parts

Spares shortages within the multinational Eurofighter program (UK, Germany, Spain, and Italy) have at times had adverse effects on Typhoon readiness: A 2011 UK National Audit Office report on the Eurofighter program declared “shortages of spares and long timescales for equipment repairs on some of these contracts” and noted the need to cannibalize parts from some of the fleet’s Typhoons to make others usable.³³ The contracts were amended in 2012, although the RAF reportedly continued to use parts from its Typhoon sustainment fleet to optimize aircraft availability through 2015.³⁴ To further address the problem of spares shortages, in 2016 the RAF adopted a new national management approach for its Typhoon fleet that identifies and prioritizes spare part “choke points” that might drive costs, delays, and maintenance burdens.³⁵

Spare parts supply chains have also challenged the Spanish and German Eurofighter fleets. In 2014, the Spanish press reported that only six Eurofighters within Spain’s QRA were at that time capable of taking off, due to breakdowns, spare parts shortages, and long inspections wait times.³⁶ Media reports in April 2018 indicated that nearly the entire German Typhoon fleet was temporarily grounded, with only

³³ National Audit Office, “Management of the Typhoon Project,” United Kingdom, March 2, 2011, p. 6; Comptroller and Auditor General, United Kingdom National Audit Office, “Ministry of Defence: Management of the Typhoon Project,” House of Commons 755 Session 2010–2011, London, March 2, 2011; and House of Commons, Committee of Public Accounts, Management of the Typhoon Project, Thirteenth Report of Session 2010–2012, London, HMSO, April 15, 2011.

³⁴ Mark A. Lorell and James Pita, *A Review of Selected International Aircraft Spares Pooling Programs: Lessons Learned for F-35 Spares Pooling*, Santa Monica, Calif.: RAND Corporation, RR-999-AF, 2016, p. 18; and Ben Glaze, “RAF Butchers Four Typhoon Jets Worth £500m for Spare Parts to Keep Warplanes Flying,” *The Mirror*, December 2015.

³⁵ Robbin Laird, “The Coming of TyTan: The UK Works Its Typhoon Sustainment Strategy,” *SLDInfo.com*, June 2, 2018. This report describes “physically organized parts by a red, amber, or green characterization. The various suppliers had been organized into support cells rather than being located into isolated industry cells; and the support cells were directed towards prioritization on repairs. Red being the priority parts needed right now by the fleet; amber within a few days; and green as not urgent.”

³⁶ Steve Thallantyre, “Most Spanish Eurofighter Jets Can’t Fly: Report,” *The Local*, October 27, 2014.

ten of the Typhoons considered combat ready because of a temporary shortage in a component required for the Typhoon's self-protection system.³⁷ Subsequently, a November 2019 German parliamentary report highlighted the stabilization of spare parts supplies as a key factor in improving aircraft availability.³⁸

Operational Tempo

For a number of European allies, high operations tempos have increased maintenance costs and equipment wear beyond anticipated levels.³⁹ Currently operating beyond its doctrinal level of ambition, the French air force continuously deploys an average of 20 combat aircraft in operations in the Sahel to counter the Islamic State.⁴⁰ In 2017, the French Defense Ministry reported an 80-percent availability of aircraft for overseas operations but acknowledged that this prioritization had forced the services to cut training flight time and reduce aircraft availability for domestic operations.⁴¹

A 2019 review of the RAF concluded that the current operations tempo is "eroding the RAF's current and future readiness" and undermining its ability to contribute to a collective defense scenario.⁴² Heavy use of RAF platforms has shortened their service lives: In 2009, the RAF was using its Eurofighters at about twice the rate of other

³⁷ Winter, 2018; and Andrea Shalal and Susan Fenton, eds., "Germany Confident Eurofighter Supplier Issue Can Be Resolved Soon," Reuters, May 2, 2018.

³⁸ "German Ministry of Defense, 2019.

³⁹ Jane's, "France: Air Force," October 31, 2019. OPTEMPO measures the rate of military unit activity. According to the U.S. Congressional Research Service, "Tempos are too high/low if they are causing forces to lose their capacity to sustain operations and meet crises . . . the most significant negative impact of tempos that are too high is the reduction in time and resources for relevant, necessary training, the basis of readiness and long-term effectiveness." Congressional Research Service, "Military Readiness, Operations Tempo (OPTEMPO), and Personnel Tempo (PERSTEMPO): Are U.S. Forces Doing Too Much?" Washington, D.C. January 14, 1998.

⁴⁰ Jane's, "France: Air Force," October 31, 2019.

⁴¹ Tran, 2017.

⁴² Mark Gunzinger, Jacob Cohn, Lukas Autenried, and Ryan Boone, *Towards a Tier One Royal Air Force*, Center for Strategic and Budgetary Assessments, March 29, 2019, p. 42.

aircraft.⁴³ The German Ministry of Defense also reported that the increased tempo of German training missions and deployments since Russia's 2014 intervention in eastern Ukraine has increased the strain on existing equipment.⁴⁴ Other allies have similar dilemmas as they try to maintain national and NATO commitments while arranging for a sufficient training and exercise schedule.

Budget Constraints

Ultimately, limited defense budgets prompt difficult decisions about internal prioritization, as air forces seek to introduce new equipment while maintaining the availability of existing platforms. A 2019 report critiquing the RAF could well have been written about many of NATO's air forces. Budget constraints, it argues, have left the RAF unable to meet current operational requirements while also maintaining a sufficient level of readiness to respond quickly to a major security crisis and modernizing to prepare for future challenges.⁴⁵

One possible indicator of sufficient investment in readiness, including equipment availability, is the percentage of defense funds allocated to operations and maintenance. Although inexact and by itself insufficient, this metric provides a rough indication of a defense establishment's priorities as it makes trades across its operations and maintenance, personnel, procurement (including research and development), and infrastructure accounts. Figure 5.1 compares overall defense budgets with each nation's operations and maintenance spending across all services and domains. Although publicly available information in this regard remains limited, a further and service-specific analysis of spending trends could yield additional insights on platform availability and broader combat air readiness challenges.

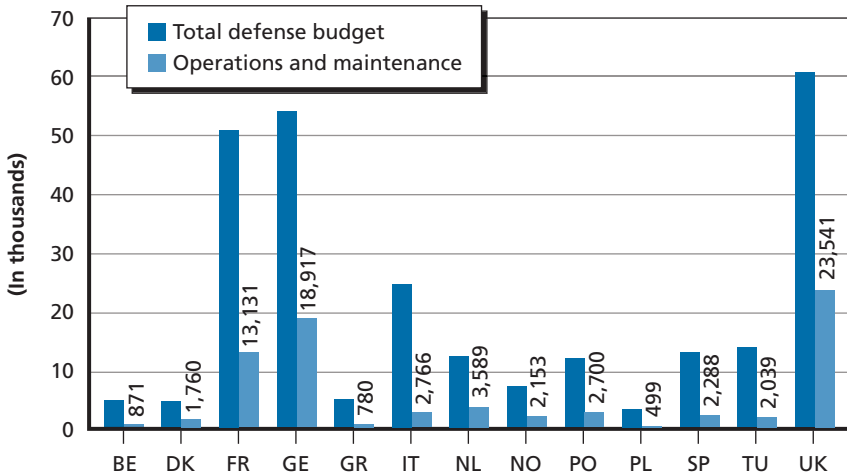
Larger defense budgets could ease the pressure on this juggling act to the extent air forces receive their share of any increases. In the

⁴³ Gunzinger et al., 2019; and Andrew Doyle, "UK Looks to Extend Eurofighter Typhoon's Fatigue Life," *FlightGlobal*, August 26, 2009.

⁴⁴ George Allison, "German Air Force Hosts Multinational Air Exercise," *UK Defense Journal*, March 2, 2019a.

⁴⁵ Gunzinger et al. 2019, p. ii.

Figure 5.1
European Military Operations and Maintenance Budgets in 2019



SOURCE: Based on data from NATO, "Defence Expenditure of NATO Countries (2013–2019) Communiqué," NATO Public Diplomacy Division, November 29, 2019, tables 2 and 8A. The 2019 figures represent NATO estimates and prices and exchange rates as of November 2019. Military Operations and Maintenance budget category includes all expenditures not dedicated to equipment, personnel, or infrastructure.

meantime, particular attention will need to be devoted to some of the common availability challenges identified in this chapter—including aging platforms, spare parts pipelines, and operational strain. These fleets, which comprise the quantitative bulk of NATO's air forces, will need to be maintained to ensure adequate availability rates even as national expenditures are dedicated to acquiring and operationalizing new platforms such as the F-35. As indicated above, the availability of combat aircraft varies significantly among allies, among platforms within a national fleet, and even over time as spare parts shortages, upgrades, or other maintenance difficulties temporarily reduce overall combat readiness. However, if European ministries of defense sought to maintain an average of 70 percent of their combat air fleets at mission-capable status—the level of the U.S. Air Force at the recent nadir of its platform availability—this could improve Europe's contribution to deterrence.

Maintaining Future Fifth-Generation Fleets

As seven European air forces transition to the F-35, maintenance of fifth-generation fleets presents new challenges. Aircraft availability has been problematic for the United States, the primary F-35 user. According to a Department of Defense report, less than half of the U.S. Air Force's 148 F-35s were mission capable in 2018.⁴⁶ As of April 2019, this number was 53 percent.⁴⁷ The 80 percent mission-capable objective set by Department of Defense leadership included the F-35. To meet this objective by September 2020, the F-35 Joint Program Office announced in May 2019 a strategy that included improving supply chain performance by increasing repair capability and accelerating depot repair and material delivery, accelerating modifications and retrofits, and optimizing plans for unit-level maintenance.⁴⁸ Implementation of each of these approaches could help to improve F-35 availability rates over time, but as of November 2019, U.S. defense officials continued to criticize the program, stating that the "operational suitability of the F-35 fleet remains at a level below service expectations. . . . For all variants, aircraft are breaking down more often than planned and taking longer to fix."⁴⁹ Four key issues that will dictate F-35 readiness are global sustainment, global spare parts, logistics information, and operations and maintenance (O&M) costs.

Global Sustainment

For European F-35 partners, sustainment will be facilitated by the introduction of regional maintenance and sustainment centers. This approach creates a new paradigm in which Italian F-35 pilots must

⁴⁶ Stephen Losey, "Aircraft Mission-Capable Rates Hit New Low in Air Force, Despite Efforts to Improve," *Air Force Times*, July 26, 2019b.

⁴⁷ U.S. Government Accountability Office, 2019.

⁴⁸ Department of the Air Force, Presentation to the House Armed Service Committee, Tactical Air and Land Forces Subcommittee, Washington, D.C., May 2, 2019.

⁴⁹ Anthony Capaccio, "Stealthy Lockheed F-35 Breaks Down Too Often, Pentagon Says," Bloomberg, November 13, 2019.

rely on Dutch mechanics to service their aircraft, and vice versa.⁵⁰ In 2018, Italy opened the first F-35 airframe final assembly and check-out (FACO) facility in Europe with an air vehicle depot in Cameri, Italy, which will also support sustainment.⁵¹ The Netherlands will serve as a European maintenance, repair, overhaul, and upgrade (MRO&U) sustainment hub, and in 2019 opened a multi-use F-35 European Regional Warehouse for F-35 spares.^{52,53} The United Kingdom will offer MRO&U services for avionics and aircraft components.⁵⁴ Norway is also slated to provide F-35 sustainment capabilities.⁵⁵ Turkey had been slated to produce over 900 parts for the F-35, but with its pending removal from the program, the parts will initially be sourced from the United States.⁵⁶ This approach, known as the Global Support Solution (GSS), is intended to provide worldwide availability of parts and repairs for F-35 partners. It represents a fundamentally new concept: traditionally, repairs and upgrades are facilitated through the U.S. Foreign Military Sales (FMS) process in a hub-and-spoke approach with the United States at the center.

During a theater conflict, geographic versatility for service and maintenance could mean that a given air force is not anchored to one operating location. Increasing agility and mobility can compli-

⁵⁰ Michele Nones, Giovanni Gasparini, and Alessandro Marrone, "Europe and the Joint Strike Fighter Program," Istituto Affari Internazionali, *Quaderini IAI*, No. 16, July 2009.

⁵¹ Sean J. Stackley and Christopher C. Bogdan, Testimony Before the House Armed Services Committee, Washington, D.C., March 23, 2016. Stackley was at the time assistant secretary of the U.S. Navy; Bogdan served as an F-35 program executive officer.

⁵² Lockheed Martin, "The Royal Netherlands Air Force First Operational F-35 Rolls Out," press release, January 30, 2019.

⁵³ Department of the Air Force, Presentation to the House Armed Service Committee, Tactical Air and Land Forces Subcommittee, Washington, D.C., May 2, 2019.

⁵⁴ Gary Schaub Jr. and Hans Peter H. Michaelsen, *Integrating the F-35 into Danish Defence*, Centre for Military Studies, University of Copenhagen, November 19, 2018, p. 12.

⁵⁵ Stackley and Bogdan, 2016.

⁵⁶ John A. Tirpak, "Lord: U.S. to Take Over Turkish F-35 Parts; Pentagon Targets IP Theft," *Air Force Magazine*, August 26, 2019b.

cate adversary responses.⁵⁷ For this reason, allies engaged in “Ample Gain” aircraft cross-servicing events during the Cold War in an effort to ensure that allied aircraft could be “combat turned” at any NATO base.⁵⁸ During a summer 2019 theater security package (TSP) event, U.S. F-35s were cross-serviced at Orland Air Force Base in Norway and at Marham RAF Base in the United Kingdom.⁵⁹ These events were significant and perhaps provided a first step toward a modern-day version of Ample Gain. However, participating nations would need to make a dedicated commitment to developing and retaining appropriately skilled maintenance staff to ensure that cross-servicing would offer a viable option for allied F-35 fleets.

Global Spare Parts

The F-35 program has also introduced the Global Asset Management (GAM) system for pooling of spare parts. Under typical arrangements, each country purchases its own spare parts. A new architecture in which the F-35 Joint Program Office manages a pool of spare parts, to be distributed globally via regional centers, is intended to lower costs compared with the existing hub-and-spoke approach.⁶⁰ Currently, parts continue to return to the United States for processing. Figure 5.2 illustrates the current approach to spare parts distribution and compares it with the future vision for the GAM system.

To date, the GAM system's approach has met with regulatory hurdles on both sides of the Atlantic, including regulations restricting import and export activities and international weapon control laws.⁶¹ In 2018, the United States issued revised arms transfers language that streamlined foreign weapons sales, helping to pave the way for a GAM.⁶² The approach currently remains dependent on European

⁵⁷ Telephone interview, European airpower expert, October 12, 2019.

⁵⁸ JAPCC, 2018, p. 101.

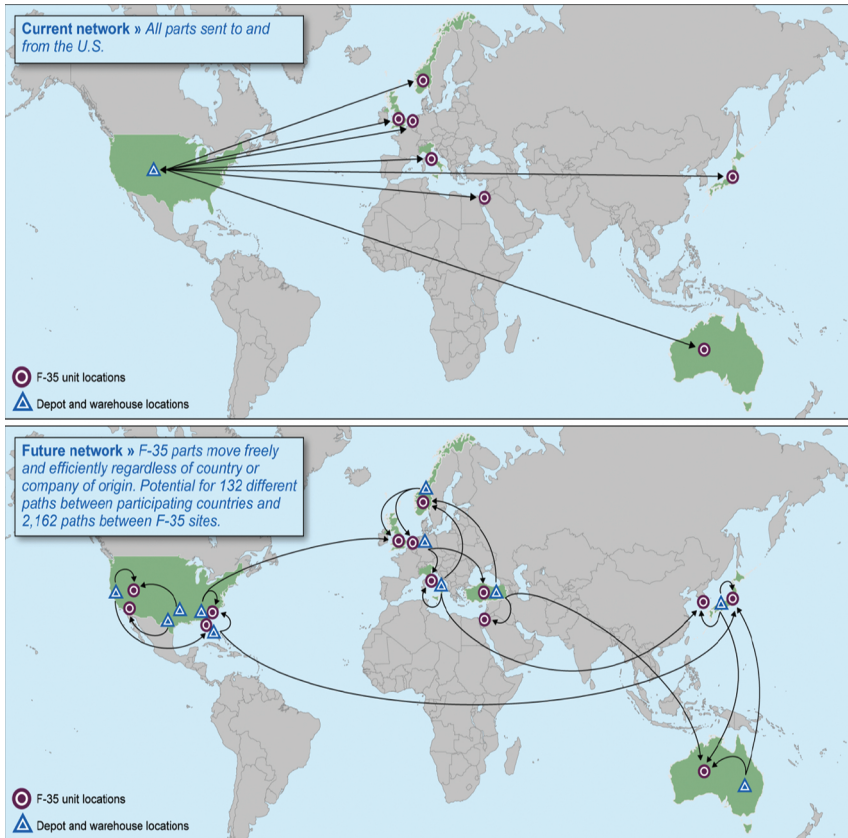
⁵⁹ U.S. European Command, “USEUCOM F-35 Theater Security Package Overview,” unclassified briefing, September 11, 2019.

⁶⁰ Nones, Gasparini, and Marrone, 2009, p. 76.

⁶¹ U.S. Government Accountability Office, 2019, p. 37.

⁶² “United States Conventional Arms Transfer Policy,” U.S. Department of State, fact sheet, April 2018.

Figure 5.2
Global Asset Management System for the F-35



SOURCE: U.S. Government Accountability Office, *F-35 Aircraft Sustainment: DoD Needs to Address Substantial Supply Chain Challenges*, GAO-19-321, Washington, D.C.: GAO, April 2019.

regulatory decisions.⁶³ Notably, European defense analysts have underscored the significance of the European regulatory environment for a global F-35 sustainment system for over a decade.⁶⁴

The timely delivery of spare parts remains a central challenge for the F-35 program: The Joint Program Office has cited spare parts

⁶³ Interview, airpower expert, Washington, D.C., September 11, 2019.

⁶⁴ Nones, Gasparini, and Marrone, 2009, p. 76.

shortages as “the major contributor” to readiness problems.⁶⁵ In May 2019, F-35 program executive Vice Admiral Mathias Winter stated that the Department of Defense (DoD) was “hitting a stagnant plateau with Lockheed Martin because they are 600 parts behind on average: 600 parts not on the production line when I need them.”⁶⁶ As of April 2019, the average time for depot-level repair of an F-35 aircraft part was 188 days, over twice the objective of 60 to 90 days, with a backlog of about 4,300 parts.⁶⁷ A Government Accountability Office (GAO) report critiquing the program concluded that “the F-35 supply chain does not have enough spare parts available to keep aircraft flying enough of the time necessary to meet warfighter requirements.”⁶⁸

Given the ambitious nature of GAM, it is not entirely surprising that spare parts currently represent a limiting factor. A 2016 RAND study highlighted the challenges associated with implementing a spare parts pooling arrangement and implications for the F-35 program. The report noted that for the Eurofighter, “the international spares pooling contracts led to significant shortages of spares for the RAF Typhoons, negatively affecting readiness and availability rates”⁶⁹ In its review of pooling arrangements for aircraft spares, the study found that most historical attempts had foundered on a few key challenges, including

1. stabilizing the supply of spare parts and prioritizing demand
2. configuration control, and how to manage divergence from a common configuration baseline while encouraging innovators
3. managing participants unable or unwilling to pay their agreed share to the spares pooling effort.⁷⁰

⁶⁵ John A. Tirpak, “GAO Hits F-35 Readiness, Blames Parts Pipeline,” *Air Force Magazine*, April 25, 2019a.

⁶⁶ Valerie Insinna, “One of the F-35s Cost Goals May Be Unattainable,” *Defense News*, May 2, 2019a.

⁶⁷ U.S. Government Accountability Office, 2019, Appendix IV: Accessible Data, p. 85.

⁶⁸ Tovey Bachman and Pat Kumashiro, “Why DoD Should ‘Hedge’ Its Approach to Meet F-35 Sustainment Needs,” *Defense News*, July 31, 2019, as cited in U.S. Government Accountability Office, 2019.

⁶⁹ Lorell and Pita, 2016.

⁷⁰ Lorell and Pita, 2016.

The 2016 report cautioned that the F-35 spares pooling program would need to develop comprehensive strategies to address each of these issues to avoid a similar fate.⁷¹ The GAO's more recent assessment suggests that the first issue of security of supply and demand prioritization, at least, remains problematic. In May 2019, the GAO's report noted that fleet-wide spares shortages had strained the program's current approach to prioritizing scarce parts and that comprehensive business rules are needed in order to transparently allocate parts among competing U.S. and international requirements.⁷² More broadly, the GAO report observes that the global network for moving parts is several years behind schedule and highlights the need for a detailed plan with clear requirements to establish the spares network, as well as a way to identify and mitigate the risks of delays.⁷³

Logistics Information

In light of the multinational nature of the F-35 program, concerns about national sovereignty have limited the sharing of information among program partners. The autonomic logistics information system (ALIS) supports F-35 operations, mission planning, supply chain management, and maintenance. In the ideal situation, data provided by ALIS would allow the F-35 Joint Program Office (JPO) and Lockheed Martin to assess aircraft health and anticipate when and where maintenance and spare parts are needed, reducing the time that jets remain on the ramp.⁷⁴ After F-35 partners reportedly threatened to quit the program amid sovereignty concerns about sensitive data, the program offered a new "ALIS Sovereign Data Management" system to foreign partners.⁷⁵ Should this data be too closely guarded, however, it could hinder the management of global F-35 sustainment model. One analyst, recalling the success of sustainment information sharing

⁷¹ Lorell and Pita, 2016, p. 49.

⁷² U.S. Government Accountability Office, 2019, p. 54.

⁷³ U.S. Government Accountability Office, 2019, p. 54.

⁷⁴ Valerie Insinna, "Two F-35 Partners Threatened to Quit the Program. Here's Why They Didn't," *Defense News*, June 12, 2019b.

⁷⁵ Insinna, 2019b.

within the F-16 Multinational Fighter Program, notes that within the F-16, sharing sustainment information from a large number of aircraft has “allowed users to anticipate maintenance issues based upon the experiences of others, analyze the effects of different use patterns, and therefore engage in better fleet management—including extending the life expectancy of the fleet as a whole.”⁷⁶ This approach does not yet appear to have been fully implemented for the F-35 program. Although the F-35 JPO has proposed compiling and distributing information from users about maintenance procedures, staffing requirements, and other key metrics, there is currently no mechanism to share sustainment lessons learned among program partners.⁷⁷

Within the United States, sustainment requirements associated with the program's logistics system itself have received criticism. According to the 2019 GAO report, one U.S. Air Force unit estimated that it was spending the “equivalent of more than 45,000 hours per year performing additional tasks and manual workarounds, including for supply-related functions, because ALIS was not functioning as intended, including missing or corrupted electronic spare parts data that are required to install a part on an aircraft, necessitating extensive research and troubleshooting to resolve.”⁷⁸ In August 2019, the United Kingdom's RAF acknowledged some “short unplanned outages to components or elements of the [ALIS] system” but said that the faults had been addressed and did not significantly impact the F-35 fleet.⁷⁹ The GAO report further notes that ALIS maintenance and supply systems were not communicating with each other, resulting in difficulty in electronically tracking the movements of aircraft parts, limited automated capabilities requiring manual and sometimes duplicative steps for receiving, tracking, and managing

⁷⁶ Gary Schaub Jr., *Learning from the F-16*, Centre for Military Studies, University of Copenhagen, April 2015, p. 12.

⁷⁷ Andrea Shalal, “European F-35 Fighter Jet Users Push to Drive Down Operating Costs,” Reuters, September 10, 2018.

⁷⁸ U.S. Government Accountability Office, 2019.

⁷⁹ Tim Ripley, “UK MoD Admits Unplanned Outages of F-35 Support System,” Jane's, August 28, 2019.

parts.⁸⁰ The U.S. Air Force has sought to address this through initiatives such as the Mad Hatter coding effort.⁸¹ While not necessarily atypical for an acquisition of the scope and scale of the F-35, these issues nonetheless pose a challenge in terms of operational capacity, at least until quantities of aircraft in national fleets increase.

Cost of F-35 Operations and Maintenance

Another issue frequently raised regarding U.S. F-35s and likely to also affect European militaries is the high cost per flying hour. According to congressional testimony, operating costs for the F-35 are currently about \$39,000 per flight hour, which the U.S. Air Force seeks to reduce to \$25,000 by 2025.⁸²

Ultimately, cutting costs may require careful balancing to find areas of cost savings without sacrificing the quality of the platform or training. For example, in order to cut operating and maintenance costs, one analysis suggests the use of “less expensive and less experienced pilots for testing” and “less stressful missions such as flying straight and level in good weather conditions instead of high altitude missions in colder weather with lots of maneuvering” to decrease stress on an aircraft and maintain lifespan.⁸³ Although this approach could indeed reduce operating costs, it is potentially problematic because it could risk inadequate testing and requires reduced utilization of what is a new system with advanced capabilities.

Overall, recent approaches to F-35 sustainment and spare parts have the potential to create a more agile, unpredictable allied fleet that could impose additional strains on adversary planning and operations. However, until the growing pains that the new program is experiencing are adequately addressed—including spare parts shortages, logistics

⁸⁰ U.S. Government Accountability Office, 2019.

⁸¹ Rachel S. Cohen, “Mad Hatter Begins Delivering Apps to F-35 Flightline,” *Air Force Magazine*, May 10, 2019.

⁸² Email correspondence with McAleese and Associates, March 10, 2020; Rachel S. Cohen, “JPO Seeks to Slash F-35A Flight-Hour Costs,” *Air Force Magazine*, May 2, 2019.

⁸³ Pat Host, “Barrett Vows to Prioritize Reducing F-35A Cost per Flying Hour,” *Jane’s Defence Weekly*, September 13, 2019b.

system inefficiencies, and maintenance timelines—the low aircraft availability will detract from an otherwise formidable element of NATO's combat air capability.

Replenishing and Maintaining Munitions Stockpiles

In addition to maintaining operationally ready platforms, NATO air forces will also need to continue to invest in munitions stockpiles. While PGM have become the munitions of choice for many NATO countries in recent operations, even the most capable and well-resourced European air forces have continued to face challenges replenishing their PGM stocks while engaged in protracted conflicts abroad.⁸⁴ As noted in Chapter Two, several leading NATO air forces effectively exhausted their weapons supplies in Libya. More recently, European contributions to missions to counter the Islamic State of Iraq and the Levant (ISIL) have further depleted PGM supplies. During the 12-month period after December 2015, the United Kingdom dropped 1,036 Paveway IV bombs and fired over 100 dual-mode Brimstone missiles against ISIL targets in Syria and Iraq.⁸⁵ Precision-guided munitions remain among the top capability priorities for NATO operations.⁸⁶

PGM stockpiles will be driven by a mix of national decisionmaking, the trajectory of multinational initiatives, and European production capacity.

National Decisions to Replenish Munitions Stocks

Since the 2011 Libya operation, many European allies have taken steps to modernize, replenish, and maintain their air-launched munitions

⁸⁴ Barry D. Watts, *The Evolution of Precision Strike*, Center for Strategic and Budgetary Assessments, 2013; Francesco Esposito, "Precision-Guided Munitions of the Future and the Related Challenges to NATO," *Journal of the JAPCC*, Vol. 28, Spring–Summer 2019, p. 29; and P. Taal and V. Tsiamis, *Roadmap and Implementation Plan on Precision Guided Ammunition*, European Defense Agency, March 7, 2012.

⁸⁵ Andrew Chuter, "Paveway IV Leads UK Investment in Munitions Replenishment for Anti-ISIS Fight," *Defense News*, April 13, 2017.

⁸⁶ JAPCC, 2018.

stockpiles. The common decision to invest is likely a product of several convergent factors. At a minimum, allies need to replenish their stocks to sustain current operations. Looking ahead, procurements stand to improve and ensure NATO's combat readiness, a requirement prompted by the renewed concerns about Russian aggression in Eastern Europe and the NATO Readiness Initiative.⁸⁷ Also during this period, developments driven by the NATO Agencies Reform process and the European Defense Agency (EDA) presented many European allies and partners with new ways to more efficiently purchase munitions.⁸⁸

Some European allies have also made noteworthy unilateral purchases and investments, many discussed in Chapter Four. Designed to fill national-level supply gaps, these efforts also aim to reduce Europe's collective dependence on the United States. Europe's MBDA Missile Systems consortium continues to update its missile lines and provide a European source of replenishment of PGM stockpiles after Libya.⁸⁹ Through this mechanism, French PGM stocks were restored to pre-Libya levels by 2013.⁹⁰

Investments in missile inventories require a dedicated national financial commitment: As of 2015, a single Paveway IV bomb cost about \$92,000 and a single Storm Shadow missile cruise missile cost \$1,040,000.⁹¹ The UK Ministry of Defense undertook a major effort to replenish PGM supplies during the counter-ISIL campaign,

⁸⁷ Stephanie Pezard, Andrew Radin, Thomas S. Szayna, and F. Stephen Larrabee, *European Relations with Russia: Threat Perceptions, Responses, and Strategies in the Wake of the Ukrainian Crisis*, Santa Monica, Calif.: RAND Corporation, RR-1579-A, 2017.

⁸⁸ NATO, "NATO Support and Procurement Agency: NSPA at a Glance," NATO Support and Procurement Agency, fact sheet, 2016; and Taal and Tsiamis, 2012.

⁸⁹ Andrew Chuter, "Britain Set to Order Brimstone Missiles, Stocks Still Low After Libya Op," Atlantic Council, January 14, 2013.

⁹⁰ Dave Majumdar, "Does France Have Enough Bombs to Smash ISIS?" *The National Interest*, November 17, 2015.

⁹¹ Royal Air Force, Correspondence describing cost to maintain Tornado GR4 and Lightning II planes, Headquarters Air Command, October 27, 2014; and Gerald Wright, "The Storm Shadow Cruise Missile," *UK Defense Journal*, October 20, 2015. Pounds converted to dollars using December 2019 exchange rates.

including through \$500 million in Paveway IV bombs ordered from Raytheon's joint U.S.–UK program between 2015 and 2017.⁹² Overall, the RAF's 2016 Equipment Plan allocated \$17.8 billion over the course of a decade to weapons procurement, including Brimstone 2 and Storm Shadow.⁹³

Additionally, many allies have made munitions purchases from the United States. Table 5.2 identifies congressional notifications of State Department approval for the possible sale of bombs, air-to-air missiles, and air-to-surface missiles to select European allies since 2011. While it does not provide definitive proof of final purchases, congressional notification usually occurs late in an arms purchase process and thus offers a useful sketch of the scale and types of air munitions requested by European governments.

Multinational Efforts to Replenish Munitions Stocks

Restrictions on the U.S. FMS program, through which NATO members purchase most of their PGM, have presented a perennial challenge for allies seeking to increase their stockpiles.⁹⁴ In 2015, allies collaborated with the United States to create a special legal framework that accommodates third-party purchasing and transfer of battle decisive munitions (BDM). The arrangement expanded the charter of the NATO Support and Procurement Agency (NSPA), the Alliance's main logistics and procurement organization, to include major multinational weapon systems acquisition.⁹⁵ This system is designed to consolidate NATO military requirements and centralize associated logistics management activities while circumventing "slow-moving and

⁹² Hoyle, 2012. Paveway IV was codeveloped by the British and U.S. Raytheon for the RAF, assembled in the United States with parts from the United Kingdom and United States.

⁹³ Commons Select Committee, 2017. Pounds converted to dollars using December 2019 exchange rates.

⁹⁴ Historically, U.S. restrictions on third-country transfers have stemmed from the fact that purchase arrangements are bilateral between an ally and the United States, each with its own set of conditions. Brooks Tigner, "NATO Group Agrees on Joint Purchases of U.S. Guided Bombs," *Jane's Defence Weekly*, December 15, 2016.

⁹⁵ NATO Support and Procurement Agency, "NSPA: 60th Anniversary, 1958–1960," 2018.

Table 5.2
Congressional Arms Sales Notices for European Munitions in 2011–2019

Country	Number	Munition	Type	Year
Belgium^a	N/A	<i>See NATO Support and Procurement Agency</i>	N/A	N/A
Denmark^a	28	AIM-120 C-7 AMRAAM	Air-to-air missile	2018
France	200	AGM-114K1A Hellfire missile	Air-to-surface missile	2015
Germany^b	91	AGM-88E advanced anti-radiation guided missile	Air-to-surface missile	2019
Greece^a	N/A	<i>See NATO Support and Procurement Agency</i>	N/A	N/A
Italy	156	AGM-114R2 Hellfire missile	Air-to-surface missile	2015
	30	GBU-12 laser-guided bomb	Bomb	2015
	30	GBU-49 enhanced joint direct attack munition	Bomb	2015
	30	GBU-49 laser-guided bomb	Bomb	2015
	30	GBU-54 laser joint direct attack munition	Bomb	2015
Netherlands^a	26	AIM-120 C-7 AMRAAM	Air-to-air missile	2019
	26	AIM-120 C-7 AMRAAM	Air-to-air missile	2017
	250	AGM-114R Hellfire II missile	Air-to-surface missile	2017
	240	MK-82 inert low-drag general purpose bomb	Bomb	2013
	90	GBU-12 inert laser-guided bomb	Bomb	2013
	60	GBU-38 inert GPS-guided bomb	Bomb	2013
	28	AIM-9X Sidewinder Block II all-up round missile	Air-to-air missile	2012
Norway^a	60	AIM-120 C-7 AMRAAM	Air-to-air missile	2017
	200	AIM-9X Sidewinder tactical missile	Air-to-air missile	2015
Poland	36	AIM-120 C-7 AMRAAM	Air-to-air missile	2014
	93	AIM-9X Sidewinder Block II tactical missile	Air-to-air missile	2019
	65	AIM-120 C-7 AMRAAM	Air-to-air missile	2019
	42	GBU-49 Enhanced Paveway II bomb	Bomb	2019
	200	GBU-54 laser joint direct attack munition	Bomb	2019
	642	BLU-111 general purpose bomb	Bomb	2019

Table 5.2—Continued

Country	Number	Munition	Type	Year
	127	MK-82 general purpose bomb	Bomb	2019
	80	BLU-117 general purpose bomb	Bomb	2019
	4	MK-84 inert general purpose bomb	Bomb	2019
	150	AIM-120 C-7 AMRAAM	Air-to-air missile	2017
	70	AGM-158 JASSM extended range	Air-to-surface missile	2016
	40	AGM-158A JASSM	Air-to-surface missile	2014
	93	AIM-9X-2 Sidewinder Block II tactical missile	Air-to-air missile	2012
	65	AIM-120 C-7 AMRAAM	Air-to-air missile	2012
	42	GBU-49 Enhanced Paveway II bomb	Bomb	2012
	200	GBU-54 laser joint direct attack munition	Bomb	2012
	642	BLU-111 general purpose bomb	Bomb	2012
	127	MK-82 general purpose bomb	Bomb	2012
	80	BLU-117 general purpose bomb	Bomb	2012
	4	MK-84 inert general purpose bomb	Bomb	2012
Portugal^a	N/A	<i>See NATO Support and Procurement Agency</i>	N/A	N/A
Spain^a	N/A	<i>See NATO Support and Procurement Agency</i>	N/A	N/A
Turkey	145	AIM-120 C-7 AMRAAM	Air-to-air missile	2014
	117	AIM-9X-2 Sidewinder Block II all-up missile	Air-to-air missile	2013
United Kingdom^a	500	AGM-114 N4/P4 Hellfire missile	Air-to-surface missile	2013

SOURCES: Federal Register, National Archives, website, October 2019; Stockholm International Research Institute, Arms Transfers database, October 2019; International Institute for Strategic Studies, *The Military Balance*, 2012–2019.

^a Indicates the country also procured munitions through the NATO Support and Procurement Agency (NSPA).

^b The Government of Germany procured munitions from the United States unilaterally through the NATO Support and Procurement Agency. It is not a participant in the NSPA A2G-PGM project as of November 2019.

NOTE: This table includes only munitions outfitted for fixed-wing combat platforms, with the exception of the Hellfire missile that can be fired from fixed- or rotary-wing aircraft; includes only munitions purchased from the United States and excludes training missiles. Figures report possible arms sales.

regulation-heavy procurement” procedures.⁹⁶ The United States supports this effort under its Lead Nation Procurement Initiative (LNPI) for any U.S.-sourced munitions acquired under the framework.⁹⁷ Recently, this arrangement was modified to include non-NATO members on a case-by-case basis.⁹⁸

The NSPA, acting as “lead nation,” is responsible for the NATO Air-to-Ground (A2G-PGM) project.⁹⁹ Launched in 2014 at the Wales Summit, the project allows participating forces to draw on a common PGM stockpile when in need—for example, during extended air operations or in a crisis.¹⁰⁰ Standardizing NATO’s diverse arsenals has been a challenge since its formation; A2G-PGM is intended to move the Alliance toward a more interoperable weapons inventory.¹⁰¹ As NATO Deputy Secretary General Rose Gottemoeller explained, the A2G-PGM initiative “seeks to address a problem that NATO first encountered during the Libya operation: when some allies ran out of their stockpiles of munitions, they found it incredibly difficult to use those of other air forces. We realized that we needed a new, flexible approach to the provision of air-to-ground precision-guided

⁹⁶ Paul McCleary, “NATO Stocks Up on Bombs, Giving Smaller States More Punch,” *Breaking Defense*, November 5, 2018.

⁹⁷ The LNPI allows for international organizations to serve as the “lead nation” on behalf of other nations in a Foreign Military Sale with the United States. LNPI was created specifically to support NATO’s cost-sharing procurement initiatives. See U.S. Defense Security Cooperation Agency, press release, February 4, 2015.

⁹⁸ NATO Support and Procurement Agency, 2018, p. 9.

⁹⁹ The A2G-PGM project is not the only one of its kind. The NSPA also runs the Land Battle Decisive Munitions (LBDM) project and Maritime Battle Decisive Munitions (MBDM) project, which provide similar services for NATO’s land and maritime forces. The LBDM project currently involves 16 allies and three partner nations; the MBDM project currently involves seven allies and one partner nation. See NATO, “Air-to-Ground Precision Guided Munition,” NATO Support and Procurement Agency, fact sheet, October 2019; Army Technology, “NATO Multinational Projects Attract New Participants,” July 1, 2019; and Nathan Gain, “NATO Countries Sign MoU on Maritime Battle Decisive Munitions Initiative,” *Naval News*, June 27, 2019.

¹⁰⁰ NATO, “Air-to-Ground Precision Guided Munition,” 2019.

¹⁰¹ John Vandiver, “NATO Receives First Lot of U.S. Precision-Guided Munitions,” *Stars and Stripes*, August 24, 2018.

munitions.”¹⁰² Camille Grand, NATO Assistant Secretary General for Defense Investment, similarly highlighted the initiative’s

[S]ignificant amount of flexibility to Allies with regard to sharing their stockpiles of precision-guided munitions. It will further enable the Alliance to address a capability and interoperability gap in this area and support some European allies while reducing reliance on the United States when it comes to air-to-ground operations.¹⁰³

The first attempt at a collective purchase through FMS authorized the NSPA to receive and transfer PGM and Joint Direct Attack Munition (JDAM) guidance kits on behalf of 12 European countries for \$320.5 million.¹⁰⁴ The United States delivered the first Tranche in August 2018, worth \$20 million, and two more are underway.¹⁰⁵ According to a NSPA report, this process has already helped lower the per unit cost by 15 to 20 percent.¹⁰⁶ In addition, the administrative and technical transfer processes that previously took months are now completed in a matter of days.¹⁰⁷ As of November 2019, there are 13 nations participating in the A2G-PGM project, including 12 NATO allies and one partner nation.¹⁰⁸ In June 2019, NATO announced it would expand the project to include air-to-air missiles.¹⁰⁹ And, in the future, “nations might also choose to store their munitions in shared ware-

¹⁰² Tom Dunlop, “NATO Support and Procurement Agency Deliver First Shipment of Precision Guided Munitions,” *UK Defense Journal*, September 6, 2018.

¹⁰³ NATO, “NATO Helps Allies Speed Up Sharing of Weapons,” March 27, 2019.

¹⁰⁴ U.S. Defense Security Cooperation Agency, “NATO Support and Procurement Agency—Precision Guided Munitions,” press release, November 19, 2018.

¹⁰⁵ Dunlop, 2018.

¹⁰⁶ NATO, “Air-to-Ground Precision Guided Munition,” 2019.

¹⁰⁷ NATO, “Air-to-Ground Precision Guided Munition,” 2019.

¹⁰⁸ As of November 2019, the participating NATO members in the A2G-PGM project are Germany, Czech Republic, Greece, Norway, Portugal, Spain, Belgium, the Netherlands, Hungary, United Kingdom, Italy, and Slovakia. The only non-NATO participant is Finland. See NATO, “Air-to-Ground Precision Guided Munition,” 2019.

¹⁰⁹ Army Technology, 2019.

houses, further reducing cost.”¹¹⁰ Overall this initiative represents an important step toward addressing the gaps in PGM inventories identified after the 2011 Libya operations.

European Precision-Guided Munitions Production Capacity

During a longer conflict, indigenous PGM production capacity would prove important as stockpiles were depleted. Even the United States has struggled to sustain stockpiles during longer operations: By the ninth week of Operation Enduring Freedom in 2001, U.S. forces had expended about half of the approximately 10,000 JDAM kits in their inventory.¹¹¹ More recently, a persistently high pace of PGM expenditure between 2014 and 2017 forced the United States to redistribute munitions across combatant commands to meet surging demand in the Middle East.¹¹² Ultimately, a \$2 billion U.S. investment in bomb production stimulated manufacturer output and helped address the shortfall.¹¹³

In 2012, EDA created a roadmap for improving indigenous European PGM production.¹¹⁴ The MBDA consortium, which includes France, the United Kingdom, Italy, Germany, and Spain, provides a European missile production capability, producing the Storm Shadow/SCALP, Brimstone, ASRAAM missiles, among others.¹¹⁵ Although MBDA has bolstered European missile production in recent years, it is unclear whether the continent would have the industrial capacity to produce the PGM levels required for a prolonged high-intensity fight or the ability to coordinate a multinational effort during wartime. In the absence of this capacity, European nations would need to rely on other national producers, such as the United States, for resupply

¹¹⁰ NATO, “Air-to-Ground Precision Guided Munition,” 2019.

¹¹¹ Watts, 2013, p. 23.

¹¹² Mueller, 2015; Paul D. Shinkman, “ISIS War Drains U.S. Bomb Supply,” *U.S. News and World Report*, February 17, 2017.

¹¹³ Shinkman, 2017.

¹¹⁴ Taal and Tsiamis, 2012.

¹¹⁵ MBDA Missile Systems, website, undated.

during a protracted conflict, notwithstanding there are doubts about U.S. capacity to provide enough munitions for U.S. forces during a conflict, let alone allies.¹¹⁶

Conclusion

In recent years, NATO allies—and the United States in particular—have stressed the need to increase spending on defense modernization and acquisition. During this time period, allied air forces have made important military investments in new aircraft and PGM that could prove critical in a major conflict. As this chapter has highlighted, a renewed focus within the Alliance on stockpiling PGM, as well as new arrangements for pooling spare parts and munitions, certainly contributes to a more ready and effective European combat air capability.

The Alliance has also sought to improve the readiness of its armed forces more broadly, including through the NATO Readiness Initiative. This goal also has budgetary implications. As this chapter has indicated, European air forces may struggle to maintain platforms that are strained from rigorous deployment, in need of scarce parts, or nearing the end of their operational life. These challenges all detract from the combat readiness of the aircraft and thus their availability and readiness during a conflict. Addressing this phenomenon requires high-level attention and budgetary commitment. Setting a public goal for fleet-wide, combat-capable status—perhaps at the 70-percent lower bound of recent U.S. Air Force readiness—could provide a tangible objective that would measure the output of platform availability rather than a budgetary input. To help achieve this objective, European allies could also move toward more consistent and transparent readiness information.

Any major conflict with a near-peer adversary would require deep stocks of relevant munitions. NATO has emphasized the need for PGM acquisition over the past two decades and most recently since the 2011 Libya operation. The recent establishment and implementation of the

¹¹⁶ Watts, 2013, p. 23.

A2G-PGM project represents an innovative step in this regard; European governments have also made notable national-level investments to build stockpiles. Allies will need to continue to improve platform and PGM availability levels to more credibly deter a large-scale conflict in the European theater.

This chapter has identified areas for emphasis as Europe strives to improve the availability of its combat air platforms. In particular, spare parts supplies appear to be a significant limiting factor, particularly for the national Eurofighter fleets as well as for the less-established Joint Strike Fighter program: Secure pipelines should be prioritized as a readiness requirement. For the F-35 program, clearer rules for the GAM program would improve the transparency of spare parts allocation while an ongoing overhaul of the ALIS system may enhance efficiencies across the fleet. The program's GSS, which could prove critical during a theater war in Europe, should be thoroughly stress-tested to ensure that a sufficient number of national personnel in each location are able to provide a reliable maintenance and sustainment option for all F-35 users in peacetime or otherwise. More broadly, continued purchases of PGM, whether on a national or multinational basis, will help ensure that stockpiles are sufficient for at least the initial phases of a major conflict.

Overall, this chapter's insights suggest that investments in new platforms such as the F-35 must be balanced with a simultaneous financial commitment to ensuring that European combat fleets remain available and adequately armed should the need arise.

Preparing the Force for Combat Missions

Despite advances in remotely piloted platforms and highly capable weaponry, humans remain essential to the application of airpower, at least for the time frame of this report. Thus, in addition to investments in purchasing and maintaining the necessary aircraft and munitions, air forces must be able to train and retain an adequate pool of personnel prepared to operate piloted platforms and perform high-intensity combat missions. The ability of allied pilots to work together across nations and across platforms is also critical to the collective combat potential of the force. Ideally, integrated training and exercises among fourth- and fifth-generation fighters could prepare pilots to leverage the strengths and mitigate the limitations of each platform. As discussed in Chapter Four, one example could include F-35 pilots flying closer to threats to provide SEAD and to serve as sweep-escort for fourth-generation fighters carrying greater payloads.¹ This chapter first considers current challenges associated with European pilot retention and national measures to address them. It then reviews the state of pilot training and exercises among NATO's European allies, and identifies steps taken in recent years to adapt training and exercises in response to evolving security threats as well as the integration of fifth-generation platforms.²

¹ Osinga, 2016.

² Other factors beyond the scope of this study include similar personnel issues for nonpilots and training for functions such as airfield operations and command and control of large-scale multinational formations.

Maintaining an Adequate Pilot Pool

Across a number of European air forces, budgetary constraints have contributed to shortfalls in personnel, and particularly pilots. As of April 2019, the RAF was reportedly 331 personnel (18 percent) below its pilot needs, following increased fast-jet aircrew requirements in the 2015 SDSR.³ The Dutch air force has identified persistent 6 to 10 percent personnel shortfalls across the Royal Netherlands Air Force (RNLAf), despite recruitment and retention efforts over the past two decades.⁴ Germany's Luftwaffe also reportedly faces understaffing: As of 2017, jet pilot shortfalls stood at 35 percent.⁵ The Spanish air force, which had nearly 40 percent budget cut between 2008 and 2018, has identified an immediate requirement of 5,000 personnel additional across the service.⁶ While this number covers personnel for both current and future missions, including space and cyber defense, Spanish air force leadership has specifically cited pilot shortfalls as an area of concern.⁷ And although the Italian air force is considered to be a "well-trained, combat-ready force," funding pressures have resulted in significant downsizing in personnel as well as total number of aircraft.⁸

For Denmark's Royal Danish Air Force (RDAF), the number of pilots has also been a limiting factor. Until 2007, when the number of operative F-16s was reduced from 60 to 48, Denmark still lacked the pilots to man its fleet.⁹ The number of pilots and aircraft was further reduced following the Danish Defence Agreement for 2013–2017:

³ National Audit Office, "Investigation into Military Flying Training," United Kingdom, September 4, 2019, p. 8.

⁴ Jane's, "Netherlands: Air Force," October 9, 2019.

⁵ German Bundestag, *Information from the Parliamentary Commissioner for the Armed Forces: Annual Report 2017 (59th Report)*, February 20, 2018, p. 22. Only 65 percent of the 235 target for jet pilots was filled.

⁶ NATO Air Power Roundtable, 2019; Jane's, "Spain: Air Force," October 14, 2019.

⁷ Jane's, "Spain: Air Force," October 14, 2019.

⁸ Jane's, "Italy: Air Force," World Air Forces database, June 10, 2019.

⁹ Schaub and Michaelsen, 2018, p 17.

RDAF currently maintains about 50 pilots to man its 30 operational F-16s—a number viewed by the Danish Ministry of Defense as adequate for the Danish level of ambition.¹⁰ The need to retrain existing F-16 pilots to operate the F-35, however, will likely constrain Danish capacity during the transition.

For many air forces, including the RAF, salary levels lower than comparable civilian opportunities have hurt recruitment and retention.¹¹ Recruitment of military pilots by commercial airlines has reduced the ranks. One European air force practitioner noted that while air forces can “maintain and train to the various mission sets that we have, we are stressed on pilot retention. Airlines hire them out: we train them well and because of that, the airlines want military pilots. It’s an easy transition for both parties and is a low cost to the airline because it reduces training requirements.”¹² Low retention because of competition from civilian companies is historically a cyclical consideration: The problem intensifies in a good economy when airlines are hiring and decreases in times of stagnation or recession. While retention seems likely to remain an issue in the near term, it could be less of a problem in an economic downturn.

Some air forces such as the RDAF have sought to address retention challenges through new terms of employment: Danish pilots agree to a longer service commitment after pilot training and receive increased pay to more closely rival civilian pilot salaries.¹³ Within the RNLAf, a retention bonus has had some mitigating impact on Dutch pilot attrition.¹⁴ The British strategy, which prioritizes growing RAF’s front line, has also increased pay while introducing the concept of flexible service to incorporate family and other responsibilities.¹⁵ The RAF, recognizing the likelihood of spousal career concerns, has also

¹⁰ Schaub and Michaelsen, 2018, p. 17.

¹¹ IISS, 2019, p. 86.

¹² NATO Air Power Roundtable, 2019.

¹³ Schaub, 2015.

¹⁴ Interview, European airpower expert, Washington, D.C., June 5, 2019.

¹⁵ NATO Air Power Roundtable, 2019.

encouraged its personnel to be “more domestically settled,” seeking to incentivize stability by avoiding frequent moves for its personnel.¹⁶

In Germany, efforts to create a more attractive work environment and “present the military as a normal company” have perversely created additional bureaucratic hurdles for Luftwaffe pilots. According to one account, the approach has contributed to working-hour rules and regulations incompatible with military training needs. If service members going through combat training would like to exercise longer than mandated, for example, they are prohibited from doing so because of stringent rest requirements.¹⁷ Six Luftwaffe pilots resigned in the first half of 2018, an uptick from 11 resignations over the preceding five years.¹⁸ While some commentators attributed this flux to lucrative opportunities in civil aviation, others argue that it was likely due in part to frustration with onerous bureaucratic regulations.¹⁹

Turkey has a unique personnel challenge among NATO allies: A series of purges following the failed coup attempt in 2017 targeted the Turkish air force and decimated its ranks. According to one report, the purges resulted in the dismissal of 280 pilots, reducing the available pool by nearly 40 percent.²⁰ Although Turkey has since sought to train new pilots and had about 400 by 2018, it will likely take several years to restore combat readiness.²¹

In the context of a potential Article 5 conflict with a near-peer adversary, retention of trained personnel is particularly important. The number of individuals with the skill sets for high-end conflict is finite and would be in demand across the range of operational requirements. Increasingly sophisticated training associated with fifth-generation platforms preparing for multirole missions further compounds the importance of pilot retention.

¹⁶ NATO Air Power Roundtable, 2019.

¹⁷ NATO Air Power Roundtable, 2019.

¹⁸ Volker Witting, “German Air Force Short on Pilots, Not Planes,” *Deutsche Welles*, April 9, 2019.

¹⁹ Witting, 2019; NATO Air Power Roundtable, 2019.

²⁰ Flanagan et al., 2020.

²¹ Flanagan et al., 2020.

Training to Develop and Maintain Combat Skills

The collective skills of an air force's pilots may arguably be as significant to victory as the platforms themselves. As one European military expert recalled, while the inheritance of East German pilots at the end of the Cold War may have nominally increased the ranks of German pilots by several dozen, stark differences in East German training levels limited their ability to contribute.²²

Designing Modern Training Programs

Training often adapts to reflect anticipated operational realities and, in recent years, NATO has shifted to account for different circumstances. Following Allied Force in 1999, NATO air forces adapted air-to-ground strike training from low to medium altitude, reflecting the tactics employed during that conflict in response to Serbian air defense capabilities.²³ Later, as allies engaged in counterterrorism and counterinsurgency operations, close air support skills became increasingly relevant. Today, NATO is adapting to a new security environment that requires a change in mindset from low-intensity operations to the potential for a first-entry mission against a near-peer adversary. As acknowledged in the 2018 JAPS, allied air forces can no longer assume air superiority. Many NATO air forces, therefore, are increasingly prioritizing training preparedness for high-end conflict in which airspace will be highly contested.²⁴

A transition to multirole fighters from aircraft defined by single missions expands the training requirements for any given pilot. In the Danish military, for example, F-16 pilots of the 1980s spent from 70 to 80 percent of training time on air-to-air missions, while in more recent times their successors have spent the majority of their time on air-to-ground.²⁵ Today, most European air forces employ aircraft intended for multiple roles, thus also requiring multirole training for

²² Anrig, 2011, p. 167.

²³ NATO Air Power Roundtable, 2019.

²⁴ NATO Air Power Roundtable, 2019.

²⁵ Schaub, 2015.

their crews.²⁶ As one airpower analyst has noted, multirole crew training poses challenges because pilots “require more total flying hours, and possibly less for each role.”²⁷

Integration of fifth-generation platforms adds further complexity to today's training environment. Some air forces acquiring fifth-generation capabilities are transitioning a portion of their fourth-generation pilots to the F-35 while also seeking to have them maintain existing fourth-generation qualifications.²⁸ This approach is cost-effective: It only takes four months to transition an existing fighter pilot with 500 hours of experience to an F-35, while it takes ten months to train a new one.²⁹ But this risks temporarily overstressing the force: Pilot shortages have historically occurred during periods of aircraft transition.³⁰ Those air forces incorporating fifth-generation capabilities are already taking steps to get fourth-generation pilots accustomed to integrated and complex information flows in order to reduce the time needed to transition pilots.³¹

Rapidly evolving tactics and technologies in the air domain have made near-consistent training particularly critical. While previously pilots serving in nonoperational roles for a year could return to a relatively predictable training syllabus, a gap of even a few months could make it difficult to catch up with evolving TTPs.³² Thus there has been an increased focus among some NATO air forces on maintaining sufficient refresher training to avoid unnecessary repetition later.

While combat pilot training is largely standardized across NATO, some variations occur at the national level.³³ At the entry level, stan-

²⁶ Anrig, 2011, p. 58.

²⁷ Anrig, 2011, p. 58.

²⁸ Schaub and Michaelsen, 2018.

²⁹ Schaub and Michaelsen, 2018, p. 15.

³⁰ Schaub and Michaelsen, 2018, p. 17.

³¹ NATO Air Power Roundtable, 2019.

³² NATO Air Power Roundtable, 2019.

³³ NATO Air Power Roundtable, 2019; interview, European airpower expert, August 27, 2019.

dardization is reinforced by multinational programs such as the Euro-NATO Joint Jet Pilot Training program (ENJJPT), discussed below. As one expert noted, when pilots leave basic training and are assigned to an operational squadron, they will not find national training books on the bookshelf because everyone is training to NATO standards.³⁴

However, some variations occur organically, including the frequency and intensity of training and national prioritization.³⁵ For example, France's extensive operational commitments over the past 15 years have reduced the number of flying hours for preparation in favor of flights in theaters of operation. Additionally, French training missions reflect current operational priorities, including close air support and air interdiction in uncontested environments, possibly neglecting other roles such as counter-air missions.³⁶

Generally, allies seek to synchronize national training materials with NATO even as tactics and technologies progress. For example, when the Italian air force began to update its traditional training syllabus to incorporate advanced fourth-generation or fifth-generation systems, it found that the materials had become too divergent from NATO's and later made revisions to ensure that the training curricula aligned.³⁷ To maintain updated materials, some practitioners have proposed extensive liaison arrangements between those countries integrating fifth-generation capabilities: for example, U.S. personnel could be embedded in Italian units and vice versa.³⁸

Updating Basic Fighter Training

While a few European nations retain a national entry-level training establishment, many NATO fighter pilots pursue their early phase of fighter training through the ENJJPT venue, an international under-

³⁴ NATO Air Power Roundtable, 2019.

³⁵ Interview, August 27, 2019.

³⁶ Tanguy Benzaquen, "New Perspectives for Simulation," in *Air and Space Challenges for French Sovereignty and Freedom of Action*, Paris: Revue Defense Nationale, 2019, p. 179.

³⁷ NATO Air Power Roundtable, 2019.

³⁸ Interview, European airpower expert, August 27, 2019.

graduate pilot training program hosted by the United States at Sheppard Air Force Base (AFB) in Texas. Comprised of 14 partner nations with varying levels of participation, the program includes European and U.S. instructor pilots as well as undergraduate student pilots. Course syllabi and program management are determined by an international steering committee.³⁹ Over half of all U.S. Air Force fighter pilots graduate from the Introduction to Fighter Fundamentals (IFF) course at Sheppard, and five European allies—Belgium, Denmark, Germany, the Netherlands, and Norway—rely solely on ENJJPT to produce fighter-qualified student graduates for their own air forces.⁴⁰ The number of pilots in each class is proportional to each country's financial contribution to the program. Germany, the largest contributor, currently holds the Operations Group Commander position and owns a significant portion of the program's T-38C training aircraft.⁴¹

With over 9,000 square miles of air space and generally suitable flying weather, the program prides itself in being a “world standard for the training and development of tomorrow's next-generation NATO warfighter, while building the trust and friendship that will serve as the foundation in future coalition air operations.”⁴² Today, students in the program's IFF course learn a range of air-to-air and air-to-ground missions, preparing to operate platforms that include the F-16, Tornado, Eurofighter, and now the F-35. As a number of the program's participation countries transition to the F-35, ENJJPT plans to continue emphasizing basic contract flying, including OCA, DCA, and air-to-ground missions. Although recent NATO operations have predominantly employed high-altitude precision strike missions, ENJJPT

³⁹ Soren Neilsen, “Training the Future NATO Pilots,” *FLYMAG Scandinavian Aviation Magazine*, No. 1, February 28, 2018.

⁴⁰ “80th Flying Training Wing Synopsis,” unpublished brief produced by 80th Flying Training Wing Commander's Action Group and Public Affairs, Sheppard Air Force Base, Wichita Falls, Tex., July 1, 2019.

⁴¹ Germany owns 39 T-38C. Operations Group Commander rotates between the Germans, Italians, and the United States. “80th Flying Training Wing Synopsis,” 2019; telephone interview, airpower expert, October 8, 2019.

⁴² “80th Flying Training Wing Synopsis,” 2019.

instructors continue to practice low-level air-to-ground ordnance missions in order to develop the pilot skills needed to operate more effectively amid SAM threats.⁴³

Following guidance from NATO's Supreme Allied Command Transformation, ENJJPT added two virtual reality labs at the program, half simulating a T38 trainer and half simulating a T6. Basic simulators in the dorms also allow students to train and study at their convenience. About half of overall ENJJPT training is virtual, with a heavier emphasis on virtual capabilities in the first phase pilot basics course.⁴⁴

Looking ahead, ENJJPT seeks to update training platforms to better emulate emerging combat air technologies. Specifically, the acquisition of a T-7 training platform would streamline pilot transition to more advanced platforms, including the Eurofighter and F-35, with avionics, data links, blue force tracking, maneuverability, efficiency, and refueling systems that more closely replicate advanced fighters.⁴⁵ Additionally, the program is considering how to grow beyond its current class size to address pilot shortages in the United States and other partner nations.⁴⁶ Table 6.1 shows student throughput in fiscal year 2019.

Italy also serves as a host for international basic flight training, welcoming student and instructor pilots from France, Greece, the Netherlands, Spain, and the United States, as well as other non-NATO nations, at the 61st Wing in Galatina in southern Italy.⁴⁷ The program covers primary pilot training as well as instructor and operational training with a T-346A to prepare pilots to transition to a Eurofighter or F-35. Italy has recently invested in 13 new M-345 jet trainers and seeks to expand its national and international training programs through an International Flight Training School (IFTS)

⁴³ Telephone interview, airpower expert, September 11, 2019.

⁴⁴ Telephone interview, airpower expert, October 8, 2019.

⁴⁵ Telephone interview, airpower expert, October 8, 2019.

⁴⁶ Neilson, 2018.

⁴⁷ "International Flight Training School: First Two M-346 Aircraft Landed into the Italian Air Force's 61st Wing Base," *European Defense Review*, February 1, 2019.

Table 6.1
European Pilots in the Fiscal Year 2019 ENJJPT
Fighter Fundamentals Course

Nation	Pilots in Fiscal Year 2019
Belgium	4
Denmark	4
Germany	9
Netherlands	6
Norway	4

SOURCE: "80th Flying Training Wing Synopsis," unpublished brief produced by 80th Flying Training Wing Commander's Action Group and Public Affairs, Sheppard Air Force Base, Wichita Falls, Tex., July 1, 2019.

concept.⁴⁸ An agreement for public-private partnership-style funding of the school was signed in July 2018 between the Italian air force and Leonardo: The curriculum will draw from the existing syllabus from Italy's 61th Wing Training School as well as the integrated training system developed by Leonardo.⁴⁹ In June 2019, Decimomannu Airbase in Sardinia was selected as a second site for IFTS, with plans to host over 70 advanced training courses flying more than 8,000 hours per year at the site.⁵⁰

Training NATO F-35 Pilots

For European fighter pilots who have passed the IFF fighter training course at ENJJPT or an equivalent course elsewhere and are preparing to fly F-35s, Luke Air Force Base in Arizona provides the next phase of specialized training. Luke also offers courses for F-16 or other fighter pilots transitioning into an F-35 role. The United Kingdom is the exception: As of September 2019, all F-35 training is conducted

⁴⁸ Tom Kington, "Italy Buys 13 Jet Trainers, Inks Naval Industry Deal," *Defense News*, June 13, 2019.

⁴⁹ Luca Peruzzi, "Leonardo and Italian Air Force Launch the 'International Flight Training School' Initiative," *European Defense Review*, July 19, 2018.

⁵⁰ Beth Stevenson, "Decimomannu Selected as Second Base for IFTS," *AIN Online*, June 19, 2019.

with two training JSF squadrons at RAF Station Marham.⁵¹ Between 2013 and 2019, two squadrons of British F-35 pilots trained at the U.S. Marine Corps Air Station in Beaufort, South Carolina.⁵²

Most countries acquiring the F-35 have invested upfront in training their aircrews in preparation for the transition, creating a larger training footprint than one might expect at steady state. The Dutch have been training at Luke AFB since 2013, beginning with four pilots and 20 maintenance personnel; by 2019, the RNLAf was slated to have enough trained instructor pilots to man their own training squadron at Luke.⁵³ Norway established a F-35 unit at Luke in 2015 for conversion training for pilots and maintenance personnel and has continued training there since.⁵⁴ The first two Italian F-35 pilots also began training at Luke in 2015.⁵⁵

F-35 training at Luke focuses heavily on offensive counter-air roles, with particular emphasis on the SEAD mission. Training for basic qualifications incorporates multilayered targeting against advanced SAMs.⁵⁶ Although courses continue to address other missions such as close air support and air interdiction, and despite the interest of some partners in the defensive counter-air role, the predominance of training emphasizes SEAD and similarly advanced operations.⁵⁷ Throughout the course, instructors encourage students to leverage the relative strengths of the platform: In contrast to a B-52 or an A-10, which can be identified at a distance by an adversary, an F-35 student pilot is taught to “get in and accomplish the mission without people knowing you are there until they see the effects.”⁵⁸

⁵¹ “UK’s Second F-35 Training Squadron Arrives at RAF Marham,” *Air Force Technology*, July 19, 2019.

⁵² “UK’s Second F-35 Training Squadron Arrives at RAF Marham,” 2019.

⁵³ Schaub and Michaelsen, 2018, p. 11.

⁵⁴ Schaub and Michaelsen, 2018, p. 11.

⁵⁵ Robbin Laird, “Three Historic Firsts for Italy in the F-35 Program During 2015,” press release, U.S. Air Force, December 8, 2015.

⁵⁶ Telephone interview, airpower expert, August 27, 2019.

⁵⁷ Telephone interview, airpower expert, October 12, 2019.

⁵⁸ Telephone interview, airpower expert, October 12, 2019.

Multiple sources commented on the relative maturity and skill set of a graduate from Luke: a lieutenant training on prior generations of aircraft could not have mastered the range of missions and functions now available to the F-35 trainee.

Multinational training at Luke AFB contributes to future fighter interoperability in a number of ways. As with ENJPPT, the program forms international linkages at the basic level, allowing pilots from differing nations to build mutual trust and familiarity in the early phases of their careers. Because they operate inside a training “bubble” with training software rather than country-specific and often sensitive mission data files, Norwegian, Italian, or Dutch pilots are able to fly one another’s planes as well as U.S. platforms.⁵⁹ Additionally, Luke is breaking new ground by taking F-35 basic course students to participate in U.S. Red Flag exercises, allowing European student pilots to fly U.S. aircraft as well as to conduct missions with fourth-generation fighters. Finally, as one Italian pilot noted, routine training with other allied pilots at Luke AFB allows students to build common TTPs from the ground up.⁶⁰ Overall, partner countries have described the operational training and evaluation (OT&E) experience in the United States as outstanding, allowing each partner to learn from the others. The Dutch, for example, desire to extend the OT&E arrangement even though it comes at a high cost of several aircraft that would otherwise be available for training and operations.⁶¹

As at ENJPPT, about half the training at Luke AFB is conducted on simulators. The initial courses are predominantly synthetic, and as pilots gain experience they transition to live sorties.⁶² Synthetic training allows F-35 student pilots to, among other tasks, conduct fourth- and fifth-generation integration training.

⁵⁹ Telephone interview, airpower expert, October 12, 2019.

⁶⁰ As the pilot emphasized, “The young guys will grow up in a very advanced warfighting and multi-national environment because of this program. They will be used to not just working together from time to time in an exercise, but will build in common tactics from the ground up and help each other innovate as well.” Laird, 2015.

⁶¹ Interview, European airpower expert, Washington, D.C., June 5, 2019.

⁶² Telephone interview, airpower expert, October 12, 2019.

High-end training at Luke leaves European graduating lieutenants “indistinguishable” from their U.S. counterparts, with skills that are “as good if not better.”⁶³ Reportedly, however, F-35 pilots that leave Luke miss the frequency and intensity of training received there.⁶⁴ There is concern that as European pilots return to their home countries, they will receive fewer opportunities to train together, share tactics, and maintain common practices.⁶⁵ One suggestion to remedy this challenge is the establishment of a dedicated F-35-centric program of multinational exercises and training, as well as a robust exchange program across the F-35 user community.

Modernizing NATO Leadership Training

As NATO combat pilots progress in their careers, most have an opportunity to attend the Tactical Leadership Program (TLP), a training center formed with an MOU among ten NATO nations: Belgium, Denmark, France, Germany, Greece, Italy, Netherlands, Spain, United Kingdom, and United States. TLP’s mission is to “increase the effectiveness of Allied Tactical Air Forces through the development of leadership skills, mission planning, briefing, tactical flying, and debriefing skills, and conceptual/doctrinal initiatives.”⁶⁶ Hosted by Spain, the program currently runs about ten academic and four flying courses annually, and is planning to add an additional flying course in the coming years.⁶⁷ TLP trains around 500 NATO aircrew annually, of whom about 100 are fighter pilots.⁶⁸ Early career pilots are eligible for academic courses, while the TLP flying courses require 500 hours of experience in the jet the pilots are to train on.⁶⁹

⁶³ Telephone interview, airpower expert, August 27, 2019.

⁶⁴ Telephone interview, airpower expert, August 27, 2019.

⁶⁵ Telephone interview, airpower expert, August 27, 2019.

⁶⁶ Col Andres Maldonado, “Summary on TLP Prepared for Dr. Anika Binnendijk,” unpublished brief, October 22, 2019.

⁶⁷ Maldonado, “Summary on TLP Prepared for Dr. Anika Binnendijk,” 2019.

⁶⁸ Telephone interview, airpower expert, October 22, 2019.

⁶⁹ Telephone interview, October 22, 2019.

At the core of TLP flying courses is the Composite Air Operation (COMAO). A COMAO is the coordination actions of dissimilar types of aircraft—usually between 20 and 100—with complementary roles to achieve defined military objectives within a given time and geographical area.⁷⁰ Within the COMAO format, TLP participants train on nine live fly missions, which were recently updated to reflect evolving security concerns as well as the integration of fifth-generation platforms. Of these missions, several explicitly hone the combat skills and roles that might be required for a high-intensity conflict with a near-peer adversary. The list of skills are as follows:

- Plan and execute air interdiction using targeting and threat analysis.
- Introduce close air support, strike control and reconnaissance, and time-sensitive targeting.
- Conduct offensive combat air and degrade enemy airfield in a medium-threat environment.
- Plan and execute operations using targeting/threat analysis in a high-threat environment with advanced air defenses.
- Expose participants to interaction with friendly surface-based air defenses.
- Suppress and degrade enemy IADS in a medium- to high-threat environment.⁷¹

The TLP has also sought to upgrade its facilities to reflect the need to prepare for new threats, as well to integrate modern platforms in the NATO fleet. In order to create more complex and challenging scenarios, TLP has invested in an array of innovations to replicate a contested or degraded environment, including communications, GPS, and radar jammers, as well as realistic threat emitters, important

⁷⁰ P. K. Fredriksen, "Interaction in Aerial Warfare: The Role of the Mission Commander in Composite Air Operations (COMAO)," in *Interaction: "Samhandling" Under Risk: A Step Ahead of the Unforeseen*, ed. G.-E. Torgersen, Oslo: Cappelen Damm Akademisk, 2018.

⁷¹ Maldonado, "Summary on TLP Prepared for Dr. Anika Binnendijk," 2019. Note that SEAD is referred to by TLP as "OCA I."

for F-35 to simulate the countering of adversary air defenses.⁷² The program has successfully expanded its flying range at Albacete to a rectangular area that is 170 miles long, 100 miles wide, and includes 100 miles over land, the latter necessary for rehearsing air-to-ground missions such as air interdiction or SEAD. Available for the first TLP course of 2020, it will be, according to one sources, the best airspace for combat air training in Europe designed to address modern fighter integration training needs. Infrastructure upgrades, including new fiber communications, deployed debriefing facility locations, and new security measures address the needs of the F-35, and a U.S. Air Forces in Europe site survey determined that the site offered a suitable airfield for F-35 operations.⁷³ Finally, the program has developed new doctrine for the integration of fighter tactics, creating a classified fighter integration chapter to be finalized in 2020.⁷⁴ These upgrades reflect the prioritization that TLP has placed on fourth- and fifth-generation integration, as six of the ten participating nations are adding F-35 capabilities to their fleets.

Overcoming National Training Constraints

Beyond multinational training opportunities, NATO combat pilots also conduct much of their annual training requirements on a national basis. NATO sets a standard of 180 flying hours per year for a combat pilot, with 40 of those hours permitted in a simulator.⁷⁵ The ability of allies to meet this standard has been mixed. In recent years, Dutch pilots flew between 150 and 180 hours, and for 2018, the number approached 180.⁷⁶ Spain has decided to reduce its total number of pilots flying annually in order to increase the number of flight hours for each remaining pilot.⁷⁷

⁷² Maldonado, "Summary on TLP Prepared for Dr. Anika Binnendijk," 2019.

⁷³ Maldonado, "Summary on TLP Prepared for Dr. Anika Binnendijk," 2019.

⁷⁴ Maldonado, "Summary on TLP Prepared for Dr. Anika Binnendijk," 2019.

⁷⁵ Witting, 2019.

⁷⁶ Interview, European airpower expert, Washington, D.C., June 5, 2019.

⁷⁷ Jane's, "Spain: Air Force," October 14, 2019.

For the French air force, a combination of budgetary constraints, operational exigencies, and military export support requirements have strained pilot training. French fighter pilots averaged 150 hours in 2015.⁷⁸ As of 2016, French military budget law allocated 159 hours to pilot flight time.⁷⁹ High operational demands increased fighter pilots' flying hours to 168 hours in 2016.⁸⁰ Ongoing French military operations have led to an uneven distribution of flight training hours: After returning to France from operational duty, pilots may remain idle for months to avoid flying more than their budgeted time.⁸¹ Additionally, French trainers play a central role in supporting Rafale export clients—high international demand for Rafale training can thus impinge on training for French crews.⁸² France is also seeking to overhaul its training program as part of a broader military modernization.⁸³

Elsewhere, one broadly cited training constraint is platform availability. One report noted, for example, that only about 58 percent of German Luftwaffe pilots (512 of 875) were able to meet NATO's flight-hours standard because their aircraft were grounded by maintenance issues.⁸⁴ Italian air force training flight hours have reportedly also been negatively affected by budget constraints; however, recent national investments in flight training aircraft may have reversed this trend.⁸⁵

The British RAF has met with similar difficulties in training platform availability: A 2011 report identified the lack of spare parts as

⁷⁸ Jane's, "France: Air Force," October 31, 2019.

⁷⁹ Pierre Tran, "French Pilot Training Suffers at Expense of Rafale Sales Support," *Defense News*, November 3, 2016.

⁸⁰ Tran, 2016.

⁸¹ Jane's, "France: Air Force," October 31, 2019. Jane's notes that "pilots may fly up to 100 hours in two months when deployed and they then have to remain idle for large periods of time when in France in order not to fly more than their budgeted time."

⁸² Tran, 2016.

⁸³ Brian W. Everstine, "French Air Force Begins Research into Sixth Generation Aircraft," *Air Force Magazine*, February 7, 2019. Currently, the French air force uses five airframes to train pilots for combat over the course of three years but seeks to reduce this to two years using a recently completed fleet of modernized PC-21 training platforms for Rafale pilots.

⁸⁴ Huggler, 2019.

⁸⁵ Jane's, "Italy: Air Force," February 27, 2019.

contributing to the RAF's inability to meet its target for annual flying hours, and our interviews suggested that this remains an issue.⁸⁶ At that time, prioritization requirements had tangible implications for RAF's operational capabilities: Because pilot training was limited to preserving the Typhoon's primary air defense role in lieu of more complex tasks, only 15 percent of British pilots had enough training hours to perform missions beyond air defense.⁸⁷ RAF pilots are trained through the Military Flying Training System (MFTS), initiated in 2008 in an effort to modernize pilot training across the military services.⁸⁸ The program, which has experienced delays in recent years, takes a RAF fast-jet pilot an estimated seven and half years to complete.⁸⁹ As of February 2019, the MFTS program had received unspecified penalties from the UK Ministry of Defense for late delivery of assets and training courses.⁹⁰ According to a BBC Freedom of Information request, 350 British fixed-wing and rotary trainee pilots were waiting to fly because there were twice as many plane and instructor shortages as in 2018.⁹¹ At that time, over half of the RAF's 81 Hawk T1 jets, used for training as well as aerobatics displays, were in storage or maintenance.⁹² Notably, the 2010 British SDSR had reduced aircraft quantities and, by extension, the number of pilots, contributing to a wind-down in training from which it may have been difficult to recover.⁹³

A second limiting factor for European domestic training is an absence of expansive air training space. Advanced aircraft training for multirole missions requires a large airspace that permits pilots to train

⁸⁶ Comptroller and Auditor General, 2011, p. 6.

⁸⁷ Comptroller and Auditor General, 2011.

⁸⁸ Mick Tucker, "Hundreds of Trainee Military Pilots Waiting to Start Flying," BBC News, March 5, 2019.

⁸⁹ Tucker, 2019.

⁹⁰ Gareth Jennings, "MoD Reveals Ascent Penalties for Late Pilot Training Delivery," *Jane's Defence Weekly*, March 5, 2019a.

⁹¹ Tucker, 2019.

⁹² Christopher Woody, "The British Air Force Just Got New Fighter Jets, but There Are Doubts About Whether Its Fleet Is Ready to Fight," *Business Insider*, January 24, 2019.

⁹³ Jennings, 2019a.

in all scenarios, including at supersonic speeds or at lower altitudes.⁹⁴ The Dutch air force, for example, is limited in its flight training over land by domestic regulations, and so much of the training airspace is over the North Sea, making it difficult to replicate ground-based threats. Because of this, the Dutch have had more opportunity to practice air-to-air combat than air-to-ground.⁹⁵ The Dutch do conduct some training at the detachment and squadron level on ranges in Germany and the United Kingdom, providing the RNLAF pilots one of their few opportunities to train on air-to-ground attack.⁹⁶

As is the case with most allies in northern Europe, the RAF has limited airspace over land. It practices low flying over central Wales, northern Scotland, and the border area of Scotland and northern England.⁹⁷ The RAF currently uses five air weapons ranges.⁹⁸ The largest, the Cape Wrath training area, offers nearly 100 square miles of moorland and is the only range where the RAF can train using live 1,000-lb bombs.⁹⁹ In Lincolnshire, bombing range Donna Nook air weapons range (AWR) spans about 3.4 square miles of beach, saltmarsh, and sand dunes, with about 12.4 square miles of sea danger area, while Holbeach AWR spans 15 square miles, predominantly mudflats and saltmarsh.¹⁰⁰ Scotland's RAF Lossiemouth, home to four Eurofighter squadrons, includes the Tain AWR covering just 4.2 square miles.¹⁰¹ In Wales, Pembrey Sands AWR, where "every fast jet pilot in the RAF has been trained," covers only 4.3 square miles of land with another 3 miles off the coast.¹⁰² As one interviewee noted, the RAF and other allies training over sea may have to contend with Russian trawlers on their

⁹⁴ Steve Bigg, "Training in a Military Pilot's Sandbox," *Skies Magazine*, January 13, 2017.

⁹⁵ Interview, European air power expert, Washington, D.C., June 5, 2019.

⁹⁶ Interview, European air power expert, Washington, D.C., June 5, 2019.

⁹⁷ Government of the United Kingdom, "Low Flying Military Aircraft," website, undated.

⁹⁸ Government of the United Kingdom, "Low Flying Military Aircraft," undated.

⁹⁹ Government of the United Kingdom, "DTE East," public information leaflet, undated.

¹⁰⁰ Government of the United Kingdom, "DTE East," undated.

¹⁰¹ Royal Air Force, "RAF Lossiemouth," website, undated.

¹⁰² "Pembrokeshire," public information leaflet, UK Assets Publishing Service, undated.

coastline and may risk revealing particularly sensitive fifth-generation capabilities.¹⁰³

For Germany, elevation and speed restrictions also constrain domestic training.¹⁰⁴ In light of this challenge, Germany previously trained its Tornado pilots at Holloman AFB in New Mexico. However, the German Tornado pilot training program departed Holloman in 2017 and currently takes place at Kropp-Jagel in Schleswig-Holstein.¹⁰⁵ German pilots also train at Italy's Decimomannu Air Base, which includes larger ranges that can accommodate air-to-air missions and air-to-ground bombing.¹⁰⁶ In July 2019, Italy hosted U.S. and British F-35s for joint training out of Amendola.¹⁰⁷

To mitigate platform and airspace limitations and to keep pace with technological advances, many European air forces are increasingly turning to virtual training through computer simulators. The Dutch are targeting 50 percent simulated training across RNLAf fleets by 2024, although, like most air forces, they do not consider synthetic training to be a flight-hour-for-flight-hour replacement.¹⁰⁸ The Dutch figure is comparable with other European allies: British F-35 pilots are also likely to spend 50 percent of their time in simulators.¹⁰⁹ In August 2019, the first RAF Typhoon pilot graduated from the U.S. Air Force's Pilot Training Next program, for virtual reality pilot training, as part of a RAF effort to identify ways to reduce learning time and accelerate pilot production through synthetic training.¹¹⁰

¹⁰³ Interview, October 12, 2019.

¹⁰⁴ Jane's, "Germany: Air Force," July 18, 2019.

¹⁰⁵ Jane's, "Germany: Air Force," July 18, 2019.

¹⁰⁶ Stevenson, 2019.

¹⁰⁷ "UK and Italy to Conduct Bilateral F-35 Training Exercise," *Air Force Technology*, July 5, 2019.

¹⁰⁸ Jane's, "Netherlands: Air Force," October 9, 2019; interview, European air power expert, Washington, D.C., June 5, 2019.

¹⁰⁹ Interview, Washington, D.C., September 12, 2019.

¹¹⁰ Stephen Losey, "Virtual Reality Pilot Training Program Graduates Latest Class, including Brits," *Air Force Times*, August 30, 2019c.

There is one advantage to synthetic training that may help prepare for high-intensity conflict. Although the simulator cannot replace the experience derived from live training and exercises, it can provide saturation levels of a high-end fight that may be difficult to replicate elsewhere.¹¹¹ To be useful for this purpose, synthetic training devices must have the right capabilities with realistic simulations, although specific scenarios may vary nationally depending on a country's specific threat perceptions.

To enhance interoperability and maximize the benefits derived from synthetic training, simulators could be linked to allow pilots from across the Alliance to operate in a shared environment and with common scenarios. Although the infrastructure to create links for combat air simulators across Europe does not currently exist, it may be worthy of further exploration and investment. One sophisticated 2018 simulator exercise, Spartan Alliance, linked simulators on several Italian air bases with the German Luftwaffe and the U.S. Air Force Warrior Preparation Center in Ramstein, Germany.¹¹² The exercise featured Eurofighters and Tornados pilots in Italy collaborating with F-18, F-15, and A-10 pilots from Ramstein, with T-346 jet trainer simulators serving as adversary aircraft.¹¹³ The Italian government has announced its intent to incorporate fifth-generation assets into the exercise by 2023.¹¹⁴

Exercising Combat Scenarios for Interoperability and Integration

The 2018 Brussels Summit highlighted NATO's efforts to "ensure the Alliance's political and military responsiveness, including through more regular exercises."¹¹⁵ In 2019, allies planned 27 exercises predominantly focused on the air domain, eclipsing the number conducted in

¹¹¹ Interview, air power expert, Washington, D.C., September 12, 2019.

¹¹² Tom Kington, "Italian Air Force Takes Part in 22-Simulator Virtual Combat," *Defense News*, July 20, 2018.

¹¹³ Kington, 2018.

¹¹⁴ Kington, 2018.

¹¹⁵ NATO, *Brussels Summit Declaration*, 2018.

the land or maritime domains.¹¹⁶ According to NATO, these exercises allow allies to hone procedures and tactics, establish best practices, and identify areas for improvement, as well as improve training, interoperability, and readiness.¹¹⁷

For pilots and other aircrew, the communication and trust developed during frequent exercises can make a critical difference to their operational cohesion. As the commander of the U.S. Air Force Warfare Center noted during one Red Flag exercise, “While it’s imperative our technology can integrate to accomplish the mission, it ultimately comes down to the Airmen of our nations working together who truly make the difference.”¹¹⁸

In order to prepare NATO personnel for high-intensity combat missions against a near-peer adversary, it is important that exercises adequately reflect the scenarios and skills required.

Previously, Alliance exercises had predominantly focused on stabilization missions, reflecting the operational requirements of the post–Cold War period.¹¹⁹ Even seasoned airmen may have limited experience in highly contested environments, as Brig Gen Robert Novotny, who oversees the U.S. Red Flag exercises, noted:

A lot of our airmen have had experience deploying downrange to places like Afghanistan, Iraq, and Syria, which gives them familiarization with employing their weapons systems against a real enemy, but those operations have been conducted in a very permissive environment with uncontested air superiority and freedom of movement in all domains.¹²⁰

As one European practitioner put it, NATO is experiencing a “totally different environment with a peer competitor than we have

¹¹⁶ NATO, “Key NATO and Allied Exercises in 2019,” fact sheet, February 2019b.

¹¹⁷ NATO, “Key NATO and Allied Exercises,” 2019b.

¹¹⁸ Jenna Bigham, “62nd Fighter Squadron Brings Its Partner Nation Cohesion to the Fight at Red Flag,” press release, U.S. Air Force, March 27, 2019.

¹¹⁹ Osinga, 2016, p. 125.

¹²⁰ James Kitfield, “Red Flag 2019: First Great Power Air War Test in Years,” *Breaking Defense*, March 6, 2019.

the past 20 years, and we need to think about it differently. This includes how we train and prepare the crew.”¹²¹ NATO's Supreme Allied Commander Europe (SACEUR) issued a clear message in his 2019 Annual Guidance on Education, Training, Exercises, and Evaluation (SAGE 19): “I have instructed my staff to put large scale, high-intensity, all-domains warfare against a near-peer adversary at the very heart of all our training from now on, and I am prepared to assume some risk in other areas to achieve this.”¹²²

The next section will consider the contribution of NATO and multinational exercises to air forces' preparedness for a high-intensity conflict against a near-peer adversary. In particular, it will highlight exercises that present challenging scenarios and threat environments that integrate diverse platforms, including fifth-generation aircraft, and that exercise a range of skills and missions relevant to collective defense.

Planning Large-Scale Multinational Combat Air Exercises

Larger-scale exercises can offer participants an important opportunity to practice operating in a complex multinational operation. Of the larger exercises within NATO, the U.S. flag exercise “Red Flag” represents the most challenging.¹²³ Conducted several times a year, Red Flag includes a range of air-to-air and air-to-surface missions over the course of multiple weeks. Europeans have participated in Red Flag for over four decades.

Current Red Flags reflect the guidance of the U.S. National Defense Strategy to prepare for potential conflicts against near-peer adversaries. Red Flag 19-1, conducted in February 2019 and including the United States, United Kingdom, and Australia, sought to replicate the advanced weapon systems of near-peer enemies, including advanced IADS, adversary air forces, and cyber and EW capabilities such as active electronic attack, communications jamming, and GPS

¹²¹ NATO Air Power Roundtable, 2019.

¹²² Ed Wijninga, “The Fog of Day Zero: Joint Air & Space in the Vanguard—Exercises and Training Preparing for Day Zero,” presentation, Joint Air & Space Power Conference, October 9–11, 2018.

¹²³ Royal Air Force, “Exercise Red Flag 2019 Gets Underway,” January 18, 2019.

denial.¹²⁴ Increased threat and complexity meant that participants “no longer assumed that we will gain and maintain air superiority.”¹²⁵ The exercise also highlighted the relative strengths of the F-35: U.S. Air Force public affairs coverage detailed how a relatively inexperienced pilot during one counter-air mission warned a more experienced pilot of a threat and then went on to “kill” the threatening aircraft as well as three more over the course of the mission.¹²⁶

Red Flag 19-2, held several weeks later with other allies, including Belgium, Italy, the Netherlands, and Norway, featured Italian and Norwegian F-35 instructor pilots from Luke AFB participating on U.S. platforms for the first time in the history of the exercise.¹²⁷ This was also the first time that trainees flew an F-35 as the dedicated SEAD asset, which provided participating units with insights into the integration of the F-35 in a strike package.¹²⁸ In this second scenario, however, the threat was reportedly similar to Libya, with less advanced SAMs, described by a European air expert as “excellent training but against a limited threat.”¹²⁹ Another European airpower expert noted that the “issue with Red Flag is there are two flavors to it: a Five Eyes and an international.”¹³⁰

U.S. concerns about foreign disclosures have limited the contributions of Red Flag to NATO combat air interoperability.¹³¹ Because of existing security restrictions, foreign pilots may have restricted access to information or communications among participants.¹³² Numerous interviewees identified security restrictions as a major barrier to maximizing the value of the F-35: Until pilots can freely brief, debrief, and

¹²⁴ U.S. Air Force, 2019.

¹²⁵ U.S. Air Force, 2019.

¹²⁶ U.S. Air Force, 2019.

¹²⁷ Bigham, 2019.

¹²⁸ Bigham, 2019.

¹²⁹ Interview, Washington, D.C., June 5, 2019.

¹³⁰ Interview, September 12, 2019.

¹³¹ Interview, Washington, D.C., June 5, 2019.

¹³² Telephone interview, August 28, 2019.

communicate with one another, full interoperability remains elusive. Notwithstanding legitimate security concerns, addressing this information-sharing challenge would enable advances in multinational training.

Two other frequently cited allied flag exercise, Frisian Flag and Maple Flag, have both suffered from constraints that limited their applicability to a high-end conflict scenario. Frisian flag, hosted by the Netherlands, offers excellent opportunities to train on coalition air-to-air missions. However, because most of the airspace is over the North Sea, air-to-ground missions are limited, as are the SAM threats that can be simulated.¹³³ Canada's Maple Flag exercise has traditionally taken advantage of the 7,300 square miles of unrestricted airspace that includes 88 target complexes and eight mock airfields.¹³⁴ However, the exercise was postponed in 2018 and 2019 as Canada initiated infrastructure updates, including the improvement of threat emitter pods to more accurately replicate the threat posed by integrated air defenses as well as infrastructure for classified planning sessions and data link and communications systems upgrades.¹³⁵

Of the larger exercises in Europe, the relatively recent addition of biennial exercise Arctic Challenge stands out. The exercise itself builds on ongoing cooperation through the Nordic Cross-Border Training program, a mechanism that allows Norway, Sweden, and Finland to train with each other and in each other's airspace on a routine basis. In 2017, Nordic air chiefs, along with USAFE, signed a letter of intent to expand the regional exercise to a full-spectrum European flag-level exercise with broad international participation.¹³⁶ The 2019 exercise included more than 100 aircraft, 94 of which were fighter aircraft, from nine nations.¹³⁷ The scenario, based on a UN mandate, pitted

¹³³ Interview, June 5, 2019.

¹³⁴ Bigg, 2017.

¹³⁵ David Pugliese, "Maple Flag Exercise Postponed So Improvements Can Be Made to Cold Lake Base and Range," *Ottawa Citizen*, December 12, 2018.

¹³⁶ Jessica Hines, "Nordic Air Chiefs Sign Letter, Develop Arctic Challenge," U.S. Air Force, October 17, 2019.

¹³⁷ David Oliver, "EDR On-Line Attends Europe's Largest Air Exercise—Arctic Challenge Exercise (ACE) 2019," *European Defense Review*, June 4, 2019.

a large international force against a highly skilled, near-peer competitor.¹³⁸ According to one U.S. press release, “All facets of air operations were tested, including offensive and defensive scenarios consisting of both air-to-air and air-to-ground missions.”¹³⁹ In 2019, the United States used Arctic Challenge to train on the SEAD mission with Block 52 F-16s.¹⁴⁰ During the earlier iteration, in 2017, the United States exercised three B-52 strategic bombers operating out of RAF Fairford as part of the exercise.¹⁴¹ As the second-largest nonhost contributor to the exercise, France deployed ten Rafales and four Mirage 2005s to the 2019 exercise.¹⁴² The United Kingdom also contributed heavily, for the first time exercising the RAF Tranche 3 RAF Typhoons with Meteor missiles in a multinational exercise.¹⁴³

Honing NATO’s Tactical Edge

Smaller exercises seek to focus on individual tactics and procedures that are critical for specific missions. For example, the 2016 Serpentex exercise, led by France over the Island of Corsica, included aircrews and joint terminal attack controllers from over ten NATO air forces to exercise air and land integration, including close air support, air interdiction with dynamic targeting, strike coordination and reconnaissance, and live ordnance operations.¹⁴⁴

Other exercises develop the skills required for defensive counter-air. Many NATO air forces engage in regular QRA exercises for

¹³⁸ Jim St. Clair, “169th FW Wrap Up Arctic Challenge Exercise in Sweden,” U.S. Air Force, June 10, 2019b.

¹³⁹ Jim St. Clair, “Swamp Foxes Wrap Up a Successful Arctic Challenge Exercise in Sweden,” U.S. Air Force, June 9, 2019a.

¹⁴⁰ Kyle Rempfer, “Air Force Trains to Defeat Enemy Air Defense 50 Miles South of the Arctic Circle,” *Air Force Times*, May 20, 2019.

¹⁴¹ Curtis Beach, “Historic Bomber Operations BALTOPS, Saber Strike Conclude at RAF Fairford,” U.S. Air Force, June 21, 2017.

¹⁴² Ministry of Defense, “France and the New Strategic Challenge in the Arctic,” briefing, 2019.

¹⁴³ David Oliver, “ESDPA Attends Europe’s Largest Air Exercise—Arctic Challenge Exercise (ACE) 2019,” European Security and Defense Press Association, 2019.

¹⁴⁴ Sara Keller, “Exercise SERPENTEX 16; Cleared Hot,” U.S. Air Force, March 7, 2016.

the defense of their national airspace. The French and British exercise bilateral coordination of QRA capabilities in the regular Sheihan River exercise.¹⁴⁵ The Ramstein Alloy series, held three times a year over Baltic airspace, trains fighter aircraft for NATO's Baltic Air Policing mission, among other Alliance missions.¹⁴⁶

France exercises the platforms and skills required for its strategic strike mission. Relatedly, the French rehearse and demonstrate the ability to conduct long-range missions into adversary territory. In February 2019, the French air force conducted a long-range nuclear strike exercise mission in which a Rafale flew against simulated air defenses to launch an unarmed ASMP-A cruise missile at Bordeaux-Mérignac test range.¹⁴⁷ The 11-hour-long exercise included refueling from a C135 and A330 and simulated a real mission.¹⁴⁸

Finally, Annual Tiger is a medium-sized tactical-level event held since 1961, offering important opportunities for allied pilots to improve tactical coordination within COMAO format across the range of combat missions.¹⁴⁹ The 2018 Tiger Meet, held in Poland, convened 19 squadrons of aircraft that included fighter jets, transport aircraft, and helicopters working together in a COMAO.¹⁵⁰ The event featured 50 missions spanning the range of combat air roles, including air interdiction/deliberate targeting missions, defensive combat air, "massive offensive strikes behind enemy lines," and SEAD sorties.¹⁵¹ The 2019 event, held in France, hosted 60 European fighter jets and incorporated French land-based air defense units including Crotale, Mamba,

¹⁴⁵ Royal Air Force, "RAF and Armée de l'Air Joint QRA Exercise," March 23, 2018.

¹⁴⁶ Lithuanian Armed Forces, "NATO Allies and Partners to Conduct Exercise Ramstein Alloy 19-2 in the Baltic Region Air Space," June 21, 2019.

¹⁴⁷ Everstine, 2019.

¹⁴⁸ Everstine, 2019.

¹⁴⁹ George Allison, "NATO Tiger Squadrons Meet for Training in France," *UK Defense Journal*, May 26, 2019c.

¹⁵⁰ Philippe Amiel, "NATO Tiger Meet 2018—Rafale," *Omnirole-Rafale*, June 6, 2018; NATO Tigers, "Program," website, undated. An average two-week Tiger meet includes about 800 sorties by fighter as well as support aircraft.

¹⁵¹ Amiel, 2018.

Scribe, SA-6, and SA-8, the latter two presumably to serve as threat emitters.¹⁵² Germany deployed its Tornado ECR and IDS aircraft to the event.¹⁵³

Initiating Fifth-Generation Integration and Interoperability

Exercises have begun to incorporate fifth-generation aircraft. From May to July 2019, a U.S. Air Force TSP that included a squadron of F-35s from Hill AFB offered new opportunities to exercise the integration of fourth- and fifth-generational platforms in Europe. Over the course of the summer, the TSP offered opportunities for U.S. F-35s to engage in training with a range of allies, including at the TLP in Spain, the Fighter Weapons Instructor Training program in the Netherlands, and with individual German fighter units.¹⁵⁴

In early June, the Astral Knight exercise demonstrated multi-domain interoperability between U.S. and Italian fourth- and fifth-generation aircraft and successfully trained participants in DCA missions against cruise missile and aircraft strikes.¹⁵⁵ With eight sorties a day over four days, the exercise represented the first operational integration between U.S. and Italian F-35s, and the two nations' aircraft successfully communicated over MADL for the first time.¹⁵⁶ However, the exercise also indicated the issues in Link-16 connectivity and security that precluded effective communication between fourth- and fifth-generation fighters in Europe.¹⁵⁷ Security precautions surrounding briefings further limited the scope of information that aircrew were able to share with one another.¹⁵⁸

Several weeks later, the U.S. F-35s exercised with British and French air forces over the North Sea in Exercise Point Blank 19-2.

¹⁵² The Aviation Magazine, No. 64 (July–August 2019), June 29, 2019.

¹⁵³ NATO Tigers, "Tiger Meet—2019," website, undated.

¹⁵⁴ Interview, Washington, D.C., September 12, 2019.

¹⁵⁵ Ed Adamczyk, "U.S. Italian F-35As Integrate for First Time in Astral Knight Exercise," United Press International, June 7, 2019a.

¹⁵⁶ Adamczyk, 2019a.

¹⁵⁷ Interview, Washington, D.C., September 12, 2019.

¹⁵⁸ Interview, Washington, D.C., September 12, 2019.

Normally a bilateral air exercise held several times a year between the United Kingdom and the United States, Point Blank's June 2019 iteration was intended to "prepare coalition warfighters for a highly contested fight against near-peer adversaries by providing a multi-dimensional battle-space to conduct advanced training in support of U.S., UK, and French national interests."¹⁵⁹ During a Point Blank exercise several months earlier, British F-35B and Typhoon combat aircraft and French Rafales had exercised OCA missions with U.S. F-15E Strike Eagles to strike simulated targets on the British coast while engaging in air-to-air combat, addressing simulated surface missile threats, and contending with electronic jamming.¹⁶⁰ In the June exercise, air forces were able to achieve interoperability, although communication with fourth-generation pilots was again limited by technical challenges associated with the Link-16 network.

Interoperability at the 2018 and 2019 Point Blank exercises built on the 2017 Atlantic Trident exercise, which brought together U.S. F-22s and F-35s, British Typhoons, and French Rafales to exercise basic fighter maneuvers, DCA and OCA operations from Langley-Eustice AFB in Virginia.¹⁶¹ The exercise was the brainchild of a French-UK-U.S. (FRUKUS) trilateral strategy group that meets regularly to improve interoperability among the nations' air forces.¹⁶² There has been a particular effort to ensure that the United Kingdom and United States would be able to incorporate French fighter pilots and platforms into high-end operations even as the U.S. and British air forces incorporate the F-35. As one U.S. squadron commander participating in Atlantic Trident 2019 put it, "All these aircraft have tremendous capabilities, but if we don't plan them and integrate them and understand each other's capabilities and limitations, and use them to their full

¹⁵⁹ "Point Blank 19-2 Exercise Featured U.S., French, and Royal Air Force," Army Update, July 2, 2019.

¹⁶⁰ Simon Michelle, "New Capabilities Demonstrated at 'Point Blank' Exercise," *Jane's International Defense Review*, December 11, 2018.

¹⁶¹ U.S. Air Force, "Trilateral, Cross-Generation Integration at Langley," April 28, 2017.

¹⁶² U.S. Air Force, 2017.

potential, then we could lose in any combat scenario . . . it's more about the human element.”¹⁶³

Exercising and Demonstrating Readiness

A number of exercises seek to demonstrate allied readiness in order to support rapid mobilization during a time of crisis. Several of these are joint exercises, addressing the readiness of joint capabilities across the NATO Response Force (NRF), including its spearhead Very High Readiness Joint Task Force (VJTF). In order to meet stringent NATO certification standards, national units must train and exercise for between six and 18 months to integrate and standardize their procedures before assuming the role of an NRF high-readiness unit.¹⁶⁴ Beginning in 2017, NATO initiated a four-part “Brilliant” exercise series designed to certify the 2018 VJTF component commands.¹⁶⁵ Of these, Brilliant Arrow 2017 tested VJTF air capabilities by exercising NATO air forces that do not routinely train together: F-16s from Greece, Poland, and Turkey with German Eurofighters in combined operations under a new Air Operations Command led by Germany.¹⁶⁶ The exercise took place over German and Dutch airspace and practiced missions in COMAO format including SEAD, air interdiction, and ground attack in an EW-intensive environment.¹⁶⁷

NATO's largest exercise in decades, Trident Juncture 2018, rehearsed an Article 5 collective defense scenario to test capabilities in northern Europe across land, air, and maritime domains. The air portion of the exercise involved some 250 aircraft and 3,500 air personnel.¹⁶⁸ Of these, Italy made the largest contribution with four

¹⁶³ U.S. Air Force, 2017.

¹⁶⁴ NATO, “NATO Response Force,” website, undated.

¹⁶⁵ Lara Martinho, *NATO Exercises: Evolution and Lessons Learned*, draft report of NATO Parliamentary Assembly Defense and Security Committee, April 9, 2019.

¹⁶⁶ Martinho, 2019.

¹⁶⁷ Paul Van Harten, “Brilliant Arrow,” *Northern Star: Magazine for HQ JFC Brunssum*, November 2017; Jane's, “Poland: Air Force,” September 13, 2019.

¹⁶⁸ Norwegian Armed Forces, “Facts and Information: Exercise Trident Juncture 2018 (TRJE18),” fact sheet, 2018.

Eurofighters, six Tornados, a KC-767 tanker, and a G-550 airborne early-warning aircraft.¹⁶⁹ Missions included a COMAO involving 50 to 60 aircraft performing functions such as close air support and tactical support of maritime operations over the sea.¹⁷⁰ In some cases, tasks varied dynamically between air-to-air to air-to-ground, taking advantage of the large number of multirole platforms in the exercise.¹⁷¹

Allies are also beginning to develop a multinational air group, with Germany taking responsibility “for standing up . . . larger formations of Allied Air Forces . . . to provide NATO with interoperable, well-trained and operational flying assets” though combined training and exercises.¹⁷² The intent is to establish an initial operational capability by 2023 and full operational capability by 2026, an ambitious target but one in line with NRI and related efforts.¹⁷³ In 2019, four weeklong “Magday” exercises prepared groups of allied air forces for combat missions and as of mid-2019 included Polish F-16, Czech Gripens, unspecified French aircraft, and German Eurofighters and Typhoons.¹⁷⁴

Conclusion

Guidance from NATO's SACEUR reflects the need for increased training and exercises to prepare for high-intensity missions against near-peer adversaries. Overall, training and exercise trends appear to reflect this growing realization. Today's NATO combat pilots are increasingly trained to operate in contested and degraded environments, moving away from the crisis management model that defined much of the post-Cold War period.

¹⁶⁹ Tony Garner, “Ice Warriors,” *Eurofighter World Magazine*, May 13, 2019.

¹⁷⁰ Garner, 2019.

¹⁷¹ Garner, 2019.

¹⁷² George Allison, “Germany Hosts Second Air Exercise over North Sea in 2019,” *UK Defense Journal*, April 2, 2019b.

¹⁷³ Allison, 2019a.

¹⁷⁴ Allison, 2019a.

Among several priority areas, there is dedicated focus on SEAD with fifth-generation fighters, which could prove critical in the early phases of a conflict with Russia. F-35 pilots are developing and honing their skills through training received at Luke AFB, Red Flag, and NATO's TLP program. Periodic exercises such as Tiger Meet also exercise SEAD skill sets. The limited number of fourth-generation platforms able to conduct SEAD means that few NATO pilots have SEAD experience, making the new emphasis on these skills particularly important. Advanced threat emitters are required to maximize F-35 SEAD training. TLP in Spain reports that it is updating its threat emitters, which may offer important future training opportunities for NATO F-35 pilots. In December 2018 the U.S. Air Force awarded a \$450 million contract for delivery and maintenance of the Joint Threat Emitter (JTE), a mobile air defense EW threat simulator that accurately replicates SAM and anti-aircraft artillery threats for training purposes.¹⁷⁵ The deal includes an FMS component and could plausibly benefit NATO allies over the coming years.

Other missions also reflect the new challenges that NATO air forces could encounter during a high-intensity theater conflict. France's nuclear strike exercise in 2019 notably required the Rafale to fly against simulated air defense threats. Allies participating in U.S. Red Flag exercises conducted missions including defensive counter-air and strike in an environment that included advanced IADS, adversary air forces, active electronic attack, and communications jamming. New DCA scenarios, such as those in Astral Knight 2019, rehearsed defending allied territories against cruise missiles.

In order to maximize the operational impact of European F-35 purchases as well as the value of integrated exercises, the United States and NATO allies will need to develop guidance for F-35 interoperability across NATO fleets. Currently, aircrew are constrained by the nature and modes of information they are able to share with counterparts from other air forces. The United States and other NATO air forces will need to refine guidelines that define F-35 interoperability

¹⁷⁵ Pat Host, "U.S. Air Force Awards Northrop Grumman Joint Threat Emitter Delivery Order," *Jane's Defence Weekly*, May 21, 2019a.

and indicate desired levels of compatibility across the Alliance. A high-level F-35 interoperability policy could address a range of issues, including whether nations could operate on the same MADL system, software compatibility, the nature of information aircrew could share, and whether aircrew could brief and debrief in each other's secure facilities.

To further improve NATO combat air capability, allied training could pursue a dedicated training program focused on the integration of multinational fourth- and fifth-generation fighters. Individual national training schedules could be more closely integrated through the establishment of "routine Alliance training conferences . . . to identify interoperability training opportunities among individual Allies' training schedules."¹⁷⁶ Regularized training among allies—perhaps quarterly or even monthly—including with the integration of fourth- and fifth-generation aircraft, could offer important opportunities for routine and iterative common learning.¹⁷⁷ One model for this approach could be the Nordic Cross-Border Training (CBT) program.¹⁷⁸ Since 2009, the Norwegian Air Force has conducted combined combat air training missions on nearly a weekly basis with the Swedish and Finnish air forces, each operating from their northern home bases.¹⁷⁹ Similarly, the U.S.-UK Point Blank exercises, which began in 2016 as a grassroots officers' initiative to offer a more affordable and accessible alternative to Red Flag, now occurs regularly throughout the year and could provide a model to expand on.¹⁸⁰ While it could be difficult to balance a time-intensive multinational commitment with the rigorous domestic exercise schedules required to ensure unit readiness, the

¹⁷⁶ "Additionally, this training conference could identify and review advanced training." JAPCC, 2016, p. 98.

¹⁷⁷ Interview, September 12, 2018.

¹⁷⁸ Søren Nielsen, "Cross Border Training," *FLYMAG Scandinavian Aviation Magazine*, 2019.

¹⁷⁹ Swedish Armed Forces, "Arctic Challenge Exercise 2019: Nordic Cooperation in the Concept of Cross Border Training," 2019.

¹⁸⁰ "Point Blank 19-2 Exercise Featured U.S., French, and Royal Air Force," 2019. Since its nascence, Point Blank has included over 20 exercises and 400 aircraft. See Amy McCullaough, "Point Blank Provides European-Based Fighters an Affordable Alternative to Red Flag," *Air Force Magazine*, November 29, 2018.

potential benefits for collective readiness merit closer examination. Additionally, the establishment of a robust liaison program across the allied F-35 community, as low as the squadron or group levels, could facilitate rapid exchange and updates of common tactics and procedures.

Across NATO, allies are increasingly turning to synthetic training as a cost-effective way to provide realistic simulations of high-intensity combat. This trend is likely to persist as European militaries train on F-35 simulators, particularly given the \$39,000-per-flight-hour price tag associated with the F-35. To the extent that they are technically and financially feasible, linkages among NATO simulators that would allow allied pilots to train together against a common scenario could pay dividends for future interoperability.

A NATO Air Warfare Center could offer one venue to facilitate regular and financially sustainable multinational air training in Europe.¹⁸¹ The center could help to apply the theoretical evolution of NATO airpower and serve as a fulcrum to coordinate future training and exercise themes across the alliance.¹⁸² Recent investments by Spain and Italy in training infrastructure, ranges, and curriculum could make either country a logical host for such a center.¹⁸³

¹⁸¹ JAPCC, 2016, pp. 198–199.

¹⁸² JAPCC, 2016, pp. 198–199.

¹⁸³ The JAPCC report also highlights Greece.

Conclusion

Since 2014, NATO has sought to strengthen deterrence and reinvigorate warfighting competencies, but the air domain has received relatively scant attention, at least among policymakers. High-profile adaptations such as enhanced Forward Presence and the Very High Readiness Joint Task Force took on a land-centric character, while the more recent attention on anti-submarine warfare and the North Atlantic portend an increased level of interest in maritime issues. More recently, however, NATO's 2018 Joint Air Power Strategy, a recognition that airpower will be critical to implementing the NATO Readiness Initiative, and the introduction of fifth-generation aircraft has begun to shift this dynamic.

Consider a potential conflict from the Russian air planner's perspective. Russia possesses approximately 1,250 combat-capable fighter aircraft. Fifth-generation procurements by the Russian Federation Air Force are experiencing major technical and industrial hurdles. Notwithstanding several years of an increased exercise tempo, readiness remains a major concern. Now, looking at the NATO order of battle, the planner sees 1,900-plus non-U.S. aircraft and hundreds of U.S. aircraft positioned in Europe and the Middle East. With key modernization ongoing, including the acquisition of F-35s by European allies, each of the factors typically considered in Russian COFM analysis appears to be growing less favorable. Modern aircraft with long-range munitions, if in sufficient quantity, can hold a wide array of targets at risk. The F-35's combat ISR mode enables revolutionary targeting and situational awareness that can enhance the effectiveness of larger air and joint formations. Allies are also beginning to invest more in personnel,

training, and equipment availability. Taken together, these developments could impart major doubt about Russia's ability to achieve its political-military objectives in a theater-wide conflict.

Our examination of the recent past and trajectory of European airpower, as well as Russian perceptions on the topic, suggests several findings and recommendations concerning the evolution of Europe's air forces and the opportunities and challenges that they confront. In particular, five overarching findings emerge, with an associated series of recommendations.

Findings

First, Russian political and military leadership remains concerned about NATO's relative advantage in the air domain—a dynamic that will likely intensify over the next five years as large numbers of fifth-generation fighters enter NATO inventories. Russia enjoys a relative advantage in rapidly deployable ground forces in regions close to Russian borders, notably the Baltic states and Poland. However, Russian strategy documents, statements, and actions indicate particular concern about the depth and speed provided by NATO's advanced platforms and munitions, which could serve to blunt Russia's ground advantage. Furthermore, observations of Western targeting practices over the past two decades have raised Russian concerns about the vulnerability of Russian ground forces, military bases, and critical infrastructure, as well as political leadership, to NATO's combat air capabilities. Although the perceived extent of NATO's relative airpower advantage is unclear, Russian defense analysts evaluating the combat potential of Western military aircraft have historically considered qualities such as firepower, mobility, survivability, and command and control, as well as a platform type's contributions to units and larger formations. These are all areas where the increase in capability resulting from NATO's modernization efforts will become more pronounced in the next five years. Extensive Russian investment in IADS underscores the significance with which Russia views the air domain a central dimension of its military planning.

Looking ahead, NATO's increased capability may deter Russian offensive action or force Russian planners to adjust their own operations or force structure. It also seems likely that any Russian offensive operation would attempt to destroy or ground NATO air forces and long-range weapons at their source—their bases or naval vessels. If NATO can demonstrate the existence of credible forces that can adequately defend NATO bases and infrastructure, this may influence Russia's assessment of effectiveness and probability of success. Based on these factors, NATO force structure and training actions before a conflict in these areas (deep strike, SEAD, and DCA) are the ones most likely to deter Russia from engaging in an offensive strike on NATO.

Second, European air forces currently possess fleets with relatively limited capabilities for conducting the most-demanding missions expected in a high-intensity conflict and of most concern to Russia. Currently, the European allies considered in this report maintain about 1,900 combat aircraft, fewer than 100 of which are fifth generation. European air forces made substantive contributions to previous allied and coalition air operations across the spectrum of combat air missions, but typically in less contested operating environments. During the opening phases of a conflict with Russia, vulnerability to advanced ground-based threats would constrain the roles of most fourth-generation and so-called fourth-generation-plus platforms. While limited in a highly contested environment, these aircraft could still perform defensive counter-air missions over national airspace or other strategically significant locations, long-range (outside of advanced IADS range) missile strikes with precision-guided munitions and electronic warfare attacks. As long as an extensive IADS threat persisted, more advanced platforms such as the Rafale or Eurofighter could theoretically perform strike missions inside the threat zone in conjunction with fifth-generation platforms, although this approach could yield unacceptable attrition. If the threat posed by adversary air defenses were reduced, fourth-generation aircraft could begin to conduct a broader range of traditional roles such as offensive counter-air or close air support to ground forces.

Another complication likely to stress NATO planners—particularly in light of the demise of the Intermediate-Range Nuclear

Forces Treaty—will be the need to reserve enough sorties for protection of national airspace, air bases, and other sensitive sites from cruise and ballistic missile attack.

Third, European acquisition of fifth-generation fighters will improve NATO's capacity for operations in a high-intensity conflict with Russia, though new capabilities are needed above and beyond the platform itself. By 2025, the seven F-35-acquiring European allies will, in aggregate, possess more than 200 F-35s stationed in Europe.¹ This will exceed the number of U.S. fifth-generation aircraft stationed in the European theater by a wide margin.² By 2030, the total number of fifth-generation fighters in these air forces will exceed 300 and is likely to approach 400 aircraft, which would account for 30 percent of combat aircraft among the nations considered.

In the opening days of a notional conflict, the F-35's stealth and sensor fusion will enable unprecedented situational awareness and the potential to acquire and service targets at rapid tempos. This will be impactful across the range of combat air missions, including SEAD in the early hours and days of a campaign and conducting counterland operations to delay, damage, and destroy enemy maneuver forces. These missions could be accomplished by the F-35 directly or with the F-35 performing a combat ISR role and securely passing targeting data to other air and joint platforms.

As capable as they are, fifth-generation fighters operate as part of a broader system of platforms and capabilities. Some nations are acquiring world-class fourth-generation-plus aircraft, though others have yet to commit to recapitalizing their fleets in the 2020s. Uncertainties remain as to which nations will invest in AESA radar technology, advanced and long-range munitions, and secure communication links, among other important capabilities. The degree to which European air forces acquire these technologies will directly impact their ability to contribute to the range of combat air missions expected in a high-intensity conflict. At the same time, reliance on the F-35 for

¹ We assume that Turkey will not acquire F-35s.

² Currently, the United States plans to station two F-35 squadrons at RAF Lakenheath beginning in 2021. Dennis, 2019.

combat ISR functions previously performed by longer-range, ISR-dedicated standoff aerial systems (e.g., RC-135W River Joint, E-8 Sentinel, and E-3 Sentry) raises the question of capacity and prioritization alongside other demands such as SEAD, counter-land operations, and air defense.

Fourth, a high degree of interoperability and integration between European fifth-generation fighters and NATO's other air and joint forces is required to maximize the Alliance's combat potential. As both Western and Russian analysts have observed, the combat potential of an individual aircraft is, in part, a function of its ability to work effectively within a broader formation. Fifth-generation platforms have the potential to serve as a force multiplier across a combined force, improving the performance of other platforms by enhancing their situational awareness. Fourth-generation fighters—many able to wield greater firepower than their stealthier fifth-generation counterparts and projected to account for about 70 percent of NATO's inventory by 2030—will still constitute an important element of airpower. It is reasonable to assume that the Russian military would seek to disrupt this synergy during a conflict, particularly in light of recent Russian investments in EW capabilities.

Already, allies have undertaken initial steps to establish common tactics, techniques, and procedures (TTP) for incorporating fifth-generation assets into combined operations through targeted exercises as well as preliminary synthetic training systems that link fourth- and fifth-generation aircraft. Recent training and exercises have emphasized operations in contested environments and prioritized missions such as SEAD, a skill set new to most European air forces. Important progress has been made, though it has been limited by policy and technological constraints to real-time information sharing among platforms and between allies.

Over the coming years, the need to familiarize aircrew across the Alliance with combined operations integrating fifth-generation aircraft will increase as the F-35 comes online. Major European air forces without fifth-generation capabilities, such as France, have ample opportunity to participate as full partners by joining in the development of emerging operational concepts. Additionally, air forces require clear

policy guidance for fifth-generation interoperability and information sharing, secure and reliable communications links, and additional resources for combined training in denied and degraded environments.

Fifth, even as many allied governments pursue procurement of advanced combat platforms, all European air forces still struggle to maintain high levels of readiness. To be operationally relevant during a theater conflict, NATO's air forces must maintain a sufficient number of available aircraft, munitions, and aircrew. Currently, most European air forces maintain around half of their existing fleets or less at mission-capable status, with some allies falling below that mark. For many fourth-generation fleets, rising maintenance costs from platform age, operational wear and tear resulting from a high operational tempo, and challenges associated with spare parts pipelines serve as significant constraints to aircraft availability. Early challenges within the F-35 program—in particular implementing an envisioned global spare parts pooling concept and overcoming malfunctions of the ALIS—could limit the benefits from European investments in the platform if left unaddressed. European investments in PGMs, including standoff weapons, deepen the allied arsenal and, if sufficient in quantity, would allow for a more sustained contribution to a collective defense operation should the need arise. Finally, insufficient airspace for exercises and the number of pilots and skilled maintainers represent limiting factors for most allied air forces.

Recommendations

Over the coming decade, European air forces will be increasingly capable of playing a significant role at the outset of a high-intensity collective defense operation. In particular, current and planned acquisitions of fifth-generation aircraft and their use within combat ISR, SEAD, and counter-land roles could fundamentally change the way that NATO conducts air operations, improving survivability and lethality and enabling greater European involvement across some of the most-demanding mission sets. Drawing from these findings, the recommendations made here are designed to inform European investments, the

implementation of JAPS, and other forms of multinational collaboration that make the most of emerging technology.

1. **Prioritize investments that enable fourth-generation aircraft and other platforms to complement the F-35's unique capabilities.** In order for the F-35 to maximize its impact across a conflict, the following investments should be made by allies to improve the survivability, firepower, and connectivity of existing platforms:
 - Upgrade fourth-generation aircraft radars. In particular, an AESA radar system for Eurofighter Typhoon fleets would enhance survivability during a high-intensity conflict.
 - Continue to stockpile munitions, including new options such as the Joint Strike Missile and recently developed or expected anti-radiation missiles. Using mechanisms such as the NATO Air-to-Ground project (known as A2G-PGM) as well as collaboration with European industry, allies should continue to expand their PGM arsenals with particular attention to anti-armor weapons and air-to-ground missiles with ranges between 100 km and 1,000 km, including anti-radiation missiles that provide fourth-generation aircraft a SEAD and strike capability from standoff ranges.
 - Ensure that fourth-generation aircraft as well as ground and maritime systems can receive targeting information from the F-35 in a timely and secure manner. Since NATO communications are a likely focus of Russian electronic attack, these must be robust and sufficiently redundant in the context of jamming and other interference.
2. **Prepare fifth-generation fleets across NATO to undertake operations within the range of Russia's most sophisticated air defenses.** To maximize the impact of European F-35 purchases for collective defense, fleets must be capable of contributing to challenging missions in the initial phases of an air operation. To enable this contribution, NATO air forces should initiate the following:
 - Include the SEAD mission in training and exercises beyond the initial training program at Luke AFB in the United States.

This will necessitate trainer aircraft that closely simulate the capabilities of the F-35 as well as realistic threat emitters and electronic jammers, among other features.

- Develop operational concepts for locating, tracking, engaging, and destroying moving armored formations in contested environments and ensure that training and exercises provide adequate opportunities to rehearse blunting large-scale ground offensives.
 - Hone international cross-maintenance practices to facilitate distributed operations and reduce predictability with flexible aircraft servicing that enables forward refueling and rearming.
3. **Institute routine combined training and exercises for multinational formations, including with the F-35.** The introduction of fifth-generation aircraft alters existing NATO concepts of operation and creates the need for closer synergy among aircrew. To improve operational cohesion over the coming decade, NATO air forces should institute the following:
- Train on a regular basis as often as practicable—ideally quarterly or even monthly—in combined multinational formations that include fifth- and fourth-generation systems. Initiatives can draw from the experiences of the long-standing multinational F-16 training program, Nordic Cross-Border Training arrangement, and recent UK-hosted Point Blank exercises.
 - Identify options for linked synthetic training among NATO air forces, potentially expanding on the 2018 Spartan Alliance simulator exercise.
 - Establish a NATO Air Warfare Center to facilitate regular and financially sustainable multinational air training, perhaps taking advantage of relatively large airspace and existing facilities available in Italy or Spain.
 - Leverage multinational advanced training events, such as U.S. Red Flag, to permit all members of the European F-35 user group to practice high-intensity combat air operations.
 - Initiate a robust personnel exchange program across allied F-35 users in order to rapidly standardize TTPs based on maturing fifth-generation operational concepts.

- Ensure that the French air force, which does not participate in the Euro-NATO Joint Jet Pilot Training program, has ample opportunity to participate in combined training.
4. **Commit to a greater level of public objectives and transparency for combat aircraft availability.** Data on the mission-capable rates of European air platforms are not generally publicized. Public agreement by NATO leaders on standard availability objectives could provide renewed political and budgetary focus on efficient and adequately funded maintenance and sustainment. The recent U.S. nadir of an average overall 70-percent mission-capable rate might offer a reasonable NATO-wide objective. This report identifies the following actions to improve availability levels:
 - Invest in measures to improve current limiting factors such as spare parts shortages and lengthy maintenance timelines within both the F-35 program and fourth-generation fleets.
 - Continue to address malfunctions within the F-35 ALIS logistics system.
 - Continue to develop a predictable and transparent system for spare parts allocation across the F-35 global spares pool.
 5. **Update national and F-35 program policies and procedures to allow U.S. and European air forces to enhance collaboration for training and operations.** At present, unclear and sometimes unnecessary restrictions on information sharing and planning stifle cooperation among air staffs and reduce their ability to adequately prepare for high-end multinational operations. In particular, senior-level attention can take the following actions:
 - Release an updated F-35 interoperability policy that identifies guidelines on information sharing within the consortium in a way that balances legitimate security needs without unduly restricting multinational cooperation.
 - Facilitate collaboration among U.S., European, and NATO planners to synchronize TTPs and concepts of operation, perhaps through the establishment of standing liaisons at the squadron and/or group levels.

Implications and Topics for Additional Research and Analysis

European investments in combat air capabilities and increased emphasis on training and preparation for high-intensity missions are likely to improve European contributions to a notional collective defense scenario over the coming decade. These developments could also enhance deterrence—an objective at the forefront of NATO's agenda since 2014—by making it more likely that Europeans would be able to impose extensive military costs on Russia in response to aggression against a NATO member. One common scenario considers a calculation by the Russian government that Russia could leverage a regional imbalance in ground forces to occupy some slice of NATO territory, employ air defenses to stave off allied air forces, present a *fait accompli* similar to that seen in Crimea, and politically divide NATO by calling for negotiations.³ The ability of European fifth-generation fighters to penetrate Russian air defenses, attack Russian ground forces, and make other significant combat contributions from the opening hours of a response would most likely challenge the logic behind this scenario, improving deterrence by increasing the Russian risks associated with this approach.

Further analysis should consider alternative perspectives. To the extent that the Russian government perceives an existential threat from NATO's long-range strike capabilities and believes that strategic air operations favor prompt offensive action, Russia could feasibly be incentivized to conduct preemptive strikes during a moment of crisis in order to degrade fifth-generation capabilities. Seen through the lens of Russian insecurity and the “besieged fortress mentality,” allied efforts to enhance deterrence could perversely have destabilizing effects on European security. Full consideration of this argument, which would require wargaming and deeper technical analysis, is important but lies beyond the scope of this report.

Within Europe, the broader implications of divergent combat air investment decisions also merit further attention. France and Germany,

³ Shlapak and Johnson, 2016.

two of the most significant European military powers, will experience a generation-long gap in their combat air capabilities as they bypass fifth-generation capabilities in favor of collaboration on a European future combat air system slated to be completed in the 2040 time frame.

For France, upgrades to the Rafale as well as investment in stand-off munitions would still allow it to play a constructive role in the initial phases of a conflict with Russia, particularly if communication systems permitted the platform to be networked with the F-35. However, this concept would require the French air force to be reliant on targeting and threat data from other European platforms, running somewhat counter to the French inclination toward strategic autonomy. In light of the prominent French role in previous NATO air operations, additional research and analysis could assess potential trajectories for French strategic and operational leadership within a range of future air conflict scenarios.

For Germany, a 20-year gap in combat air capabilities could undercut aspirations for a leadership role in European security. Germany's current lack of fifth-generation aircraft, technologies such as the AESA radar, or long-range missile arsenal would constrain German offensive combat contributions in a high-intensity conflict with Russia, likely circumscribing the Luftwaffe's role to defensive counter-air missions beyond the range of Russian surface-to-air missiles. Germany's contribution would not be negligible in light of the extensive NATO infrastructure on German soil, but the implications of German absence from a forward combat air role, and uneven distribution of operational risk across the alliance, merit further discussion. Furthermore, while it is beyond the scope of this paper, further analysis should consider the implications for NATO nuclear burden sharing of a Germany unable to credibly perform NATO nuclear missions in a denied and degraded environment.

Ultimately, European military investments presume a benefit to European security through the deterrence of further military aggression on the European continent and empowerment of European militaries to make substantial contributions to future operations. This RAND study, premised on the validity of that assumption, concludes that in the air domain, at least, trend lines with regard to platform

modernization lead in the right direction. European investment in modernizing combat aircraft fleets and building PGM arsenals improve allies' collective combat capability, with air training and exercises increasingly reflecting emergent requirements. With additional budgetary and policy attention to increasing platform availability, air-base survivability, and interoperable data links, Europe has the opportunity to significantly enhance its combat airpower over the coming decade.

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Airpower is critical to improving NATO's defense and deterrence posture in response to Russia's aggressive actions and continued military modernization, as recognized in NATO's 2018 Joint Air Power Strategy. The capabilities of European air forces to defend allies in conflict are evolving, and the trend line in platform modernization is leading in the right direction, most critically with the introduction of fifth-generation aircraft. European allies are also beginning to invest more in personnel, training, and equipment availability. Taken together, these developments could decrease Russia's ability to achieve its operational and political-military objectives in a theater-wide conflict.

The authors—drawing from interviews, an expert roundtable, and relevant literature—assess the specific opportunities and challenges that European air forces need to address to position themselves as central contributors to NATO's deterrent posture at the vanguard of any foreseeable combat air campaign. Specifically, they focus on maximalist conditions—high-intensity operations that would require rapid and large-scale application of airpower, conducted in the European theater. Their analysis examines the capabilities of the 13 allied air forces in Europe capable of making the most substantial contribution to large-scale combat operations.

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