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Distributed Operations in a Contested Environment

Implications for USAF Force Presentation

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Library of Congress Cataloging-in-Publication Data is available for this publication.

ISBN: 978-1-9774-0232-5

Published by the RAND Corporation, Santa Monica, Calif.

Preface

Because of increasing air and missile threats to air bases, the Air Force is developing concepts to operate from a large number of small operating locations in a conflict with a near-peer competitor. This type of distributed air operations in a contested environment represents a significant shift in the way the Air Force has operated since the end of the Cold War. The Air Force therefore asked the RAND Corporation whether the Air Force needs to adjust how it presents forces to the joint commander. This report identifies capabilities the Air Force needs to carry out distributed operations in a contested environment. It then assesses whether the current force presentation model can provide these capabilities and how it compares with alternative models.

The research reported here was commissioned by Maj Gen Brian Killough, Director of Strategic Plans, Office of the Deputy Chief of Staff for Strategic Plans and Requirements, and conducted within the Strategy and Doctrine Program of RAND Project AIR FORCE as part of a FY 2018 project Distributed Operations.

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This report documents work originally shared with the U.S. Air Force on August 2, 2018. The draft report, issued on September 17, 2018, was reviewed by formal peer reviewers and U.S. Air Force subject-matter experts.

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Summary

The 2018 National Defense Strategy instructed the services to prioritize capabilities for conflict with another great power. This gave new urgency to ongoing initiatives within the Air Force to prepare for growing air and missile threats to bases and a contested communications environment. There is a wide range of possible counters to the particular problem of air base vulnerability, including greater reliance on long-range systems, active defenses, hardening of bases, and on-base dispersal of assets. This study focuses on a particular set of emerging concepts for distributed operations that call for using a larger number of air bases to complicate enemy targeting and using a more decentralized command and control (C2) approach. The U.S. Air Force (USAF) asked the RAND Corporation to consider whether the USAF needs to change its force presentation model (FPM), the way it organizes to use airpower as part of a joint operation, to implement these concepts.

Since the Air Force has not developed a single detailed concept for distributed operations, this report synthesizes and extends the logic of emerging concepts. It then identifies an initial list of capabilities the Air Force may need in order to protect, command and control, and sustain fighter forces at a larger number of operating locations. Finally, the report assesses whether the current Air Force FPM for fighter forces provides these capabilities and identifies the trade-offs associated with force presentation changes.

Protecting Distributed Bases

Potential U.S. adversaries have made significant quantitative and qualitative improvements in their air and missile capabilities in recent decades. China's missile inventory, in particular, is the most significant threat to U.S. air bases. Surviving in a contested environment will require a portfolio of defensive capabilities. This portfolio will include a mix of active defenses, such as short-range and theater missile defenses, and passive defenses, such as on-base dispersal of aircraft.

Operating from a larger number of air bases provides protection by increasing the number of targets that the adversary would need to attack for an equivalent reduction in U.S. air operations. Distributed basing would likely use a mix of operating location types. This report describes three ideal types. A "Stay and Fight" base would have more significant active and passive defenses and greater capability to recover from attacks than today's major air bases. "Drop-in" bases would have fewer defenses, only sufficient capabilities to recover from an attack to evacuate aircraft, and more limited sustainment capabilities than Stay and Fight bases. Austere forward arming and refueling points would open up for only hours at a time so that fighter and mobility

aircraft teams could use them before an enemy could detect their location and coordinate a missile attack.

The threat of damaging ground attacks on air bases is also more severe in a conflict with another great power. As with a missile threat, a larger number of operating locations reduces the damage that can be produced with a single ground attack. At the same time, protecting more airfields increases the number of security force units needed.

Command and Control of Distributed Forces

Potential U.S. adversaries have the capability to attack long-distance communications systems, including satellites and long-distance fiber. As a result, there may be significant disruptions or degraded communications between the air operations center, where the Air Force conducts centralized planning, and forward operating locations. Communications between bases in the forward area would likely be more reliable, in part because of alternative options such as courier planes, but disruptions, delays, and bandwidth limitations are still likely.

To make C2 more resilient in a communications-contested environment, the Air Force may adopt a more decentralized approach by delegating more authorities and providing planning capabilities to lower echelons. Air Force leaders have also called for using mission, rather than detailed, orders to allow subordinates to determine how to achieve objectives in line with the commander's intent when communications are disrupted. This type of distributed control may require more trust and shared understanding between commanders and their subordinates.

Sustaining Distributed Forces

Adversary attacks will disrupt sustainment by damaging or destroying airfield operating surfaces; fuel, parts, and munitions storage; maintenance facilities; aerospace ground equipment; runway repair equipment; and other support facilities and equipment. Additionally, such attacks are likely to wound or kill maintenance, engineer, security force, and other personnel key to sustainment activities. Nonlethal attacks will disrupt sustainment by hindering communications among units (e.g., requests for resupply) and possibly compromising the integrity of databases, maintenance software, and decision support systems.

A contested environment changes the mission of combat support forces from one of operating at peak levels of efficiency and safety at sanctuary bases to one of generating sorties from forward bases despite enemy efforts to stop them. In the second case, such efficiencies are lost due to the larger number of operating locations, the defensive measures required to prepare for attack, and enemy actions that disrupt work, rest, and eating schedules, damage vital equipment, and wound or kill personnel.

Implications for Force Presentation

We identified five critical dimensions of force presentation that may affect warfighting effectiveness in a contested, degraded environment:

- size of units at operating locations
- the lowest echelon with defense and support units
- the lowest echelon with significant planning capabilities
- the lowest echelon with multiple aircraft types
- the highest wartime echelon that regularly trains together in peacetime.

Drawing on Air Force policy and practice, we describe the current USAF FPM for major combat operations. Operating locations are typically wing sized. Wings are also typically the lowest echelon with support units and multiple aircraft types and the highest fighter echelon that regularly trains together in peacetime. Significant planning capabilities are centralized in the joint air operations center (JAOC) under the direction of the commander, Air Force forces, for the operation (also dual hatted as the joint force air component commander).[1]

Wing-sized units at main operating bases and centralized planning capabilities in the JAOC represent significant vulnerabilities in a conflict with a near-peer competitor. Changes to these and other dimensions of the USAF FPM could increase warfighting effectiveness but would also create trade-offs (e.g., greater personnel and materiel requirements).

Findings

The U.S. Air Force Force Presentation Model and Operating Concepts Are Based on Assumptions That Are Incompatible with a Contested Environment

A conflict with a great power will overturn two key assumptions about the operating environment that have prevailed during counterinsurgency (COIN), counterterrorism (CT), and stability operations in recent decades: that air bases are sanctuaries and communications reliable. In this setting, wing-sized units at main operating bases and centralized planning at the JAOC mean that the enemy could disrupt air operations with attacks on a few high-payoff targets.

[1] Air Force documents often refer to the AOC as the generic term for any air operations center. In practice, the AOC becomes a JAOC for joint air operations and a combined air operations center for coalition operations. We use the acronym JAOC throughout the report since, at a minimum, conflict against a near-peer competitor would be a joint undertaking.

The Contested Environment Will Force the U.S. Air Force to Trade Efficiency for Survivability

Regardless of the concept it uses, the Air Force will have to trade efficiency for survivability in a high-end fight. If the Air Force pursues distributed operations, it will need more resources (e.g., combat support personnel, base defense personnel, headquarters staff, communications equipment) to support a greater number of operating locations and enable distributed control. Alternatives to distributed operations, such as conducting air operations from more distant bases, would also come with inefficiencies. Operating from more distant bases would, for example, increase flying time and reduce the rate of sorties that the Air Force could generate. Alternatives to distributed operations would also come with higher costs. Flying from more distant bases, for example, could require new acquisition programs, longer flight times, and lower sortie rates.

Some concepts, FPMs, and beddowns may be less resource intensive than others. But these choices are not likely to overcome the fundamental inefficiency and significant resource demands of air operations against a near-peer adversary. Prioritizing survivability over efficiency will also require a significant cultural change for the Air Force, which has been largely focused on efficiency to sustain COIN and CT operations.

Developing Concepts for Distributed Operations Will Require Close Collaboration Between Operations and Combat Support Communities

During discussions with USAF personnel, we heard frustrations from both the operations and support communities. Operators are driving many of the concepts for distributed operations and, in some cases, are frustrated with what some perceive as resistance from the combat support communities. At the same time, some in the combat support community are concerned that the distributed operations concepts are being developed without a realistic understanding of support constraints, burdens, and resource demands they create. If the Air Force continues to develop distributed operations concepts, operators will spend more time thinking about logistical constraints while sustainment professionals will spend more time thinking about warfighting.

The Force Presentation Model for Distributed Operations in a Contested Environment Must Enable Lower Echelons to Plan and Execute Offensive and Defensive Operations

Since wing-sized operating locations are vulnerable, each operating location is likely to have smaller units. This means that echelons below the wing will need support and defense capabilities to operate from a separate air base and to make more decisions independently.

Gaining and Maintaining Political Access Is a Precondition for Distributed Operations

Distributed operations call for a larger number of air bases in partner countries than in the past. Past research has shown that partner decisions to allow access will likely be contingent on the scenario and the broader political relationship between the United States and each host country. The Air Force can prepare for this uncertainty by developing contingency plans and having processes for dynamic changes in posture during wartime. However, the number of facilities available for distributed operations may be limited by uncertain political access at the outset of and during a contingency operation.

More Analysis Is Needed on Command and Control, Support, and Other Implications of Distributed Operations for Nonfighter Forces

This report focused on distributed fighter operations. Operating fighter forces in this way would create many implications for Air Force forces such as intelligence, reconnaissance, electronic warfare, mobility, and tanker aircraft that were not analyzed in detail here. If these forces operate in a distributed way as well, there would be additional consequences for C2, support, and protection. The Air Force will need to consider these additional implications as it develops concepts for and assesses the viability of distributed operations.

Recommendations

These findings suggest seven recommendations for USAF leaders and planners. In some cases, the Air Force is already pursuing related initiatives, so our recommendations reinforce the importance of these activities or point to a need for greater emphasis.

Determine Resource and Access Requirements for Distributed Operations. The Air Force has voiced concerns about the shortage of resources to carry out current activities, so it is unlikely to be able to make the investments needed for distributed operations without a change in resource levels or commitments.[2] A first step in determining whether these concepts are viable is to identify both the access and resource requirements for distributed operations. Ongoing initiatives on distributed operations (e.g., Adaptive Basing from Headquarters Air Force [HAF] and Agile Combat Employment from U.S. Pacific Air Force [PACAF]) are beginning to grapple with some of these questions, including through exercises.

Simulate Heavy Air, Missile, and Ground Attacks in Home Station Training and Exercises. Simulating air base attacks is important for practicing survivability measures and conducting tasks under attack. Meeting the demands of a contested environment will require intensified training to prepare to operate under heavy attacks. From a C2 perspective, commanders can also consider how to set priorities between air and ground operations, make decisions under more stressful conditions, and continue operations in the face of casualties. Discussions with Air Force personnel suggest that this type of training has not been a priority for

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[2] David Goldfein, "Remarks from Air Force Chief of Staff Gen. David L. Goldfein," Air Force Association Air, Space and Cyber Conference, National Harbor, Md., September 19, 2017b; Heather Wilson, "State of the Air Force Speech," Air Force Association Air, Space and Cyber Conference, National Harbor, Md., September 18, 2017.

most units in recent decades as the joint force has been largely focused on COIN and CT operations.

Consider Creating Integrated Base Defense Units. A capable adversary may coordinate multiple types of attacks on bases. Different attacks can require different mitigation strategies, which require a commander to weigh the relative risk of each and set priorities for defensive responses.[3] The Air Force should therefore develop a concept for and explore the benefits of creating integrated base defense units.

Hold Regular Exercises That Include Communication Disruptions. Both command post and field exercises that include leaders at multiple echelons could give leaders practical experience with transitioning authorities, writing mission orders, acting on commanders' intent from higher echelons, and developing situational awareness. Including commanders from multiple echelons who will likely fight together could have the additional benefit of developing trust and shared understanding, which may facilitate distributed control and mission-type orders.

Cross Train Airmen to Reduce the Personnel Demands of Distributed Operations. Distributed operations require more personnel in maintenance, security force, headquarters staff, and other positions. Moreover, operations in a contested environment may also lead to much heavier casualty rates than in recent operations. Cross training airmen so they can carry out functions beyond their specialty could help with both challenges. The Air Force may gain broader insights about cross training from an ongoing pilot program to cross train maintenance personnel.

Consider the Possible Role of the Group in Distributed Operations Before Eliminating the Peacetime Group Echelon. Air Combat Command is experimenting with a new peacetime structure for the wing that eliminates the group echelon. However, depending on the specific distributed operations concept that the Air Force decides to pursue, there may be a valuable wartime role for the group. If so, retaining the group in peacetime may be advisable to create opportunities for leader development and minimize the friction involved in changing organizational structures for wartime.

Use Exercises and Additional Analysis to Explore Force Presentation Implications of Distributed Operations. Chapter 6 identifies a number of trade-offs associated with changes to the Air Force's FPM. Determining the severity of these trade-offs in a contested environment will require additional exercises and analysis. PACAF is already exercising distributed operations concepts and considering force presentation implications. The Air Force should look for additional opportunities to explore force presentation alternatives in its exercises.

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[3] The USAF and joint force developed effective organizations, authorities, tactics, techniques, and procedures for air base defense in both Iraq and Afghanistan. Although the threat was limited to ground attacks, many lessons are applicable to defense of distributed locations against air, missile, and ground attacks during a major war. Shannon W. Caudill, *Defending Air Bases in an Age of Insurgency*, Maxwell Air Force Base, Ala.: Air University Press, 2014.

Acknowledgments

The authors thank Maj Gen Brian Killough (then HAF/A8X) for commissioning the study and Col Bryan Cannady (then HAF/A5SC) for his many contributions to project design. Colonel Cannady also ensured that the project team was integrated with ongoing HAF efforts to enhance the USAF FPM. The project was transferred to the new Air Force Warfighting Integration Capability (AFWIC) in March 2018. We thank Maj Gen Clinton Crosier (Commander, AFWIC) and Brig Gen S. Clinton Hinote for their support and helpful feedback on interim analytical products.

Thanks to project action officers Lt Col Kenyatta Ruffin, Lt Col Cory Hollon, and Lt Col Aaron Gibney for their valuable feedback and suggestions.

Staff in Headquarters USAF, PACAF, USAFE, 3rd Wing, and the Curtis E. LeMay Center for Doctrine and Education all shared their expertise on various aspects of distributed operations. We also acknowledge the hospitality of leaders and staff at the 613th Air Operations Center, PACAF Headquarters, and the 1st Fighter Wing during visits to discuss distributed operations.

We thank Mark Hvizda for assembling and formatting the document.

Finally, we thank reviewers Michael Spirtas, Eric Heginbotham, and Bruce McClintock for their insightful and practical suggestions on an earlier draft.

Abbreviations

AB	Air Base
ABDR	aircraft battle damage repair
ACC	Air Combat Command
ACE	Agile Combat Employment
ACS	Agile Combat Support
ADR	airfield damage repair
AEF	air expeditionary force
AEG	air expeditionary group
AES	air expeditionary squadron
AETF	air expeditionary task force
AEW	air expeditionary wing
AFB	Air Force Base
ALCM	air-launched cruise missile
ALIS	Automatic Logistics Information System
AOC	air operations center
ARFORGEN	Army force generation
ARG	amphibious ready group
ATC	air traffic control
ATO	air tasking order
BCT	brigade combat team
BEAR	basic expeditionary airfield resources
C2	command and control
CCDE	centralized control and decentralized execution
CCDR	combatant commander
CENTCOM	U.S. Central Command
CEP	circular error probable
CNMI	Commonwealth of Northern Marianas Islands

COIN	counterinsurgency
COMAFFOR	commander, Air Force forces
C-RAMD	Counter-Rocket, Artillery, Mortar and Drone System
CRG	contingency response group
CSG	carrier strike group
CT	counterterrorism
CVN	aircraft carrier, nuclear
CVW	carrier air wing
DoD	Department of Defense
DOTMLPF-P	doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy
DPRK	Democratic People's Republic of Korea
EFS	expeditionary fighter squadron
EOD	explosive ordnance disposal
ESG	expeditionary strike group
EW	electronic warfare
FARP	forward arming and refueling point
FP	force presentation
FPM	force presentation model
HAF	Headquarters Air Force
HF	high frequency
HMMWV	high-mobility multipurpose wheeled vehicle
IFPC	Indirect Fire Protection Capability
ILS	instrument landing system
ISR	intelligence, surveillance, and reconnaissance
JAOC	joint air operations center
JB	Joint Base
JFACC	joint force air component commander
JFC	joint force commander
JTF	joint task force
LOS	line-of-sight

MAGTF	Marine air-ground task force
MANPADS	man-portable air defense system
MEF	Marine expeditionary force
MEU	Marine expeditionary unit
MRBM	medium-range ballistic missile
NAF	numbered air force
NATO	North Atlantic Treaty Organization
NDS	National Defense Strategy
O-FRP	optimized fleet response plan
OIF	Operation Iraqi Freedom
PACAF	U.S. Pacific Air Forces
PATRIOT	Phased Array Tracking Radar to Intercept on Target
PLA	People’s Liberation Army
PLAAF	People’s Liberation Army Air Force
QRF	quick reaction force
RADR	Rapid Airfield Damage Repair
SATCOM	satellite communication
SOF	special operations forces
SRBM	short-range ballistic missile
SUAS	small unmanned aerial system
TBM	theater ballistic missile
THAAD	Terminal High-Altitude Area Defense
TTP	tactics, techniques, and procedures
USAF	U.S. Air Force
USINDOPACOM	U.S. Indo-Pacific Command
UTC	unit type code
VBIED	vehicle-borne improvised explosive device

1. Introduction

The 2018 National Defense Strategy (NDS) reorients the Department of Defense (DoD) away from counterinsurgency (COIN) operations and toward competition with other great powers.[1] The change in strategy underscores the importance of ongoing U.S. Air Force (USAF) and joint initiatives to develop new concepts for conventional conflict with a near-peer competitor.[2] Unlike recent conflicts, Air Force operations would take place in a contested environment. We use this term to encompass all adversary attempts to disrupt U.S. and partner military operations throughout the depth of the battlespace, including both kinetic and nonkinetic attacks. For example, a near-peer competitor could use long-range ballistic and cruise missiles, cyber attacks, electronic warfare (EW), and offensive space weapons to attack vital elements of U.S. military power including air bases and communications systems.

In theory, there is a wide range of possible counters to the particular problem of air base vulnerability, including greater reliance on long-range systems, active defenses,[3] hardening of bases, and dispersal of assets.[4] As a practical matter, however, near-term U.S. choices are more limited. For example, even if it were determined to be the most cost-effective solution, it would take decades to substantially change the USAF force mix to be predominantly long range or to greatly increase the number of missile defense systems. Therefore, near-term enhancements to air base survivability will depend heavily on new operating concepts supported by modest investments in capabilities that can be acquired in a relatively short period of time (e.g., deployable shelters, fuel bladders, and rapid runway repair kits).

In particular, Air Force concepts envision carrying out what this report calls distributed operations, employing combat aircraft from a larger number of geographically separated bases.[5]

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[1] Jim Mattis, *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge*, Washington, D.C.: U.S. Department of Defense, 2018.

[2] See, for example, U.S. Department of Defense, *Joint Operational Access Concept (JOAC)*, Washington, D.C.: U.S. Department of Defense, Version 1.0, January 17, 2012.

[3] See, for example, Carl Rehberg and Mark Gunzinger, *Air and Missile Defense at a Crossroads: New Concepts and Technologies to Defend America's Overseas Bases*, Washington, D.C.: Center for Strategic and Budgetary Assessments, 2018.

[4] As will be discussed in Chapter 2, a mix of these improvements has historically proven to be the most robust approach to air base defense; recent analyses generally align with this conclusion.

[5] U.S. Air Force, *Air Force Future Operating Concept: A View of the Air Force in 2035*, Washington, D.C.: U.S. Department of Defense, September 2015, pp. 31, 36. Our definition of distributed operations expands on the narrower use of the term in Air Force command and control (C2) doctrine to refer to geographically separate forces that plan or make decisions together. Curtis E. LeMay Center for Doctrine Development and Education, *Air Force Glossary*, Maxwell Air Force Base, Ala.: Curtis E. LeMay Center for Doctrine Development and Education, July 18, 2017, p. 29; Annex 3-30, *Command and Control*, Washington, D.C.: Headquarters U.S. Air Force, November 7, 2014, p. 24.

Although the United States has used aircraft from multiple air bases in recent conflicts, it has not operated from a large number of bases, under attack, and with disrupted communications. Distributed operations in a contested environment, therefore, represent a significant shift in the operational environment and the way most airpower has been employed since the end of the Cold War.

Several organizations within the Air Force are grappling with the details of how the Air Force would conduct distributed operations.[6] As a result, there is not yet a set of best practices or a fully developed list of capabilities needed for distributed operations. Yet, given the time it takes to make significant changes to Air Force organization, training, and education, the Air Force needs to begin thinking about the possible implications of distributed operations in a contested environment.

The Air Force asked the RAND Corporation to consider, in particular, whether concepts for distributed operations necessitate a change to the Air Force's force presentation model (FPM). An FPM is the way a service typically organizes its forces for a joint operation. In order to respond to that request, this study asked three questions:

- What capabilities does the Air Force need in order to conduct distributed operations in a contested environment?
- Would the current Air Force FPM have shortcomings in a contested environment?
- In what ways could the Air Force change its FPM to improve warfighting effectiveness in a high-end fight, and what would be the trade-offs?

Since the concepts for distributed air operations are still emerging, this report is necessarily exploratory and conceptual. We synthesize and expand on existing concepts for distributed operations in order to identify possible capabilities for distributed operations as a starting point for identifying implications for force presentation. We focus in this study on presenting forward deployed fighter forces.

Force Presentation

There is no official Air Force or joint definition of force presentation. Airmen typically use the term to describe the preferred organizational construct through which a service offers its capabilities to a joint commander. These include the Army's brigade combat team (BCT), the Marine Corps' Marine air-ground task force (MAGTF), the Navy's carrier strike group (CSG), or the Air Force's air expeditionary task force (AETF). Yet *force presentation* is also often used

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[6] A prominent concept is the Agile Combat Employment (ACE) Concept from the U.S. Pacific Air Forces (PACAF). Amy McCullough, "Ace in the Hole," *Air Force Magazine*, May 17, 2017a. For a list of other Air Force concepts for distributed operations in recent years, see David Dammeier, Meka Toliver, and Logan Smith, "Overcoming a Power Projection Problem," *CE Online*, Spring 2016.

to refer to other concepts and processes. Past RAND research identified six separate functions that are often associated with force presentation: size forces, deploy forces, employ forces, sustain forces, manage force rotations, and articulate service purpose.[7] As can be seen in Table 1.1, none of the services has found a single overarching construct to perform all six functions. Some constructs (e.g., the Air Force squadron) serve multiple roles, but the functions are so varied it is hard to imagine a single model applicable to all. In our judgment, it is more productive to focus on force presentation options for specific functions or at most pairs of functions.

Table 1.1. Service Force Presentation Constructs

	Size Forces	Deploy Forces	Employ Forces	Sustain Forces	Manage Force Rotations	Articulate Service Purpose
USN	CVNs, CVWs, combatant vessels	CSG/ESG	CSG/ESG	Combat Logistics Force	O-FRP	CSG/ESG offers presence & crisis response
USMC	MEFs, divisions, air wings	MEU	MEU	MAGTF & ARG	R-Plus or D-Minus	MEU/ARG offers presence & crisis response
Army	Divisions	BCT	BCT	Division & Corps	ARFORGEN	FP plays no role in service narrative
USAF	Squadrons	UTC, AES, squadron	Squadron, wing, EFS, AEG, AEW, AETF	AEG, AEW, or wing	AEF	FP plays no role in service narrative

SOURCE: Vick, 2018.
NOTE: USN = U.S. Navy; USMC = U.S. Marine Corps; CVN = aircraft carrier, nuclear; CVW = carrier air wing; MEF = Marine expeditionary force; CSG = carrier strike group; ESG = expeditionary strike group; MEU = Marine expeditionary unit; BCT = brigade combat team; UTC = unit type code; AES = air expeditionary squadron; EFS = expeditionary fighter squadron; AEG = air expeditionary group; AEW = air expeditionary wing; AETF = air expeditionary task force; MAGTF = Marine air-ground task force; ARG = amphibious ready group; O-FRP = optimized fleet response plan; R-Plus and D-Minus are USMC force management processes; ARFORGEN = Army force generation process; AEF = air expeditionary force; FP = force presentation.

This report focuses on the characteristics that an FPM needs to have in order to conduct and sustain air operations in a contested environment. The current Air Force approach to these functions, described in this section, emphasizes flexibility to meet joint commander needs and has little relationship to its permanent units.

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[7] Alan Vick, *Force Presentation in U.S. Air Force History and Airpower Narratives*, Santa Monica, Calif.: RAND Corporation, RR-2363-AF, 2018, p. 1.

Some Air Force forces are assigned to a combatant command as a component major command (C-MAJCOM, e.g., PACAF) or a component numbered air force (C-NAF, e.g., 12th Air Force [Air Forces Southern]). In a contingency, however, additional forces may be attached to these existing Air Force service components. When there is no existing Air Force service component, such as when the operation is conducted by a joint task force (JTF), the Air Force forces are attached as an AETF. The Air Force service component, whether C-MAJCOM, C-NAF, or AETF, is led by the commander, Air Force forces (COMAFFOR), and is scalable to meet the requirements of the joint force commander (JFC). Depending on the scale of the AETF, it includes subordinate organizations such as AEWs, AEGs, or EFSs.[8]

The AEF is the Air Force process for deploying and managing rotations of forces that are attached to the Air Force service component and its subordinate organizations.[9] Today, entire permanent wings, groups, and squadrons do not generally deploy together to make up these expeditionary units. Rather, the AEF process combines personnel and equipment from multiple units to create elements, identified by a UTC, with particular capabilities. These UTCs are combined to create the AETF's expeditionary units. In recent years, UTCs have varied in size with some as small as a single airman.[10]

The Air Force needs to consider many factors in deciding whether to change any aspect of its FPM.[11] For example, the Air Force approach to managing rotations needs to account for the possibility of distributed operations in a conflict with a near-peer competitor as well as continued demands for other types of operations such as CT. This report focuses on how changes to the way the Air Force employs and sustains airpower would affect warfighting effectiveness. Although it does not analyze all of the implications in detail, the report notes a range of additional considerations the Air Force will need to make as it selects an FPM for employment and sustainment of fighter forces in a contested environment.

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[8] Air Force Instruction 38-101, *Air Force Organization*, Washington, D.C.: U.S. Air Force, U.S. Department of Defense, AFI 38-101, January 31, 2017; Air Force Instruction 10-401, *Air Force Operations Planning and Execution*, Washington, D.C.: U.S. Air Force, U.S. Department of Defense, AFI 10-401, 2006, Incorporating Through Change 4, March 13, 2012, p. 40; Annex 3-30, 2014, pp. 2, 30, 55–64.

[9] Annex 3-30, 2014, p. 54; Air Force Instruction 10-401, 2006. When the AEF concept was formulated in the 1990s, it was intended to be both the process for managing force rotations and a standard unit of measure for presenting forces. However, the Air Force later decided to present tailored packages of forces based on combatant commander (CCDR) needs rather than through a standard-sized AEF unit. The term AEF also refers to available forces that can be drawn from to build AETFs. Jeffrey Hukill, Kristal Alfonso, Scott Johnson, and John Conway, *The Next-Generation Expeditionary Air Force*, Maxwell Air Force Base, Ala.: Air University, Air Force Research Institute Papers 2012-2, February 2012a, pp. 15–21.

[10] Air Force Instruction 10-401, 2006, p. 6.

[11] For a discussion of some of these factors, see Hukill, Alfonso, et al., 2012a.

Methodology

The analysis in this report has two primary elements: identifying the capabilities the Air Force needs to carry out distributed operations in a contested environment and generating implications for force presentation. As this section details, we began by identifying key assumptions about the contested environment. We then designed a framework to systematically identify capabilities that the Air Force would need to conduct distributed air operations. We identified possible ways of generating these capabilities, including changes to doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy (DOTMLPF-P). Finally, we assessed whether the current Air Force approach to force presentation could provide those capabilities and identified trade-offs associated with FPM changes.

This broad and systemic approach allowed us to identify capabilities that directly affect force presentation as well as to place changes to force presentation in context. If many of the capabilities needed for distributed operations are unrelated to force presentation, then the Air Force may wish to emphasize other policy changes. Relatedly, if force presentation alternatives are unlikely to significantly affect warfighting effectiveness, the Air Force may wish to consider other priorities in choosing an FPM.

Assumptions About the Contested Environment

We reviewed a range of unclassified assessments to characterize the contested environment. We identified two broad types of disruptions that would have a major effect on air operations: air and missile attacks on air bases and disruptions to the communications links between Air Force operating locations. China represents the most capable potential threat to U.S. operations on these dimensions, and so throughout the report we use it and the geography of the Western Pacific as an exemplar of the types of challenges a contested environment poses to air operations.

We also make a series of assumptions about the nature of the conflict with a near-peer competitor in which distributed operations would take place. First, we assume the United States and its adversary would be engaged in a major conflict that motivates each to devote large numbers of forces and engage in large-scale conventional operations. Second, we assume that the United States would have access to a large number of air bases prior to the conflict. This assumption is critical because, currently, the United States does not have enough peacetime overseas air bases to conduct distributed operations. Although we make this assumption for the purposes of our analysis, we also discuss the practical challenges in gaining and maintaining access elsewhere in the report.[12]

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[12] For example, during peacetime, the USAF has six permanent bases in the Western Pacific (Kadena, Yokota, Misawa, Osan, and Kunsan Air Bases [ABs] as well as Andersen Air Force Base [AFB]). Michael J. Lostumbo, Michael J. McNerney, Eric Peltz, Derek Eaton, David R. Frelinger, Victoria A. Greenfield, John Halliday, Patrick Mills, Bruce R. Nardulli, Stacie L. Pettyjohn, Jerry M. Sollinger, and Stephen M. Worman, *Overseas Basing of U.S. Military Forces: An Assessment of Relative Costs and Strategic Benefits*, Santa Monica, Calif.: RAND Corporation, RR-201-OSD, 2013, pp. 25–29.

Third, we assume that the United States has pre-positioned materiel throughout the theater and has the time and transportation assets necessary to open a network of bases on an appropriate time line. As with assumptions about access, the challenges of preconflict pre-positioning and logistics are significant and merit their own detailed analysis. For the purposes of this study, we assume equipment and operating locations are available in order to explore the demands and challenges created once all of those operating locations are opened.[13] Finally, we assume that the joint force would provide capabilities that enable the Air Force to operate in a distributed manner. The U.S. Army, for example, would likely play a key role in providing theater logistics and ground-based air and missile defenses.

Although other platforms may operate in a distributed manner also, the focus in this analysis is on fighter operations. There are two reasons for this focus. First, fighters make up the bulk of combat air force platforms and would require more locations for distributed operations than would be required for smaller fleets. Second, because of their shorter range, fighters need to operate from within higher air and missile threat rings than tankers, bombers, and other long-range aircraft. As a result, distributed operations for fighter forces represent the Air Force's most significant challenge. To develop a refined distributed operations concept and fully evaluate the viability of distributed operations concepts more generally, the Air Force will need to conduct additional analysis for nonfighter forces.

Framework for Identifying Capabilities for Distributed Operations

To identify the capabilities needed to conduct distributed air operations, we developed a framework based on the joint functions (Table 1.2). The joint functions, categories of warfighting activities, include C2, intelligence, fires, movement and maneuver, sustainment, and protection.[14]

We identified disruptions the Air Force could face in carrying out each joint function in a contested environment. Then, drawing on a wide range of sources, we identified capabilities that could mitigate those disruptions. The sources included documents and discussions with subject-matter experts relating to the Adaptive Basing Concept of Headquarters Air Force (HAF) and PACAF's ACE concept.[15] In addition, we drew from exercises, lessons learned in U.S. combat operations, and existing doctrine. In some cases, the capabilities we discuss have already been

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[13] Regarding the importance of the global combat support basing architecture, see Mahyar A. Amouzegar, Ronald G. McGarvey, Robert S. Tripp, Louis Luangkesorn, Thomas Lang, and Charles Robert Roll Jr., *Evaluation of Options for Overseas Combat Support Basing*, Santa Monica, Calif.: RAND Corporation, MG-421-AF, 2006. On the general challenges of designing support systems under conditions of uncertainty, see James S. Hodges and Raymond A. Pyles, *Onward Through the Fog: Uncertainty and Management Adaptation in Systems Analysis and Design*, Santa Monica, Calif.: RAND Corporation, R-3760-AF/A/OSD, 1990.

[14] We do not consider information, the newest joint function, because it has not yet been fully described. Joint Publication 1, *Doctrine of the Armed Forces of the United States*, Washington, D.C.: Joint Chiefs of Staff, March 25, 2013, Incorporating Change 1, July 12, 2017.

[15] For a brief overview of PACAF ACE, see McCullough, 2017a.

identified by the Air Force or outside analysis. In other cases, we extended the logic of existing concepts to more fully develop these ideas or identify capabilities that have not yet been widely considered.

In generating capabilities for distributed operations, we assumed that the Air Force approach to each joint function could depend on the type of distributed operating locations the Air Force used. We therefore considered the capabilities needed for three types of operating locations—Stay and Fight bases, Drop-in bases, and forward arming and refueling points (FARPs)—which are described in Chapter 2 (Table 2.1).

Table 1.2. Framework for Identifying Capabilities for Distributed Operations

		Capabilities by Type of Operating Location		
Joint Function	**Potential Disruption**	**Stay and Fight**	**Drop-In**	**FARP**
C2				
Intelligence				
Fires				
Movement and maneuver				
Sustainment				
Protection				

Identify DOTMLPF-P Solutions

Joint processes use the DOTMLPF-P construct to identify the categories of changes that can produce a required capability.[16] Similarly, we use the DOTMLPF-P framework to identify specific ways that the Air Force might mitigate the disruptions to each joint function in a contested environment. As with identifying capabilities, we drew from interviews, exercises, past research, and Air Force concept documents to identify possible DOTMLPF-P solutions. This initial analysis provides a way to begin identifying the force presentation implications of distributed operations in a contested environment. However, as the Air Force continues to develop its concepts for distributed operations, it will need to conduct more detailed DOTMLPF-P analysis.

The DOTMLPF-P framework contains multiple categories of changes that the Air Force could consider. Doctrine is defined as the "fundamental principles that guide the employment of U.S. military forces in coordinated action toward a common objective."[17] This category includes

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[16] Chairman of the Joint Chiefs of Staff Instruction 3170.01I, *Joint Capabilities Integration and Development System (JCIDS)*, Washington, D.C.: Chairman of the Joint Chiefs of Staff, U.S. Department of Defense, CJCSI 3170.01I, January 23, 2015.

[17] *Manual for the Operation of the Joint Capabilities Integration and Development System (JCIDS)*, February 12, 2015, including errata as of December 18, 2015.

changes to joint and Air Force operational doctrine as well as tactics, techniques, and procedure (TTP) documents.[18] Organization focuses on the structures under which individuals work to accomplish the mission. It includes the ways in which different echelons interact and coordinate actions. Training involves employing doctrinal constructs to prepare for a future mission; can take place at the individual, unit, or staff level; and includes home station activities as well as large-scale exercises. Materiel includes the use of commercial or previously fielded military equipment. It does not include development of new products. Leadership and education includes changes to professional development requirements, while the personnel category focuses on the type of individuals needed for a mission. Buildings and other structures used to shelter and protect aircraft or runways and roads fall within the facilities category. Policy includes changes to interagency, international, and DoD policies that affect the other factors.[19] We do not treat policy changes separately in this study, because the preceding DOTMLPF-P changes each require adjustments to policy that are outlined in the relevant section.

Assess Current Force Presentation Model and Identify Trade-Offs Associated with Changes

The final stage of the analysis asked whether the current Air Force FPM is well suited for conducting distributed operations in a contested environment. To determine this, we identified the characteristics of the current Air Force FPM and compared them with the capabilities for distributed operations identified in the preceding analysis. Finally, we considered the trade-offs the Air Force would face if it changed the current FPM to improve warfighting effectiveness and survivability in the contested environment.

Report Organization

Chapter 2 provides background on the changes in the operating environment that have given rise to a demand for distributed air operations. Although the project reviewed each of the joint functions, the report is organized around the capabilities needed for the three functions with the most significant implications for force presentation: protection (Chapter 3), C2 (Chapter 4), and sustainment (Chapter 5). These chapters highlight the most important insights from our analysis of the other joint functions as well. Chapter 6 considers the implications of distributed operations in a contested environment for force presentation. Chapter 7 concludes with the report's findings and recommendations.

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[18] U.S. Department of Defense, *DoD Dictionary of Military and Associated Terms*, Washington, D.C.: Department of Defense, June 2018, p. 125.

[19] *Manual for the Operation of the Joint Capabilities Integration and Development System (JCIDS)*, 2015.

2. Demand for Distributed Operations

Potential U.S. adversaries are acquiring a larger number of more capable aircraft and missiles, making U.S. air bases increasingly vulnerable to physical attack. Air and missile attacks along with cyber, EW, and antisatellite capabilities also threaten the communications systems that the joint force uses to command and control air operations. Numerous DoD assessments and concepts highlight these threats and the growing need for adaptation.[1]

China represents the pacing threat to air bases and communications systems; therefore, we focus on Chinese capabilities in this chapter. First, it possesses a growing quantity and quality of long-range precision cruise and ballistic missiles that can threaten key targets on air bases.[2] Second, People's Liberation Army (PLA) writings call for seizing information dominance early in a campaign, including by degrading or interfering with enemy communications links. China also has the capability to degrade or destroy long-haul, high-bandwidth communications links, such as commercial satellite communication (SATCOM) and submarine cables.

These two threats have led to new concepts for distributing aircraft to more operating locations and using a more distributed communications infrastructure. Distributing aircraft across more locations improves survivability; an adversary must fire more missiles to achieve the same effect. As the 2012 Joint Operational Access Concept observed: joint forces could "disaggregate large bases into a greater number of smaller bases, decreasing vulnerability through redundancy and complicating the enemy's targeting efforts."[3]

As a result, the 2018 NDS prioritized investments in

> ground, air, sea, and space forces that can deploy, survive, operate, maneuver, and regenerate in all domains while under attack. Transitioning from large, centralized, unhardened infrastructure to smaller, dispersed, resilient, adaptive basing that include active and passive defenses will also be prioritized.[4]

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[1] Office of the Secretary of Defense, U.S. Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2018*, Washington, D.C.: U.S. Department of Defense, 8-0F67E5F, May 16, 2018a; Defense Intelligence Ballistic Missile Analysis Committee, *Ballistic and Cruise Missile Threat*, Wright-Patterson Air Force Base, Ohio: National Air and Space Intelligence Center, NASIC-1031-0985-17, June 2017; U.S. Department of Defense, 2012; Donald J. Trump, *National Security Strategy of the United States of America*, Washington, D.C.: The White House, December 2017.

[2] Jeff Hagen, Forrest E. Morgan, Jacob Heim, and Matthew Carroll, *The Foundations of Operational Resilience—Assessing the Ability to Operate in an Anti-Access/Area Denial (A2/AD) Environment: The Analytical Framework, Lexicon, and Characteristics of the Operational Resilience Analysis Model (ORAM)*, Santa Monica, Calif.: RAND Corporation, RR-1265-AF, 2016.

[3] U.S. Department of Defense, 2012, p. 20.

[4] Mattis, 2018, p. 6.

The threats to current systems may force the Air Force to take a more distributed approach to communications as well. By using a more diverse set of communications pathways and systems, the Air Force can mitigate some of the effects of adversary attacks on communications. Still, these systems increase latency and have other shortcomings. Therefore, the USAF needs to be ready to operate in a disconnected, interrupted, and low-bandwidth communications environment.

The rest of the chapter expands on these themes. The first section discusses the missile threat in greater detail as the motivation for distributed operations. The second section details the threats to communications and alternative communications approaches that the Air Force could use in a contested environment.

Motivation for Distributed Basing

This section discusses the growth in air and missile threats to bases, the logic behind using distributed basing to mitigate these threats, and the types of distributed operating locations the United States may use.

Air and Missile Threats to Bases

For much of the history of the USAF, the vulnerability of air bases has been a concern. Air bases have been threatened by nuclear weapons delivered by Soviet bombers,[5] nuclear weapons delivered by intercontinental ballistic missiles,[6] and conventional weapons.[7] The USAF responded with a variety of measures: hardening and defending bases, developing runway repair and other postattack recovery capabilities, and training personnel to operate under attack from conventional and chemical weapons. The infrastructure improvements were a wise investment for a USAF that expected to fight primarily from a relatively small number of major operating bases. The collapse of the Soviet Union created a brief window during which the Air Force could generally treat its air bases as sanctuaries.[8] In post–Cold War conflicts, the USAF usually

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[5] See, for example, the classic study of the vulnerability of strategic bombers to nuclear attack and potential ways of addressing it: Albert Wohlstetter, Fred Hoffman, R. J. Lutz, and Henry S. Rowen, *Selection and Use of Strategic Air Bases*, Santa Monica, Calif.: RAND Corporation, R-266, 1954.

[6] Albert Wohlstetter and Fred Hoffman, *Defending a Strategic Air Force After 1960: With Notes on the Need by Both Sides for Accurate Bomb Delivery, Particularly for the Big Bombs*, Santa Monica, Calif.: RAND Corporation, D-2270, 1954; Albert Wohlstetter, Fred Hoffman, and Henry S. Rowen, *Protecting U.S. Power to Strike Back in the 1950's and 1960's*, Santa Monica, Calif.: RAND Corporation, R-290, 1956, pp. 71–81.

[7] See, for example, James Bonomo and James A. Thomson, *The Promise of Passive Defenses*, Santa Monica, Calif.: RAND Corporation, P-7320, 1987; Christopher J. Bowie, "The Lessons of Salty Demo," *Air Force Magazine*, March 2009; Bruce W. Don, Donald E. Lewis, Robert M. Paulson, and Willis H. Ware, *Survivability Issues and USAFE Policy*, Santa Monica, Calif.: RAND Corporation, N-2579-AF, 1988.

[8] USAF bases in Korea were the exception to this rule. They remained at risk of attack by Democratic People's Republic of Korea (DPRK) ballistic missiles, aircraft, and special operations forces (SOF), including weapons

operated from expeditionary locations rather than its peacetime bases. Advances in missile guidance and related technologies now offer U.S. adversaries a means to attack U.S. air bases (both major peacetime bases and expeditionary locations) without first defeating the Air Force in the air.[9] In future conflicts, the USAF will likely use peacetime bases when feasible, but most forces will operate from more expeditionary settings.

China has the most active ballistic missile program in the world and represents the pacing precision missile threat to air bases.[10] Although China's Second Artillery Corps was established in 1958, until the early 1990s it was primarily concerned with operating nuclear-armed ballistic missiles.[11] With the fall of the Soviet Union and the expansion of precision-guided weapons, however, the Second Artillery took on a conventional role.[12] This conventional role expanded dramatically during the 1990s and 2000s; by 2010 it had fielded over 1,000 accurate conventional short-range ballistic missiles (SRBMs) as well as medium-range ballistic missiles (MRBMs), accurate ground-launched cruise missiles, and air-launched cruise missiles (ALCMs).[13] Figure 2.1 summarizes how the reach and quantity of China's conventional long-range missiles

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armed with chemical warheads. Thus, USAF forces based in or deploying to Korea have sustained a culture of "fighting the base," including base recovery and resiliency measures. See, for example, Gideon Grudo, "Air Force Expanding Chemical Warfare Training in Pacific," *Air Force Magazine*, September 18, 2017.

[9] John Stillion and David T. Orletsky, *Airbase Vulnerability to Conventional Cruise-Missile and Ballistic-Missile Attacks: Technology, Scenarios, and U.S. Air Force Responses*, Santa Monica, Calif.: RAND Corporation, MR-1028-AF, 1999; Christopher J. Bowie, *The Anti-Access Threat and Theater Air Bases*, Washington, D.C.: Center for Strategic and Budgetary Assessments, 2002; Andrew F. Krepinevich, *Why AirSea Battle?* Washington, D.C.: Center for Strategic and Budgetary Assessments, 2010; Eric Heginbotham, Michael Nixon, Forrest E. Morgan, Jacob Heim, Jeff Hagen, Sheng Tao Li, Jeffrey Engstrom, Martin C. Libicki, Paul DeLuca, David A. Shlapak, David R. Frelinger, Burgess Laird, Kyle Brady, and Lyle J. Morris, *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996–2017*, Santa Monica, Calif.: RAND Corporation, RR-392-AF, 2015; Alan J. Vick and Jacob L. Heim, *Assessing U.S. Air Force Basing Options in East Asia*, Santa Monica, Calif.: RAND Corporation, 2013, Not available to the general public.

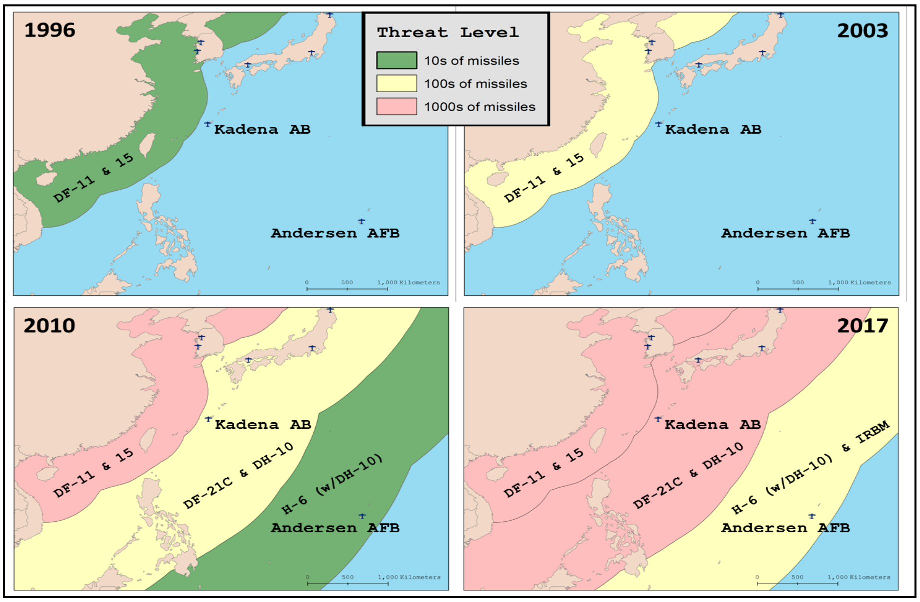
[10] Defense Intelligence Ballistic Missile Analysis Committee, 2017, p. 3. The most comprehensive publicly available treatment of Chinese missile capabilities is Heginbotham et al., 2015. For a discussion of the role of missiles in Chinese strategy, see Roger Cliff, Mark Burles, Michael S. Chase, Derek Eaton, and Kevin Pollpeter, *Entering the Dragon's Lair: Chinese Antiaccess Strategies and Their Implications for the United States*, Santa Monica, Calif.: RAND Corporation, MG-524-AF, 2007. For an operational analysis of the impact of missile attacks in a potential conflict, see David A. Shlapak, David T. Orletsky, Toy I. Reid, Murray Scot Tanner, and Barry Wilson, *A Question of Balance: Political Context and Military Aspects of the China-Taiwan Dispute*, Santa Monica, Calif.: RAND Corporation, MG-888-SRF, 2009.

[11] Kenneth Allen and Maryanne Kivlehan-Wise, "Implementing PLA Second Artillery Doctrinal Reforms," in James Mulvenon and David M. Finkelstein, eds., *China's Revolution in Doctrinal Affairs: Emerging Trends in the Operational Art of the People's Liberation Army*, Alexandria, Va.: Center for Naval Analyses, 2005, pp. 159–219.

[12] Allen and Kivlehan-Wise, 2005.

[13] Office of the Secretary of Defense, U.S. Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2017*, Washington, D.C.: U.S. Department of Defense, C-B066B88, May 15, 2017.

Figure 2.1. Growing Reach and Inventory of Chinese Missiles



SOURCE: Heginbotham et al., 2015, p. 51.
NOTE: The 2017 numbers are China's projected missile capabilities at the time of the report writing.

have expanded over the years. By 2017, it had about 1,200 SRBMs, was fielding 200–300 conventional MRBMs, and had fielded the DF-26 intermediate-range ballistic missile, which is capable of conducting conventional and nuclear precision strikes against ground and naval targets as far away as Guam.[14] In addition to the growing reach and inventory of its missile force, China has dramatically improved the quality of this force; its theater ballistic missiles (TBMs) are solid-fueled, road-mobile systems that possess high accuracy.[15] China has developed a wide range of payloads for these missiles, including submunitions.[16] On December 31, 2015, China

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[14] Office of the Secretary of Defense, 2017, pp. 31, 49, 57.

[15] A common measure of accuracy is a weapon's circular error probable (CEP), the radius within which 50 percent of rounds are expected to land when fired at a target. If ten weapons, each with a 50-m CEP, are fired at a target, five would be expected to land within 50 m of that target. As of 2015, the most modern variants of China's SRBMs and MRBMs had CEPs of 50 m or less. Heginbotham et al., 2015, p. 48. Since then, open source analyses estimate that China has continued to improve the accuracy of its missiles. For example, open source assessments estimate that the most accurate variants of the DF-21 have CEPs of 10–20 m. Jane's by IHS Markit, "DF-21," *Jane's Strategic Weapon Systems*, April 10, 2018d.

[16] Jane's by IHS Markit, "DF-15," *Jane's Strategic Weapon Systems*, May 29, 2018c; Jane's by IHS Markit, "DF-11 (CSS-7/M-11)," *Jane's Strategic Weapon Systems*, January 22, 2018b; Jane's by IHS Markit, 2018d.

renamed the Second Artillery Corps the PLA Rocket Force and upgraded it to the level of a full service, reflecting its increased influence and centrality to Chinese military strategy.[17]

Complementing its growing inventory of land-based ballistic missiles, the People's Liberation Army Air Force (PLAAF) operates over 100 medium H-6 bombers capable of launching long-range, land-attack cruise missiles. The PLAAF has also modernized its air force significantly, but the USAF maintains an edge in air combat. Leading-edge ballistic and cruise missile strikes, however, could in some cases suppress air defenses enough to enable the PLAAF to conduct direct attacks on U.S. air bases.[18] PLA writings suggest that it views an opening wave of missile strikes as critical to enabling the PLAAF to conduct follow-on air attacks.[19] Since 2010, the PLAAF has significantly expanded its inventories of "fourth generation" fighters, including variants of the Russian Su-27 and multirole aircraft with significant ground attack capabilities like the Su-30 MKK. If American and allied air defenses were suppressed through a leading-edge missile attack, these aircraft could do a great deal of damage to an air base.

The potential reach of Chinese airpower to deliver direct-attack munitions on an air base is limited to about 800 km from China's shores. This is roughly the unrefueled fighter range of the PLAAF. China's limited number of aerial refueling tankers constrains the most significant air threat to Taiwan, Southwestern Japan, and the Northern Philippines.[20]

The People's Liberation Army Navy (PLAN) currently has a limited capability to conduct long-range land attacks. Some open source reporting claims that the latest variant of the PLAN's Type 093 nuclear-powered attack submarine has the ability to launch a naval version of the CJ-10 long-range cruise missile.[21] PLAN is also developing a new nuclear-powered guided missile submarine that will be armed with Chinese-designed land-attack cruise missiles.[22]

While China represents the most capable precision missile threat, other potential adversaries are also pursuing capabilities that could threaten air bases. Over the past ten years, Russia has fielded a small but capable suite of highly accurate precision missiles including the *Iskander* SRBM, the long-range KH-101 ALCM, and the *Kalibr* sea-launched cruise missile. The Russian military has demonstrated the effectiveness of these precision missiles in peacetime exercises

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[17] Michael S. Chase, *PLA Rocket Force Modernization and China's Military Forms*, Santa Monica, Calif., RAND Corporation, CT-489, 2018.

[18] Heginbotham et al., 2015, pp. 45–95.

[19] Oriana Skyler Mastro and Ian Easton, *Risk and Resiliency: China's Emerging Air Base Strike Threat*, Washington, D.C.: Project 2049 Institute, American Enterprise Institute, November 8, 2017, p. 4.

[20] Heginbotham et al., 2015, pp. 72, 89.

[21] Richard D. Fisher, Jr., "Image Shows New Variant of China's Type 093 Attack Submarine," *Jane's Defence Weekly*, June 23, 2016.

[22] Jane's by IHS Markit, "China—Navy," *Jane's World Navies*, June 5, 2018a, p. 33.

and operationally in Syria.[23] Iran has the largest ballistic missile force in the Middle East. While much of Iran's missile force possesses low accuracy that makes it poorly suited to carry out attacks on countervalue targets such as Saudi oil infrastructure[24] or military targets such as air bases,[25] it has begun to improve the accuracy of some of its missiles.[26] North Korea's nuclear ambitions have attracted a great deal of attention, but it already possesses several hundred conventionally armed SRBMs and MRBMs capable of reaching targets on the Korean Peninsula and Japan.[27] While most of these missiles are inaccurate, limiting their military utility, there have been reports of North Korea beginning to integrate satellite navigation capabilities into some of its ballistic missiles to improve their accuracy.[28]

Analysts have identified a number of ways that these missiles could affect U.S. air operations. Armed with small submunitions, ballistic missiles could do devastating damage to unsheltered parked aircraft.[29] Coordinated salvos of ballistic missiles armed with runway-penetrating submunitions could suppress sorties, potentially creating a window of opportunity for the adversary to seize the initiative.[30] The adversary could also employ a mixed strategy, dividing its ballistic and cruise missiles against a range of fuel storage, runway, parked aircraft, and other targets.[31]

Generating a Portfolio of Defensive Measures

To generate an effective sortie, an air base must bring together multiple elements including functional aircraft, sufficient fuel, and an operational runway. An adversary needs to deny only

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[23] Office of the Secretary of Defense, 2017, p. 35.

[24] Joshua R. Itzkowitz Shifrinson and Miranda Priebe, "A Crude Threat: The Limits of an Iranian Missile Campaign Against Saudi Oil," *International Security*, Vol. 36, No. 1, Summer 2011.

[25] Jacob L. Heim, "The Iranian Missile Threat to Air Bases: A Distant Second to China's Conventional Deterrent," *Air and Space Power Journal*, Vol. 29, No. 4, July–August 2015.

[26] Doug Richardson, "Iran Boasts of Fateh-110 Accuracy," *Jane's Missiles & Rockets*, August 22, 2012. Iran claims that some variants of the Fateh-110 have CEPs under 10 m. See Jane's by IHS Markit, "Fateh A-110," *Jane's Strategic Weapon Systems*, May 15, 2018e.

[27] Office of the Secretary of Defense, U.S. Department of Defense, *Military and Security Developments Involving the Democratic People's Republic of Korea: Report to Congress 2017*, Washington, D.C.: U.S. Department of Defense, 9-600987B, February 13, 2018b, p. 10.

[28] Eleanor Albert, "North Korea's Military Capabilities," *Council on Foreign Relations*, June 6, 2018.

[29] Stillion and Orletsky, 1999.

[30] Shlapak, Orletsky, et al., 2009, pp. 37–44.

[31] Part of RAND's Combat Operations in Denied Environments analytic methodology enables analysts to examine a wide range of such "attack vectors" to identify which are the most dangerous and how the different vectors respond to potential mitigations. Brent Thomas, Mahyar A. Amouzegar, Rachel Costello, Robert A. Guffey, Andrew Karode, Christopher Lynch, Kristin F. Lynch, Ken Munson, Chad J. R. Ohlandt, Daniel M. Romano, Ricardo Sanchez, Robert S. Tripp, and Joseph Vesely, *Project AIR FORCE Modeling Capabilities for Support of Combat Operations in Denied Environments*, Santa Monica, Calif.: RAND Corporation, RR-427-AF, 2015, pp. 28–31.

one of these elements to prevent a sortie. For example, an undamaged and fully fueled airplane will not be able to fly if it does not have an operational runway. It does no good to make one element of the air base totally invulnerable if other elements remain exposed, because an adaptive adversary could shift its targeting strategy to exploit the vulnerable elements. In this sense, an air base is only as resilient as its weakest link.

Recognizing this reality, air base defenders have historically avoided making any single element of the air base invulnerable and instead focused on building a portfolio of defensive measures that, in combination, protect a wide range of air base elements. These measures can be grouped into active defenses (e.g., PATRIOT [Phased Array Tracking Radar to Intercept on Target] air defense systems and THAAD [Terminal High-Altitude Area Defense] ballistic missile defense systems) and passive defenses (e.g., camouflage and concealment; hardening of key facilities; dispersal of aircraft, fuel, and payloads on airfields and across multiple airfields; and postattack recovery).[32]

Adversaries can develop countermeasures to each element of the portfolio. For example, they could add missile defense countermeasures such as decoys, jammers, and maneuvering reentry vehicles to their ballistic missiles to reduce the effectiveness of active defenses. If the United States relied on only a single measure, that would make it easier for an adversary to focus its efforts on overcoming that form of defense. If the United States uses a mixed portfolio of air base resilience capabilities, its adversaries will have to divide their efforts across fielding multiple types of countermeasures, which is more difficult.[33]

Distributed Basing to Increase Survivability

Distributed basing, the focus of this study, is an important element in this portfolio of defensive measures. Distributing aircraft across more bases increases the number of missiles that

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[32] Alan J. Vick, *Air Base Attacks and Defensive Counters: Historical Lessons and Future Challenges*, Santa Monica, Calif.: RAND Corporation, RR-968-AF, 2015, p. 39.

[33] Relying exclusively or predominantly on ballistic missile defense would be a risky strategy against a capable competitor like China. Ballistic missile defenses generally require "midcourse discrimination," or the ability to identify reentry vehicles amid a cloud of debris and countermeasures in the vacuum of space. Owing to the challenge of midcourse discrimination and other factors, a National Academies of Science report concluded, "There is no unequivocal answer to the question of whether a missile defense can work against countermeasures. It depends on the resources expended by the offense and the defense and the knowledge each has of the other's systems. Thus, defense effectiveness against countermeasures inevitably will vary with time as the offense-defense competition unfolds." National Research Council, *Making Sense of Ballistic Missile Defense: An Assessment of Concepts and Systems for U.S. Boost-Phase Missile Defense in Comparison to Other Alternatives*, Washington, D.C.: The National Academies Press, 2012, pp. S-8–S-10.

an adversary must employ in order to achieve the same effect.[34] As will be discussed in subsequent chapters, distributed operations are resource intensive and create many additional complications for air operations. Still, the Air Force has been exploring concepts for distributed operations because of the significant benefits to survivability discussed in this section.

As noted above, there are a number of ways that an adversary could target bases. For example, Figure 2.2 illustrates a case where a force of 120 fighters is distributed evenly across one to ten bases. It illustrates the benefits of distributing forces against an enemy missile attack. (For the sake of the illustration, we do not include the more complex case of attacks by aircraft or combinations of missiles and aircraft.)

If we assume that it takes eight TBMs to close each base's runway for a period of time, the number of missiles required to conduct an initial runway blockade against these 120 fighters will vary from 8 to 80.[35] As the number of bases increases, the number of fighters whose sorties are disrupted per eight TBMs decreases from 120 to 12. In addition to the larger salvos required to attack all these bases, the larger number of bases increases the probability that at least one of these bases will be able to continue operations. If we assume that an eight-TBM salvo has a 90 percent chance of closing a single runway for a period of time, there is only a 35 percent chance that the 80-TBM salvo will close all ten runways.[36] In other words, there is a 65 percent chance that at least one runway will remain open after the 80-TBM salvo, whereas there is only a

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[34] This is one motivation for the Adaptive Basing Concept being developed by HAF and the ACE Concept being developed by PACAF. On the Adaptive Basing Concept, see Enterprise Capability Collaboration Team, U.S. Air Force, *Air Superiority 2030 Flight Plan*, Washington, D.C.: U.S. Department of Defense, May 2016; Dammeier, Toliver, and Smith, 2016. On the ACE Concept, see Westin Warburton, "Service Members Exercise New Operational Concepts During ARCTIC ACE," *Kadena Air Force Base News*, August 9, 2017. During the 1980s, distributing aircraft across more bases was identified as a good way (when combined with other measures) to help mitigate the growing threat posed by Soviet conventionally armed tactical missiles. Stephen A. Fleet, *The Role of Air Base Operability in Tactical Missile Defense*, Maxwell Air Force Base, Ala.: Air University, 88-920, 1988, p. 27; Bonomo and Thomson, 1987, p. 12. More recent discussions of ways to mitigate the risk posed by Chinese conventionally armed ballistic and cruise missiles also identify distributing aircraft across more operating locations as an important element of strategies to improve air base resilience. See, for example, Mastro and Easton, 2017, pp. 13, 17. Detailed analyses have quantified the benefits of distributing operations in the face of precision missile threats. Michael J. Lostumbo, David R. Frelinger, Jacob L. Heim, Brian A. Jackson, Amariah Becker, and Stephen M. Worman, *Cluster Basing: A Joint Solution to the Anti-Access Challenge*, Santa Monica, Calif.: RAND Corporation, 2014, Not available to the general public.

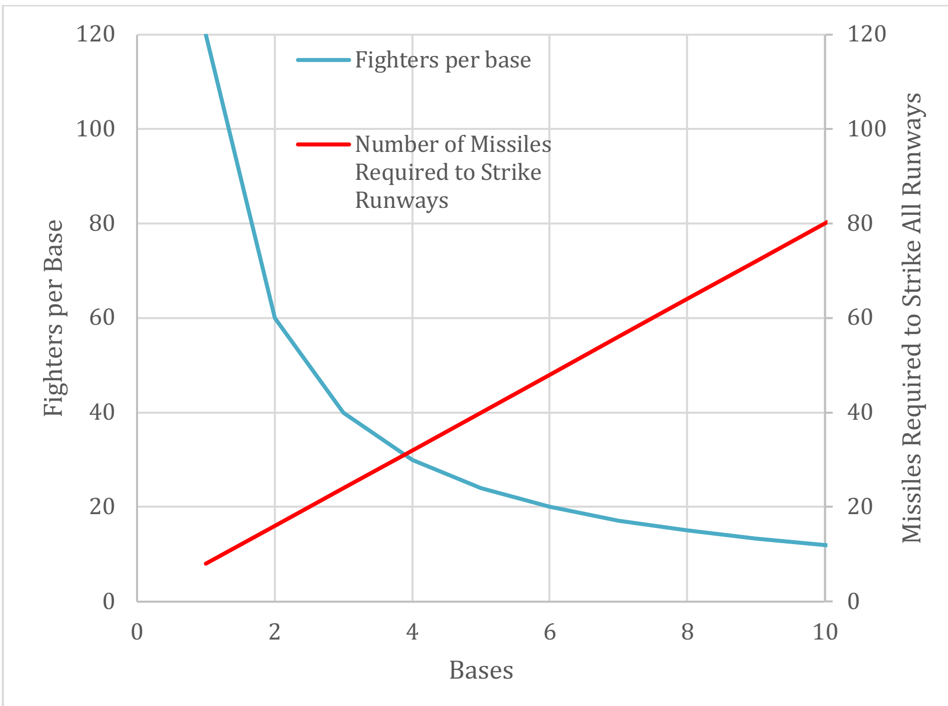
[35] While this is an illustrative example, the choice of eight TBMs flowed from some simple assumptions. First, assume that each base has a 12,000-ft runway and a parallel taxiway and that the adversary is attempting to deny a 5,000-ft minimum operating surface at each base. If the dispersal bases had shorter runways, the line's slope might be shallower because attacking the additional bases could require fewer than eight TBMs. This means that it wants to fully cut both the runway and the taxiway in at least two points, leading to a total of four runway aim points per base. We further assume that each ballistic missile is armed with runway-penetrating submunitions so that a single missile can create multiple craters. We finally assume that the adversary fires two ballistic missiles at each cut point to hedge against in-flight failures and the accuracy of the missiles. For more discussion of these sorts of assumptions, see Heginbotham et al., 2015, pp. 56–58.

[36] The probability calculation is $0.9^{10} = 0.349$.

10 percent chance that a runway will be open after the eight-TBM salvo at the concentrated base case. This illustrates the underlying logic of why distributing air bases improves resilience.[37] Distributed basing allows dispersion across bases and facilitates dispersing assets on each base.

Distributed basing could also complicate enemy intelligence collection efforts. In the example summarized in Figure 2.2, it would presumably be easier for an enemy to maintain surveillance on a single airfield that is home to 120 fighters than to maintain surveillance on ten distributed airfields, each with only a dozen fighters. Maneuvering aircraft among bases might create opportunities for deception operations.

Figure 2.2. Illustration of the Resilience Benefits of Distributing Aircraft Against Missile Attack



NOTE: Assumes eight missiles required per base to close its runways for a period of time.

Types of Distributed Operating Locations

The USAF will likely use a range of operating locations in a contested environment. As will be detailed below, greater distribution increases support and defense costs; as a result, a

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[37] Related analysis from over 60 years ago showed that distributing a B-36 wing of 30 bombers across three bases instead of one would increase the number of targets that an enemy would have to attack threefold. U.S. Air Force Project RAND, *The Cost of Decreasing Vulnerability of Air Bases by Dispersal: Dispersing a B-36 Wing—Cost Analysis Section*, Santa Monica, Calif.: RAND Corporation, R-235, 1952.

distributed basing plan will likely require trade-offs between maximum disaggregation for survival and some concentration for efficiencies. One way to manage this trade-off is to temporarily use austere bases to increase survivability in conjunction with a network of fixed bases with more infrastructure (that offer some efficiencies associated with permanent facilities and modest concentration).[38] The exact mix of fixed and temporary bases will depend on many factors, including the specific geography, political access, enemy capabilities, and U.S. combat support capabilities.

The Air Force is developing concepts for specific types of operating locations through initiatives such as the HAF Adaptive Basing Concept and major command efforts such as PACAF's ACE.[39] We deliberately avoided the specific basing terminology discussed in those concepts for two reasons. First, these concepts were not finalized when this research was under way, and so we did not want to rely on terminology that would be outdated before this report was published. Second, and perhaps more importantly, we are attempting to identify the broadest and most enduring types of distributed operating locations, and so we did not want to become tied to details in specific concepts.

This project, therefore, examines three representative basing types: a Stay and Fight base, a Drop-in base, and a Fighter FARP. The terms *Stay and Fight base* and *Drop-in base* come from previous RAND studies that synthesized broader concepts used in past research, wargames, and informal discussions within the Air Force. A Stay and Fight base describes a fixed air base intended to sustain a squadron of fighters for about a month, while Drop-in bases would be used by these forces for shorter periods of time.[40] The *Fighter FARP* term describes the use of bases for hours at a time supported by air mobile combat support.[41] PACAF has repeatedly exercised a specific manifestation of this concept, called Rapid Raptor, using F-22s.[42] These three alternatives provide examples of the trade-off between maneuver and resilience. The Stay and Fight base can sustain operations for the longest time and has the greatest ability to mitigate and recover from attacks. The Drop-in and FARP locations trade away some resilience for a lighter

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[38] The Joint Operational Access Concept discusses the need to disaggregate large bases into a greater number of smaller permanent bases while also employing austere temporary bases to further improve survivability and complicate the enemy's targeting. U.S. Department of Defense, 2012, p. 20.

[39] On ACE, see McCullough, 2017a. On adaptive basing, see Dammeier, Toliver, and Smith, 2016.

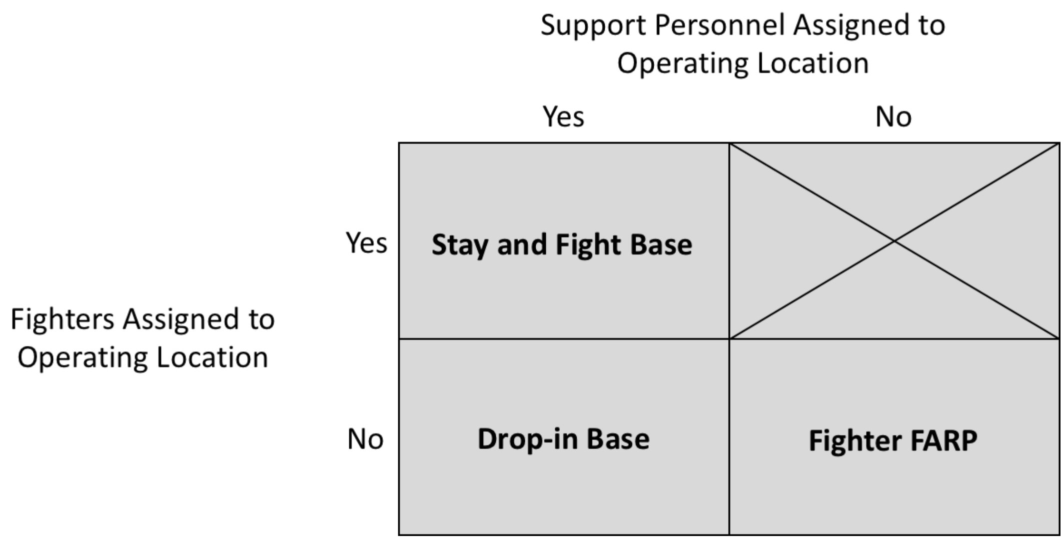
[40] We are grateful to RAND colleagues Patrick Mills, Rachel Costello, and their research teams for sharing their analyses of Stay and Fight and Drop-in bases.

[41] Col Robert Davis described this emerging concept in a 2014 article. Robert D. Davis, "Forward Arming and Refueling Points for Fighter Aircraft: Power Projection in an Antiaccess Environment," *Air and Space Power Journal*, Vol. 28, No. 5, September–October 2014, p. 12. The Air Force has a longer history of operations using the general concept of FARPs, including exercising A-10s using German highways as runways during the Cold War. After a 30-year lull, A-10s are once again landing on European highways. See Ryan Browne, "A-10s Make Rare Highway Landing Near Russian Border," *CNN.com*, June 27, 2016.

[42] Amy McCullough, "Rapid Raptor 2.0," *Air Force Magazine*, March 7, 2017b; Warburton, 2017.

footprint and the ability to redeploy more often. The three types of locations also vary depending on which have enduring combat support and which have an enduring fighter presence. Figure 2.3 summarizes this; the Stay and Fight base is assigned combat support and fighter forces for as long as the air base remains open. The Drop-in base is assigned combat support personnel while the base is in use, but fighter units rotate through (there may be gaps in fighter presence); and the Fighter FARP has a temporary combat support and fighter presence.

Figure 2.3. Summary of Alternative Types of Distributed Operating Locations

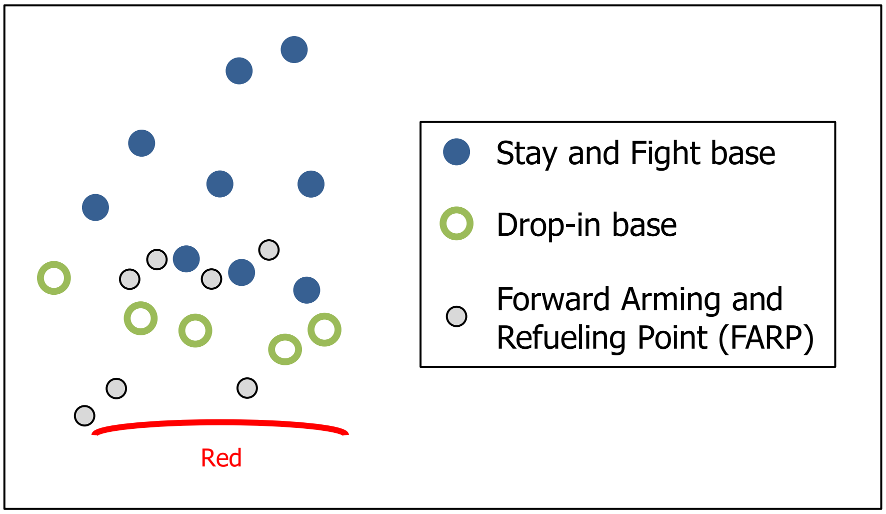


The Air Force would likely use a mix of these three basing types. During the course of a campaign a commander could also adjust the mix of basing types his or her forces use. For example, one concept that could help manage some of the trade-offs would be to form interdependent clusters of nearby bases to share maintenance and other resources. This study does not examine these possibilities in detail, but detailed analysis of the variations in distributed operations concepts should be considered as the Air Force continues to refine the concept.

Figure 2.4 illustrates how a given beddown might combine the three base types at a moment in time. There are, of course, many beddown variations and more complex options such as creating clusters of interdependent bases.[43] As concepts for distributed operations continue to evolve, the Air Force should evaluate the relative costs and benefits of each of these concepts. For our analysis of the broad implications of distributed operations, the precise details of the basing scheme are less important than the broad insight that the Air Force is likely to use a mix

[43] On the general concept of cluster basing, see Lostumbo, Frelinger, et al., 2014.

Figure 2.4. Notional Beddown with Three Distributed Basing Types



of geographically separated static and temporary bases with varying amounts of infrastructure. The following subsections discuss each representative base type in more detail.

Stay and Fight Base

The original concept for the Stay and Fight base envisioned a fighter squadron operating from a single location for about 30 days, though the broad approach could be applied to other unit sizes or periods of time. Stay and Fight bases have the most robust infrastructure, combat support, and airfield damage repair capabilities because they are designed to sustain air operations, even in the face of repeated attacks, for longer periods (Table 2.1).[44] Passive defenses could include on-base dispersal of aircraft, hardened aircraft shelters, and robust capabilities to reconstitute critical infrastructure after an attack.

As we discuss further in Chapter 3, the United States has a limited number of active defense systems, and some operating locations may not have active defenses. Of the three base types examined here, Stay and Fight bases would get priority in having active defenses. To support a fighter squadron, each Stay and Fight base would need approximately 1,200 Agile Combat Support (ACS) personnel to support sortie generation, repair, airlift throughput, and base operations.[45]

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[44] The USAF could use some of its agile combat support capabilities to turn an operating location without some of this permanent infrastructure into a Stay and Fight base. For example, USAF civil engineers can use basic expeditionary airfield resources (BEARs) to provide facilities such as kitchens and billeting at operating locations where permanent facilities are unavailable. The USAF has a limited amount of these resources and personnel to erect them, so it would prefer to leverage locations with quality available permanent infrastructure for Stay and Fight bases when possible.

[45] Patrick Mills, James A. Leftwich, John G. Drew, et al., unpublished RAND research, 2017.

Table 2.1. Minimum Required Infrastructure for Each Representative Base Type

Category	Stay and Fight Base	Drop-In Base	Fighter FARP
Runway and taxiways	Mobility and fighter aircraft capable	Mobility and fighter aircraft capable	Mobility and fighter aircraft capable
Fuel storage	Permanent	Fuel bladders	Transport aircraft provides
Parking	Extensive aprons enable on-base dispersal	Extensive aprons enable on-base dispersal	Enough for 1 mobility and 4 fighter aircraft (no dispersal)
Power, water, firefighting	Permanent with backups	Expeditionary (e.g., generators)	Carried on or provided by transport aircraft
Instrument landing system (ILS), air traffic control (ATC)	Permanent	Expeditionary	None required
Hangars and munitions storage	Permanent, may include hardened aircraft shelters	Expeditionary munitions storage, no hangars	None required
C2, communications, operations center	Permanent	Expeditionary	Carried on transport aircraft
Billeting, dining	Permanent	Expeditionary	Not applicable (base occupied for 1–2 hours)
Perimeter defenses	Perimeter fencing, lighting, fighting positions	Perimeter fencing, lighting, fighting positions	Unattended ground sensors, small unmanned aerial systems (SUASs), mobile reaction force

NOTE: This table lists minimum requirements. Any of these basing approaches could use bases with more robust capabilities than the minimum characteristics listed here. For example, a Fighter FARP could use an international airport with extensive parking, fuel storage, and ILS, but it does not require any of this infrastructure.

Drop-In Base

Drop-in bases trade away some active defenses and reconstitution capabilities in exchange for more operating locations. Passive defenses would be less robust than the Stay and Fight base, with, for example, smaller airfield damage repair teams. An expeditionary combat support unit would manage base defense and support activities, but no fighters would be permanently stationed at this type of operating location. Rather, fighters from a Stay and Fight base would use this location for shorter periods (e.g., up to seven days) to distribute the unit further or enable operations in a higher-threat region.

Unlike Stay and Fight bases, Drop-in bases are not designed for sustained operations under attack. These locations derive some resilience owing to the temporary nature of the operating location. In the event that the adversary does attack a drop-in location, the base has only enough reconstitution capability to evacuate surviving aircraft from the location. In other words, this basing mode relies primarily on a mix of passive defenses and movement, rather than active defenses, to mitigate the effects of a missile attack. Movement includes both shifts of forces among locations (some of which may not be detected immediately) and the expectation that only a handful of aircraft would be on the ground at any moment.

In its original conception, this type of location is sized to perform four integrated combat turns at the same time and host less than a squadron of fighters.[46] For these specifications, each drop-in location would have approximately 300 combat support personnel to support sortie generation, repair, airlift throughput, and base operations.[47]

Fighter Forward Arming and Refueling Point

Fighter FARPs are locations, typically austere airfields closer to the center of a conflict, that fighters from a Stay and Fight or rear base would use temporarily (e.g., hours at time) to operate in higher-threat areas. All supporting capabilities (e.g., fuel, munitions, maintenance, security) would arrive onboard a cargo aircraft. Only about four fighters would be at a single location at any one time. An early description of this concept of operations defines a group of four fighters as a "cell" that would be supported by a C-17 carrying the necessary support personnel and equipment.[48] Each Fighter FARP cell would be supported by fewer than 100 personnel on the mobility aircraft.[49]

FARPs rely entirely on mobility to avoid missile attack. FARPs do not have passive and active defenses or reconstitution capabilities. Rather, FARPs are only used for hours at a time. So, the intention is that by the time the adversary detects that a base was being used as a FARP, the fighters and supporting transport aircraft would already be gone. Up-to-date intelligence on the status of the airfield and security situation in the surrounding area would be used as part of the planning process prior to occupation of the FARP. This might be provided by local human intelligence; host nation forces; U.S. airborne intelligence, surveillance, and reconnaissance (ISR); unattended ground sensors; or some combination thereof.

The Air Force has been exercising the current Fighter FARP concept since 2009. One analysis found that there are at least 163 airfields in the Western Pacific that have sufficient runway length and weight-bearing capacity to accommodate the F-22s and C-17s.[50] That said, FARPs create a significant demand on mobility aircraft and political access; therefore, they would likely be a supplementary rather than primary type of operating location.

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[46] During an integrated combat turn, ground crews simultaneously rearm and refuel the fighter in order to minimize its time on the ground.

[47] Patrick Mills, James A. Leftwich, John G. Drew, et al., unpublished RAND research, 2017.

[48] Davis, 2014.

[49] The 100 personnel number is derived from the maximum capacity of a C-17. Air Force Pamphlet 10-1403, *Air Mobility Planning Factors*, Washington, D.C.: U.S. Air Force, U.S. Department of Defense, AFPAM 10-1403, December 12, 2011, p. 12.

[50] Davis, 2014, pp. 12, 14–15.

Motivation for Distributed Communications

A wide range of factors, from deliberate enemy action to environmental conditions to a congested spectrum, can produce a degraded, intermittent, and low-bandwidth (DIL) communications environment.[51] This section explains why a DIL communications environment is a central feature of the contested environment U.S. forces would face in a conflict with another great power. We also briefly survey alternative communications approaches the Air Force could use to mitigate some of the challenges in that environment.

Assessment of the Communications Environment

The United States uses a mix of long-haul and short-haul communications to command and control air operations, both of which could be disrupted or degraded in a conflict with a near-peer competitor. For the purposes of this discussion, we define long-haul communications as those over several thousand miles, such as from Hawaii to Guam. We define short-haul communications as those that take place over several hundreds of miles, for example, between Manila and Zamboanga in the Philippines.

Long-haul communications links rely on a small number of nodes, which are vulnerable to a variety of kinetic and nonkinetic attacks. The two main methods of long-distance communications in the Pacific are communications satellites and undersea cables. Both of these communications methods would face threats in the event of a war. In 2015, a RAND study assessed that Chinese counterspace capabilities posed a moderate-to-high threat to U.S. space-based communications capabilities.[52] Moreover, PLA writings emphasize the necessity of "destroying, damaging, and interfering with the enemy's reconnaissance . . . and communications satellites" in the event of war.[53] China could also attack undersea cables. While the existing network of undersea cables is quite resilient to single-point failures, numerous and simultaneous cable faults (such as those caused by a targeted attack) could create significant and prolonged service disruptions.[54] Submarine cable routes and landing sites are publicly documented, which facilitates the targeting of the network by malicious actors.[55] A nation-state with ships and

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[51] DIL is a term employed by systems engineers to describe the challenge of communicating on the battlefield. Keith Scott, Tamer Refaei, Nirav Trivedi, Jenny Trinh, and Joseph P. Macker, "Robust Communications for Disconnect, Intermittent, Low-Bandwidth (DIL) Environments," MILCOM 2011 Military Communications Conference, Baltimore, Md., November 7–10, 2011.

[52] Heginbotham et al., 2015, p. 251.

[53] Office of the Secretary of Defense, 2017, p. 35.

[54] U.S. Department of Homeland Security and U.S. Office of the Director of National Intelligence, *Threats to Undersea Cable Communications*, Washington, D.C.: U.S. Office of the Director of National Intelligence, 031991, September 28, 2017, pp. 6–7.

[55] U.S. Department of Homeland Security and U.S. Office of the Director of National Intelligence, 2017, p. 8.

undersea vehicles could "mount a simultaneous attack against multiple cables or multiple attacks against a single cable system that could cause serious long-term disruptions."[56] The magnitude of this threat is exacerbated by the fact that there are relatively few cables connecting the major islands in the Western Pacific.[57]

Short-haul communications can also be attacked, but they are likely to be more reliable than long-distance communications. Line-of-sight (LOS) datalinks and terrestrial fiber are important options for short-haul communications. Military datalinks have features that make them resistant to jamming, but if a sufficiently powerful jammer gets close enough, it can block the datalink.[58] Operating locations on the same landmass could communicate over terrestrial fiber networks that are more extensive, and therefore more difficult to entirely disrupt, than submarine cable networks.

The scope of these threats should not, however, be overstated. Even an extremely successful attack against U.S. SATCOM and undersea cables in the Western Pacific would not eliminate communications among U.S. operating locations. In the extreme, aircraft could ferry couriers among operating locations. Some operating locations may be on the same landmass, enabling them to send couriers over land or leverage any available terrestrial communications infrastructure. Looking to the future, one could also envision communicating between two locations using aircraft as LOS datalink relays. These work-arounds, however, would have their own limitations in terms of bandwidth, reliability, and latency. Therefore, we conclude that the USAF needs to be ready to operate in an interrupted and low-bandwidth communications environment.

Alternative Communications Methods

To improve communications links in this environment, the Air Force could use alternatives to those it has relied on in recent years. Two alternatives for very long-range (2,000 miles or more) communications are using long-range aircraft to courier information and using high-frequency (HF) radios.[59] The USAF has many types of aircraft that it could use for the long-range courier mission. Figure 2.5 uses the unrefueled range of the C-17 as an illustration.[60]

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[56] The assessment goes on to conclude that intentional sabotage involving "coordinated cuts of multiple cables . . . could bring a country or regional to a standstill." U.S. Department of Homeland Security and U.S. Office of the Director of National Intelligence, 2017, pp. 8, 22.

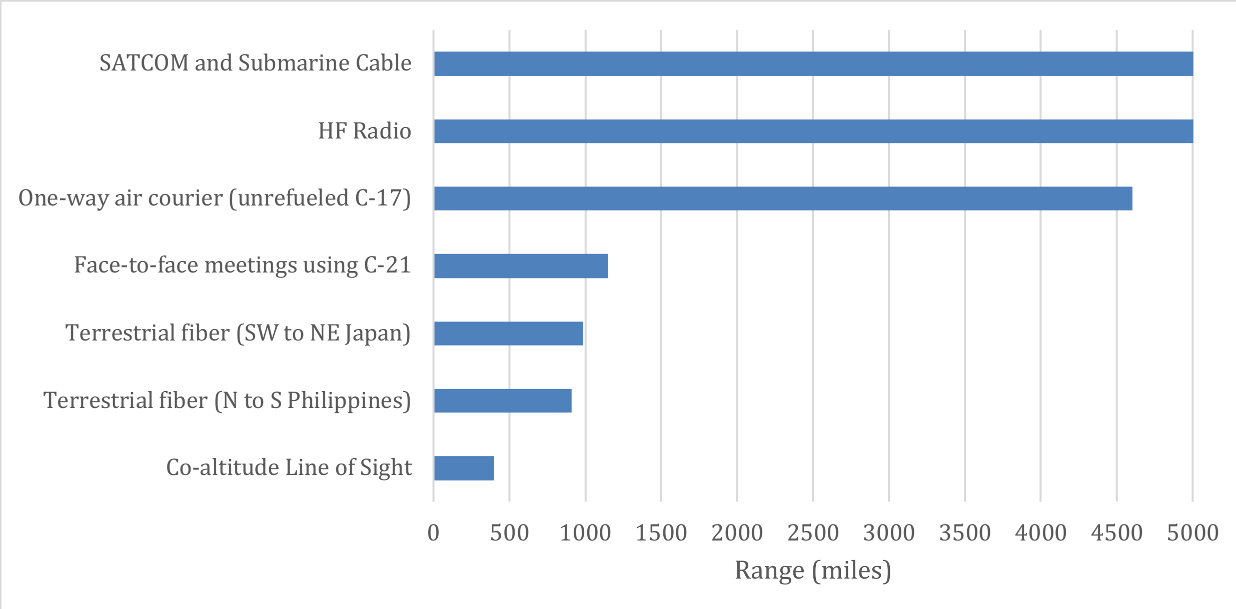
[57] U.S. Department of Homeland Security and U.S. Office of the Director of National Intelligence, 2017, pp. 1, 8. As of September 2017, there were about 18 transpacific cable systems in operation or in development. U.S. Department of Homeland Security and U.S. Office of the Director of National Intelligence, 2017, p. 13.

[58] Carlo Kopp, "Network Centric Warfare Fundamentals: Part 3—JTIDS/MIDS," *Defence TODAY Magazine*, 2015.

[59] The Air Force used courier aircraft in this way because of poor communications in the early phases of Operation Desert Storm. Gulf War Air Power Survey, "Part II: Command and Control," in *Planning and Command and Control*: Vol. I, Washington, D.C.: Government Printing Office, 1993b, p. 108.

[60] Air Force Pamphlet 10-1403, 2011, p. 13.

Figure 2.5. Representative Communications Options at Various Ranges



NOTE: One-way air courier mission range based on C-17 one-way unrefueled range. Range for face-to-face meetings using C-21 assumes a three-hour one-way mission. Terrestrial fiber ranges based on measurement of extent of main islands in Japan and the Philippines. Coaltitude LOS calculation assumes two aircraft orbiting at 35,000' and the potential of up to a 6,500' mountain between them.

HF radio waves can reflect off the ionosphere, enabling very long-range communications under optimal conditions. However, the range of HF radios can vary widely because of variations in the ionosphere created by seasonal changes, solar activity, and day/night changes.[61] This propagation behavior can make HF transmissions more easily detectable than higher-frequency wavelengths, but HF communications can still be secured through encryption.

At shorter ranges, more communications options become feasible. Figure 2.5 cites two methods: using small aircraft to facilitate face-to-face meetings and using airborne aircraft and LOS datalinks to create temporary connections between sites.

Using Small Aircraft to Courier Information or Enable Face-to-Face Meetings

The USAF could use small transport aircraft such as the C-21 as intratheater couriers or taxis for commanders (or their representatives) to have periodic face-to-face meetings when long-distance communications are interrupted, unreliable, and low bandwidth.

There would be many impediments to using transport aircraft to shuttle information or personnel for meetings, including limited aircraft availability and support costs. Still, using aircraft in this way is one option the Air Force could consider as it seeks to maintain

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[61] Craig Payne, *Principles of Naval Weapons Systems*, 2nd ed., Annapolis, Md.: Naval Institute Press, 2010, pp. 22–23.

communications in a contested environment. To illustrate this option, we explain how a C-21 might be used in this role. The C-21 is based on the civilian Lear Jet 35. It can carry eight passengers and 42 ft^3 of cargo, which is sufficient for a commander and a small amount of support staff and equipment.[62] Since it requires only a 5,000-by-70-foot runway, the C-21 should be able to operate from any runway that supports fighter operations.[63] While the maximum range of the C-21 is about 2,300 miles, other factors affect the maximum distance over which one would want to use the C-21 for these sorts of command missions. For example, a commander's time is valuable and presumably he or she would not want to spend an inordinate amount of time commuting to meetings. To produce an illustrative bound on how long would be "inordinate," we made the assumption that a commander would want to keep the one-way mission time under three hours.[64] Based on the C-21's block speed, it could support meetings up to 1,150 miles away with a mission time under three hours.[65]

Airborne Aircraft and Line-of-Sight Datalinks

Another option for intratheater communications would use LOS datalinks on airborne aircraft. Figure 2.6 illustrates the approach. Each base launches an aircraft that uses an LOS datalink to connect to the other aircraft and its home base.

Assuming that the aircraft orbit at 35,000 ft and that a 6,500-foot obstruction is at the midpoint in between them, the two aircraft could be about 400 miles apart from one another and still have a clear LOS.[66] Commanders might not be able to devote enough aircraft to maintain

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[62] U.S. Air Force, "C-21," May 2014.

[63] Air Force Instruction 11-2C-21, *Flying Operations: C-21 Operations Procedures, Guidance Memorandum*: Vol. 3, Washington, D.C.: U.S. Air Force, U.S. Department of Defense, AFI 11-2C-21V3_AFGM1, March 6, 2015, p. 56.

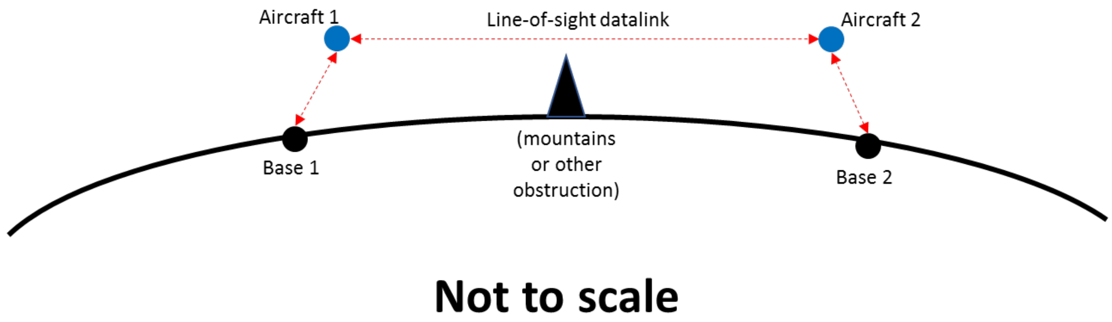
[64] This is, of course, subjective. A three-hour one-way mission would mean that the commander would spend six hours commuting to and from the meeting. Adding two hours on the ground for meetings leads to a total trip time of eight hours. While that would represent a significant chunk of the commander's day, it would still leave him or her some time before and after the mission to take care of other business.

[65] Assumes a block speed of 334 knots at 1,000 nautical miles. See Adam D. Simoncic, *Aircraft Block Speed Calculations for JOSAC/USTRANSCOM Aircraft Using Linear Regression*, graduate research paper, Wright-Patterson Air Force Base, Ohio: Air University, 2013, p. 25.

[66] This is an elementary calculation derived from basic geometry:

coaltitude LOS $= 2 * \sqrt{2 * R(h-a) + h^2 - (a)^2}$, where R is the radius of the earth, h is the height of the obstruction halfway between the two aircraft, and a is the altitude of each aircraft (assumed to be equal). For a = 35,000 ft, h = 6,500 ft, and R = 20,900,000 ft, coaltitude LOS is 413.6 miles. We round down to 400 to provide a conservative estimate. These estimates do not take any credit for the lateral distance between the orbiting aircraft and its home base.

Figure 2.6. Illustration of Aircraft Using LOS Datalink to Link Two Bases



this communications relay orbit 24 hours a day, but it would be relatively straightforward to launch a relay aircraft on a preplanned schedule to provide regular windows of connectivity between locations. Other alternatives include using remotely piloted or autonomous aircraft as the relays.[67] Legacy LOS datalinks could enable basic coordination for the two sites through text messages, but they have limited bandwidth and so would not be suitable for passing large amounts of data such as digital images. Newer datalinks offer much larger bandwidth and would enable more data sharing between the sites.[68]

Conclusion

Distributed operations are inefficient and difficult. They are not the USAF's preferred method of operations. It is the need to find a way to survive and fight in an increasingly contested environment that has led the USAF to consider distributed operations. In a long conflict, as the adversary expends its stock of long-range precision weapons and the United States begins to blunt the power projection capabilities of the enemy air force, it may be possible to eventually operate from a smaller number of main operating bases as the United States does today. But to reach that point, the USAF must survive the initial onslaught of enemy precision missile salvos. Distributed operations could play a key role in enabling the USAF to survive an initial phase of a conflict with a near-peer competitor. In other words, the Air Force is considering distributed operations because it has to, not because it wants to.

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[67] David Cenciotti, "EQ-4 Global Hawk Drone Deployed to UAE with a Battlefield Airborne Communications Node Payload Reaches 20K Flight Hours," *The Aviationist*, February 16, 2018.

[68] An example of a newer datalink is Tactical Targeting Network Technology (TTNT). Mark Stanley, "Tapping into Tactical Targeting Network Technology," *Microwaves & RF*, May 24, 2018.

3. Protection

This chapter considers distributed air operations from the perspective of the protection joint function, with a focus on defense of air bases from air, missile, and ground attack. After decades of operating largely in sanctuary from heavy enemy attack, USAF forward bases now face an increasingly lethal and complex array of threats.[1] In addition to the missile and air threats outlined in Chapter 2, adversary ground forces can employ standoff attacks with mortars, rockets, sniper rifles, and man-portable air defense systems (MANPADSs); commando-style penetrating attacks; car/truck bomb attacks at entry points; and combinations of these tactics.[2] The global proliferation of drone technology gives terrorists, insurgents, and regular military forces another means to conduct surveillance against or to attack air bases.[3]

Distributed operations present unique trade-offs for air base defense. As discussed in Chapter 2, operating from a larger number of bases complicates adversary targeting. Similarly, SOF would have to attack more bases to significantly disrupt air operations. However, using more operating locations also increases demands for limited air base defense resources, such as Army missile defense units or USAF Security Force squadrons. Whether an airfield is used by a squadron or wing of aircraft, the requirements associated with defending the operating surfaces from missile attack or protecting its perimeter and surrounding area from ground attack are largely the same. Thus, the ratio of air base defense assets to aircraft increases as those aircraft are distributed across more bases.

We explore protection against air and missile attacks in greater detail in the next section. A subsequent section considers protection against ground threats. The final section discusses possible DOTMLPF-P changes to defend against both types of attack.

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[1] For an overview of the history of air base attacks and defensive counters, see Vick, 2015. An excellent history of efforts to defend air bases from manned aircraft attack from World War I through the Yom Kippur War of 1973 is John F. Kreis, *Air Warfare and Air Base Air Defense, 1914–1973*, Washington, D.C.: Office of Air Force History, U.S. Air Force, 1988. For a thorough treatment of air base defense and recovery techniques, see Sal Sidoti, *Airbase Operability: A Study in Airbase Survivability and Post-Attack Recovery*, Canberra, Australia: Aerospace Centre, RAAF Base Fairbairn, 2001.

[2] These are explored in more detail in David A. Shlapak and Alan J. Vick, *"Check Six Begins on the Ground": Responding to the Evolving Ground Threat to U.S. Air Force Bases*, Santa Monica, Calif.: RAND Corporation, MR-606-AF, 1995.

[3] For example, small drones have already been weaponized by ISIS and other groups in Syria to attack Russian forces at Hemeimeem AB. Alexander Harper, "Drones Level the Battlefield for Extremists," *RealClearDefense*, April 20, 2018; Neil MacFarquhar, "Russia Says Its Syria Bases Beat Back an Attack by 13 Drones," *New York Times*, January 8, 2018.

Capabilities for Protecting Against Air and Missile Attack

As discussed in Chapter 2, the Air Force will likely need to adopt a diverse portfolio of defensive measures against air and missile threats. The precise mix of resilience capabilities depends on a host of factors including the range and quantity of the adversary's missiles, the number and location of the bases, and the relative costs of the various mitigations.[4] This section discusses some of the other elements of a defensive portfolio that the Air Force may use in conjunction with distributed operations.[5]

Hardening

Hardening infrastructure is one of the most direct ways of addressing the vulnerability of an air base. Building concrete aircraft shelters or underground facilities reduces the number of aircraft or base infrastructure lost per arriving weapon, thereby reducing the operational impact of the adversary's missile attacks. Hardening is, however, expensive, and since facilities cannot be moved, the benefits are tied to a particular base and theater. Some hardening concepts (e.g., expeditionary aircraft shelters) are lower cost and redeployable but offer a lower level of protection. Key factors to consider when deciding whether and how to harden an air base include the accuracy and payload of the threat, the size of the target, and the vulnerability of the target relative to other elements of the air base system. For example, if one created an impenetrable aircraft shelter but made no other improvements, an adaptive attacker

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[4] Portfolio analysis helps balance diverse investments to meet objectives while managing risk and limited resources. A familiar application is managing a financial portfolio of stocks and bonds to maximize expected returns at a given level of risk. For a notional example of portfolio analysis, see Paul K. Davis, Russell D. Shaver, and Justin Beck, *Portfolio-Analysis Methods for Assessing Capability Options*, Santa Monica, Calif.: RAND Corporation, MG-662-OSD, 2008, pp. 45–103. There are many tools available to support portfolio analysis; for example, see Paul K. Davis and Paul Dreyer, *RAND's Portfolio Analysis Tool (PAT): Theory, Methods, and Reference Manual*, Santa Monica, Calif.: RAND Corporation, TR-756-OSD, 2009; Richard A. Moynihan, *Investment Analysis Using the Portfolio Analysis Machine (PALMA) Tool*, Bedford, Mass.: The MITRE Corporation, 05-0848, July 2005. Two examples of recent analytic frameworks for portfolio analysis for air base defense are Thomas et al., 2015; Hagen et al., 2016. For a Cold War example, see Donald E. Emerson, *TSAR and TSARINA: Simulation Models for Assessing Force Generation and Logistics Support in a Combat Environment*, Santa Monica, Calif.: RAND Corporation, P-6773, 1982.

[5] As with the broader point that air base vulnerability is not a new concern, these broad categories of resiliency capabilities are not new either. During the late Cold War, for example, studies identified the following base survivability elements: active defenses (including antiaircraft artillery, electronic countermeasures, etc.), passive defenses (camouflage, on-base dispersal, hardening, etc.), damage control (firefighting, damage assessment, etc.), robustness in system design (backup power generators, short field operations, etc.), and recovery of mission capability (runway repair, pipeline repair, etc.). Don et al., 1988, pp. 39–41.

could destroy the air base's runways and deny sorties just as effectively as if it had destroyed all the aircraft on the base.[6]

On-Base Dispersal

Dispersing assets on base provides another way of protecting against air and missile threats. Expanding the distance between parked aircraft, for example, is a particularly inexpensive way of reducing the number of aircraft that can be destroyed by a single arriving weapon.[7] Other key air base assets can also be dispersed as well. For example, dispersing fuel storage across a base in fuel bladders and using refueling trucks or mobile pumps to move the fuel to aircraft greatly increases the number of munitions that the attacker must commit to attacks on fuel storage.[8] Munitions storage areas could also be dispersed, decreasing their vulnerability and raising the attacker's costs. Like other elements of an air base protection portfolio, on-base dispersal creates trade-offs. Dispersal reduces the efficiency of an air base in order to improve its resilience. At the most elementary level, parking aircraft far apart increases the transit time for pilots and maintenance personnel, as well as for aircraft taxiing.[9]

Active Defenses

In addition to improving resiliency through distributed operations, passive defenses, and dispersal on a base, there are active defense options for shooting down incoming ballistic and

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[6] DoD conducted a two-year effort exploring new techniques for protecting key facilities from attack. The Hardened Infrastructure Protection for Persistent Operation (HIPPO) Joint Capability Technology Demonstration (JCTD) was the first major DoD research on hardened structures since the Cold War. See "Two-Year Hardened Installation Effort Ends on a High Note," *U.S. Army Corps of Engineers News*, July 5, 2013. The HIPPO JCTD developed new technologies and materials to protect against a variety of threats. Kenneth R. Dorner, William B. Hartman, and Jason M. Teague, "Back to the Future: Integrated Air and Missile Defense in the Pacific," *Air and Space Power Journal*, Vol. 29, No. 1, January–February 2015, pp. 71–72.

[7] The cheapest case occurs when there is already a great deal of aircraft parking available at the base; recent RAND work has illustrated the benefits of on-base dispersal in this case. Scott Savitz, Alan J. Vick, Paul Dreyer, Stephen M. Worman, and Sarah E. Evans, *On-Base Aircraft Dispersal as a Counter to Missile and Mortar Attack*, Santa Monica, Calif.: RAND Corporation, 2015, Not available to the general public.

[8] The USAF has fuels operational readiness capability equipment (FORCE) that provides a mobile, air-transportable fuel delivery system. FORCE includes trailer-mounter pumps, filters, and plumbing assemblies. When combined with fabric fuel bladders, this provides a deployable fueling system for aircraft. See Air Force Handbook 10-222, *Bare Base Assets*: Vol. 2, Washington, D.C.: U.S. Air Force, U.S. Department of Defense, AFH 10-222, February 6, 2012b, pp. 81–84.

[9] Incidentally, the Strategic Rocket Force faces a similar trade-off between increasing survival by dispersing and minimizing cost and complexity by consolidating forces. For example, "Although the many points and broad area of the operational deployment [of a missile unit] facilitates the increase of survivability, it brings about a great deal of difficulty in providing campaign command, [providing] the various items of support and in synchronizing the campaign." Zhang Yuliang, Yu Shusheng, and Xiaopeng Zhou, *The Science of Campaigns*: Vol. 2, Beijing, China: National Defense University Press, 2006, p. 710.

cruise missiles. Current and planned capabilities include the Army THAAD ballistic missile defense system,[10] the Army PATRIOT air defense system,[11] Navy cruisers and destroyers armed with SM-3 interceptors,[12] USAF fighter caps near bases (for cruise missile defense), Army Indirect Fire Protection Capability (IFPC),[13] and close in weapon systems like the Army land-based Phalanx weapon system.[14] Even if these defenses do not provide an impenetrable[15] shield, they can force an adversary to expend more missiles than it would otherwise.[16] Larger salvo sizes reduce the scope and duration of attacks that can be made with a given inventory. Thus, even imperfect missile defenses can have value as part of the larger portfolio of operational resilience capabilities. However, the United States' inventory of ballistic missile defense systems is small, limiting the number of locations that can be protected.[17]

In addition to these existing missile defense capabilities, the United States is pursuing new technologies such as an air-launched ballistic missile interceptor, directed energy systems, and rail guns. All of these new capabilities face technology risks as well as significant research and

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[10] Jane's by IHS Markit, "THAAD Completes First All-Up System Flight Test," *Jane's Missiles and Rockets*, June 13, 2006.

[11] Jane's by IHS Markit, "MIM-104 Patriot," *Land Warfare Platforms: Artillery and Air Defence*, November 15, 2017.

[12] Jane's by IHS Markit, "Standard Missile-3 (SM-3) (RIM-161A/B/C/D)," *Weapons: Naval*, August 16, 2018f.

[13] The Army is planning on fielding Block 1 of its new IFPC in 2021 to provide improved protection against small unmanned aerial systems and cruise missiles. James H. Dickinson, *Fiscal Year 2019 Priorities for Missile Defense: Statement Before the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. House of Representatives*, Washington, D.C., April 17, 2018, p. 15.

[14] Jane's by IHS Markit, "Land-Based Phalanx Takes Aim at Rockets, Artillery and Mortars," *International Defence Review*, September 20, 2005; Raytheon Company Missile Systems, *Land-Based Phalanx Weapon System: High Value Site Defense System*, Tucson, Ariz.: Raytheon Company, 2006.

[15] A good survey of how various parameters interact to affect overall missile defense effectiveness can be found in Dean A. Wilkening, "A Simple Model for Calculating Ballistic Missile Defense," *Science & Global Security*, Vol. 8, No. 2, 2000. Layering missile defenses, where different defensive systems engage the incoming salvo in sequence, can outperform cases where there is only a single defensive system. An illustration of this can be found in Michael V. Finn and Glenn A. Kent, *Simply Analytic Solutions to Complex Military Problems*, Santa Monica, Calif.: RAND Corporation, N-2211-AF, 1985, pp. 33–38.

[16] These additional missiles could be used to suppress missile defenses or to saturate the capacity of the missile defenses. The question of whether an attacker ought to focus on suppressing missile defenses or pursue a leakage strategy is quite complex and sensitive to a host of parameters. For a technical discussion of the complexity of this issue, see A. Ross Eckler and Stefan A. Burr, *Mathematical Models of Target Coverage and Missile Allocation*, Arlington, Va.: Military Operations Research Society, 1972, pp. 211–217.

[17] For example, as of 2016 the United States planned to procure only a total of seven THAAD batteries. Missile Defense Agency, U.S. Department of Defense, *Selected Acquisition Report (SAR): Ballistic Missile Defense System (BMDS) as of FY2017 President's Budget*, Washington, D.C.: U.S. Department of Defense, March 23, 2016, p. 20. As of 2018, the Army had a total of 15 PATRIOT battalions. Office of the Under Secretary of Defense (Comptroller)/ Chief Financial Officer, U.S. Department of Defense, *Program Acquisition Cost by Weapon System: United States Department of Defense Fiscal Year 2019 Budget Request*, Washington, D.C.: U.S. Department of Defense, 3-3F796C5, February 2018, pp. 4–6.

development costs, but they may be part of the future portfolio of defenses for forward air bases.[18]

Operating Under Attack and Recovering Rapidly

Another key element in operational resiliency is the ability to rapidly recover from attack. Rapidly recovering from attack includes the ability to make prompt repairs to damaged infrastructure such as runways and fuel as well as the TTPs for operating the air base while under attack.[19] Air Force engineering teams such as Prime Base Engineer Emergency Force and Rapid Engineer Deployable Heavy Operational Repair Squadron Engineers can establish and recover base infrastructure. These units have already begun updating their capabilities and will need to continue to do so as the missile threat evolves.[20] Over the past decade, the USAF has developed a new runway repair capability—Rapid Airfield Damage Repair (RADR)—that represents a significant improvement on legacy runway repair methods in several ways.[21] First, RADR uses new materials and methods to fill more craters faster. Second, these repairs are far more durable than legacy expedient repairs. Thousands of aircraft can pass over the restored area without degrading it. Finally, these repairs are suitable for both fighters and heavier aircraft, whereas

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[18] The Airborne Weapon Layer was widely discussed in the 2012–2013 time frame; its current status is unclear. Maria Malenic, "U.S. Requests Airborne Weapon Data for BMD System," *International Defense Review*, January 25, 2012; Mike Corbett, "A New Approach to Ballistic Missile Defense for Countering Antiaccess/Area-Denial Threats from Precision-Guided Weapons," *Air and Space Power Journal*, Vol. 27, No. 2, March–April, 2013. Directed energy systems are intended to offer a cheaper and higher-capacity magazine than that offered by legacy defense methods that depend on interceptor missiles; however, they still have many hurdles to overcome. Mark Gunzinger and Chris Dougherty, *Changing the Game: The Promise of Directed-Energy Weapons*, Washington, D.C.: Center for Strategic and Budgetary Assessments, 2012; Ryan Fedasiuk and Kingston Reif, "Reasons to Doubt Laser Missile Defense," *Arms Control Now* (blog), Arms Control Association, May 14, 2018. The Office of Naval Research has been researching and developing a prototype electromagnetic rail gun since 2006 that is supposed to offer extremely high speeds, high rates of fire, long range, and deep magazines. Ronald O'Rourke, *Navy Lasers, Railgun, and Gun-Launched Guided Projectile: Background Issues for Congress*, Washington, D.C.: Congressional Research Service, R44175, July 5, 2018.

[19] Previous research has illustrated the importance of rapid runway repair for recovering from missile attacks. Heginbotham et al., 2015, pp. 45–70.

[20] Air Force Handbook 10-222, *Civil Engineer Bare Base Development*: Vol. 1, Washington, D.C.: U.S. Air Force, U.S. Department of Defense, AFH 10-222, January 23, 2012a.

[21] Regarding the new technique, see R. Craig Mellerski, *Airfield Damage Repair–The Future Now*, Tyndall Air Force Base, Fla.: Air Force Research Laboratory, AFRL-TX-TY-TP-2009-4560, August 2009. The USAF is in the process of training its civil engineers in the RADR approach. During the transition to RADR, the USAF will still have the capability to perform repairs using legacy techniques, which are slower and produce less durable repairs. On RADR, see Stephen G. Eigel, "Pacific Air Force Civil Engineers Improve Airfield Repair Skills," *U.S. Indo-Pacific Command News*, September 16, 2016. On legacy repair methods, see Air Force Pamphlet 10-219, *Rapid Runway Repair Operations*: Vol. 4, Washington, D.C.: U.S. Air Force, U.S. Department of Defense, AFPAM 10-219, April 1, 1997.

legacy expedient repair methods use different techniques for fighters and heavier aircraft.[22] The USAF is also developing rapid repair capabilities for other critical infrastructure, such as fuel systems.[23]

The broader ability to fight through and recover from an attack requires training as well as TTPs. During the 1980s, renewed concerns about the vulnerability of air bases to Soviet attack led to efforts to train personnel to survive in the face of attack. At the time, USAF officers concluded that to "fight, survive, and recover to sustain air operations [in the face of enemy attack], air base personnel are going to need the synergy and staying power that can only come through leadership, cohesion, discipline and training."[24] While the precise nature of the threat has changed, the underlying importance of the human element in operational resiliency has not. Future wing-level exercises could be used to validate technologies and also provide a realistic environment to prepare personnel to carry out their mission under attack and in the face of major disruptions.[25] Discussions with Air Force personnel suggest that, outside of Korea, such exercises have not been common for most Air Force units during the past two decades as the Air Force has been focused on CT and COIN operations.[26] Meeting the demands of a contested environment will require intensified training to prepare all of a wing's combat support and combat elements to operate together effectively under heavy attacks.

Electronic Warfare, Camouflage, Concealment, and Deception

EW, camouflage, concealment, and deception can increase resiliency, especially when combined with other defensive measures. For example, if EW can be used to deny targeting intelligence, it might be easier to deceive the adversary about the actual location of FARPs. These capabilities could also create false targets and degrade adversary ISR, forcing the

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[22] Previous research has illustrated the importance of these faster runway repair methods for recovering sortie generation. See Chapter 3 in Heginbotham et al., 2015, pp. 45–70.

[23] For example, the new Water and Fuels Expedient Repair System was tested and commissioned in 2017. Air Force Civil Engineer Center, *SME Directory 2017*, Washington, D.C.: U.S. Department of Defense, Winter 2017, p. 14.

[24] John A. Ballard and Jon A. Wheeler, "Air Base Vulnerability: The Human Element," *Air Force Journal of Logistics*, Vol. 13, No. 3, Summer 1989, p. 3. Chinese writings discuss designing attacks specifically to magnify psychological pressure on the enemy. Harassing military strikes can make "the enemy think that no rules apply," thereby creating "great psychological pressure [on] the enemy." Yuliang, Shusheng, and Zhou, 2006, pp. 730–731.

[25] During the spring of 1985, for example, the USAF ran a major wing-level exercise at Spangdahlem AB titled Salty Demo to test the USAF's ability to fight its bases under attack. Bowie, 2009.

[26] Air Force bases in South Korea are an exception to this larger trend. Air Force units in Korea continued to exercise to defend and recover their bases from a range of North Korean threats including ground forces, mortar attacks, and missile attacks, as well as chemical, biological, and radiological weapons. A conflict with China or Russia would pose additional threats to those posed by North Korea, including large inventories of highly accurate weapons. For a description of a recent exercise at Osan AB in South Korea, see Alex Echols, "Beverly Herd Exercise Tests Readiness at Osan," *Defense.gov*, September 18, 2017.

adversary to choose between wasting missiles on uncertain targets and ceasing shooting for fear of wasting valuable missiles.[27]

Capabilities for Protecting Against Ground Threats to Distributed Bases

In conflicts with major powers, long-range ballistic and cruise missiles will likely present the greatest and most sustained threats to air bases. That said, between 1940 and 2018 ground forces have destroyed or damaged over 2,000 aircraft in both penetrating and standoff attacks. The effectiveness of past attacks has varied greatly, driven primarily by the skill and daring of the attackers. The most successful penetrating attacks were British Special Air Service commando raids on Luftwaffe bases in North Africa during World War II, which destroyed 367 Luftwaffe aircraft.[28] The most successful standoff attacks were North Vietnamese Army and Viet Cong rocket and mortar attacks on U.S. air bases in Vietnam. These attacks destroyed 387 aircraft and damaged 1,164.[29] In contrast, during Operations Iraqi Freedom and Enduring Freedom, Iraqi and Afghan insurgents were unable to conduct effective standoff attacks against USAF bases, in part because most were conducted using small numbers of low-accuracy rockets, but also because of substantial U.S. and coalition efforts to prevent, detect, and defeat such attacks. With one notable exception, insurgents also were unable to destroy aircraft via penetrating attacks.[30]

In future conflicts, however, ground forces may present a much greater threat to USAF aircraft and operations for three reasons: (1) Three potential adversaries possess SOF capable of attacking USAF bases, (2) precision standoff weapons such as guided mortar rounds will give more adversaries the ability to conduct effective attacks, and (3) the rapid proliferation of small drones vastly improves the ability of adversary agents or SOF to observe airfield operations and attack aircraft or personnel in the open.

Russia, China, and the DPRK possess special forces that are capable of attacking U.S. air bases. Soviet special forces were assessed as a "significant threat" to North Atlantic Treaty Organization (NATO) airfields during the Cold War. Given that heritage, it is probable that Russian SOF would have similar assignments in a conflict with NATO. Chinese military writers

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[27] Jonathan F. Solomon, "Maritime Deception and Concealment: Concepts for Defeating Wide-Area Oceanic Surveillance Reconnaissance-Strike Networks," *Naval War College Review*, Vol. 66, No. 4, Autumn 2013.

[28] Alan J. Vick, *Snakes in the Eagle's Nest: A History of Ground Attacks on Air Bases*, Santa Monica, Calif.: RAND Corporation, MR-553-AF, 1995, pp. 19, 57.

[29] In "sapper" penetrating attacks, 5 aircraft were destroyed and 21 damaged. Vick, 1995, p. 89.

[30] That exception is the September 14, 2012, Taliban commando attack on Camp Bastion, Afghanistan, that destroyed six AV-8B Harrier jets and damaged two. Alissa J. Rubin, "Audacious Raid on NATO Base Shows Taliban's Reach," *New York Times*, September 16, 2012.

note that SOF have important roles to play in attacks on enemy air bases.[31] U.S. and Republic of Korea forces have trained for years to defend against the DPRK SOF threat.[32]

Enabling technologies (e.g., mortar rounds guided by a global positioning system [GPS]) are rapidly proliferating and will give both special forces and less skilled adversaries the ability to strike with precision from distances up to 8 km from a base.[33] Aircraft parked in the open or in revetments are particularly vulnerable to precision mortar attacks.[34] Third, rapid advances and the proliferation of drones may vastly increase the threat to aircraft in the open. In particular, software advances that enable swarming behavior will allow small drones to be used in large numbers to search for and attack targets.[35] Current antidrone technologies are not designed to defeat this type of attack.

USAF Security Force capabilities are not keeping up with these evolving threats. USAF base defenders are undermanned and underequipped to control the standoff attack zone, protect the perimeter, and defeat emerging threats such as swarming drones. The USAF has 2,391 deployable defenders.[36] An emerging USAF concept for managing Security Force deployments envisions using this manning to create 16 150-man "Flags." This, however, is a minimalist force. As will be discussed in the next section, during Operation Iraqi Freedom (OIF) over 900 USAF personnel were assigned to Joint Base (JB) Balad to defend the perimeter and standoff zone. The JB Balad force of over 900 appears to be a more accurate estimate of the manpower requirement for a more ambitious mission. Current USAF Security Force manning can meet that requirement for only 2.6 locations.[37]

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[31] Director of Central Intelligence, *Warsaw Pact Nonnuclear Threat to NATO Airbases in Central Europe: National Intelligence Estimate*, Langley, Va.: Central Intelligence Agency, NIE 11/20-6-84, October 25, 1984, pp. 32–36; Cliff et al., 2007, p. 63.

[32] For a discussion of the DPRK threat to USAF air bases in Korea, see Shlapak and Vick, 1995, pp. 1–6, 40–43.

[33] For a discussion of related enabling technologies, see James Bonomo, Giacomo Bergamo, David R. Frelinger, John Gordon IV, and Brian A. Jackson, *Stealing the Sword: Limiting Terrorist Use of Advanced Conventional Weapons*, Santa Monica, Calif.: RAND Corporation, MG-510-DHS, 2007.

[34] For a quantitative analysis of the effects of precision mortar attacks on aircraft parked in the open, see Savitz et al., 2015.

[35] In 2016 the Strategic Capabilities Office demonstrated a swarm of over 100 small "Perdix" drones that were able to collaboratively sense and respond to their environment while pursuing an objective provided by a human operator. U.S. Department of Defense, "Department of Defense Announces Successful Micro-Drone Demonstration," *Defense.gov*, January 9, 2017.

[36] This number was calculated by the USAF using UTCs with a posture code of "DW," which AFI 10-401 defines as "the maximum simultaneous deployment capability of the unit." Air Force Instruction 10-401, 2006, p. 183. Security Force manning data from briefing titled Headquarters Air Force, A4SX, *Manpower Unit Type Code Update*, Washington, D.C.: U.S. Department of Defense, April 17, 2018.

[37] JB Balad manning data from Joseph A. Milner, "The Defense of Joint Base Balad: An Analysis," in Shannon W. Caudill, ed., *Air Bases in an Age of Insurgency*, Maxwell Air Force Base, Ala.: Air University Press, 2014, p. 221. Security Force Flag concept described in Headquarters Air Force, 2018.

Air base ground defense is typically organized around three core tasks. Although the terminology in doctrinal and tactical publications has varied over time, in essence these tasks are (1) control the standoff zone, (2) defend the perimeter and entry points, and (3) protect critical assets inside the air base. Below, we describe how the Air Force may approach each of these tasks in the context of distributed operations in a contested environment.

Control the Standoff Zone

Air base ground defense is best understood from the outside in. The standoff zone is defined as the area in which the enemy can attack the air base with standoff weapons (e.g., mortars, rockets, drones, sniper rifles) or, using MANPADS or antiaircraft artillery, threaten aircraft on approach or departure. USAF doctrine calls this the base security zone (BSZ).[38] The shape and size of the BSZ will vary depending on expected threats, local geography, and other particulars of a given base. During the Vietnam War, USAF practice sought to deny the enemy "unhindered operational access to all areas within a 10,000 meter radius of the base," with a focus on the 5- to 10-km belt "where the enemy could employ 81-, 82- and 120-mm mortars, and 122- and 140-mm rockets."[39] The 10-km radius is still a good rule of thumb for indirect fire threats; Russian 82-mm mortars (6-km range) and 122-mm rockets (11-km range) are found throughout the world and were used routinely against U.S. bases in Iraq and Afghanistan.[40]

Modern defenders must also account for the proliferation of capable MANPADS that can threaten aircraft on approach to or departure from airfields. MANPADS footprints (extending from the end of the runway to the point where aircraft are outside the slant range of MANPADS) can extend out to 15 km.[41] Given the potential size of the standoff zone, a combination of

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[38] Joint doctrine distinguishes between the airfield perimeter and the base boundary. The perimeter is understood to be the physical boundary of the installation, typically marked by fencing or other security barriers. Joint doctrine defines the base boundary as "a line that delineates the surface area of a base for the purpose of facilitating coordination and deconfliction of operations between adjacent units, formations, or areas." USAF doctrine adds the "Base Security Zone" to delineate the area from which enemy ground-based systems can threaten the air base. Joint Publication 3-10, *Joint Security Operations in Theater*, Washington, D.C.: Joint Chiefs of Staff, November 13, 2014, p. GL-4; Annex 3-10, *Force Protection*, Washington, D.C.: Headquarters U.S. Air Force, April 17, 2017; Air Force Policy Directive 31-1, *Integrated Defense*, Washington, D.C.: U.S. Air Force, U.S. Department of Defense, AFPD 31-1, October 28, 2011.

[39] E. Vallentiny and D. G. Francis, *Project CHECO Southeast Asia Report: Attack on Udorn*, Hickam Air Force Base, Hawaii: Headquarters, Pacific Air Forces, DOTEC-68-79, December 27, 1968, pp. 3–4.

[40] Mortar and rocket ranges are from Paul M. Thobo-Carlsen, "A Canadian Perspective on Air Base Ground Defense: Ad Hoc Is Not Good Enough," in Shannon W. Caudill, ed., *Defending Air Bases in an Age of Insurgency*, Maxwell Air Force Base, Ala.: Air University Press, 2014, p. 54. For additional information on Russian 107-, 122-, and 140-mm rockets, see Office of the Adjutant General, U.S. Department of the Army, *Rocket Study, Extract from Operational Report—Lessons Learned, Headquarters, II Field Force Vietnam Artillery, Period Ending 31 October 1968*, Washington, D.C.: U.S. Department of Defense, March 21, 1969.

[41] Thobo-Carlsen, 2014, pp. 54–56.

airborne ISR platforms, observation posts, snipers, ground patrols, and the cooperation of the local population is necessary to minimize threats emanating from it. (Active defense against standoff weapons is discussed in the next section.)

USAF Security Forces are not manned to patrol 200–400 km^2 of terrain per airfield. This would be true even if the Air Force were operating only from a small number of major bases, let alone several dozen distributed locations. In past conflicts, U.S., host nation, and allied nation ground forces have provided most of these forces. For example, in Vietnam, USAF Security Forces were "charged solely with internal security."[42] The standoff zones were patrolled by U.S. Army, U.S. Marine Corps, Republic of Vietnam, and other allied forces (e.g., the Korean "Tiger" Division).[43]

During OIF, however, a new model was developed for the defense of JB Balad. In this model, USAF Security Forces patrolled the BSZ (comprising 243 km^2) under the tactical control of the battlespace owner, the Army force commander who was responsible for a large adjacent area (measuring over 3,000 km^2). The USAF Security Forces focused on preventing and disrupting attacks on the base, freeing local Army forces to focus on COIN operations.[44] It should be noted, however, that the successful innovation at JB Balad was enabled by an unusually large Security Force contingent, a group rather than a squadron. This was the first time since the Vietnam War that the USAF deployed more than 900 airmen to defend a single base.[45]

In addition to more generous manning, Security Force squadrons deployed in combat environments for prolonged periods have been provided systems (e.g., the Raven SUAS and armored fighting vehicles) not typically available to Security Force squadrons stationed in the continental United States (CONUS) (and therefore unlikely to be available in a short-notice deployment to a major war). In short, the USAF Security Force overall is neither structured nor equipped to defend a large number of bases from a capable adversary.[46]

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[42] Roger Fox, *Air Base Defense in the Republic of Vietnam, 1961–1973*, Washington, D.C.: Office of Air Force History, U.S. Air Force, 1979, p. 108.

[43] The role of allied combat forces in the Vietnam War is often overlooked by Americans. Over the course of the war, Koreans, Australians, and New Zealanders served in ground combat alongside U.S. forces. Philippine, Thai, and Taiwanese forces also provided small forces serving in support functions. Stanley Robert Larsen and James Lawton Collins, Jr., *Vietnam Studies: Allied Participation in Vietnam*, Washington, D.C.: U.S. Department of Defense, CMH Pub. 90-5-1, 1975.

[44] Milner, 2014, pp. 223–229.

[45] Milner, 2014, p. 221.

[46] The Desert Hawk and Raven SUASs were deployed in Iraq under the USAF Force Protection Airborne Surveillance System program but are not assigned to CONUS Security Force squadrons. USAF Security Forces in a variety of deployed locations have access to similar SUASs. Discussions with HAF and PACAF headquarters Security Force personnel; Erik K. Rundquist, "A Short History of Air Base Defense: From World War I to Iraq," in Shannon W. Caudill, ed., *Defending Air Bases in an Age of Insurgency*, Maxwell Air Force Base, Ala.: Air University Press, 2014, p. 32; Robert D. Sagraves, "Air Support for Base Defense: Lessons for the Noncontiguous

Looking to the future, the USAF is better prepared to hinder adversary use of the standoff zone, but the mission remains inherently difficult and will become more so with a larger number of operating locations. Unless the Air Force significantly increases the number of security personnel, USAF Security Forces will need to be supplemented by joint or host nation ground forces. Base defenders would also benefit from better access to advanced technologies such as drones (both ISR and attack) so that threats can be identified and neutralized before they launch attacks on the air base.

Defend the Perimeter and Entry Points

Any airfield capable of supporting fighter aircraft will have a relatively long perimeter owing to the runway length. For example, an 8,000-foot runway with parallel safety buffers results in a perimeter roughly 5 km in length, not including space required for parking, maintenance, billeting, and fuel or munitions storage. Nor does this illustrative minimalist perimeter offer much defensive value to aircraft and personnel. For these reasons, airfields used by the USAF in past conflicts have generally been much larger. Perimeter lengths have ranged from 15 to 26 km in six representative airfields from conflicts occurring between 1965 and 2018 (see Table 3.1).

Table 3.1. Representative Airfield Perimeters from Six Conflicts, 1965–2018

Operation	Airfield Location	Perimeter (km)
Vietnam War	Tan Son Nhut	18
Operation Desert Storm	Shiek Isa AB, Bahrain	18
Operation Allied Force	Aviano AB, Italy	10
Operation Enduring Freedom	Bagram AB, Afghanistan	15
OIF	JB Balad, Iraq	21
Operation Inherent Resolve	Al Udeid AB, Qatar	26

SOURCES: Vietnam: Fox, 1979, p. 64; OIF: Milner, 2014, p. 224; all others: Google Earth measurements by RAND project staff.

USAF distributed fighter operations would likely make use of a wide variety of airfields, ranging from small, austere facilities to large bases. Although access would be contingent on the particular conflict, there are over 100 airfields in East Asia that could support USAF fighter

Battlefield," in Shannon W. Caudill, ed., *Defending Air Bases in an Age of Insurgency*, Maxwell Air Force Base, Ala.: Air University Press, 2014, p. 179.

operations.[47] Table 3.2 displays a sampling of fighter-capable airfields that might be available in a notional East Asia conflict. The perimeters of these airfields range from 8 to 20 km in length.

Table 3.2. Sampling of Airfield and Airport Perimeters in East Asia

Country	Airfield	Perimeter (km)
Japan	Kadena AB	17
Japan	Iwo To	10
CNMI	Tinian Airport	8
U.S. Territory of Guam	Andersen AFB	18
Philippines	Clark Field	15
Philippines	Puerto Princesa Airport	8
Vietnam	Cam Ranh International	12
Malaysia	Butterworth AB	9
Singapore	Tengah AB	15
Australia	RAAF Tindal	20

SOURCE: Google Earth measurements by RAND project staff.

Before discussing the particular challenges associated with defending 8–20 km of perimeter, the level of threat must first be established. Defensive measures necessary to prevent unauthorized entrance or defeat attacks by small forces are quite different from those required to defeat a large conventional ground force.

USAF air base defenses have never been designed to defeat attacks by large enemy maneuver forces (e.g., battalion size or larger). Such threats are most typically countered by situating air bases well behind the forward line of battle. In less linear conflicts (e.g., the Vietnam War), friendly ground maneuver forces operating outside the constraints of a fixed position are the best counter to such threats. Air base perimeter defenses are designed instead to hinder penetrations by individuals or small units and to provide the basis for defense against adversary maneuver forces no larger than a company. Joint doctrine specifies three levels of threats to Joint Security Areas as shown in Table 3.3. USAF air base defense (now force protection) doctrine has long held that organic USAF Security Forces need to be capable of defending against Level I and II threats but not Level III. Joint Publication 3-10 also states that “Level III threats are beyond the

[47] There are 101 F-16–capable airfields in Southeast Asia alone. Stacie L. Pettyjohn and Alan J. Vick, *The Posture Triangle: A New Framework for U.S. Air Force Global Presence*, Santa Monica, Calif.: RAND Corporation, RR-402-AF, 2013, pp. 26–27.

Table 3.3. Levels of Threat to Joint Security Areas

Threat Level	Examples
Level I	Agents, saboteurs, sympathizers, terrorists, civil disturbances
Level II	Small tactical units, unconventional warfare forces, guerillas; may include significant standoff weapon threats
Level III	Large tactical force operations, including airborne, heliborne, amphibious, infiltration, and major air operations

SOURCE: Joint Publication 3-10, 2014, p. I-3.

capability of base and base cluster security forces, and can only be effectively countered by a tactical combat force (TCF) or other significant forces."[48]

To defeat the Level I and II threats, USAF Security Forces rely on a mix of proactive measures, infrastructure improvements, and quick reaction forces (QRFs). Patrols and observation posts outside the base provide warning of nearby enemy forces. Perimeter sensors, trip flares, and observation towers detect intrusions. For example, during OIF, the 332nd Expeditionary Security Force Group at JB Balad used 550 sensors to cover the 21 km of perimeter.[49] Fences, minefields, and obstacles slow and channel attackers. Hardened positions and vehicle barriers at entry points allow for the processing of authorized traffic and defense against vehicle-borne improvised explosive devices and other attacks. A limited number of fighting positions (bunkers and towers) along the perimeter, typically equipped with medium machine guns, provide firepower against more determined attacks, but USAF base defenders rely more on QRFs to defeat attacks. These forces are equipped primarily with high-mobility multipurpose wheeled vehicles (HMMWVs) equipped with medium machine guns or grenade launchers, although mine-resistant ambush-protected vehicles were used in Iraq during OIF.[50]

This approach to perimeter defense worked well for a small number of joint bases in Iraq and Afghanistan where the only threat was enemy ground forces and the conflict extended over many years, allowing for the allocation of additional resources and infrastructure investments over time. In contrast, during a major war with China, some distributed fighter operations would presumably be conducted from major bases like Kadena AB, but others would be flown from airfields with limited infrastructure and perhaps few or no nearby friendly ground forces. In these cases, USAF air base defenders may need to depend more on surveillance technologies and QRFs. For example, Security Force squadrons still lack organic drones for ISR. Small drone

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[48] Joint Publication 3-10, 2014, p. I-4; Annex 3-10, 2017, pp. 20–21.

[49] Balad was unusual in having a Group assigned to its defense (with two subordinate squadrons), as opposed to the more typical assignment of one Security Force squadron per base. One squadron (the 332nd ESFS) was assigned perimeter and interior security. The other squadron (the 532nd ESFS) was responsible for entry control points and patrolling out to 8 km from the base. Milner, 2014, pp. 220–224.

[50] Craig Lifton, "Security Forces Employ Tough, Agile Vehicle," *U.S. Air Force News*, October 20, 2008.

technology is advancing rapidly and has the potential to vastly improve early warning of attack. The combination of drones and perimeter sensors is an important force multiplier for relatively small base defense forces. Small armed drones (e.g., Switchblade) offer base defenders the ability to surveil and strike targets out to 10 km beyond the perimeter.[51] In distributed settings, QRFs will need more mobility and firepower so that they can rapidly respond to perimeter penetrations and decisively defeat enemy forces. This may require additional enhancements to HMMWV-class vehicles or perhaps a move to a more survivable infantry combat vehicle.

Protect Critical Assets Inside the Air Base

Finally, when adversary weapons or forces penetrate the first two layers of defense, base defenders rely on terminal defenses of various types, including both active and passive measures.

Indirect fire weapons such as rockets and mortars can be defeated through active defenses. For example, the Counter-Rocket, Artillery and Mortar System was used to detect and intercept insurgent rockets and mortar rounds in Iraq and Afghanistan.[52] Counter-drone defenses are rapidly changing, moving from ad hoc methods to defeat crude individual drones to more systematic approaches that can defeat larger numbers of more sophisticated drones. This is reflected in the increasing use of C-RAMD (Counter-Rocket, Artillery, Mortar and Drone System) to describe future system requirements.

Active defense against enemy elements that have penetrated the perimeter and threaten critical assets (e.g., parked aircraft, headquarters, communications facilities, fuel, munitions, billeting) occurs in two ways. First, personnel at the site provide self-defense and slow the enemy attackers. Second, particularly high-value assets may also be protected by defensive personnel manning checkpoints, bunkers, or towers. Finally, the QRF will respond to such threats, bringing mobile firepower to bear.

Passive defenses include hardening of critical assets against weapon effects (e.g., underground fuel storage, hardened aircraft shelters), additional fencing, HESCO barriers, and personnel shelters.

Although some airfields used for distributed operations will have sophisticated infrastructure, most USAF and partner nation airfields have no hardened structures for critical assets. Outside of Korea, USAF bases rarely have hardened headquarters, fuel storage, personnel shelters, or hardened aircraft shelters. For example, of the airfields listed in Table 3.2, only two have hardened aircraft shelters, and none of the locations is fully hardened. Unless the Air Force invests in significantly more infrastructure, passive critical asset protection during distributed operations will be dependent on what USAF base defenders can bring with them or construct in

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[51] For Switchblade specifications, see AeroVironment, Inc., "Switchblade," webpage, undated.

[52] Milner, 2014, p. 226; Dan Lamothe, "Meet the Impressive Guns Protecting U.S. Bases from Rocket Attacks in Afghanistan," *Washington Post*, October 21, 2015.

the field. C-RAMD units could mitigate against these shortfalls to some degree, but there is no current plan for the Army or Air Force to provide this capability for air base defense.

Potential DOTMLPF-P Changes

Operating from a larger number of distributed operations can improve survivability against air and missile threats, but protecting more bases will also substantially increase personnel, facilities, and equipment requirements. Rather than simply listing some of the possible DOTMLPF-P changes, this section discusses how using multiple types of operating locations, each with a different mix of DOTMLPF-P changes, could help manage limited resources. The DOTMLPF-P changes discussed here are not comprehensive or fully validated, but they illustrate how using multiple base types could be a useful tool to manage the trade-offs associated with distributed operations.

Using only one highly defended type of air base would be extremely resource intensive. To illustrate this, Table 3.4 uses three notional basing arrangements. In the first scenario, the USAF has a fighter wing at each of its six existing bases along with an IFPC battery for cruise missile defense, C-RAMD system, and 150 Security Force personnel.[53] In the second scenario, each wing's squadrons are distributed among three locations with the same types of defenses, resulting in three times as many active defense systems and Security Force personnel. Finally, if each wing had five bases, the USAF would have 30 locations to defend, generating requirements for 30 IFPC, 30 C-RAMD, and 4,500 Security Force personnel.[54] The number of airfield damage repair teams required would scale with the number of airfields. Demand for expeditionary fighter shelters, on the other hand, remains the same across the three basing scenarios.[55]

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[53] The Army plans to equip its IFPC batteries with at least two types of interceptor missiles. The first is optimized against cruise missiles and larger unmanned aerial systems. The second is designed to defeat rockets, artillery, mortars, and smaller drones. If this plan proves viable, a separate C-RAMD system will not be required, but the number of IFPC launchers will have to be expanded to ensure sufficient magazine depth for both threats. Thus, the total force structure required per base in a contested environment is likely to be similar (i.e., two batteries per base). Jen Judson, "U.S. Army Seeks New Missile to Counter Drones, Rockets and More," *DefenseNews*, February 23, 2018.

[54] USAF Security Forces are considering an approach to air base defense that would use existing manning to build 18 deployable and self-sustaining "Flags" of 150 personnel each. This would provide basic defenses for up to 18 air bases.

[55] In practice, the number of expeditionary shelters required could be lower since some airfields already have permanent hardened aircraft shelters. For example, Misawa AB has about 60 hardened shelters that date back to the Cold War. If it were serving as a Stay and Fight base, it would not require any expeditionary shelters. Of course, in the case of Misawa AB serving as a Stay and Fight base, the extra 36 shelters remain there and make no contribution to meeting shelter needs at other locations.

Table 3.4. Illustrative Defense Requirements for Concentrated Versus Distributed Forces

Defense	Concentrated (1 Airfield/Wing)	Moderately Distributed (3 Airfields/Wing)	Highly Distributed (5 Airfields/Wing)
IFPC batteries	6	18	30
C-RAMD batteries	6	18	30
Security Force PAX	900	2,700	4,500
Airfield damage repair (ADR) teams	6	18	30
Expeditionary fighter shelters	432	432	432

If, however, the Air Force were to use a mix of types of distributed operating locations, distributing aircraft could be less resource intensive. Table 3.5 illustrates some of the differences

Table 3.5. Possible DOTMLP-F Solutions for Protection Against Air, Missile, and Ground Attacks

	Stay and Fight	Drop-In	Fighter FARP
Doctrine	• Integrated approach to defend against air, missile, and ground attacks • Recovery after attacks	• Integrated approach to defend against air, missile, and ground attacks • Limited use of mobility for protection • Base evacuation and planning	• Rely heavily on mobility for protection • Abandon base if attacked
Organization	• Integrated base defense units at each operating location • ADR team for each operating location	• Integrated base defense units at each operating location • Small ADR team	• Small security element
Training	• All airmen trained in base defense, survivability, and recovery • Small arms training for all airmen	• All airmen trained in base defense, survivability, and recovery • Small arms training for all airmen	• All airmen trained in base defense and survivability • Small arms training for all airmen • Maintenance personnel cross train in more than one specialty
Materiel	• ADR equipment, advanced EOD • Fuel bladders • Short-range air defense, C-RAMD • Standoff surveillance capabilities	• Minimal ADR & EOD • Expeditionary fuel bladders • Standoff surveillance capabilities	• Standoff sensors and weapons for minimalist ground defense (including small drones)
Leadership/education	• Airmen educated to think of air base as contested space		
Personnel	• Aircraft and facility repair and EOD	• Limited aircraft and facility repair and EOD personnel	

	Stay and Fight	Drop-In	Fighter FARP
Facilities	• Hardening of facilities • Strong perimeter defenses • Large parking areas	• BEAR • Large parking areas	

in DOTMLPF-P solutions for each type of operating location introduced in Chapter 2. Stay and Fight bases would have a robust portfolio of active and passive defenses, including a mix of shelters for aircraft, key equipment, and personnel; fighting positions; fencing; sensors; short-range defenses against mortars, drones, manned aircraft, and missiles; distributed fuel and munitions storage; and robust airfield damage repair capabilities. At the other extreme, Fighter FARPs rely almost entirely on mobility and a small footprint to avoid detection and mitigate their vulnerabilities. Hence, they would have no active defense capabilities other than a small security force and personnel trained in basic survivability practices. The Drop-in bases lie in between these two extremes. They include some limited passive defenses such as small airfield damage repair teams and moving periodically to complicate the adversary's targeting cycle.

One common requirement for all three types of bases is training. Table 3.5 lists three possible training enhancements. First, both individual and unit training (and exercises) should place all airmen in situations where they face some of the problems that would confront them under heavy attack. These include, but are not limited to, responding to warning of air, missile, and ground attack; air base defense; firefighting; building evacuation; unexploded ordnance avoidance; explosive ordnance disposal (EOD); individual first aid and care for mass casualties; and airfield recovery more generally. Stay and Fight and Drop-in bases will likely experience some or all of these challenges. Second, all airmen need to be skilled in small arms use both to protect their work areas and to supplement Security Force personnel in perimeter or strongpoint defense. Small arms training has been standard for airmen deployed to Korea and as part of predeployment training for stability operations in the Middle East and Southwest Asia,[56] but this program may need to be expanded. In general, training standards and curricula should be reviewed and enhanced where needed to meet the unique demands of distributed operations in a contested environment. Finally, some subset of maintenance personnel need cross training to support Drop-in base and FARP operations.

By using operating locations that take different approaches to protection, the Air Force could reduce the demands for certain types of defensive capabilities. In Table 3.4, we assumed a uniform basing approach. Conversely, Table 3.6 assumes a mix of basing types. In this model, Stay and Fight bases (three per wing) have the active defenses described above. Drop-in bases, we assume, would have only one IFPC and one C-RAMD for every two bases and only

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[56] Paul J. Kasuda, "Setting the Right Glide Slope: Preparing the Air Force for the Next Counterinsurgency Campaign," in Shannon W. Caudill, ed., *Defending Air Bases in an Age of Insurgency*, Maxwell Air Force Base, Ala.: Air University Press, 2014, pp. 288–290.

50 Security Force personnel per location. Thus, if each wing had three Stay and Fight bases and two Drop-in bases, it would need four IFPC, four C-RAMD, and 550 Security Force personnel

Table 3.6. Illustrative Defense Requirements for Stay and Fight and Drop-In Bases

Defense	Concentrated (1 Airfield/Wing)	Stay and Fight Bases (3 Airfields/Wing)	Stay and Fight & Drop-In Bases (5 Airfields/Wing)
IFPC batteries	6	18	24
C-RAMD batteries	6	18	24
Security Force PAX	900	2,700	3,300
ADR teams	6	18	30
Expeditionary fighter shelters	288	288	336

for its five locations. The notional six-wing force therefore requires a total of 24 IFPC, 24 C-RAMD, and 3,300 personnel.

Some passive defense capabilities will scale with the number of bases, while others might not. As an example of the former, one would want an ADR team at both Stay and Fight and Drop-in bases, though Stay and Fight base teams would be larger.[57] Expeditionary fighter shelters are an example of a passive defense requirement that might not scale with the number of bases. In fact, the wings might conclude that at least a third of their aircraft will be airborne during high-intensity operations and therefore require shelters for only two-thirds of their forces. This means that each squadron would require only 16 shelters (assuming a squadron concentrated basing case, these 288 shelters would be spread across six bases [48 at each base]). The Stay and Fight case would have the same total number of shelters. In the case where each wing has two Drop-in bases, the total number of shelters would increase slightly to 336 owing to the extra 48 shelters to protect fighters visiting Drop-in locations.[58]

Conclusion

This chapter explored some of the implications of distributed operations for the protect function, including resource requirements and potential DOTMLPF-P changes. Distributed operations also make C2 more challenging, particularly against adversaries that possess the

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[57] As discussed earlier in this chapter, USAF civil engineers are in the process of training in the new RADR approach. While all locations would want the RADR capability, a near-term contingency could see a mix of RADR and legacy ADR capabilities.

[58] If each wing has two Drop-in locations, the total force in this example has 12 Drop-in bases. If each Drop-in base has four expeditionary fighter shelters to protect transient aircraft, this adds 48 shelters to the total number required for the force.

capability and intention to disrupt communications. Threats to C2 and options to mitigate those threats are the topic of the next chapter.

4. Command and Control

The C2 joint function includes tasks such as establishing command relationships, planning, allocating resources, assigning tasks, and assessing progress toward objectives.[1] In recent decades, the communications network the Air Force relies on to perform these activities has been largely uncontested. As the former commander of Air Combat Command (ACC) explained, this has created a "generation of Airmen accustomed to leveraging a robust, unparalleled C2 architecture."[2]

This uncontested communications environment has enabled a highly centralized approach to C2 of air operations. Centralizing air planning in a joint air operations center (JAOC) has allowed the joint force to maximize planning efficiency, ensuring that senior leaders can weigh in on politically sensitive issues, and reallocate resources flexibly as priorities change. Using this approach in a contested environment, however, would create a major vulnerability for air operations: an attack on the JAOC or significant disruptions to long-haul communications could leave forward forces without the capability to plan and coordinate air operations. This chapter, therefore, describes the concepts the Air Force is developing and capabilities it needs to enable a more decentralized approach to C2 of air operations.

Since this report aims to generate recommendations for force presentation of Air Force fighter forces, this chapter focuses on the C2 for employment of those forces. It is important to remember, however, that air operations against a near-peer competitor would almost certainly be fought by joint and coalition forces. Fighter forces would also need to coordinate with bombers, ISR platforms, EW aircraft, mobility air forces, support forces, SOF, and others. Moreover, the Air Force is exploring ways to more deeply integrate operations across domains including cyber and space, which could lead to additional C2 considerations.[3] Therefore, C2 of fighter forces is only one aspect of a range of C2 issues the Air Force and joint community need to consider as they prepare for distributed operations in a contested environment.

This chapter begins by describing the disruptions to C2 that could result from attacks on communications systems and bases. We then present an overview of concepts, capabilities, and DOTMLPF-P changes that the Air Force may adopt to make C2 more resilient in a contested environment.

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[1] Joint Publication 3-0, *Joint Operations*, Washington, D.C.: Joint Chiefs of Staff, January 17, 2017, pp. III-2–III-3.

[2] Gilmary Michael Hostage III and Larry R. Broadwell, Jr., "Resilient Command and Control: The Need for Distributed Control," *Joint Forces Quarterly*, No. 74, 3rd Quarter 2014, p. 40.

[3] David Goldfein, *CSAF Focus Area: Enhancing Multi-Domain Command and Control . . . Tying It All Together*, Washington, D.C.: United States Air Force, March 2017a.

Disruptions to Command and Control in a Contested Environment

Since World War II, Air Force doctrine has promulgated a C2 philosophy known as centralized control and decentralized execution (CCDE).[4] A limited supply of aircraft can most easily be massed or reallocated as priorities shift when they are under the control of a single airman. At the same time, decentralized execution is intended to give forward commanders flexibility in how a mission is accomplished.[5] However, in practice, forward commanders today have little flexibility.[6] Since Operation Desert Storm, a COMAFFOR, dual hatted as the joint force air component commander (JFACC), has typically conducted centralized air planning through a JAOC or tactical air control center (TACC).[7] This planning results in detailed direction to tactical units through an air tasking order (ATO). As current doctrine explains, decentralized execution today means that

> once a sortie has been tasked through the air tasking order, a COMAFFOR and [air operations center (AOC)] staff should not normally get involved in how the mission is executed. While the AOC may have planned most of the enabling details and provided the operational constraints, the operational unit accomplishes the detailed mission planning and selection of tactics necessary to successfully meet mission tasking.[8]

Echelons below the JFACC, such as the AEW, have little practical role in the operational chain of command. As an Air Force doctrine developer explained, operational experience in Central Command for nearly two decades has led to a mistaken view that "centralized control/decentralized execution of airpower means control at the combatant commander (CCDR)-level COMAFFOR and decentralized execution at the mission commander or flight lead level. Intervening AEWs, AEGs, or AESs operated primarily as force providers not as potential force execution nodes."[9]

The Air Force recognizes that this approach to C2 would have significant vulnerabilities in a contested environment.[10] A physical attack on the JAOC or disruption of long-distance

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[4] Stephen J. McNamara, *Air Power's Gordian Knot: Centralized Versus Organic Control*, Maxwell Air Force Base, Ala.: Air University Press, August 1994. CCDE is also enshrined in joint doctrine. Joint Publication 3-30, *Command and Control of Joint Air Operations*, Washington, D.C.: Joint Chiefs of Staff, February 10, 2014, p. I-3.

[5] Annex 3-30, 2014, pp. 8–9.

[6] See, for example, T. J. O'Shaughnessy and Matthew Strohmeyer, *Multi-Domain Command and Control: Ensuring Offensive Initiative at the Theater AOC and Below in a Contested Environment*, Joint Base Pearl Harbor-Hickam, Hawaii: Pacific Air Forces, Strategic Thinking White Papers, 2018; Miranda Priebe, Laurinda L. Rohn, Alyssa Demus, Bruce McClintock, Derek Eaton, Sarah Harting, and Maria McCollester, *Promoting Joint Warfighting Proficiency: The Role of Doctrine in Preparing Airmen for Joint Operations*, Santa Monica, Calif.: RAND Corporation, RR-2472-AF, 2018, pp. 18–20.

[7] Air University, *USAF Doctrine Advisory on the Continuing Relevance of Centralized Control/Decentralized Execution*, Maxwell Air Force Base, Ala.: Air University, 2014a. For a description of the TACC, a precursor to the JAOC, see Gulf War Air Power Survey, 1993b.

[8] Core Doctrine, *Basic Doctrine*: Vol. I, Washington, D.C.: Headquarters U.S. Air Force, February 27, 2015, pp. 67–68. Quote on p. 68.

[9] Brian McLean, "Reshaping Centralized Control/Decentralized Execution for the Emerging Operating Environment," *Over the Horizon: Multidomain Operations and Strategies*, March 13, 2017.

[10] U.S. Air Force, 2015; Enterprise Capability Collaboration Team, 2016. Joint concepts also recognize this vulnerability. U.S. Department of Defense, 2012.

communications would leave forward forces without the capability to plan, execute, and assess air operations. In the Indo-Pacific theater, for example, forward forces may "experience degraded and often denied communications with a headquarters located 5000 miles from the tactical fight."[11] Moreover, although communications in the forward area could be more reliable, even local communications links may be interrupted for periods of time.

This chapter focuses on key C2 tasks that could be disrupted in this environment. In particular, because of the vulnerability of the JAOC and its communications links, the joint force will need to change how it establishes authorities among subordinates, prepares plans, prioritizes and allocates resources, and communicates orders.[12] Moreover, even when communications links between the JAOC and a forward location are available, low bandwidth could limit file sizes, making it more difficult to share images and video. As a result, the JAOC may no longer be able to provide forward forces with all of the information they need to gain situational awareness.[13]

Capabilities for Command and Control in a Contested Environment

In the long term, the United States will continue to innovate and pursue new technologies that make communications more resilient. Success of these programs could potentially allow the United States to command and control forces much as it does today. In this chapter, however, we focus on the more challenging problem of overcoming disruptions to C2 given existing technology. Chapter 2 described how the Air Force could use traditional (e.g., SATCOM, fiber) and alternative (e.g., courier flights) systems to make a more resilient and redundant communications network between operating locations in advance of a conflict (Figure 4.1). This section describes and expands on other emerging ideas about C2 capabilities for a contested environment.

Distributed Control

In light of threats to communications, the Air Force is developing new concepts for more decentralized control of air operations.[14] As Chief of Staff of the Air Force Gen. David Goldfein explained, the Air Force is "shifting our doctrinal dependence on large vulnerable centralized

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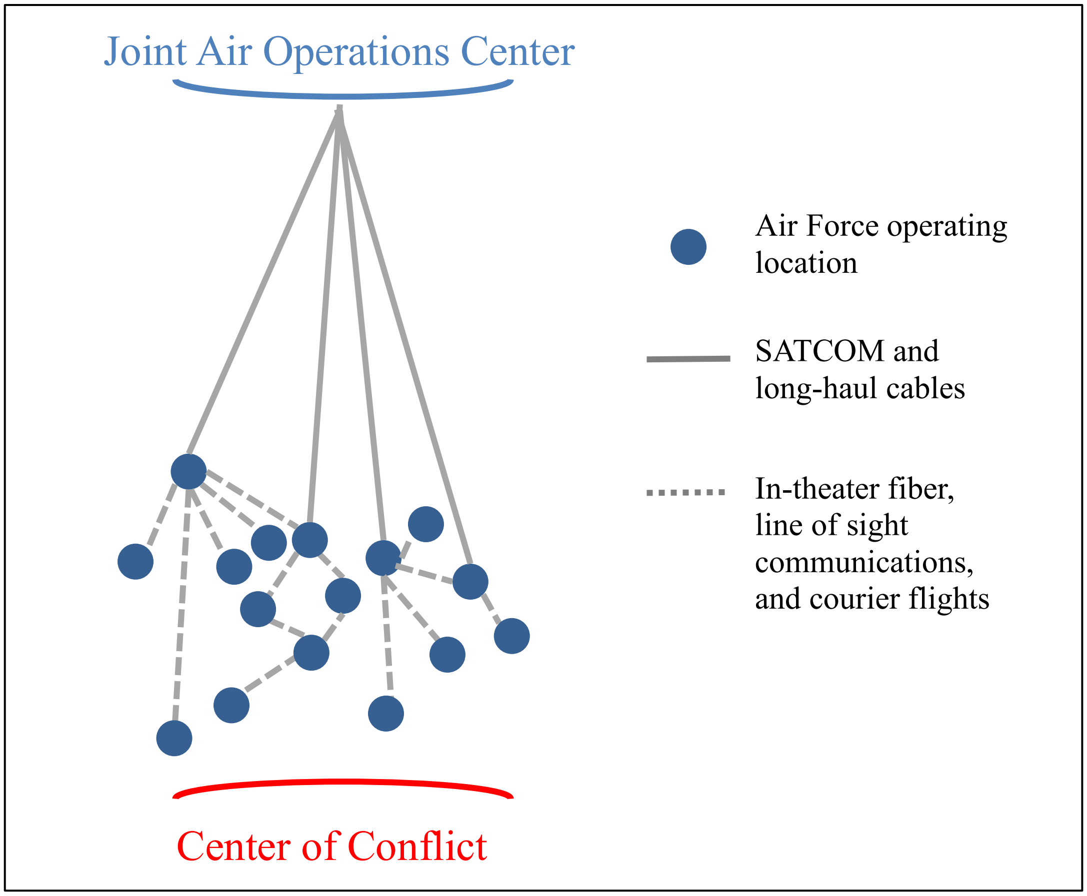
[11] O'Shaughnessy and Strohmeyer, 2018.

[12] For a discussion of C2 tasks, see Joint Publication 3-0, 2017, pp. III-3–III-3.

[13] Eric Theriault, "Empowered Commanders: The Cornerstone to Agile, Flexible Command and Control," *Air and Space Power Journal*, Vol. 29, No. 1, January–February 2015, p. 102.

[14] U.S. Air Force, 2015; Enterprise Capability Collaboration Team, 2016; U.S. Department of Defense, 2012, p. 28; Hostage III and Broadwell, Jr., 2014; James W. Harvard, "Airmen and Mission Command," *Air and Space Power Journal*, Vol. 27, No. 2, March–April 2013; Sydney J. Freedberg, Jr., "Decentralize the Air Force for High-End War: Holmes," *Breaking Defense*, October 13, 2017; Alan Docauer, "Peeling the Onion: Why Centralized Control/Decentralized Execution Works," *Air and Space Power Journal*, Vol. 28, No. 2, March–April 2014; James W. Hinote, *Centralized Control and Decentralized Execution: A Catchphrase in Crisis?* Maxwell Air Force Base, Ala.: Air Force Research Institute, Research Paper 2009-1, March 2009.

Figure 4.1. Notional Depiction of U.S. and Allied Communications Pathways



command and control nodes to more agile, networked solutions . . . moving to distributed control and decentralized execution of multi-domain operations."[15]

Distributed control would mean moving from a single C2 node, the JAOC, to multiple C2 nodes. There are many possible ways that the Air Force could approach distributed control. In the event of war with the Soviet Union, for example, late Cold War NATO plans envisioned the commander of Allied Air Forces in Central Europe providing broad daily guidance and allocating resources to subordinate allied tactical air forces (ATAFs). ATAF commanders would provide more detailed allocations to subordinate operations centers, which would provide mission details to the tactical fighter wings.[16] Today, PACAF anticipates establishing subordinate C2 nodes, perhaps at the NAF or wing level. If communications with the JAOC were

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[15] Dan DeCook, "Innovation, National Defense Strategy, the Future: CSAF at Air Force Association Air Warfare Symposium," *U.S. Air Force News*, February 23, 2018.

[16] Gerard L. Rifenburg, *Command and Control of the NATO Central Region Air Forces*, Maxwell Air Force Base, Ala.: Air War College, Research Report, March 1989, pp. 10–16; SofTech, Inc., *USAFE Annex to USAF Functional Area Requirement*, Falls Church, Va.: SofTech, August 20, 1982, pp. 2-4–2-6.

disrupted, these nodes would have the capability to continue providing direction to and coordination among forward forces.[17]

The remainder of this section describes how distributed control might work by developing a notional C2 arrangement for distributed control (Figure 4.2). In this scenario, the geographic CCDR (e.g., U.S. Indo-Pacific Command [USINDOPACOM] commander) leads the operation as the JFC.[18]

Following the arrangement used in other recent major conflict operations, our notional C2 arrangement has a single commander responsible for sustaining, organizing, employing, tasking, and allocating Air Force forces. In theory, these responsibilities could be held by two separate people from different services, but in practice an Air Force officer has usually held these authorities as a dual-hatted COMAFFOR and JFACC.[19] For simplicity, the discussion that follows refers only to the JFACC and does not separate the authorities that flow from each role.

Given that local communications would likely be more reliable than long-haul communications, we assume that the JFC would divide the joint operations area into multiple geographic sectors. During periods of reliable communications, the JFACC might reallocate air assets across sectors. However, in the event of significant disruptions, a joint sector air commander would have the capability to continue sector operations with his or her available assets. Although the use of geographic sectors sounds similar to the route packages used in the Vietnam War, the C2 arrangement is distinct. In the Vietnam War, there was a "convoluted chain of command" for air operations, and route packages simply helped the services coordinate.[20] The lack of a single airman overseeing air operations resulted in the inefficient use of air assets and continual tensions over authorities and use of assets.[21] Unlike the arrangement for the Vietnam War, in this notional organizational structure, each joint sector air commander is directly

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[17] O'Shaughnessy and Strohmeyer, 2018.

[18] This is consistent with recent major combat operations when the U.S. Central Command (CENTCOM) commander led operations in Iraq and Afghanistan. Alternatively, the CCDR could establish one or more subordinate JTFs for the operation. For a discussion of some of the trade-offs involved with these models, see Brien Alkire, Sherrill Lingel, Caroline Baxter, Christopher M. Carson, Christine Chen, David Gordon, Lawrence M. Hanser, Lance Menthe, and Daniel M. Romano, *Command and Control of Joint Air Operations in the Pacific: Methods for Comparing and Contrasting Alternative Concepts*, Santa Monica, Calif.: RAND Corporation, RR-1865-AF, 2018.

[19] The COMAFFOR has administrative control, the authority to sustain and organize Air Force forces. The JFC typically delegates operational control to the COMAFFOR, giving him or her the authority to employ these forces as well. As the JFACC, this airman would be responsible for planning and overseeing air operations and would have authority to task and allocate all aircraft that the service component commanders designate as available for joint tasking. Joint Publication 3-30, 2014, pp. II-2–II-3; Annex 3-30, 2014; Air University, *USAF Doctrine Update on COMAFFOR and JFACC Relationship*, Maxwell Air Force Base, Ala.: Air University, September 26, 2014b.

[20] Gulf War Air Power Survey, *A Statistical Compendium and Chronology*: Volume V, Washington, D.C.: Government Printing Office, 1993c, p. 145.

[21] James A. Winnefeld and Dana J. Johnson, *Command and Control of Joint Air Operations: Some Lessons Learned from Four Case Studies of an Enduring Issue*, Santa Monica, Calif.: RAND Corporation, R-4045-RC, 1991.

subordinate to a single airman, the JFACC, with authority to task and reallocate all aircraft available for joint tasking, regardless of sector. During periods of disruption, the sector air commanders would achieve unity of effort by following the JFACC's previously stated intent.

Since even local communications could be contested, wing commanders would serve as another C2 node that could provide intermediate direction and coordination when operating locations have poor communications with the sector commander and the AOC. We call these distributed wings since their groups would be spread out at multiple operating locations. Figure 4.2 depicts a sector with two distributed fighter wings. Figure 4.3 shows these

Figure 4.2. Notional C2 Arrangement for Distributed Control of Fighter Forces

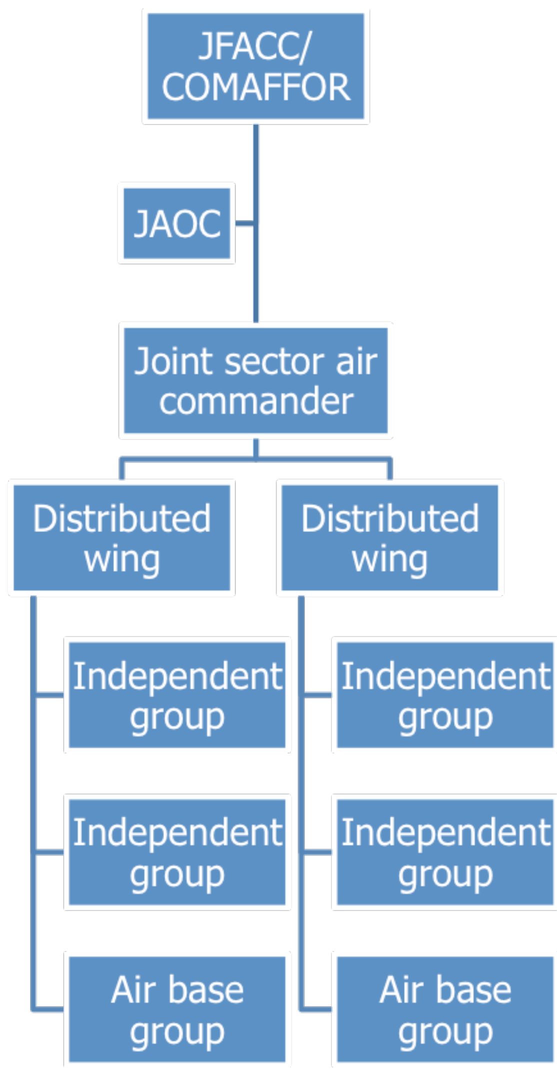
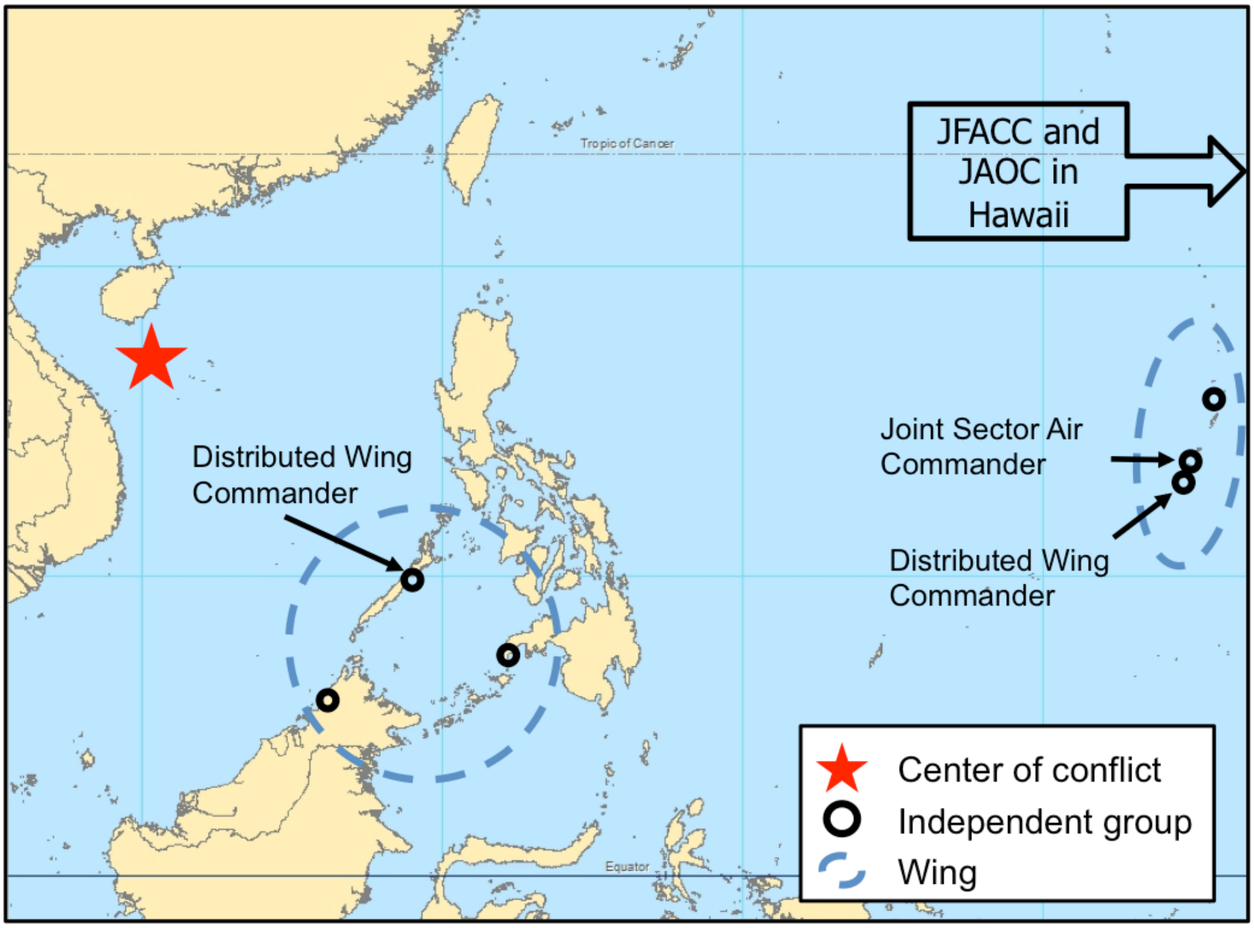


Figure 4.3. Notional Sector for a Conflict in the Pacific



organizations distributed within a notional sector in the Pacific.[22] As noted above, this chapter focuses on fighter forces. However, any C2 structure needs to account for other assets, including tankers, EW, and ISR aircraft that are typically part of fighter mission packages. Chapter 6 discusses the choices the Air Force faces in determining which echelon should have multiple aircraft types.

Each independent group (Figure 4.4) includes a fighter squadron as well as base support and defense units. Each group would be located at a Stay and Fight base. The air base group depicted in Figure 4.2 would be responsible for base operations and defense at other operating locations (e.g., Drop-in bases or FARPs) that the independent groups' flying squadrons might use during the conflict. For simplicity, we did not depict these additional operating locations in Figure 4.3.

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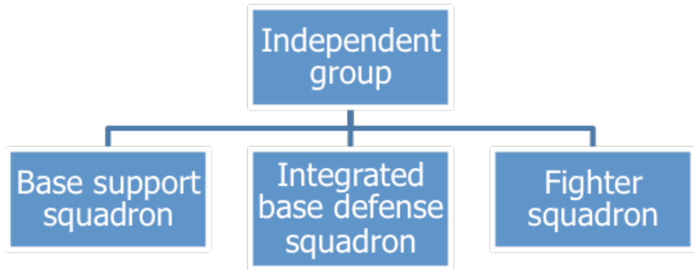
[22] Although not depicted here, the JFACC would also need to consider C2 arrangements for other forces, including ISR, EW, and mobility forces.

Figure 4.4. Notional Independent Group



Many other C2 arrangements would be possible, as will be discussed in Chapter 6. The remainder of the chapter is not focused on this specific C2 arrangement. Rather, it discusses capabilities that are relevant to any situation where the Air Force distributes control by establishing C2 nodes at echelons below the JFACC.

Mission Command

Besides creating additional C2 nodes, distributed control may require a shift in how commanders provide orders to subordinates. As discussed above, in recent years, a JFACC, working through a JAOC, develops operational air plans, allocates aircraft, and provides tactical units with detailed instructions through an ATO. In a contested communications environment, this type of detailed control may not be possible. Forward units may have to continue operations in a rapidly changing environment while disconnected from higher headquarters.

Senior Air Force leaders have therefore proposed that commanders provide mission-type rather than detailed orders to subordinates.[23] Mission-type orders provide a broad statement of a commander's intent and what a subordinate unit should accomplish without detailed description of how to accomplish the mission. With a better understanding of the logic behind a commander's orders, subordinates can continue operations even when communications are disrupted or degraded or when the situation is rapidly changing. Unity of effort, in this model, is achieved through the subordinates' understanding of the commander's intent, rather than through detailed orders.[24]

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[23] Goldfein, 2017b; O'Shaughnessy and Strohmeyer, 2018; Tod Wolters, "Panel Basing for Attack: Where Do We Go?" presentation at Air Force Association Air, Space & Cyber Conference, National Harbor, Md., September 19, 2017; Kris Osborn, "Future Air Force Jets to Attack with Less 'Central' Command & Control," *Warrior Maven*, March 25, 2018. See also a discussion of giving subordinates guidance they can use during communications disruptions by Gen James Holmes prior to taking his current position as ACC commander. Geoff Fein, Grace Jean, Caitlin Lee, and Daniel Waserbly, "Getting to Grips with Air-Sea Battle," *International Defense Review*, August 9, 2013.

[24] MCDP 6, *Command and Control*, Washington, D.C.: Headquarters United States Marine Corps, October 4, 1996, pp. 112–113.

This approach is captured in the joint principle of mission command,[25] which has its roots in the Prussian army's concepts for conducting operations in poor communications environments during the nineteenth century.[26] Even in the absence of communications disruptions, the U.S. Army and Marine Corps emphasize mission command today because they see warfare as unpredictable and fast moving. In this setting, sending information on the evolving situation up the chain of command and waiting for detailed instructions on how to proceed may be too time-consuming. Mission command offers forward commanders the opportunity to quickly tailor their action to the conditions they face and exercise disciplined initiative.[27] The most recent Air Force future operating concept echoes this perspective, explaining that CCDE

> is best realized when commanders give clear strategic guidance, and Airmen are entrusted to apply that guidance in a manner appropriate to the tactical situation as it unfolds. . . . [T]he opportunity to exploit a particular situation in the dynamic future battlespace may be fleeting; senior leaders who choose not to delegate decision making to the appropriate level will find themselves outpaced by events while they attempt to gain sufficient situational awareness to direct action.[28]

Although mission command and mission-type orders are often associated with ground forces, this approach is not without precedent in the Air Force. For example, during World War II, unreliable communications made detailed direction of air operations in the Pacific infeasible. Therefore, Gen George Kenney, commander of Allied Air Forces, Southwest Pacific Area, used mission-type orders to communicate intent and delegated detailed planning as low as the group level.[29]

In a future contested environment, commanders will need to decide how much decisionmaking to entrust to subordinates. Detailed control in recent years has included the JAOC providing aimpoints and weaponeering and even providing detailed tactical guidance on how to conduct the mission after the ATO has been issued. Less detailed control, which has reportedly been employed during Operation Inherent Resolve, would leave tactics and mission planning to subordinate units.[30] During Operation Desert Storm, the 7440th Composite Wing (provisional), operating from Turkey, received only objectives and a target list from the JFACC.

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[25] Joint Publication 1, 2013, pp. V-15–V-16; Joint Publication 3-0, 2017, pp. II-1–II-2, II-7.

[26] Harvard, 2013.

[27] ADP 6-0, *Mission Command*, Washington, D.C.: Headquarters, Department of the Army, May 2012 (incorporating changes as of March 12, 2014), p. 109.

[28] U.S. Air Force, 2015, p. 12.

[29] Michael E. Fischer, *Mission-Type Orders in Joint Air Operations: The Empowerment of Air Leadership*, thesis, Maxwell Air Force Base, Ala.: Air University, 1994, p. 26.

[30] Lieutenant General Harrigian, commander of U.S. Air Forces Central Command, emphasized that his role was to provide guidance and intent to the airmen under his command and then trust them to execute. Megan Friedl, "Crushing ISIS: Air Power Operations in a Complex Battle Space," *U.S. Air Force News*, September 19, 2017.

The wing had the authority and capability to conduct weaponeering, construct mission packages, and determine other details of how to strike those targets.[31] In the extreme, the JFACC might follow Kenney's model, by assigning a subordinate unit a high-level task (e.g., suppress enemy air defenses in a particular geographic area for a set period of time) and leaving it to the unit to determine how to allocate its aircraft, design mission packages, and phase air operations to achieve that goal. In this model, the ATO would be created in a distributed fashion rather than centrally in the JAOC.

In determining the appropriate balance between detailed and mission orders, the JFACC would need to consider trade-offs.[32] As discussed above, centralized control and detailed orders have allowed the Air Force to allocate scarce resources, reallocate as priorities shift, and keep politically sensitive decisions at higher echelons. However, detailed control has also made the Air Force reliant on a small number of vulnerable nodes. Latency and disruptions in communications between the JAOC and forward forces may also make a centralized process too slow.[33] Clear rules of engagement and maintaining detailed control over operations with high potential for escalation are steps that could balance some of the risks involved in greater use-of-mission orders.

Conditional Authorities and Playbooks

A key component of distributed control is determining which authorities subordinate echelons should have and under what conditions they would have these authorities. A PACAF white paper argued that conditional authorities for air operations may devolve to the NAF or wing level when communications with the JAOC are disrupted or degraded.[34] In situations where local communications are likely to be severely contested, the JFACC may wish to establish some conditional authorities that go even lower. Regardless of where authorities devolve, the intent of higher headquarters and prescripted playbooks would guide decisions and coordinate or deconflict with other units.[35]

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[31] Lee A. Downer, "The Composite Wing in Combat," *Airpower Journal*, Vol. 5, No. 4, Winter 1991, p. 9.

[32] On the trade-offs, see MCDP 6, 1996, pp. 77–81, 109–110.

[33] The United States has made significant progress in the dynamic targeting process in an uncontested communications environment over the past two decades. Still, some have criticized its responsiveness in some situations. See, for example, Mike Benitez, "It's About Time: The Pressing Need to Evolve the Kill Chain," *War on the Rocks*, May 17, 2017. As part of a move toward more decentralized control, some have argued that DoD may need to shift from a rigid "kill chain" approach to a more adaptive "kill web" approach that can support ad hoc collaboration of different assets without centralized control. Craig Lawrence, "Adapting Cross-Domain Kill-Webs (ACK): A Framework for Decentralized Control of Multi-Domain Mosaic Warfare," Defense Advanced Research Project Agency, Proposer's Day presentation, Arlington, Va., July 27, 2018.

[34] O'Shaughnessy and Strohmeyer, 2018.

[35] On playbooks, see O'Shaughnessy and Strohmeyer, 2018.

The JFACC would need to consider the extent to which he or she wishes to pass forward authorities conditionally versus maintain some authorities at lower levels all of the time. In a changing operating environment, passing authorities and responsibilities back and forth could create additional confusion and complexity. At the same time, having authorities at lower echelons could reduce the flexibility of airpower if communications turn out to be more reliable than expected. If the JFACC relies on mission command and largely empowers forward commanders all of the time, the differences between good and bad communications environments may be minimal. Forward commanders would have significant authority throughout and be responsible for things like creating their local ATO at all times. Conversely, if the JFACC were to retain decision control and direct the ATO process from the JAOC whenever communications were good, transitions to more contested communications conditions may be more disruptive. Ultimately, the specific nature of conditional authorities will depend on the communications environment, mission, and other characteristics of the operating environment.

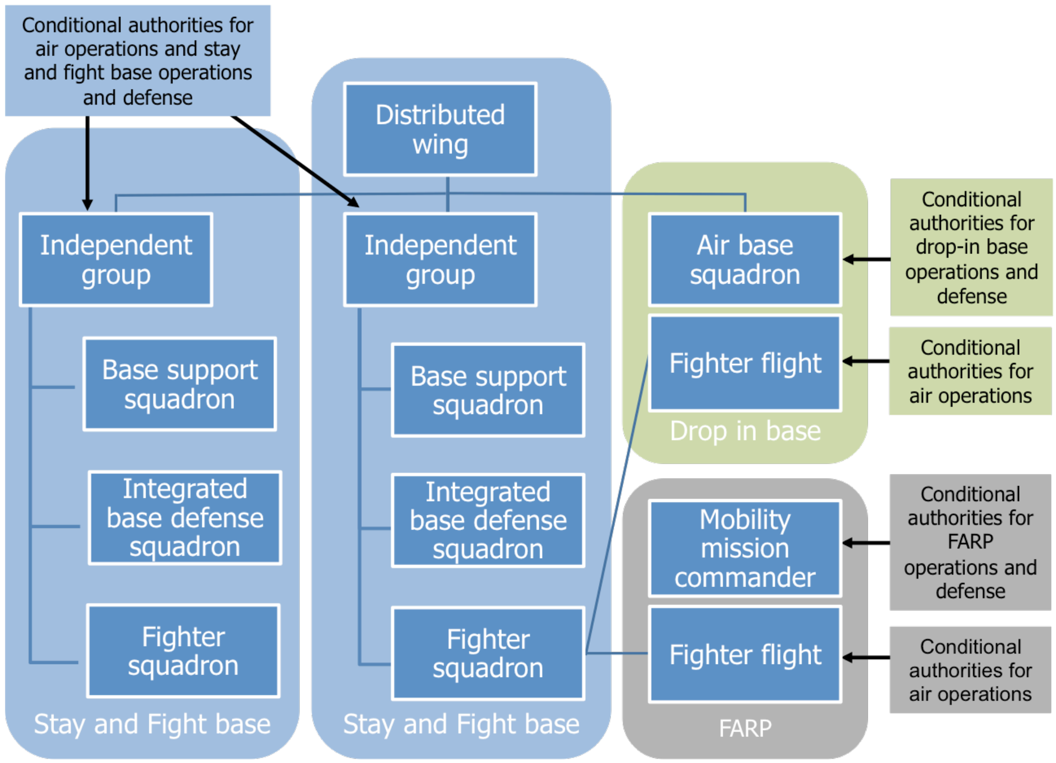
Establish Authorities for Air Base Operations and Defense

In addition to the conditional authorities for air operations, the JFACC in his or her role as COMAFFOR would need to consider authorities for base operations and defense. These authorities could be arranged in many different ways. This section provides one notional example to highlight some of the possible arrangements, and Chapter 6 explores some of the trade-offs involved in alternative approaches.

Figure 4.5 depicts a notional distributed wing using the three operating location types discussed in Chapter 2. The figure shows authorities that devolve as low as the operating location level when local communications are severely disrupted. In practice, there are a large number of specific and complex authorities to consider. For simplicity, we group authorities into three broad categories: air operations, base defense, and base support. In this notional C2 arrangement, a single commander at the Stay and Fight base, the independent group commander, would have authorities to continue air operations, base operations, and base defense during periods of disruption from higher headquarters.

In this notional structure, authorities at Drop-in bases are split. The air base squadron commander has authority for base operations and defense but not for the flying operations of its temporary tenant units. Instead, the fighter flight mission commander would have authority for air operations. Similarly, the mobility mission commander would have authority for base operations and defense at the FARP, while the fighter mission commander would have authority for decisions about air operations.

Figure 4.5. Notional Conditional Authorities During Periods of Severe Communications Disruptions



NOTE: The mobility mission commander would report to a mobility squadron, possibly dedicated to the sector (not depicted).

Generate Situational Awareness Locally

With uncontested communications, the JAOC has a significant role in providing commanders at all echelons the information they need to gain situational awareness. Air Force units generally do not have organic ISR assets to gather information on the operating environment. Rather, collection management authority is typically held at a high level, and most of the Air Force's airborne ISR aircraft are tasked through the joint collection processes. The JAOC compiles intelligence on the adversary from these aircraft as well as other sources such as space-based assets. The ATO provides information about friendly forces.[36]

However, this model may not be as viable in the contested environment. First, communications disruptions may limit the information that forward forces can send to and receive from the JAOC and other locations involved in the intelligence process. Second, distributed forces and higher threat levels in the contested environment will likely create much

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[36] Annex 2-0, *Global Integrated Intelligence, Surveillance & Reconnaissance Operations*, Washington, D.C.: Headquarters U.S. Air Force, January 29, 2015, pp. 4, 21–22, 27, 31.

greater demands for intelligence, including force protection intelligence, than the JAOC can realistically produce through a centralized process.

Lower echelons may therefore need to have the capability to gain situational awareness in their own operating area and to continue collecting on higher echelons' critical information requirements even when communications are disrupted or degraded. To do so, commanders at lower echelons will need to be able to articulate their priority information requirements to their staff. Moreover, forward forces may need organic assets, such as small remotely piloted aircraft, for gathering intelligence and additional personnel to analyze the data collected.[37] The CCDR may decide to allocate some of the theater's limited ISR capabilities to each sector or grant lower echelons with conditional authorities to task local platforms for intelligence collection during periods of communications disruptions.

Today, wings have intelligence support personnel who either remain at the wing level or are assigned to operational squadrons to assemble operational and target intelligence.[38] To support continued collection for their own situational awareness and the information requirements of higher echelons, these organizations may need to have more intelligence personnel trained in all steps in the intelligence process: planning and direction, collection, processing and exploitation, analysis and production, and dissemination.[39] This approach would be a significant change from today, where these steps in the process may take place at multiple locations. Moreover, having this type of intelligence capability at each operating location would likely be much more manpower intensive than today's model.

Finally, even with these changes, commanders at all echelons will likely need to make decisions with less situational awareness than today. Because bandwidth may be restricted, intelligence that comes from the JAOC or other operating locations may be less detailed than in the past. For example, intelligence personnel may not be able to share an image, so they may share a brief text description with another operating location instead. With less information and fewer details, intelligence personnel and commanders will need the capability and experience to make assessments based on more limited information.

Potential DOTMLPF-P Changes

Many of the concepts discussed in the previous section would require significant changes in how the Air Force operates in both war and peacetime. This section discusses some potential DOTMLPF-P changes that may enable these capabilities. This is not a validated or

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[37] During World War II, each of the composite air task forces in the Pacific had dedicated reconnaissance capabilities. Fischer, 1994, p. 36.

[38] Annex 2-0, 2015, p. 26.

[39] The steps in the intelligence process are discussed in Annex 2-0, 2015; Joint Publication 2-0, *Joint Intelligence*, Washington, D.C.: Joint Chiefs of Staff, October 22, 2013.

comprehensive list; the Air Force will undoubtedly refine and expand this list as distributed operations concepts emerge. In developing this initial list, we draw from existing proposals and generate new ideas by extending the logic of the concepts discussed above. Table 4.1 summarizes these changes.

Table 4.1. Overview of Potential DOTMLPF-P Changes for C2 of Distributed Operations

	Potential DOTMLPF-P Changes
Doctrine	• Discussion of distributed control, conditional authorities, and mission command
Organization	• More robust planning and intelligence organizations at lower echelons
Training	• Simulate poor communications environment in command post exercises to practice distributed control, transitioning authority, mission-type orders, and gaining situational awareness with little information from the JAOC • Simulate intensive air and missile attacks to replicate decisionmaking under attack • Intelligence personnel train to conduct entire intelligence process locally • Commanders likely to fight together, train together to build trust
Materiel	• More mobile SATCOM terminals • Additional LOS communications • Potentially, HF radios
Leadership/ education	• Education and development emphasize disciplined initiative as well as risk acceptance and management • Intelligence analysts prepared to make assessments in low-information environments
Personnel	• More communications experts, planners, and intelligence personnel
Facilities	• Fixed SATCOM terminals and hardened command centers at fixed facilities (e.g., Stay and Fight bases)

Doctrine

Air Force and joint doctrine acknowledge that today's approach to C2 relies on uninterrupted communications.[40] However, these documents do not offer specifics on how the approach might change in a degraded communications environment. Air Force doctrine developers have argued that the principle of CCDE should be preserved because it is broad enough to accommodate distributed control.[41] Others have suggested alternatives, such as centralized command, distributed control, and decentralized execution. Regardless of what the Air Force decides to

[40] Joint Publication 3-30, 2014, p. II-24; Annex 3-30, 2014, p. 4.

[41] For discussions of the continued relevance of CCDE, see Jeffrey Hukill and Daniel R. Mortensen, "Developing Flexible Command and Control of Air Power," *Air and Space Power Journal*, Vol. 25, No. 1, Spring 2011; Air University, 2014a; McLean, 2017.

name its C2 philosophy, doctrine needs to offer more information on what C2 would look like in different operating environments.[42]

Each JFACC would likely tailor conditional authorities to the mission, operating environment, and other factors. Still, changes to operational doctrine and TTPs can offer some broad guidance on possible ways to divide authorities and responsibilities between echelons both to expose airmen to these concepts during education and training and to offer commanders a starting point for developing the specific authorities appropriate for their situation. Deeply engaging with the joint principle of mission command is another way that Air Force doctrine could evolve for the contested environment.[43] The Air Force might also consider doctrine or TTPs for distributed production of the ATO in a communications-contested environment. In expanding C2 doctrine to account for distributed operations and mission command, the Air Force may be able to draw from its own history of more decentralized control during World War II and the Cold War.

Organization and Personnel

Lower echelons will need larger planning and intelligence organizations if the Air Force adopts distributed control.[44] During periods of good communications, these organizations could conduct planning and even help generate the ATO in close coordination with higher headquarters. However, during periods of disruption, these organizations would need the capability to plan and allocate resources in order to carry out the intent of higher echelons. This has been done successfully in the past. In the South Pacific during World War II, General Kenney increased the intelligence, planning, and operations staff at the wing level to enable distributed control and mission command.[45] Distributed control therefore likely requires substantially more personnel with C2 expertise. Further analysis would be needed to determine the requirements.

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[42] Operational doctrine often lags behind actual practice because it enshrines validated best practices. As a result, initial steps toward generating doctrine will likely continue to take place through concept documents and exercises. Recent AFTTP documents have been updated to include discussions of degraded communications environments. James Lopez and Charles Charanut, *AFTTP 3-1/3-3.AOC*, Nellis Air Force Base, Nev.: 561st Joint Tactics Squadron, 2018.

[43] Currently, mission command is not discussed in Air Force doctrine other than a passing reference in a callout box in Annex 3-30 that notes CCDE is more appropriate for airpower. Annex 3-30, 2014, p. 8.

[44] McLean, 2017. With a FARP concept, a mission planner on the C-17 would need to be able to adjust mission plans based on changes in conditions or loss of communications at the FARP. Davis, 2014, p. 17.

[45] Michael E. Fischer, *Mission-Type Orders in Joint Air Operations: The Empowerment of Air Leadership*, thesis, Maxwell Air Force Base, Ala.: Air University, May 1995.

Training

Enhancements to and new forms of training will be an important part of preparing for distributed control in a contested environment. As noted above, airmen we spoke with over the course of this study told us they had not participated in exercises that simulate heavy air base attacks. Moreover, they reported that units do not currently simulate communications disruptions between headquarters.[46] The demands of a contested environment require a new level of intensity and practice in training and exercises to prepare airmen for the conditions they could face. The Air Force is just beginning to incorporate these conditions in limited ways in training and exercises and to develop other relevant skills through regular Air Force activities.

During home station training and exercises, leaders at lower echelons will need to gain practical experience planning and making decisions that were previously made at the JFACC level. Moreover, they will need sufficient experience to feel empowered to exercise disciplined initiative when communications are degraded or disrupted. As General Goldfein explained, "What's going to be essential to our success is that we have squadron commanders who feel empowered to make decisions and take appropriate risks, especially if they're cut off from the higher echelons of command."[47] Including poor communications environments and air base attacks would give airmen opportunities to practice distributed control, transitioning authorities, writing and interpreting mission-type orders, gaining situational awareness, and making decisions with limited information.

Exercises that incorporate communications disruptions are just beginning to reemerge and in some cases occur for the first time. Red Flag exercises have long given airmen training for executing tactical missions under realistic conditions, including with communications threats.[48] However, exercises that include communications disruptions between air bases and the JAOC, however, are still under development.[49] Recent exercises are also beginning to explore other

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[46] HAF released a memo requiring that all airmen complete chemical, biological, radiological, and nuclear (CBRN) defense survival skills training every 18 months rather than the previously required 36 months. The Air Force has conducted some exercises with simulated CBRN attacks. It is not clear, however, how widespread these exercises are and whether airmen practice C2 tasks under these conditions. Conventional precision missile attacks could also present distinct challenges from CBRN attacks; airmen need to be prepared for these contingencies as well. Christopher R. Morales, "New CBRN Requirements No Issue for 773rd CES," *Joint Base Elmendorf-Richardson News*, August 24, 2017; Amber Grimm, "Emergency Responders Receive Integrated CBRN Training," *Osan Air Base News*, August 13, 2015; Jacob Farbo, "Ready Group Takes Part in Vigilant Ace 17-1," *Marine Corps Air Station Iwakuni, Japan News*, November 17, 2016; Air Force Instruction 10-2501, *Air Force Emergency Management Program*, Washington, D.C.: U.S. Air Force, U.S. Department of Defense, AFI 10-2501, April 19, 2016.

[47] Goldfein, 2017b.

[48] "414th Combat Training Squadron 'Red Flag,'" *Nellis Air Force Base News*, July 6, 2012.

[49] According to airmen we interviewed for this study, the Unified Engagement 2014 tabletop exercise included disrupted communications but did not exercise distributed control. They reported that an upcoming

aspects of C2 in the contested environment. For example, the 2017 Arctic ACE exercise, which tested some of PACAF's emerging ACE concepts, was an initial test of establishing communications in an austere location.[50]

The Air Force's ongoing initiative to shift peacetime decisions to the lowest capable level is an important step toward preparing airmen at lower echelons to take on greater responsibilities in wartime.[51] For example, in July 2017, ACC Commander General Holmes instructed wings to conduct quarterly exercises that aim to "practice the autonomy and initiative required to win" in a contested environment.[52] In response, squadrons, rather than higher echelons, led mission planning and refined TTP during Exercise Stealth Guardian, a weeklong event that integrated combat rescue assets and fifth-generation aircraft.[53] Relatedly, in 2018, the 366th Fighter Wing began testing a new wing structure that aims to help develop empowered unit leaders capable of operating with greater independence.[54]

Developing command post exercises that bring together leaders from multiple echelons would be an additional way to practice these skills more frequently. Such exercises would be less resource intensive than large-scale exercises and would focus on C2 in a contested environment. Such exercises would include commanders from multiple echelons, ideally matching leaders likely to fight together in a contingency.[55] At the tactical level, common language and tactics allow airmen from disparate units to fight together without necessarily having a prior relationship. However, habitual relationships may be more important for carrying out less scripted operational activities in the highly stressful contested environment.

USINDOPACOM field exercise will include disrupted communications for the first time. For a brief discussion of Unified Engagement, 2014, see Alkire et al., 2018, p. 9.

[50] Warburton, 2017.

[51] Goldfein, 2017b; Wilson, 2017; Peter Aguirre, "Revitalizing Squadrons: A Commander's Perspective," *U.S. Air Force*, April 4, 2018. For ACC's initiative in particular, see Stephen Losey, "ACC Boss: The Air Force's Fighters Must Be Ready to Fly in Contested Air Space," *Air Force Times*, September 17, 2017; Rasheen Douglas, "ACC Works to Empower Leaders at Every Level," *Air Combat Command*, August 11, 2017.

[52] James M. Holmes, *Memorandum for ACC Commanders: Leadership, Initiative, and War*, Joint Base Langley-Eustis, Va.: Headquarters Air Combat Command, July 20, 2017.

[53] Douglas, 2017; Korey Fratini, "Stealth Guardian Demonstrates Rescue, 5th Generation Integration," *U.S. Air Force News*, August 15, 2017; Solomon Cook, "Exercise Stealth Guardian Enhances Rescue Capabilities in Multiple Environments," *Tyndall Air Force Base News*, August 17, 2017.

[54] An explicit goal of this test is to put "decision-making authority and accountability for the mission at the squadron level." 366th Fighter Wing Public Affairs, "ACC to Test New Wing Organization at Mountain Home," *Air Combat Command*, May 17, 2018.

[55] Chairman of the Joint Chiefs of Staff, *Mission Command White Paper*, Washington, D.C.: Joint Chiefs of Staff, April 3, 2012, p. 6; U.S. Army Training and Doctrine Command, *Multi-Domain Battle: Evolution of Combined Arms for the 21st Century, 2025-2040*, Washington, D.C.: U.S. Department of Defense, Version 1.0, December 2017. Both the U.S. Army and the Marine Corps emphasize the importance of trust in enabling commanders to allow subordinate initiative. TRADOC Pamphlet 525-3-3, *U.S. Army Functional Concept for Mission Command, 2020-2040*, Washington, D.C.: Department of the Army, February 2017, pp. 13–14; MCDP 6, 1996, pp. 114–115.

Materiel and Facilities

The Air Force would need to acquire more existing systems to enable C2 of distributed operations. For example, the Air Force will need more deployable communications systems to create a more robust communications network among the larger number of operating locations. The exact materiel requirements will depend on the mix of operating locations the Air Force uses. For example, the Stay and Fight bases discussed in Chapter 2 would likely have permanent SATCOM terminals, access to local and long-distance fiber cables, and radio connections for LOS communications. Unmanned aerial vehicles may be used as airborne relays between operating locations. Since Drop-in bases would be less permanent, they might use mobile SATCOM terminals and radios to connect to LOS communications networks. Mobility aircraft used for FARPs would need to have SATCOM connections, radios for LOS communications, and a mission planning computer on the aircraft itself.[56] As with materiel, the requirements for facilities to carry out C2 vary by operating location type. More permanent facilities, such as Stay and Fight bases, may have a hardened command center. For Drop-in bases, the Air Force might rely on temporary structures for conducting planning and intelligence activities on classified systems.[57]

In the longer term, ongoing Air Force initiatives may result in more resilient, redundant, and interoperable communications networks. For example, a concept for a combat cloud aims to create a network that can rapidly collect, integrate, and distribute intelligence across multiple platforms and systems. To do this, the Air Force and other services will first need to standardize datalink frequencies and waveforms to ensure that the wide array of systems can share data and develop software to process and distribute this information.[58]

Leadership and Education

In addition to training, the Air Force may wish to review professional military education programs to ensure they develop the critical thinking and problem-solving skills airmen will need to exercise disciplined initiative in a communications-contested environment. The U.S. Army, which has a longer history with mission command, has been criticized for micromanaging, providing detailed instructions to subordinates, and disincentivizing risk

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[56] Davis, 2014.

[57] The Air Force has deployable debrief facilities for classified planning and intelligence activities, for example.

[58] Aaron Kiser, Jacob Hess, El Mostafa Bouhafa, and Shawn Williams, *The Combat Cloud: Enabling Multi-Domain Command and Control Across the Range of Military Operations*, Maxwell Air Force Base, Ala.: Air University, March 2017; David A. Deptula, "The Combat Cloud: A Vision of 21st Century Warfare," keynote address to the Association of Old Crows, Washington, D.C., December 1, 2015.

taking.[59] As a result, the Army has begun changing its educational approach to emphasize problem solving, critical thinking skills, adaptability, and decisionmaking.[60] A review of educational programs could help the Air Force identify additional ways to prepare leaders for making decisions under uncertainty as they will need to do in a contested environment.

Conclusion

The threats to communications in a contested environment will disrupt the centralized approach to C2 of air operations that has prevailed in recent decades. The Air Force has already begun developing a more resilient approach to C2 by shifting toward distributed control and using mission-type orders. These concepts, if adopted, would require significant changes in Air Force culture and the way the Air Force operates in peacetime and wartime.

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[59] Douglas A. Pryer, "Growing Leaders Who Practice Mission Command and Win the Peace," *Military Review*, November-December 2013, p. 33; Thomas M. Feltey and John F. Madden, "The Challenge of Mission Command," *Military Review*, August 27, 2014. On the history of mission command in the U.S. Army, see Clinton J. Ancker III, "The Evolution of Mission Command in U.S. Army Doctrine, 1995 to the Present," *Military Review*, Vol. 92, No. 2, March–April, 2013. Even soldiers who completed one of the Army's new educational programs reported that command culture provided few opportunities to exercise disciplined initiative. Susan G. Straus, Michael G. Shanley, Carra S. Sims, Bryan W. Hallmark, Anna Rosefsky Saavedra, Stoney Trent, and Sean Duggan, *Innovative Leader Development: Evaluation of the U.S. Army Asymmetric Warfare Adaptive Leader Program*, Santa Monica, Calif.: RAND Corporation, RR-504-A, 2014.

[60] TRADOC Pamphlet 525-8-2, *The U.S. Army Learning Concept for Training and Education, 2020-2040*, Fort Eustis, Va.: U.S. Army Training and Doctrine Command, April 2017, p. 11; U.S. Army Training and Doctrine Command, 2017, p. 24; Supunnee Ulibarri, "AWG Course Brings Army Learning Model to Life," *Army.mil*, November 18, 2014.

5. Sustainment

Previous chapters assessed the implications of distributed operations for C2 and protection of distributed forces. This chapter considers sustainment, which includes activities such as coordinating the supply of food, fuel, munitions, and equipment; maintenance of equipment; building and maintaining contingency bases; assessing, repairing, and maintaining infrastructure; and coordinating transport.[1] For the purposes of this report, we focus on activities related to posture and combat support.[2]

Global posture is a vital part of U.S. defense strategy, and its activities are not subsumed under the sustainment warfighting function.[3] Posture is generally understood to be the combination of overseas facilities, forces, and relationships necessary to protect American interests during peace and war.[4] Posture has multiple purposes,[5] and the State Department, DoD, and combatant commands play the lead role in developing posture requirements and negotiating access to partner nation air bases. This chapter focuses on the ways posture would affect the Air Force's ability to generate and sustain operational effects in a conflict with a great power. Air Force warfighting activities related to posture are so intertwined with sustainment activities that in this analysis it seems fitting to discuss the two together.

Agile Combat Support is a broad term that captures the communities that are most deeply involved in sustainment activities.[6] Since the end of the Cold War, the USAF ACS enterprise has sought to simultaneously improve peacetime efficiencies and the timeliness, quality, and agility of support to deployed forces conducting combat operations. Combat operations against insurgent and terrorist adversaries, however, offer a poor model for the sustainment demands likely to arise during a war with a major power. CT and COIN have been characterized by sustained but typically modest operational tempo, low attrition of aircraft, and prolonged

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[1] Joint Publication 3-0, 2017, p. III-43.

[2] For details see Annex 4-0, *Combat Support*, Washington, D.C.: Headquarters U.S. Air Force, December 21, 2015.

[3] For a history of U.S. global defense posture, see Stacie L. Pettyjohn, *U.S. Global Defense Posture, 1783–2011*, Santa Monica, Calif.: RAND Corporation, MG-1244-AF, 2012.

[4] Pettyjohn and Vick, 2013, p. 2; Alan J. Vick, Stacie L. Pettyjohn, Meagan L. Smith, Sean M. Zeigler, Daniel Tremblay, and Phillip Johnson, *Continuity and Contingency in USAF Posture Planning*, Santa Monica, Calif.: RAND Corporation, RR-1471-AF, 2016.

[5] For example, Pettyjohn and Vick identify the three primary purposes of posture as "1) [m]aintain security ties to close partners and key regions, 2) create and sustain operational effects, and 3) sustain global military activities." Pettyjohn and Vick, 2013, p. xii.

[6] The term *Agile Combat Support* also includes other communities such as security forces involved in base defense.

multiyear commitments. In a conflict with a near-peer adversary, the operational tempo and attrition will be extremely high, at least initially. The duration of the conflict may be short because attrition and munitions use will make it impossible to sustain. The approach to combat support in a near-peer conflict would, therefore, differ significantly.[7]

Disruptions to Sustainment in a Contested Environment

As noted in previous chapters, combat in a contested environment will be characterized by air and missile attacks on airfields, communications nodes, and supporting facilities as well as nonlethal attacks on information systems, communications, and other electronic systems.

Air and missile attacks will disrupt sustainment by damaging or destroying airfield operating surfaces; fuel, parts, and munitions storage; maintenance facilities; aerospace ground equipment; runway repair equipment; and other support facilities and equipment. Additionally, such attacks are likely to wound or kill maintenance, engineer, security force, and other personnel key to sustainment activities.

Nonlethal attacks will disrupt sustainment by hindering communications among units (e.g., requests for resupply) and possibly compromising the integrity of databases, maintenance software, and decision support systems. For example, the F-35 Automatic Logistics Information System (ALIS) depends on a network of tablets, local Wi-Fi, air base–level servers, and datalinks to the United States—all of which are potential targets for nonlethal attacks.[8]

Capabilities for Sustainment in a Contested Environment

There are many adaptations the Air Force will need to make to counter the disruptions outlined in the previous section. Distributed operations concepts are still emerging, and the concepts for supporting them are even more nascent.[9] This section describes several capabilities that could be part of a resilient posture and combat support portfolio.

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[7] For analyses of support requirements associated with stability operations in the Middle East and Southwest Asia, see Patrick Mills, James A. Leftwich, Kristin Van Abel, and Jason Mastbaum, *Estimating Air Force Deployment Requirements for Lean Force Packages: A Methodology and Decision Support Tool Prototype*, Santa Monica, Calif.: RAND Corporation, RR-1855-AF, 2017; Amanda B. Geller, David W. George, Robert S. Tripp, Mahyar A. Amouzegar, and Charles Robert Roll, Jr., *Supporting Air and Space Expeditionary Forces: Analysis of Maintenance Forward Support Location Operations*, Santa Monica, Calif.: RAND Corporation, MG-151-AF, 2004.

[8] Angus Batey, "F-35 Logistics System May Be Vulnerable to Cyberattack," *Aviation Week*, March 3, 2016; Lockheed Martin Corporation, "Automatic Logistics Information System (ALIS)," webpage, undated.

[9] Although nascent, support concepts are emerging. For a description of one of these initiatives, see Debbie Aragon, "AFIMSC Prepares to Host Second I-WEPTAC," *AFIMSC News*, February 20, 2018.

Posture

Distributed operations in a contested environment make two unique demands on posture: (1) They require more facilities and access agreements, and (2) they are more likely to generate dynamic and unpredictable demands on host nation civilian airfields, complicating the politics of maintaining access.[10]

Expanded Need for Access

Distributed operations will greatly increase the demand for airfield access. If the USAF were to operate six fighter wings exclusively out of its current bases in East Asia, the demand for airfields would be six (Osan AB, Kunsan AB, Misawa AB, Yokota AB, Kadena AB, and Andersen AFB). Limited distributed operations (three airfields per wing) could increase the requirement to 18 bases. Adding two Drop-in bases for each wing would increase the number to 30. Adding a Fighter FARP for each wing would increase the number to 36, a sixfold increase in facility requirements and associated access arrangements.[11]

Thus, gaining access to a larger number of operation locations will present challenges for posture planning, an inherently slow and contentious process. Although U.S. posture requirements may be met by a single nation for some scenarios, in many cases distributed operations will require increased access both within and across multiple partner nations.[12]

Historical experience demonstrates the difficulty of getting access to overseas bases during conflicts; multiplying the number of required partners greatly increases this challenge. If the U.S. adversary is a direct threat to the host nation, it may grant access immediately. However, in other cases, access may be delayed, restricted, or denied due to the limited interests the prospective host has in the particular conflict or because the host has been coerced by the U.S. adversary. Put another way, host nation stakes vary depending on the scenario.

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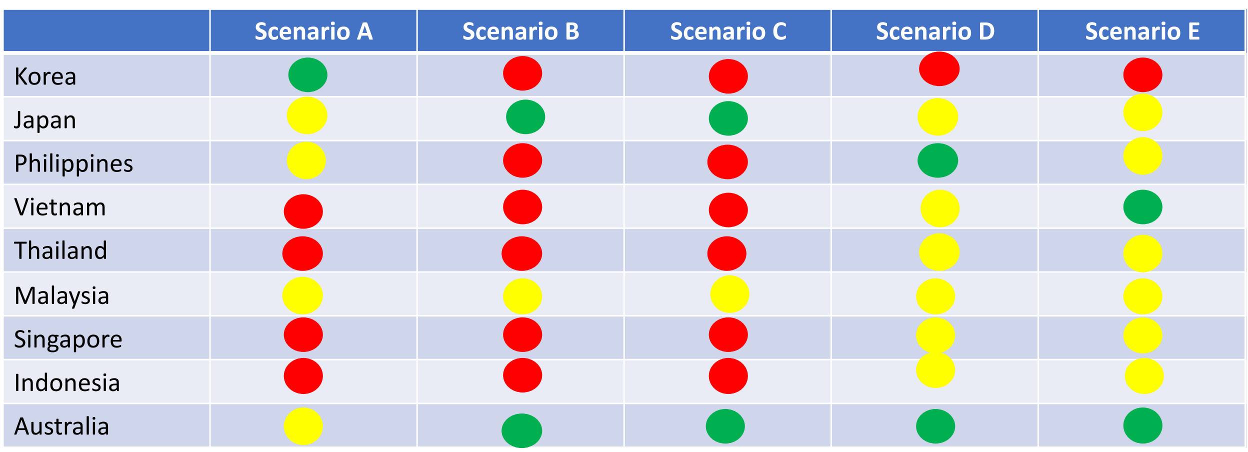
[10] For a statistical and historical analysis of variables associated with access approval and denial, see Stacie L. Pettyjohn and Jennifer Kavanagh, *Access Granted: Political Challenges to the U.S. Overseas Military Presence, 1945–2014*, Santa Monica, Calif.: RAND Corporation, RR-1339-AF, 2016.

[11] To be precise, this example includes five bases on foreign soil and one (Andersen AFB, Guam) on U.S. soil. Access to Guam is not an issue, but if a fighter wing were to distribute itself in the vicinity of Guam it might operate out of Yap, Palau, and the Commonwealth of Northern Marianas Islands (CNMI). The United States has full legal authority to conduct military operations from any of these locations because the CNMI are a U.S. commonwealth and Yap and Palau are parties to a Compact of Free Association with the United States that cedes authority for security to the United States. In peacetime, however, it has proven quite difficult to negotiate expanded military access and facility improvements at these locations. For more on U.S. authority and responsibility regarding the security of the Federated States of Micronesia (including Yap) and the Republic of Palau, see Public Law 108-188, Compact of Free Association Amendments Act of 2003, December 17, 2003.

[12] Japan has agreed (under the U.S.-Japan Guidelines for Defense Cooperation) to allow the United States greater use of civilian and dual-use facilities, but this has not yet been implemented. The Air Training Relocation program does enable U.S. units in Japan to fly out of Japan Air Self-Defense Force air bases for training. Thanks to reviewer Eric Heginbotham for sharing this.

Figure 5.1 illustrates the variation in access that host nations might grant across five purely notional planning scenarios. The purpose of the table is to illustrate the need to think holistically about basing; the colors are purely illustrative. Green means there is a high likelihood that the host will grant the USAF the desired access. Yellow means there is a modest probability that the host will grant access. Red means that access is highly unlikely. The purpose of the risk planning matrix is to illustrate the challenge facing posture planners seeking a posture that is robust across possible demands. For any given scenario, there may be only one or a few nations whose interests are sufficiently engaged that they grant access. Good posture planning has always depended on expert and realistic assessments of access likelihood. Distributed operations increase the importance and difficulty of this task because they substantially expand the number of operating locations and, in most cases, also increase the number of partner nations required.

Figure 5.1. Notional Posture Risk Matrix for Five Scenarios



Greater Use of Civilian Airfields

To achieve the large number of operating locations needed for distributed operations, the Air Force would likely need to gain access to a mix of military and civilian airfields. During an ongoing operation, a host nation's fighter base facilities will already be crowded with host nation aircraft and may be heavily targeted by the adversary. Military training and airlift bases may be available but are limited in number and capacity. Some of these partner nation airfields may actually be dual purpose, serving both military and civilian needs. Consequently, a significant number of the additional bases needed in our earlier example would, by necessity, be partly or wholly civilian airfields.

Using civilian airfields complicates military planning since existing infrastructure may not be sufficient, civilian operations (e.g., scheduled commercial airline flights) may limit military use during a crisis, and locals may be more sensitive to their use in combat operations. FARP operations may be able to take place without infrastructure changes. However, for the purely civilian airfields to be useful as Stay and Fight or Drop-in bases in wartime, many would require infrastructure improvements (e.g., additional ramp space, fuel storage, munitions storage). Ideally, war reserve materiel would also be pre-positioned in nearby warehouses during peacetime and USAF aircraft would have periodic access to the civilian airfields for training and exercises. Military improvements to civilian airfields during peacetime can be politically difficult. Local communities are often opposed because of safety and noise concerns, and current airfield users may see military uses as a threat to their access and use.[13] Improvements may be somewhat easier if the airfield is already a dual-use civilian-military facility, but many of the same issues arise between host nation military and civilian users. Since time lines for such improvements at host nation facilities can be quite long, they need to take place in advance of a contingency.

Combat Support

This section discusses some of the combat support demands that flow from the contested environment as well as a shift from concentrated to distributed operations.

More Support Resources

Distributed operations require more support resources than combat operations from a small number of major bases. One way of understanding this is by looking at the number of support personnel required per fighter as the number of operating locations increases. Figure 5.2 illustrates how adding up to three operating locations of various sizes could more than double the number of support personnel required per fighter.[14] The reason for this stems from a loss of economies of scale. Generating combat sorties requires specialized skills, such as fuels specialists and munitions specialists. If a fighter squadron needs to generate combat sorties from more locations, each location will require both fuels specialists and munitions specialists. Similarly, specialized maintenance equipment such as avionics testbeds, the F-35 ALIS, and low radar cross-section repair shelters will need to be procured in greater quantities to support distributed operations. This does not mean that every location will need the full suite of

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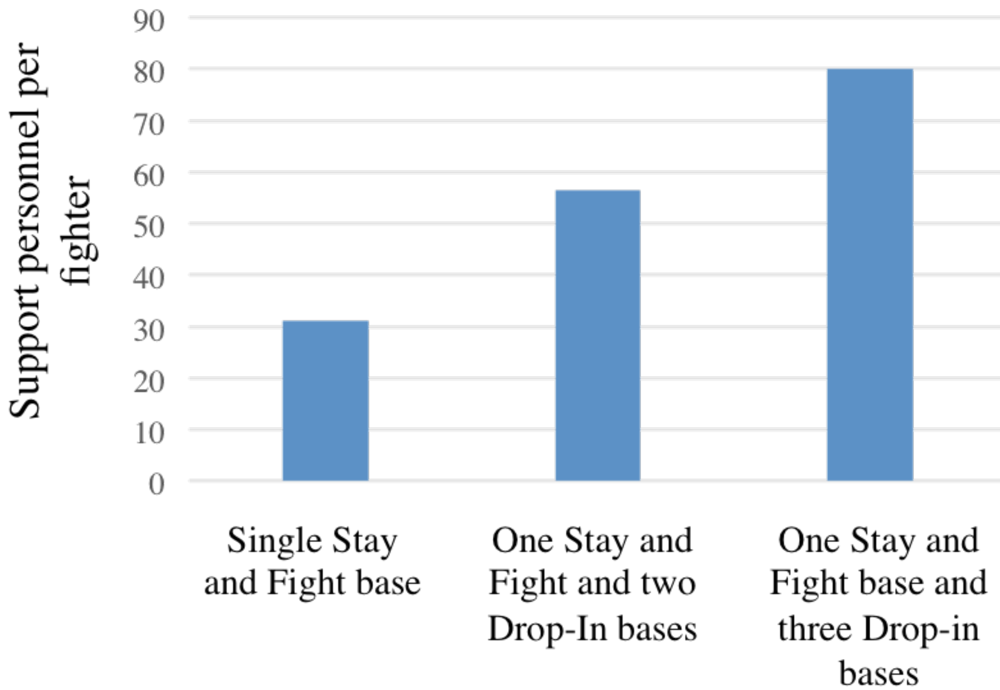
[13] The classic example of local safety concerns affecting base use is the multidecade effort by Japanese citizens on Okinawa to close MCAS Futenma. Stacie L. Pettyjohn and Alan J. Vick, "Okinawa Remains an Intractable Thorn for US and Japan," *RAND Blog*, May 25, 2012.

[14] This example counts personnel required to generate sorties and repair aircraft, base operating support personnel, and airlift throughput personnel. In the final case, two of the Drop-in bases are designed to only rearm and refuel fighters, while one Drop-in base is designed to rearm, refuel, and perform limited repairs. These examples do not include the demand created by erecting expeditionary air bases at any of these locations.

Figure 5.2. Support Personnel Requirements for Concentrated Versus Distributed Forces



SOURCE: Patrick Mills, James A. Leftwich, John G. Drew, et al., unpublished RAND research, 2017.

capabilities found at major bases today, but each operating location will need personnel involved in and equipment used for routine activities.[15] The unique maintenance requirements of fifth-generation fighters (e.g., climate-controlled shelters for some maintenance, signature detection equipment) further complicate combat support planning for distributed operations.

Support Forces and Systems Capable of Operating Under Attack

A contested environment changes the mission of combat support forces from one of operating at peak levels of efficiency at sanctuary bases to one of generating sorties from forward bases despite enemy efforts to stop them. In a contested environment, efficiencies are lost due to the defensive measures required to prepare for attack (e.g., on-base dispersal of aircraft, maintenance specialists wearing body armor and carrying weapons, munitions specialists assigned additional security-related duties) and due to enemy actions that disrupt work, rest, and eating schedules, damage vital equipment, and wound or kill personnel. To

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[15] We are grateful to Robert S. Tripp, Kristin F. Lynch, John G. Drew, Caroline Baxter, Daniel M. Romano, Rachel Costello, and James A. Leftwich for sharing their ongoing work on designing ACS networks for contested environments.

operate effectively under these conditions will require new capabilities and concepts discussed later in this chapter.

Greater Risk Acceptance

A contested environment requires support forces to accept greater risk than policy has allowed in recent operations.[16] For example, during peacetime, only aerospace engineers can certify that an aircraft is safe to fly after a repair. In a contested environment, however, an operating location may not have an engineer on site yet still may need to conduct a mission with or evacuate a repaired aircraft. In such a situation, sustainment personnel would need to work with the pilot to weigh the risk of keeping the aircraft at the base (where it might suffer further damage from missile attack) against the risk of the repair failing in flight. Making this a reality might involve creating "scenario-based" Air Force Instructions (AFIs) and alternative task orders (TOs) for austere locations.[17] All of this will require training so support specialists have experience employing these scenario-based procedures and feel empowered to make decisions when communications are disrupted.

Potential DOTMLPF-P Solutions

Table 5.1 summarizes our assessment of potential DOTMLPF-P solutions for sustaining the force in a contested environment.[18] In the text that follows we briefly discuss some of our key findings.

Doctrine

USAF combat support doctrine identifies its core processes as "Readying the Force," "Positioning the Force," "Employing the Force," and "Sustaining and Recovering the Force."[19] USAF doctrine assumes that "Positioning the Force" happens prior to or at the beginning of a conflict and revolves around wing-centric operations conducted from a relatively small number of main operating bases. It does not consider the contested environment case where the number of operating bases may be three to five times larger, where forces may relocate multiple times

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[16] For more detail on risk analysis and articulating mission impact of infrastructure resourcing, see Patrick Mills, Mane Muharrem, Kenneth Kuhn, Anu Narayanan, James D. Powers, Peter Buryk, Jeremy M. Eckhause, John G. Drew, and Kristin F. Lynch, *Articulating the Effects of Infrastructure Resourcing on Air Force Missions: Competing Approaches to Inform the Planning, Programming, Budgeting, and Execution System*, Santa Monica, Calif.: RAND Corporation, RR-1578-AF, 2017.

[17] Scenario-based AFIs or TOs would be analogous to the concept of developing "playbooks" to enable automatic delegation of authority for operations during periods of disrupted communications.

[18] As noted in previous chapters, our DOTMLPF-P analysis is preliminary, offering the Air Force a starting point for more detailed analysis and validation.

[19] See Annex 4-0, 2015.

Table 5.1. Overview of Potential DOTMLPF-P Changes for Sustaining Distributed Operations

	Stay and Fight	Drop-In	Fighter FARP
Doctrine	• Increased use of pre-positioned materiel combined with a more resilient supply chain • Increased use of host nation assets and support • Planning process recognizes that access will vary according to host nation interests • Contingency planning process for loss of access		
Organization	• Support units at the base level with sufficient personnel to contribute to FARP operations • Dynamic posture planning cell at the air component level		
Training	• Personnel trained to conduct logistics coordination with inconsistent communications • Air component conducts dynamic posture planning exercises • Base evacuation training for all units		
Materiel	• Pre-positioning of the hardest to move materiel in theater • Lighter materiel to facilitate movement		
Leadership/education	• Airmen educated to operate with limited resources owing to supply interruptions and limited maintenance staff • ACS personnel expect to operate under attack and with casualties • Airmen educated to think about air operations in a political and geographic context • Airmen sensitized to local cultures		
Personnel	• Foreign area experts to inform posture planning cell • Personnel at base level to coordinate logistics and supply • Maintenance personnel cross trained in multiple aircraft types or functions		
Facilities	• Dispersed parking • Permanent power and water • Permanent ILS and ATC facility • Permanent hangars • Pre-positioned fuel bladders, air field damage repair supplies • Munitions storage	• Dispersed parking • Expeditionary power and water • Expeditionary ILS and ATC facility • No hangars	• No dispersed parking • Power and water on mobility aircraft • Air Force Special Operations Command combat controllers may not have ATC facility • No hangars

during the conflict, and where the typical base hosts no more than a flying squadron. Ideally, USAF combat support doctrine would note where the contested environment requires different decision support systems, supply chains, approaches to pre-positioning, resources, and capabilities. For example, to rapidly open a large network of distributed operating locations, the USAF will need a network of pre-positioned support materiel in theater. But even the most farsighted planners will not foresee every need during the course of a large war. Thus, repositioning of support materiel will likely be required throughout the conflict. A more resilient communications and transportation network will be needed to support this repositioning. Both requirements would ideally be identified in combat support doctrine.

Organization

The ACS enterprise is vast and its current organization reflects sustained efforts to make it efficient in peacetime and effective in war. Our focus here is limited to organizational issues associated with distributed fighter operations in a contested environment. As we noted earlier, distributed operations will necessitate additional personnel, equipment, and materiel. Whether these should be organized into overmanned peacetime wings or some other alternative is the core organizational question for ACS in a contested environment. Chapter 6 explores two such alternatives for organizing support for distributed forces.

Decisions regarding ACS and posture may need to be made frequently during operations in a contested environment. A dynamic ACS and posture planning cell in the air component would be valuable to inform higher-level decisions as well as to plan for the movement of forward forces among operating locations.

Training

Airmen will need to be trained to conduct sustainment operations in a contested environment and under heavy attack as they are in Korea and were during the Cold War.[20] However, as noted above, airmen we spoke with during this study told us that they do not generally practice operating under high-intensity air and missile attack or evacuating and relocating bases.[21] The Air Force should conduct regular training with a wide variety of scenarios to prepare sustainment personnel to operate under adverse conditions. The USAF experience during the Cold War offers lessons that can be applied to a contested environment. On the other hand, distributed operations in the Western Pacific present some unique challenges. For example, Cold War training sought to capture the effects of a conventional and chemical attack on air base operations, but USAF bases in Europe were typically within 100 km of the next base.[22] These land lines of communication presented opportunities for mutual support not possible in an East Asian conflict. Small isolated units will have to continue to generate sorties despite casualties, damaged equipment, and communications disruptions.

Exercise Arctic Ace noted that personnel should be cross trained in multiple skills to provide options for the commander in a distributed fight.[23] Personnel should be cross trained in the most commonly required tasks. There is a limit to the range of tasks that cross-trained personnel can

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[20] Bowie, 2009.

[21] This point came up in multiple discussions with 1st Fighter Wing, 3rd Wing, and PACAF headquarters staff.

[22] Bowie, 2009.

[23] Michael Boyer, James Nolan, Anthony D’Agostino, Marc Aurilio, Kristopher Johnson, Christopher Gilbert, Nichole Nicholson, Taylor Vonasek, Cameron Schmitt, Glendon Schmitz, and Joshua Hightower, *PACAF Exercise Arctic ACE 2017: Executive After Action Report Key Findings*, 2017, p. 8.

be expected to perform successfully. Although it would be ideal if maintenance personnel could repair engines, avionics, and other systems across aircraft types, it is not feasible to expect nonspecialists to accomplish complex and difficult repair tasks. In the realm of the feasible, munitions loading and fueling may be areas where a small number of experts could supervise a larger group of cross-trained personnel.[24] The Air Force should continue experimenting with cross training personnel to develop a cross-training approach appropriate for aircraft operating in a contested environment.

There may be applicable lessons from Army support force training. The Army trains forward support companies with the specific mission-essential task of conducting sustainment support under attack.[25] The Army conducts training and exercises to simulate operating during degraded communications and other disruptions. For example, the 3rd Infantry Division Sustainment Brigade conducted an exercise that specifically focused on developing skills at the tactical level for a near-peer fight using lessons learned from the Russia-Ukraine conflict.[26] Mission command principles are also included in Army sustainment personnel training to develop agility and leadership skills in the force.[27] Noncommissioned officers are trained to improvise in unfamiliar situations and exposed to a range of sustainment areas to ensure that they are able to work outside of their specialty.[28]

Materiel

Distributed basing, because of the loss of economies of scale, greatly increases materiel and facility requirements. Peacetime pre-positioning of materiel in theater can reduce wartime lift requirements, decrease the vulnerability of war reserve materiel, and improve the resiliency of the entire basing network. As detailed above, improvements will be needed at many host nation facilities, particularly civilian airfields. The facility requirements vary depending on whether the base is a Stay and Fight, Drop-in, or Fighter FARP location.

Today materiel is somewhat concentrated overseas at a small number of major bases and logistics locations. Since most operations are conducted from such bases, this is not a problem.

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[24] The Arctic Ace exercise recommended normalizing fuels cross training across career fields, enabling a larger number of airmen to contribute to the refueling process. Boyer et al., 2017, p. 15.

[25] Headquarters, Department of the Army, *Sustainment Training Strategy and Guide*, Washington, D.C.: U.S. Department of Defense, TC 4-0.01, June 2017.

[26] John R. Abella and Alexander F. Yu, "Expeditionary Mission Command: Lessons Learned from a Sustainment Brigade's Warfighter Exercise," *Army Sustainment*, November–December 2017.

[27] For additional details on the Mission Command Training Program for sustainment leaders, see U.S. Army Combined Arms Support Command, *Sustainment Leader Development Implementation Plan*, Washington, D.C.: U.S. Department of Defense, December 2016.

[28] James S. Sims, "Preparing Our Sustainment Noncommissioned Officers," *Army Sustainment*, March–April 2017, p. 3.

Distributed operations in a contested environment require that materiel be more dispersed. This is to enable isolated airfields to continue to generate sorties when supply chains are disrupted by enemy action. Dispersed and additional materiel are also needed to account for enemy attacks on fuel and munitions storage.

Pre-positioning and dispersal of materiel varies by base type. We envision that the heaviest or bulk support materiel for Stay and Fight bases would be pre-positioned in theater, including things like airfield damage repair equipment, power generators, spare lighting, expeditionary fuel systems, and munitions.[29] Allocating munitions for distributed operations will be tricky given the variety of aircraft that might operate from a single location. Operating locations will either need a mix of munitions or be specialized for particular aircraft. Depending on water sources, materiel (or filtration equipment) may also need to be pre-positioned. Stay and Fight bases may also have redundant aerospace ground equipment.

Drop-in and Fighter FARP bases will require significantly less pre-positioning owing to their differing roles. Drop-in bases will need expeditionary fuel systems, munitions, and spares so that they can generate sorties. They also will need shelters (for personnel and possibly aircraft), food, water, medical supplies, personal protection equipment, and other basic equipment. Since they are expected to be temporary, this support materiel could be directly deployed to the Drop-in location from its pre-positioned in theater storage site or redeployed from a Stay and Fight base. Airlift, sealift, or ground transportation may need to supplement supplies if Drop-in bases operate for longer periods. FARPs would not require any pre-positioned materiel since these locations rely entirely on support materiel carried on the transport aircraft.[30]

Personnel

A larger number of distributed bases necessarily results in greater inefficiencies in manpower. Cross-trained personnel could help reduce the number of airmen needed for sustainment operations. Stay and Fight bases may have the most specialized maintenance personnel. Drop-in bases will require greater versatility with limited staffing levels. Maintenance personnel should be cross trained in multiple aircraft where possible, and support teams should be capable of rearming and refueling multiple aircraft types. Fighter FARPs require a small number of personnel to rearm and refuel aircraft. Repairs should not be necessary during the few hours of FARP operation, but if repairs are needed, they should be focused on making aircraft airworthy so that they can fly to a more advanced facility for mission-related maintenance.

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[29] This list is illustrative, not comprehensive. A Stay and Fight airfield would need spare equipment and materiel. Deciding how much spare equipment and materiel is sufficient depends on several factors, including the degree of the threat faced by that operating location and the capability of the larger sustainment system to responsively deliver additional equipment and materiel.

[30] Boyer et al., 2017, p. 19.

While cross-trained personnel will address some needs, there will also likely be gaps in capabilities, particularly as aircraft become more complex and cross training more difficult. We expect a greater use of sector aircraft battle damage repair (ABDR) teams to mitigate this risk. These sorts of on-demand teams, which were used extensively during the Vietnam War, have been successful historically.[31] A 1989 Air War College Research Report suggested that the leaner support structure of the 1990s, including manpower limitations and increasingly expensive and unique spare parts, would increase USAF reliance on ABDR teams.[32] Similar conditions are likely to make ABDR teams useful in a contested environment.[33]

In addition to aircraft maintenance and repair, more austere airfields will require teams that can rapidly assess and prepare an airfield and maintain critical C2 lines. Contingency response groups (CRGs), which have been used in disaster response conditions that require rapid establishment of airfield operations, have the capability to evaluate runways, establish control tower operations, maintain various types of aircraft, and manage airfield operations.[34] The CRG's flexible, agile capability could be particularly valuable if a large number of very small austere airfields are required. Combat controllers, airmen trained specifically to establish air traffic control and C2 in austere locations, will likely be particularly valuable and scarce personnel in a distributed environment.[35] While these types of specialized teams are inefficient, they provide the agility needed to support the sustainment needs of a distributed force.

Leadership and Education

Finally, although most airmen will not have a direct role in posture and ACS planning and execution, USAF professional military education may need to highlight the unique demands of distributed operations in a contested environment. Strategists, planners, and senior officers, in particular, may need to think differently about posture and ACS under these more dynamic conditions.

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[31] Darrell H. Holcomb, *Aircraft Battle Damage Repair for the 90s and Beyond*, Maxwell Air Force Base, Ala.: Air University Press, AU-ARI-93-4, March 1994.

[32] William R. Foster II, *Aircraft Battle Damage Repair (ABDR) 2000: Will ABDR Become the Logistics Center of Gravity by the Year 2000?* Maxwell Air Force Base, Ala.: Air University, AD-A217 374, May 1989.

[33] Improvements to the ABDR system, including the use of an electronic technical information system to streamline diagnostics, have improved speed and efficiency of ABDR teams. Ron Dierker, Charlie Botello, Scott MacBeth, and Jackie Grody, *Aircraft Battle Damage Assessment and Repair (ABDAR)*: Vol. I, *Executive Summary*, Wright-Patterson Air Force Base, Ohio: Air Force Research Laboratory, July 2000.

[34] Brian P. Mayer, *Contingency Response Groups: An Analysis of Maintenance Training*, Wright-Patterson Air Force Base, Ohio: Air University, June 2011.

[35] U.S. Air Force, "Combat Controllers," August 18, 2010.

Conclusion

A major theme emerging from this examination of the implications of distributed operations for sustainment is that USAF will need to balance the resilience and effectiveness of its ACS capabilities against efficiency. Many of the steps required to make ACS capabilities more effective and resilient in a contested environment—such as having buffer stocks of materiel to hedge against battle damage or taking time to cross train personnel instead of having personnel narrowly specialize—would be unnecessary if USAF were only going to operate in less contested environments.

In the next chapter, we consider the implications that distributed operations in a contested environment have for USAF force presentation.

6. Distributed Operations and Force Presentation

The preceding chapters discussed some capabilities the Air Force will need to develop for distributed operations in a contested environment as well as associated DOTMLPF-P changes. This chapter considers whether changes to force presentation, in particular, would help produce these capabilities. To do so, we ask two questions:

- Is the current Air Force approach to force presentation well suited for distributed operations in a contested environment?
- What would be the benefits and costs of changing the Air Force FPM for distributed operations in the contested environment?

We find that the current FPM has significant shortcomings for a contested environment.[1] In particular, wing-sized units at each operating location and the lack of significant planning capabilities outside of the JAOC would be significant vulnerabilities. Placing smaller units at each operating location and providing resources for significant planning capabilities at lower echelons would come with trade-offs but are likely essential in a contested environment. If the threats to communications or bases are less severe in other future contingencies, more modest changes to force presentation could be sufficient.

Current Fighter Force Presentation Model for Employment

As discussed in Chapter 1, force employment is a critical aspect of force presentation. Today, the Air Force employs forces through AETFs as well as subordinate task-organized units such as AEWs. Using this general framework, there are many ways the Air Force can tailor its force presentation for the employment function. From our analysis of capabilities needed for distributed operations in a contested environment, we identified five critical dimensions for force employment:

- size of unit at each operating location
- the lowest echelon with defense and support units
- the lowest echelon with significant planning capabilities
- the lowest echelon with multiple aircraft types
- the highest echelon that routinely trains together in peacetime.

[1] In evaluating the current and alternative FPMs, this chapter focuses on basing types with some infrastructure that would be used for at least days at a time (e.g., Stay and Fight bases) rather than highly austere and transient operating locations (e.g., FARPs). As discussed above, because of their high lift requirements, FARP-like operating locations would most likely be used as a supplementary rather than a primary type of operating location.

This section describes how the Air Force would likely employ fighter forces in a near-term major war. It is difficult to generate this baseline because there are differences between the way the Air Force has employed forces in recent CT and COIN operations and the way it would likely employ forces if suddenly called on to conduct air operations against a near-peer competitor.

In generating this baseline for our analysis, we draw from existing Air Force doctrine and policy as well as publicly available information on Air Force practice. Although it has been nearly 30 years since Operation Desert Storm, the Air Force FPM during that conflict is an important starting point. First, the FPM for major combat operations against a regional power is a closer analogy to how the Air Force would operate in a conflict with a near-peer competitor than the model employed during more recent COIN and CT operations. Second, Operation Desert Storm is the most recent U.S. major combat operation for which we have complete and publicly available information.[2] Table 6.1 summarizes the baseline FPM for fighter forces in major combat operations. The remainder of this section details how we generated this baseline.

Table 6.1. Baseline FPM for Fighter Forces in Major Combat Operations

Key Force Employment Variable	Current Model
Size of operational unit at each operating location	AEW
Echelon with base support and defense units	AEW
Echelon with significant planning capabilities	JFACC/COMAFFOR
Lowest echelon with multiple aircraft types	AEW
Highest echelon that routinely trains together in peacetime	AEW

NOTE: We treat the JFACC/COMAFFOR as an echelon for the purposes of this table. Some may argue that it is a level of command but not an echelon since it exists outside the squadron/group/wing/NAF hierarchy. Thanks to reviewer Michael Spirtas for this observation.

Size of Unit at Each Operating Location

Current Air Force policy envisions a single AEW at each operating location.[3] This policy is consistent with practice in Operation Desert Storm, when all but one base with fighter forces

[2] The Gulf War Air Power Survey that followed Operation Desert Storm provided a wealth of detailed information on air operations. The authors reviewed a large number of histories and lessons-learned documents for Operation Iraqi Freedom, a more recent example, but were unable to identify the analogous information. Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report*, Washington, D.C.: Government Printing Office, 1993. Current units do not always list their operating locations. See, for example, U.S. Air Forces Central Command, "332nd Air Expeditionary Wing Fact Sheet," March 1, 2018a.

[3] Air Force Instruction 10-401, 2006, p. 40.

contained a wing-level headquarters.[4] Similarly, in 2005, the Congressional Research Service reported that seven of the ten air bases supporting CT/COIN operations in Iraq (as part of OIF) had wing-sized units, while only three had groups.[5]

Lowest Echelon with Defense and Support Units

In Air Force policy, AEWs are typically the echelon with all of the capabilities needed to employ, sustain, and protect fighter forces at expeditionary bases.[6] These capabilities, collectively called expeditionary combat support (ECS), are the subset of ACS capabilities needed to operate from expeditionary sites. Mirroring the structure of permanent wings, the standard AEW organizes ECS capabilities into dependent groups and squadrons. Operations support squadrons, within the operations group, provide functions such as airfield management, weather, air traffic control, and intelligence analysis. Mission support groups include communications, base security, personnel, and civil engineering, as well as food and billeting. Maintenance groups are responsible for fuel and munitions to generate sorties as well as maintaining aircraft. Each wing also has a medical group.[7]

Lowest Echelon with Significant Planning Capabilities

As discussed in Chapter 4, in recent major combat operations, the JAOC under the direction of the JFACC has been the center of planning for air operations.[8] During ongoing operations, the JFACC develops and disseminates guidance on objectives and apportionment through the daily air operations directive (AOD). The JAOC translates the AOD's broad guidance into the ATO, which provides orders for specific tactical missions.[9] Tactical units then conduct the detailed mission planning needed to execute an assigned tactical task. Although AEWs have intelligence

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[4] The number of aircraft at these operating locations did, however, vary significantly. Gulf War Air Power Survey, 1993c, pp. 22–25.

[5] Linwood B. Carter, *Iraq: Summary of US Forces, CRS Report for Congress*, Washington, D.C.: Congressional Research Service, RL31763, November 28, 2005.

[6] Air Force Policy Directive 10-4, *Operations Planning: Air and Space Expeditionary Force (AEF)*, Washington, D.C.: Department of the Air Force, April 30, 2009, p. 8; Air Force Instruction 10-401, 2006, p. 40.

[7] Although an AEG may be subordinate to an AETF, these units are typically tenants of a base operated by a wing with the full range of defense and combat support units. Air Force Instruction 38-101, 2017, pp. 8, 26, 99; Air Force Instruction 10-401, 2006, pp. 40, 41–42. For an example of a current AEW, see U.S. Air Forces Central Command, "379th Air Expeditionary Wing Fact Sheet," June 6, 2017.

[8] The Tactical Air Control Center, the precursor to the JAOC, was the center of operational planning during Operation Desert Storm. Gulf War Air Power Survey, 1993b, pp. 2, 131–144. For centralization in later conflicts, see Benjamin S. Lambeth, *Air Power Against Terror: America's Conduct of Operation Enduring Freedom*, Santa Monica, Calif.: RAND Corporation, MG-166-1-CENTAF, 2006, pp. 324–330.

[9] Annex 3-0, *Operations and Planning*, Washington, D.C.: Headquarters U.S. Air Force, November 4, 2016, pp. 121–128.

officers and targeteers, they have not generally had the full range of information, systems, personnel, or authorities needed to develop targets, construct mission packages, or conduct other aspects of planning currently carried out by the JAOC.[10]

Lowest Echelons with Multiple Aircraft Types

For the baseline FPM for major combat operations, we identify AEWs as the lowest echelon with multiple aircraft types. During Operation Desert Storm, most fighter wings had only a single aircraft type. Still, 4 of the 11 wings with fighter aircraft had multiple aircraft types. The 7440th Composite Wing (provisional), based in Turkey, was particularly notable for having the full range of aircraft needed to carry out independent operations in northern Iraq.[11] There are some examples of lower echelons with multiple aircraft types today, such as the 451st Air Expeditionary Group at Kandahar Airfield, Afghanistan.[12] However, we were unable to identify fighter forces within such a group. Instead, fighter forces along with other aircraft types are typically found within the wing's dependent operations group.[13]

Highest Wartime Echelon That Routinely Trains Together in Peacetime

As discussed in Chapter 4, habitual peacetime relationships between Air Force commanders may help develop the trust needed to delegate authorities and empower subordinates to engage in disciplined initiative. Current Air Force policy does not emphasize habitual relationships. Instead, it envisions expeditionary wings, groups, and even squadrons being created from multiple parent organizations that would not necessarily have formalized interactions in peacetime.[14] This policy is intended to manage the demands of prolonged CT, COIN, and stability operations in the Middle East and Southwest Asia. For these operations, the USAF has not typically deployed entire wings or squadrons. Rather, AETFs have been built up using the UTC system, drawing from units across the USAF. As a result, units have not been aligned at home station with units they fight alongside.

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[10] Jeffrey Hukill, Larry Carter, Scott Johnson, Jennifer Lizzol, Edward Redman, and Panayotis Yannakogeorgos, *Air Force Command and Control: The Need for Increased Adaptability*, Maxwell Air Force Base, Ala.: Air Force Research Institute, Air Force Research Institute Papers 2012-5, July 2012b.

[11] Gulf War Air Power Survey, 1993c, pp. 22–25; Incirlik Air Base, "Incirlik Air Base History," webpage, May 17, 2013.

[12] The 451st is composed of nine squadrons: A-10s, MQ-9s, KC-135s, E-11s, HH-60s, Space Control, Maintenance, Mission Support, and Operations Support. See U.S. Air Forces Central Command, "451st Air Expeditionary Group," July 26, 2018b.

[13] Although the Objective Wing dependent group structure was developed in 1990, it was not the typical structure in that conflict. See Gulf War Air Power Survey, *Logistics and Support*: Vol. III, Washington, D.C.: U.S. Government Printing Office, 1993a, p. 49.

[14] Air Force Instruction 38-101, 2017, p. 104.

In spite of this practice in recent years, our baseline model assumes the Air Force would keep permanent fighter wings largely intact for major conflict operations against a peer competitor. In peacetime, USAF fighter squadrons are typically based together with their parent wing. Thus, the flying squadrons are able to train together and routinely work with wing headquarters staff, maintenance, and support groups. If the United States went to war tomorrow with a major power, these wings would likely, to the extent feasible, fight together, as was the plan for defending NATO against a Soviet/Warsaw Pact invasion. However, as noted above, a fighter wing might have additional aircraft types attached during wartime. For example, during Operation Desert Storm, the 363rd tactical fighter wing (provisional) had seven KC-135Rs attached.[15]

Implications of Current and Alternative Air Force Approaches to Force Employment

This section considers (1) whether the baseline USAF fighter FPM is well suited for use in a contested environment and (2) the trade-offs associated with using alternative approaches for distributed operations in a contested environment. There are many possible factors to consider in assessing the trade-offs of different FPMs.[16] We focused on how different force presentation choices may affect warfighting effectiveness and resource requirements.

Table 6.2 summarizes our assessment of the baseline model. As the USAF considers changes to its FPM, it is important to remember that there is no single best FPM for a contested environment; it will vary with the particulars of the conflict (e.g., geography, adversary capabilities, U.S. objectives), operating concept, and resources available. The sections that follow discuss the trade-offs planners should consider as they determine the right FPM for a specific contingency.

Size of Unit at Each Operating Location

As described in Chapter 2, wing-sized units at operating locations are more vulnerable to air and missile attacks than smaller operational units. However, the concentration of aircraft also creates economies of scale in support activities and defense against ground attacks. Distributing smaller operational units, such as squadrons, would reduce the fighter fleet's vulnerability to air and missile attacks but would also come at a cost (Table 6.3).

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[15] Gulf War Air Power Survey, 1993c, pp. 22–25.

[16] FPMs may, for example, affect personnel policies, recruitment, and retention. Future analysis should consider these other implications to help the Air Force refine distributed operations concepts and weighs alternative FPMs.

Table 6.2. Assessment of Current FPM in a Contested and Degraded Environment

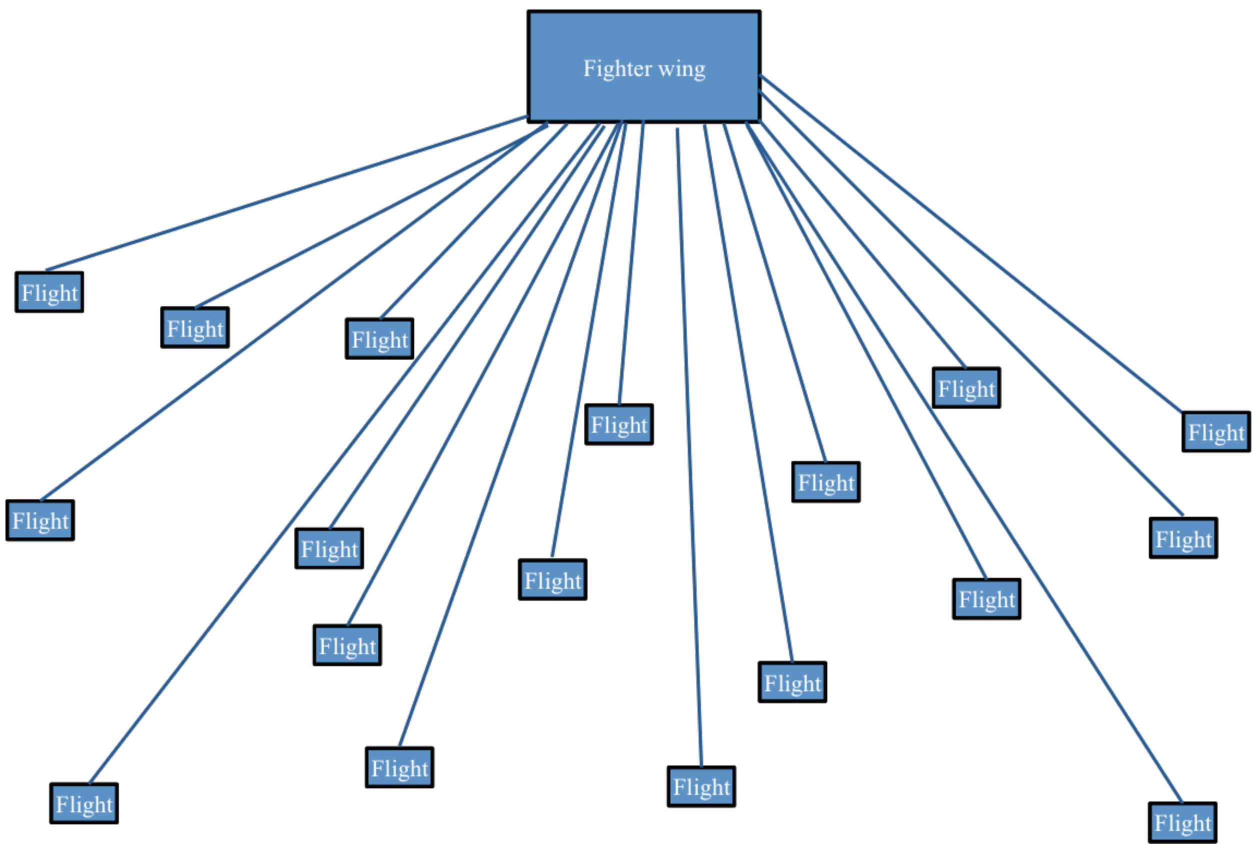
Characteristic of Force Employment Model	Current Model	Costs and Risks in a Contested Environment	Benefits in a Contested Environment
Size of operational unit at each operating location	AEW	• Concentration of aircraft makes fighter fleet vulnerable to air and missile attacks	• Less reliant on vulnerable communications systems to coordinate air operations • Concentration of aircraft reduces cost of support and defense against ground attacks • Experienced wing commanders available to oversee operations during communications disruptions
Lowest echelon with base defense and support units	AEW		
Lowest echelon with significant planning capabilities	COMAFFOR/ JFACC	• Insufficient capabilities for forward planning, direction, or coordination when communications with the JAOC are disrupted	• Efficient use of personnel and resources for planning • Facilitates senior leader control of consequential decisions
Lowest echelon with multiple aircraft types	AEW		• Higher maintenance efficiency • Experienced wing commanders are responsible for managing multiple platform types
Highest echelon that routinely trains together in peacetime	AEW	• Commanders at the wing and above may not have regular opportunities to build trust and shared understanding needed for mission command	• Flexibility to construct numbered expeditionary air forces

Table 6.3. Trade-Offs Associated with Reducing the Size of Units at Each Operating Location

	Implications of Smaller Operational Units at Each Operating Location
Benefits	• Greater distribution reduces fighter fleet vulnerability to air and missile attacks
Costs and risks	• More operating locations raises costs for support and base defense • Coordination of air operations between bases is more reliant on vulnerable communications systems • Depending on the size of distributed elements, wing commander's span of control could become too large, necessitating additional echelons • Authorities may devolve to less experienced commanders during severe communications disruptions

A successful distributed operations concept must address four challenges. First, as detailed in Chapter 5, smaller units spread over a larger area would require more manpower and materiel than a wing at a main operating base. Second, using aircraft from more operating locations increases dependence on vulnerable communications systems. Third, depending on how small the operational units become, the Air Force may need more echelons to keep each commander's span of control manageable. Figure 6.1 depicts a notional wing, which we call a swarming wing because of its large number of small flight-sized elements (four fighter aircraft per flight) distributed across 18 operating locations. Even if these flights included all flying, support, and defense forces, the wing commander would have a very large span of control. Although there is no standard span of control for military units, 18 would be far outside a wing's typical peacetime structure of four subordinate groups (operations, maintenance, mission support, medical) and, perhaps, a handful of independent squadrons. Similarly, wings engaged in operations in CENTCOM today have only four to seven groups.[17] Wings could create additional echelons to

Figure 6.1. Notional Swarming Wing



[17] U.S. Air Forces Central Command, "AFCENT Units," webpage, undated.

create manageable spans of control, but doing so would require more headquarters personnel and could create longer decision times.[18]

Finally, with smaller units at each operating location, less experienced officers would be responsible for more decisions about air operations and base defense. As discussed in Chapter 4, in a contested communications environment, some authorities may devolve as low as the ranking officer at each operating location. If the unit at each operating location is a squadron instead of a wing, these decisions would devolve to the squadron commander, who would likely have less experience integrating and managing trade-offs among air operations, base defense, maintenance, and base operations. That said, over time, empowering airmen earlier in their careers may help them develop into more effective senior leaders.

In 2018, the Air Force began a test at Mountain Home AFB to explore a new wing organization intended to facilitate squadrons operating more independently.[19] This test could provide opportunities for the Air Force to explore the resource requirements and trade-offs associated with smaller operating locations.

Lowest Echelon with Defense and Support Units

In recent operations, the wing has typically been the lowest echelon with defense and support units. Given additional personnel and equipment, the wing could theoretically reorganize these units to enable them to distribute to multiple operating locations. In the notional wing depicted in Figure 6.2, base defense, maintenance, mission support, and medical would be in the air base squadron. The fighter squadron would likely include intelligence personnel. By retaining direct control of both types of squadrons, the wing commander minimizes the number of echelons, thereby keeping the number of headquarters personnel low and potentially increasing decisionmaking efficiency.[20] Direct control also increases the wing commander's flexibility to reorganize these units.

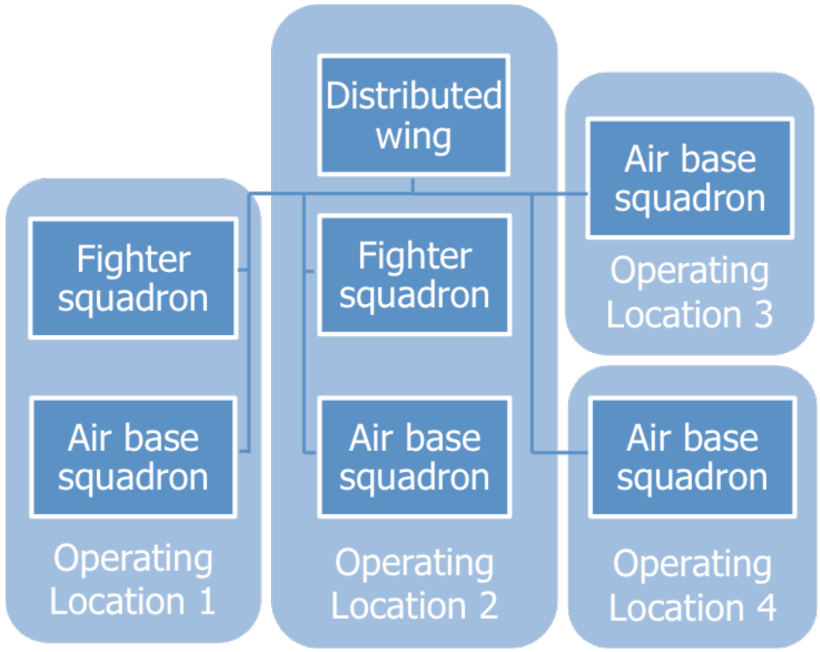
However, retaining defense and support forces at the wing level would also have drawbacks. First, depending on the number of wing operating locations, the span of control could become excessive for a single commander. Second, with both air base and fighter squadrons reporting to the wing commander, there would not be unity of command at each operating location. In a benign environment this arrangement would likely, nevertheless, result in unity of effort. Coordination between the units (informed by the wing commander's intent) would suffice in

[18] For a more detailed discussion of issues relating to span of control and number of echelons, see Alkire et al., 2018, pp. 17–20.

[19] 366th Fighter Wing Public Affairs, 2018.

[20] These considerations have contributed to the 366th Fighter Wing's decision to test a new wing structure that eliminates groups. 366th Fighter Wing Public Affairs, 2018.

Figure 6.2. Notional Distributed Wing



most cases. In the event of a disagreement, the wing commander could resolve any differences. However, during a prolonged communications disruption or an attack on the base, the squadron commanders could have different perspectives about how to respond, potentially leading to confusion or delayed reactions.[21] For example, severe damage to the air base or a serious ground threat might require "all hands on deck" to address. Flying and air base squadron commanders might agree to this on their own, but they also might be reluctant to take their personnel from other mission activities. A single commander with authority over all forces on base would presumably be in a better position to address such extreme demands.

Placing defense and support units at a lower echelon could produce unity of command at the operating location level. One way to do this would be to have base defense and support forces under the fighter squadron commander. However, this could be too much for a squadron commander to manage given his or her flying and warfighting responsibilities. As an alternative, Figure 6.3 depicts a notional wing that places all forces at a Stay and Fight base within an independent group.[22] Creating unity of command in this way, however, requires an additional

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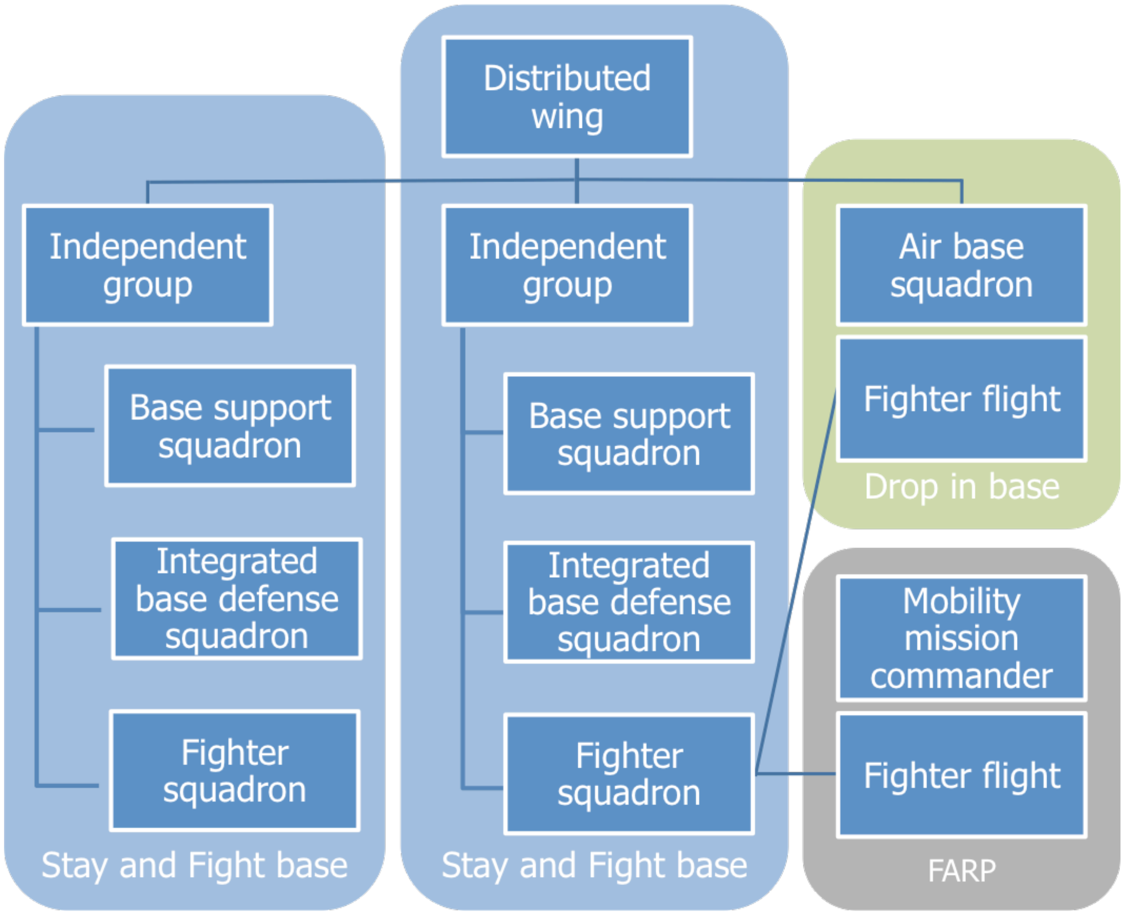
[21] There is not always unity of command at operating locations today. Air Force organizations are sometimes tenants of bases that are managed by an air base wing or another service. See, for example, Joint Base Langley-Eustis, "1st Fighter Wing," undated. On the difference between unity of command and unity of effort, see Joint Publication 1, 2013, p. V-1.

[22] Although it is not the standard approach today, current Air Force policy acknowledges the possibility of independent groups that perform a function similar to that of a wing. Air Force Instruction 38-101, 2017, p. 16.

Figure 6.3. Notional Distributed Wing with Independent Groups



echelon, which could also increase the total number of headquarters personnel within the wing as well as slow decision speeds. Additionally, because this structure dedicates resources to each group and operating location, it may lack the flexibility of a wing-centric structure. This might inhibit the wing commander from reallocating resources across operating locations in response to changing circumstances (Table 6.4).[23]

Lowest Echelon with Significant Planning Capabilities

In recent major combat operations, centralized planning at the JAOC has created a single point of vulnerability. Forward forces do not have all of the systems, personnel, authorities, or experience needed to plan, coordinate, and deconflict air operations. Therefore, in the event of an attack on the JAOC or its communications links with forward forces, air operations would largely continue

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[23] If the wing commander had sufficient capacity, he or she might mitigate this trade-off by retaining some support forces at the wing level to reallocate as needed.

Table 6.4. Trade-Offs Associated with Having Defense and Support Units at Lower Echelons

	Implications of Having Defense and Support Units at Lower Echelons
Benefits	• Unity of command at base level • Reduce wing commander's span of control (beneficial if number of operating locations is large)
Costs and risks	• If additional echelons are created, more headquarters personnel may be required and decisions could take longer • Less flexibility for the wing commander to reorganize units

based on the current ATO or prescripted playbooks. Forward forces could use their available capability to make some limited changes and defend their operating locations. But the longer the communications disruption, the more offensive air operations would be constrained.

Providing robust planning capabilities at lower echelons—including by providing additional expert personnel, systems, and authorities—would increase C2 resiliency. In the event of an attack on the JAOC, other locations would be able to continue planning and coordination. Because communications between forces in the forward area would likely be more reliable, operating locations would be more likely to have a consistent connection with the local planning node. Planning capabilities at lower echelons could be redundant capabilities, only used during periods of disruption. Alternatively, given the large number of sorties that would likely be needed in a conflict with a near-peer competitor, these planning capabilities could share the workload with the JAOC even during periods of good communications.[24] Active participation in planning by lower echelons throughout the conflict would also ensure a more seamless transition during periods of disruption.

The costs of having robust planning capabilities at lower echelons could be substantial. The number of personnel would increase and lower echelons would need the hardware and software to carry out key AOC functions.[25] The Air Force would also need to develop new doctrine and TTPs for less centralized planning.

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[24] During the first three weeks of OIF's air campaign, the combined air operations center (CAOC) at Prince Sultan AB faced an onerous workload organizing over 2,000 sorties a day. For example, the master air attack plan team was often working 15- to 18-hour shifts or longer to keep up with the rapidly changing environment. This was despite the CAOC staff having tripled from 672 to nearly 2,000 assigned personnel by the peak of the air war. Benjamin S. Lambeth, *The Unseen War: Allied Air Power and the Takedown of Saddam Hussein*, Annapolis, Md.: Naval Institute Press, 2013, pp. 207–215.

[25] For example, recent RAND research found that the headquarters and JAOC personnel requirements are higher for major combat operations led by two JTFs rather than a single geographic combatant commander. Alkire et al., 2018, pp. 32–42.

Other trade-offs could arise depending on how these planning capabilities are used. For example, if these capabilities were standing by only for disruptions, more conditional delegated authorities need to be developed and understood. If detailed planning were consistently pushed to lower levels, less experienced officers may be making consequential decisions, potentially increasing the risk of mistakes (Table 6.5).

Table 6.5. Trade-Offs Associated with Creating Significant Planning Capability at Lower Echelons

	Implications of Adding Significant Planning Capability at Lower Echelons
Benefits	• Multiple operational planning nodes reduces the effects of an attack on the AOC or long-distance communications • Potentially greater capacity to plan for the large number of sorties required for a conflict against a near-peer competitor • Potentially more reliable communications between planning echelon and subordinate forces in the forward area
Costs and risks	• Manpower and resource intensive • Additional doctrine, TTP, and training needed

Lowest Echelon with Multiple Aircraft Types

In recent stability operations, expeditionary wings were typically the lowest echelon to have multiple aircraft types. If the wing's squadrons distribute in future conflicts, individual operating locations would have only a single aircraft type.[26] This has two potential drawbacks in a contested environment. First, multiple bases would need to be involved in constructing mission packages, the group of aircraft with the capabilities required for a given mission. For example, a strike mission flown by 12 F-35s might be supported by four F-22s, 1 KC-135, an E-3 airborne warning and control system, and perhaps some other battle management/command, control, communications, intelligence, surveillance, and reconnaissance platforms. In the contested environment, limitations on communications mean that constructing this type of mission package across operating locations will likely be more difficult than it is today.[27] Second, consolidating each aircraft type, such as F-22s, at a small number of operating locations increases the risk of a catastrophic attack on that fleet.

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[26] Squadrons would likely disperse by aircraft type to separate locations based on runway length requirements, vulnerability of aircraft to attack, range of aircraft, and mission. In theory, the wing could distribute aircraft types to different operating locations but still retain direct authority. This would raise issues around unity of command similar to those described in the previous section.

[27] For a discussion of communications challenges hindering coordination of mission packages across multiple operating locations during Operation Desert Storm, see J. Scott Norwood, *Thunderbolts and Eggshells: Composite Air Operations During Desert Storm and Implications for USAF Doctrine and Force Structure*, Maxwell Air Force Base, Ala.: Air University, 1994.

There would, however, be drawbacks to placing multiple aircraft types at lower echelons and distributed operating locations. Having more than one type of aircraft at a small operating location likely would increase the number of maintenance personnel since they usually specialize in particular aircraft. However, clusters of bases could potentially increase maintenance and repair efficiency by having each base specialize in more extensive maintenance on a particular aircraft type.

Placing more than one aircraft type at a lower echelon also places greater demand on leader development. Commanders at lower echelons would need more experience with multiple platforms. If permanent organizations remain organized around a single platform in peacetime, it would be difficult for commanders to gain this experience (Table 6.6).[28]

Table 6.6. Trade-Offs Associated with Assigning Multiple Aircraft Types at Lower Echelons

	Implications of Multiple Aircraft Types at Lower Echelons
Benefits	• Less reliant on vulnerable communications to construct mission packages • Greater distribution reduces fighter fleet vulnerability to air, missile, or ground attack
Costs and risks	• Higher support burden • Commanders at lower echelons need experience with multiple platforms

Highest Echelon That Routinely Trains Together in Peacetime

For major combat operations, the baseline model would likely have wings as the highest echelon with permanent relationships in peacetime. Aligning units in peacetime that are likely to fight together in wartime and providing opportunities for frequent interactions, such as command post exercises, could make distributed control in wartime more effective. From this perspective, it could be beneficial to preserve the integrity of the wing or even to more closely align wings with the numbered Air Forces they would fight with in wartime. However, preserving these relationships could significantly limit Air Force flexibility to build tailored force packages and composite units for a contingency.

If the Air Force does not believe that peacetime alignment produces significant wartime C2 benefits, it may prioritize flexibility instead. Rather than trying to keep permanent wings largely intact, the Air Force may actually focus on the EFS as the highest echelon with a

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[28] Although Air Force wings have typically been organized around a single aircraft type, the Air Force experimented with a peacetime composite wing structure during the 1990s. As part of this experiment, the 366th Wing at Mountain Home AFB included fighter, bomber, and tanker squadrons. James W. Canan, "McPeak's Plan," *Air Force Magazine*, February 1991.

permanent peacetime relationship so that it can more easily create composite wings for distributed operations (Table 6.7).

Table 6.7. Trade-Offs Associated with Changing the Echelon That Routinely Trains Together in Peacetime

	Implications of Aligning Wings with NAFs in Peacetime	Implications of Squadrons Being the Highest Echelon That Routinely Trains Together in Peacetime
Benefits	• Potential to develop higher levels of trust and shared understanding between commanders to facilitate mission command	• Higher echelons do not have opportunities to build trust and shared understanding until a conflict
Costs and risks	• Limits flexibility to construct composite organizations and tailor force packages for the CCDR	• Greater flexibility to construct composite organizations and tailor force packages for the CCDR

Force Presentation Priorities and the Operating Environment

The costs and benefits of changing the current FPM will vary depending on the operating environment (Table 6.8). Our focus has been on the particularly difficult challenge of a conflict with a near-peer competitor that can threaten to disrupt communications systems and conduct air and missile attacks against bases. Two characteristics of the current approach to force

Table 6.8. Priorities for Force Presentation by Operating Environment

		Communications Threat Level	
		Low	**High**
Air and Missile Threat to Bases	Low	FPM emphasizes efficiency • Large units at each operating location • Centralized planning	FPM emphasizes C2 resiliency • Planning capabilities at lower echelons to promote resiliency • Retain large units at each operating location for efficiency
	High	FPM emphasizes survivability • Small units at each operating location • Retain centralized planning for efficiency	FPM sacrifices efficiency for survivability and C2 resiliency • Small units at each operating location • Planning capabilities at lower echelons to promote resiliency • Support and defense units at lower echelons to ensure unity of command at the operating location level

employment in a contested environment, wing-sized operational units and concentrated planning at the JFACC level, are significant vulnerabilities in the contested environment. Creating smaller operational units and more planning capabilities at lower echelons would be costly but would also have substantial benefits for survivability and C2 resilience. Given the likely need to make rapid decisions under attack in the contested environment, the Air Force will likely also want to place support and base defense units at lower echelons to ensure that there is unity of command at the operating location level. The balance of costs and benefits associated with preserving habitual peacetime relationships is less clear.

In other operating environments, however, the trade-offs and priorities for force presentation are likely to be different. For example, in the low air, missile, and communications threat environment the United States faces in COIN and CT operations today, the Air Force has little to gain from costly changes to the way it employs forces. In a contingency with higher threats to communications, paying the cost of placing more significant planning capabilities at lower echelons could have significant benefits for C2 resiliency. As long as air and missile threats are low, however, the Air Force could continue to benefit from the efficiencies of large operating locations and homogenous units. In a contingency with air and missile threats to bases, reducing the size of the unit at each operating location could have significant benefits for survivability. However, as long as communications threats remain low, centralized planning may remain viable. On net, the Air Force will need to consider the particular threat environment and resources available as it decides how to present forces for a given contingency.

While the Air Force can adapt its FPM for each contingency, it has to have a clear vision of the most demanding environment for which it will prepare in order to guide force presentation, organize, train, and equip decisions. For example, to the extent possible, the Air Force should try to train as it will fight and build peacetime structures that allow smooth transitions between peacetime and wartime. The 2018 NDS pointed to great power competition as the nation's priority, which suggests that the Air Force should prioritize organizing, training, and equipping to present forces for an environment with high air, missile, and communications threats.

7. Conclusion

The USAF is developing concepts to enhance force survivability and effectiveness in major conflict against other great powers. As these concepts take shape, the Air Force is beginning to think about its broader implications, including for force presentation.

This report contributes to these discussions in three ways. First, it synthesizes and expands on past and emerging concepts in order to identify capabilities needed to conduct distributed operations in a contested environment. Second, it assesses the utility of the current USAF force employment model under such conditions. Finally, it identifies the implications of changing the USAF FPM to better meet the demands of a high-end fight.

In this final chapter we present the main findings of this research, make recommendations for USAF leaders, and offer some final thoughts regarding force presentation and distributed operations.

Findings

The U.S. Air Force Force Presentation Model and Operating Concepts Are Based on Assumptions That Are Incompatible with a Contested Environment

Two key assumptions about the operating environment that have prevailed during COIN, CT, and stability operations in recent decades—that air bases are sanctuaries and communications reliable—will not hold in a conflict with another great power. USAF forward bases face an increasingly lethal and complex array of threats, including long-range missiles and aircraft, standoff attack by ground forces, and penetrating attacks by ground forces. Communications links will be threatened by attacks on SATCOM, fiber, and other systems. In this setting, wing-sized units at main operating bases and centralized planning at the JAOC mean that the enemy could disrupt air operations with attacks on a few high-payoff targets.

The Contested Environment Will Force the U.S. Air Force to Trade Efficiency for Survivability

In recent decades, the Air Force has centralized its basing, combat support, and C2, in part, to gain efficiency.[1] Regardless of the concept it uses, the Air Force will have to trade efficiency for survivability in a high-end fight. If the Air Force pursues distributed operations, it will need more resources (e.g., combat support personnel, base defense personnel, headquarters staff,

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[1] For example, in 2015 the Air Force established the Air Force Installation and Mission Support Center in order to make the best use of limited resources for installations and mission support.

communications equipment) to support a greater number of operating locations and enable distributed control. Alternatives to distributed operations would also come with higher costs. Using airpower from more distant bases, for example, could require new acquisition programs, longer flight times, and lower sortie rates.

Some concepts, FPMs, and beddowns may be less resource intensive than others. But these choices are not likely to overcome the fundamental inefficiency and significant resource demands of air operations against a near-peer adversary. Prioritizing survivability will also require a significant cultural change for the Air Force, which has been largely focused on efficiency to sustain COIN and CT operations.

Developing Viable Concepts for Distributed Operations Will Require Close Collaboration Between Operations and Agile Combat Support Communities

During the course of our discussions with USAF personnel, we heard frustrations from both the operations and support communities. Operators are driving many of the concepts for distributed operations and, in some cases, are frustrated with what some perceive as resistance from the ACS communities. At the same time, some in the ACS community are concerned that the distributed operations concepts are being developed without a realistic understanding of the resource demands they create or support constraints.

If the Air Force continues to pursue distributed operations, it will need these communities to work closely together to continue to refine these concepts. The operational community's perspective is shaped by nearly 20 years of operations during which air bases could generally be treated as sanctuaries; the ACS community's perspective on these issues is shaped by years of being pushed to create greater resource efficiencies. Operational planners will need to devote more time to building plans that can prevail despite adversary attacks on air bases and logistics networks. The ACS community will need to develop approaches tailored to sustaining operations at contested bases. In other words, operators will spend more time thinking about logistical constraints while sustainment professionals will spend more time thinking about warfighting.

The Force Presentation Model for Distributed Operations in a Contested Environment Must Enable Lower Echelons to Plan and Execute Offensive and Defensive Operations

Since wing-sized operating locations are vulnerable, each operating location is likely to have smaller units. This means that echelons below the wing will likely need support and defense capabilities. Commanders at lower echelons will also need to be able to make more decisions independently. The relatively lower operational tempo and smaller scale of CT and COIN operations have enabled Air Force leaders to retain planning capabilities and decisionmaking authorities at high levels. In a contested communications environment, detailed control by senior leaders may not be possible or advisable. Airmen at lower echelons, possibly as low as the operating location level, will, at times, have to make decisions about air base defense, support activities, and air operations. They may have to make such decisions quickly if air bases come under attack and with little guidance if communications are disrupted. To do so, they will need additional leadership development, training, authorities, and planning capabilities.

Gaining and Maintaining Political Access Is a Precondition for Distributed Operations

Distributed operations call for a larger number of operating locations than in the past. As discussed in Chapter 5, these locations may need to be spread across multiple countries. Moreover, to achieve a larger number of operating locations, the United States may need to gain access to dual-use or civilian airfields. During peacetime, the Air Force can take steps such as building relationships with partners and supporting efforts to build facilities and pre-position materiel. However, past research has shown that partner decisions to allow access will likely be contingent on the scenario and the broader political relationship between the United States and each host country. The Air Force can prepare for this uncertainty by developing contingency plans and having processes for dynamic changes in posture during wartime. However, the number of facilities available for distributed operations may be limited by uncertain political access at the outset of and during a contingency operation.

More Analysis Is Needed on Command and Control, Support, and Other Implications of Distributed Operations for Nonfighter Forces

This report focused on distributed fighter operations. Operating fighter forces in this way would create many implications for Air Force forces such as intelligence, reconnaissance, EW, mobility, and tanker aircraft that were not analyzed in detail here. If these forces operate in a distributed way as well, there would be additional consequences for C2, support, and protection. The Air Force will need to consider these additional implications as it develops concepts for and assesses the viability of distributed operations.

Recommendations

These findings suggest seven recommendations for USAF leaders and planners. In some cases, the Air Force is already pursuing related initiatives, so our recommendations reinforce the importance of these activities or point to a need for greater emphasis.

Determine Resource and Access Requirements for Distributed Operations. As described above, distributed operations are resource intensive, both before and during a conflict. The Air Force has voiced concerns about the shortage of resources to carry out current activities, so it is unlikely to be able to make the investments needed for distributed operations without a change in resource levels or commitments.[2] The 2018 NDS shifted the DoD's emphasis to great power

[2] Goldfein, 2017b; Wilson, 2017.

competition, and some reallocation of resources is under way. A first step in determining whether these concepts are viable is to identify both the access and resource requirements for distributed operations. Ongoing initiatives on distributed operations (e.g., HAF's Adaptive Basing and PACAF's Agile Combat Employment) are beginning to grapple with some of these questions, including through exercises.

Consider Creating Integrated Base Defense Units. A conflict with a great power will lead to a higher air, missile, and ground threat to bases. A capable adversary may coordinate multiple types of attacks or may choose to launch only certain types of attacks at some bases. Different attacks can require different mitigation strategies, which require a commander to weigh the relative risk of each and set priorities for defensive responses. An integrated approach to base defense would bring together all of the threat and mitigation options so that the commander can make an informed decision about how best to protect the base as a whole. The Air Force should therefore develop a concept for and explore the benefits of creating integrated base defense units.

Simulate Heavy Air, Missile, and Ground Attacks in Home Station Training and Exercises. Simulating air base attacks is important for practicing survivability measures and conducting tasks under attack. From a C2 perspective, commanders can also consider how to set priorities between air and ground operations in these settings and make decisions under more stressful conditions. This type of training should also include simulated casualties so units can consider how they would carry out operations with fewer personnel and, potentially, specialists in certain functions. Discussions with Air Force personnel suggest that, other than in South Korea, this type of training has not been a priority in recent decades as the joint force has been focused on COIN and CT operations.

Hold Regular Command Post Exercises That Include Communication Disruptions. Command post exercises that include leaders at multiple echelons could give leaders practical experience with transitioning authorities, writing mission orders, acting on commander's intent from higher echelons, and developing situational awareness. Including commanders from multiple echelons that will likely fight together could have the additional benefit of helping leaders build trust in subordinates so that they will feel more comfortable delegating authorities. At the same time, by providing opportunities for risk taking in a controlled environment, these opportunities may help subordinates gain experience in exercising initiative based on higher echelon's intent. The exercises would therefore complement the ongoing Air Force initiative to empower commanders at lower echelons in peacetime activities.

Cross Train Airmen to Reduce the Personnel Demands of Distributed Operations. Distributed operations require more personnel in maintenance, security force, headquarters staff, and other positions. Moreover, operations in a contested environment may also lead to much heavier casualty rates than in recent operations. Cross training airmen so they can carry out functions beyond their specialty could help with both challenges. This could, for example, include training maintenance personnel to perform more than one maintenance function on a single aircraft type or the same functions across multiple aircraft types.[3] This could also include training all airmen to perform another set of basic tasks (e.g., base defense, maintenance, or engineering tasks) under the supervision of qualified personnel. This would place additional burdens on support personnel and highlights the need for increasing manning in these areas. The Air Force may gain broader insights about the trade-offs involved in cross training from an ongoing pilot program to cross train maintenance personnel.

Consider the Possible Role of the Group in Distributed Operations Before Eliminating the Peacetime Group Echelon. ACC is experimenting with a new peacetime structure for the wing that eliminates the group. This reorganization is intended, in part, to prepare squadrons for operating more independently in a conflict with a near-peer competitor. However, depending on the specific distributed operations concept that the Air Force decides to pursue, there may be a valuable wartime role for the group. For example, if distributed operating locations have a squadron of aircraft, a group commander may be well suited to provide unity of command over base defense, combat support, and air operations. Since distributed operations concepts are still emerging, our analysis does not offer a definitive answer regarding the future of the group. However, our analysis does suggest that the Air Force should consider the possibility of a changing wartime role of the group as it evaluates its peacetime structure. If the group does have an important role for wartime operations, the Air Force may wish to retain the group in peacetime as well as to develop leaders and minimize the friction involved in changing organizational structures for wartime.

Use Exercises and Additional Analysis to Explore Force Presentation Implications of Distributed Operations. Chapter 6 identified a number of trade-offs associated with changes to the Air Force's FPM. PACAF is already exercising distributed operations concepts and considering force presentation implications, which may inform Air Force efforts to determine the severity of some of these trade-offs. The Air Force should look for additional opportunities to explore force presentation alternatives in its exercises. The research we presented suggests several questions that can guide future analysis.

First, how large should units at each operating location be? The answer to this question is likely to depend in large part on assessments of the air and missile threat in each contingency and could vary somewhat across theaters.

Second, is unity of command needed at each operating location? Unity of command is a principle of joint operations. However, it is not clear where unity of command should reside. Exercises may be needed to determine the importance of having a single commander in charge of all forces at a single operating location. The answer to this question could have important implications for wartime and peacetime structure of the Air Force.

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[3] It is our understanding that the USAF is conducting a small-scale test of cross training maintenance personnel. In addition to this pilot effort, some parts of the Air Force are already cross trained, such as CRG personnel trained to refuel multiple types of aircraft.

Third, how realistic is it for echelons below the wing to support multiple aircraft types? Having multiple aircraft types at a smaller operating location would require additional resources and support personnel but would greatly aid mission planning and execution when communications are disrupted.

Fourth, what planning capabilities does each echelon need? The lowest echelon that needs significant planning capabilities will likely depend in large part on the threat to communications and the geography of each potential contingency.

Finally, how important are habitual relationships to distributed control? The Army and Marine Corps emphasize the importance of trust and shared understanding to enabling mission command. This could come through habitual relationships formed at the home station or through regular exercises. It is not clear whether and how these concepts apply to USAF organizations and operations. Creating more aligned organizations might be helpful for distributed control but could reduce Air Force flexibility and make it difficult to tailor its organizations to CCDR needs. Exercises that include different relationships between commanders at various echelons could help determine how much the Air Force should prioritize habitual relationships.

Final Thoughts

There is unlikely to be a single FPM that is ideal for air operations in all contexts. The wing-centric model worked well in Operation Desert Storm, where the USAF needed to deploy and base a large force for major combat operations, but proved a poor fit for the enduring demands that shortly followed in Operations Northern and Southern Watch. To meet the rotational needs of these operations, the wing had to be supplemented with the AEF/UTC model. This model evolved as prolonged peace operations morphed into the extended demands of Operations Enduring and Iraqi Freedom. In turn, the AEF model does not address the specific requirements of distributed operations in a contested environment. In every case, trade-offs had to be made among competing objectives.

As the USAF considers changes to its FPM it should be careful not to overlearn the lessons associated with two decades of operations in the Middle East and Southwest Asia, for example, by refining the AEF to better support prolonged stability operations. The nation's priorities, as reflected in the NDS of 2018, are rapidly shifting away from stability operations toward deterring and defeating major powers in contested and degraded environments.

This analysis sought to demonstrate the depth and breadth of changes necessary to meet the exceptional demands of distributed operations in a contested environment. USAF leaders, and the institution at large, need to take a contested environment seriously for the needed innovation and culture change to be nurtured and sustained. Although the nation and USAF will face other challenges, including enduring threats from terrorism and regional instability, contested environments should be first among equals when it comes to preparing the force. Preparing the Air Force for distributed operations in a contested environment will be resource intensive, regardless of its FPM, which means that the Air Force and the nation will need to deliberately prioritize them over other demands.

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The 2018 National Defense Strategy instructed the services to prioritize capabilities for conflict with another great power. This gave new urgency to ongoing initiatives within the U.S. Air Force (USAF) to prepare for growing air and missile threats to bases and a contested communications environment. There are a wide range of possible counters to the particular problem of air base vulnerability, including greater reliance on long-range systems, active defenses, hardening of bases, and on-base dispersal of assets. The authors of this report focus on a particular set of emerging concepts for distributed operations that call for using a larger number of air bases to complicate enemy targeting and employing a more decentralized command and control approach. The USAF asked RAND to consider whether it needs to change its force presentation model (FPM), the way it organizes to employ airpower as part of a joint operation, to implement these concepts.

Since the USAF has not developed a single, detailed concept for distributed operations, in this report the authors synthesize and extend the logic of emerging concepts. They then identify an initial list of capabilities the USAF may need in order to protect, command and control, and sustain fighter forces at a larger number of operating locations. Finally, the authors assess whether the current USAF FPM for fighter forces provides these capabilities and identify the trade-offs associated with force presentation changes.

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ISBN-10 1-9774-0232-1
ISBN-13 978-1-9774-0232-5

RR-2959-AF