Command and Control of Joint Air Operations in the Pacific

Methods for Comparing and Contrasting Alternative Concepts

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Preface

The anti-access and area-denial capabilities of near-peer competitors and the vast geographic expanse of the Pacific pose potential challenges for command and control (C2) of joint air operations in the region. Alternative concepts for operational-level C2 may help overcome these challenges.[1] For instance, some alternative concepts reduce the geographic challenges by defining distinct joint operational areas and tailoring the roles, rules, responsibilities, and authorities for C2 within each. However, a command-and-control concept optimized for one type of operation, such as humanitarian assistance and disaster relief, may not be appropriate for another type of operation, such as a major war with a near-peer competitor. This report describes methods for comparing and contrasting alternative concepts for C2 of joint air operations in the Pacific. It then applies these methods to a selection of alternative C2 concepts in a series of Pacific scenarios.

This project, titled "The Future of Command and Control of Joint Air Operations in the Pacific," was sponsored by Brig Gen Dirk Smith, Director of Air and Cyberspace Operations, Headquarters Pacific Air Force.[2] It was cosponsored by Mark (Tap) Tapper, Defense Intelligence Senior Deader, Headquarters, Air Force, Directorate of Intelligence. The research was conducted between October 2015 and August 2016 and conducted within the Force Modernization and Employment Program of RAND Project AIR FORCE as part of a fiscal year 2016 core-funded study. The report should be of interest to personnel in the operations and plans division of Pacific Air Force and other major commands, personnel in the Air and Space Operations Centers, the military intelligence community, and personnel involved in operational-level control of joint military operations.

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[1] A *C2 concept* can roughly be defined as an organizational structure, along with the associated roles, rules, responsibilities, and authorities.

[2] An additional report from this effort provides a "how-to" guide for conducting the tabletop exercise methodology that is recommended in this report. See Brien Alkire, Sherrill Lingel, and Lawrence M. Hanser, *A Wargame Method for Assessing Risk and Resilience of Military Command-and-Control Organizations*, Santa Monica, Calif.: RAND Corporation, forthcoming.

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Background and Motivation

The vast geography of the Pacific poses potential challenges to command and control (C2) of air operations.[1] For instance, C2 elements may have to communicate with air forces over long distances; forces may have to conduct operations over large areas and operate from widely separated bases. We define a *C2 concept* as an organizational structure for operational-level C2 and the associated roles, rules, responsibilities, and authorities. Some C2 concepts may help mitigate these challenges. For example, some C2 concepts seek to divide the geographic region over which operations are conducted into distinct joint operational areas and define distinct roles, rules, responsibilities, and authorities for each. The anti-access and area-denial capabilities and strategies of competitors in the Pacific also pose potential challenges for C2. For instance, such competitors may develop capabilities to degrade, deny, or disrupt the content and flow of information needed for effective C2. Some C2 concepts seek to mitigate this challenge by locating C2 elements and infrastructure closer to their forces, thereby reducing dependence on long-haul communications that may be at risk. However, locating C2 elements and infrastructure closer to their forces may put them within range of an adversary's missile capability.

Many alternative C2 concepts have been used or proposed for joint operations. In the 2003 invasion of Iraq, the geographic combatant commander, GEN Tommy Franks, directly led the Phase II and Phase III operations as the joint forces commander (JFC).[2] His component commands, including the joint forces air component commander (JFACC), were the force providers for the operations. In contrast, the commander of U.S. Pacific Command (USPACOM) stood up two separate joint task forces (JTFs) for Operation Tomodachi following the tsunami and subsequent nuclear crisis in Japan in March 2011: JTF-505 was tasked to evacuate those U.S. citizens wishing to depart Japan in the wake of the crisis, and JTF-519 was tasked to safeguard the welfare of U.S. citizens in Japan and support the ongoing humanitarian assistance and disaster relief (HA/DR) operations with Japanese Self Defense Force counterparts.[3]

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[1] In Chapter 1, we define *C2* as "the means by which a JFC [joint forces commander] synchronizes and/or integrates joint force activities" (Joint Publication [JP] 1, *Doctrine for the Armed Forces of the United States*, Washington, D.C.: Joint Staff, March 25, 2013, pp. xxii–xxiii).

[2] The phase numbers refer to military operations as defined in Section E of JP 3-0, *Joint Operations*, Washington, D.C.: Joint Staff, August 11, 2011, p. V-6. See Chapter 2.

[3] Rockie K. Wilson, "Operation TOMODACHI: A Model of American Disaster Relief Efforts and the Collective Use of Military Forces Abroad," Cambridge, Mass.: Harvard University, John F. Kennedy School of Government, January 2012, p. 6.

Past research has been conducted on the information needs for C2 and the associated threats.[4] Much of this research has been conducted using modeling and simulation (M&S) techniques and produced quantitative results. Research has also been conducted on C2 organizational structures using organizational theory and management science techniques, but much of that research has been broad and does not focus specifically on C2 concepts for operations in the Pacific and in specific scenarios. The U.S. military often experiments with alternative C2 concepts during tabletop exercises (TTXs), command post exercises, and field training exercises, but these exercises are typically designed to practice operations under specific concepts, rather than to compare and contrast alternative C2 concepts in a given scenario in a rigorous way. We aimed to provide a more rigorous approach for comparing and contrasting organizational concepts for operational-level C2 of joint air operations in Pacific scenarios.

Research Questions and Scope

This project addressed two research questions:

1. What methods should be used to compare and contrast alternative concepts for C2 of joint air operations in the Pacific? This is the central topic of Chapter 2.
2. How do recently proposed C2 concepts compare and contrast in relevant Pacific scenarios? This is the central topic of Chapter 3.

In consultation with the research sponsor, we focused on C2 at the operational level, as opposed to C2 at the tactical level, and on C2 for joint operations, as opposed to bilateral C2 or C2 for coalition operations. While we considered C2 for all joint operations, the implications for C2 of joint air operations received particular emphasis. The research did not include a detailed evaluation of communication or other command, control, and communication systems that support C2. These scoping decisions were made to ensure adequate resources to complete the research and to help ensure that the results are relevant to the Air Force sponsor and associated stakeholder communities.

Approach

We formed a multidisciplinary team to conduct this research. This team included engineers and physical scientists with research experience in command, control, communications, computers, intelligence, surveillance, and reconnaissance; a computer scientist with expertise in M&S; current and former aviators in the Air Force and Navy; an industrial and organizational psychologist; a political scientist; and a medical doctor with research experience in HA/DR operations.

The research was conducted in two phases: induction and deduction. During the induction phase, we conducted extensive literature reviews to identify relevant C2 concepts and scenarios

[4] See Chapter 1 for more details on past research.

and to gather information on C2 doctrine, recent exercises conducted at USPACOM, previous research on C2 from a variety of fields, and the state of the art in M&S for C2 research. We then conducted a two-day workshop in January 2016 to elicit subject-matter expert input on the research questions. Participants included C2 researchers and military operators, among them former and current aviators from the Air Force and Navy. Participants role-played as the JFC and JFACC in a selection of scenarios set in the Pacific, considering the pros and cons of alternative C2 concepts for each. The method participants used is similar to the joint planning process, in which each alternative C2 concept was treated as a course of action for C2 of forces.[5] We developed a set of goals for the C2 of joint air operations, which we adapted from joint doctrine, and reviewed these with the participants to help ensure that C2 of joint air operations received adequate emphasis.[6] Scenarios considered included major war scenarios and lesser contingencies. We asked participants for input on what kinds of metrics would be useful for comparing and contrasting alternative C2 concepts and for the C2 concept they would prefer for each scenario based on their own qualitative assessment of the metrics. The results of the induction phase provided initial hypotheses on the answers to the two research questions.

In the deduction phase, we tested each hypothesis, drawing evidence to support each hypothesis or its alternative from two sources that were independent of those from the induction phase: (1) additional literature reviews, including a historical review to examine the consistency of the hypothesized results with historical use of C2 concepts in past operations, and (2) evaluation of C2 metrics, primarily using methods we adapted from organizational theory. The results of the deduction phase provided the findings, and insights gleaned from those findings provided a basis for developing the recommendations.

Findings

What Methods Should Be Used to Compare and Contrast Alternative Concepts for C2 of Joint Air Operations in the Pacific?

Five categories of metrics are useful for comparing and contrasting alternative C2 concepts and should be evaluated in the context of the goals for C2 of joint air operations.

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[5] The joint planning process is described in JP 5-0, *Joint Operation Planning*, Washington, D.C.: Joint Staff, August 11, 2011.

[6] We derived five operative goals for C2 of air operations from the tasks of the JFACC that are described in JP 3-30: (1) allocate and task air capabilities to accomplish individual missions; (2) evaluate priorities and recommend an apportionment that meets the operational objectives; (3) deconflict the airspace through the airspace control authority; (4) protect forces through the area air defense commander role; and (5) support space superiority and force enhancement missions through space coordination authority. See JP 3-30, *Command and Control of Joint Air Operations*, Washington, D.C.: Joint Staff, February 10, 2014, pp. x and II-2.

Resources

Different C2 concepts will have different resource requirements, especially for manpower. For instance, standing up a JTF requires manpower to staff the JTF headquarters and associated components, but these manpower requirements would not be needed for an operation the GCC leads directly. Estimating the manpower requirements for Air Force personnel in the JFC and JTF staffs, the theater JFACC and commander Air Force forces J-staffs, and the joint air and space operations center (JAOC) and joint air component coordination element staffs is useful for comparing and contrasting alternative concepts for C2 of joint air operations in a given operation or scenario.

Performance

C2 organizations contribute to the success of operational outcomes, but methods for quantitatively assessing the contributions of human decisionmaking in C2 organizations to operational outcomes remain elusive. In 2000, Sproles concluded that

> [w]hatever contribution C2 may make is generally masked by the contribution made by other component systems . . . While no solutions have been offered as to a way around this . . . the approach taken by the behavioral or soft sciences may warrant investigation.[7]

In 2001, Gonzales et al. used an agent-based model to demonstrate that a commander with superior communications and the ability to quickly recognize the main attack of an adversary could defeat that adversary even with a force advantage.[8] However, that method has not been scaled up to reflect all the intricacies of large-scale air campaign planning. In 2010, Davison and Pogel concluded that M&S techniques for assessing C2 based on force outcomes remain elusive because the C2 "ontology is not yet sufficiently developed."[9]

However, it is important to distinguish between the performance of forces in meeting the objectives of an operation and the efficiency and effectiveness of C2 organizations for enabling success in that operation. Our research applied measures of efficiency and effectiveness from organizational theory to the comparison of C2 concept performance in a given operational scenario. Specifically, we quantitatively evaluated span of control, the height of the organization, the connectivity index, and the number of organizational relationships between the JAOC and other nodes in the organizational structure. For a commander at a given position with an organizational structure, the term *span of control* refers to the number of people (or

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[7] Noel Sproles, "The Difficult Problem of Establishing Measures of Effectiveness for Command and Control: A Systems Engineering Perspective," *Systems Engineering*, Vol. 4, No. 2, 2001, p. 154.

[8] Dan Gonzales, Lou Moore, Chris Pernin, David Matonick, and Paul Dreyer, *Assessing the Value of Information Superiority for Ground Forces—Proof of Concept*, Santa Monica, Calif.: RAND Corporation, DB-339-OSD, 2001.

[9] However, the meaning of a C2 ontology and its relevance is not clear to the authors of this report. See Jim Davison and Alex Pogel, "Tactical Agent Model Requirements for M&S-Based IT→C2 Assessments," *The International C2 Journal*, Vol. 4, No. 1, 2010, p. 4.

organizational heads) that directly report to him or her.[10] If the span of control is too narrow, the C2 concept may be inefficient because the structure is top heavy with managers. On the other hand, if the span of control is too wide, the concept may be ineffective because a single person is being asked to manage too much at once. While there is no known optimal value for span of control, the U.S. Army recommends that planners should not exceed the allotted headquarters span of control, which is between two and five; the U.S. Marine Corps suggests a span of control of three to seven.[11] There is a (qualitative) correlation between the number of direct reports and the number of options that a decisionmaker has available to respond to an environment, for instance, in responding to rapidly unfolding events on the ground in an HA/DR operation or in dealing with localized security threats in irregular warfare.

However, there are limits to the number of direct reports that an individual decisionmaker can manage. Increasing options beyond these limits requires adding layers to the organizational structure, increasing its height, which is our second quantitative measure of performance. Increased height has the potential to slow decisionmaking across layers, affecting the speed of the C2 observe, orient, decide, and act loop at the affected layers. Hence, there are trade-offs to consider between the options available to respond to the environment and the speed of C2 decisionmaking. We have made separate quantitative evaluations of the span of control and height from the perspectives of a theater commander and of a JTF when it is directly leading an operation.

We also calculated the connectivity index, a function of the number of elements that can be removed from an organizational chart before it splits into separate parts. Qualitatively, higher index values imply a greater number of informal reporting and peer-to-peer relationships in an organization relative to its overall size. However, greater numbers imply that there are more relationships to manage, which may decrease efficiency. We have reported the connectivity index at the theater level and, where relevant, at the JTF level.

Our final quantitative metric is the number of relationships that the JAOC must maintain. Qualitatively, more relationships may increase options and flexibility, enhancing effectiveness of the JAOC, but managing these relationships may reduce JAOC efficiency.

Risk

The National Institute of Standards and Technology defines *risk* as

> a measure of the extent to which an entity is threatened by a potential circumstance or event, and is typically a function of the adverse impacts that

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[10] See William G. Pierce, "Span of Control and the Operational Commander: Is It More Than Just a Number?" Fort Leavenworth, Kan.: U.S. Army Command and General Staff College, School of Advanced Military Studies, January 5, 1991.

[11] See Field Manual 101-5, *Staff Organization and Operations*, Washington, D.C.: Headquarters, Department of the Army, May 31, 1997.

would arise if the circumstance or event occurs; and the likelihood of occurrence.[12]

We define *C2 risk* as the likelihood of and impact of adverse conditions on C2 performance or operational outcomes.

We developed a unique wargaming methodology to evaluate C2 risk, basing it on a technique the RAND Corporation developed for the U.S. Army in the 1990s known as assumption-based planning (ABP).[13] Our variation conducts the planning in a TTX environment and uses a retrospective futurology approach to elicit input from participants. ABP has many parallels with the risk identification and mitigation steps of the joint planning process in JP 5-0.[14] In essence, ABP is designed to examine an existing plan to identify critical assumptions that must hold for success.[15] The likelihood and impact of that assumption failing are measures of risk.

To adapt ABP for this purpose, we treated a C2 concept as a "plan" for C2 of operations in a given scenario. TTX participants were presented with an operational scenario as if the operation had already taken place. Participants then walked through each individual mission of the operation and were asked to identify C2-related assumptions and assess the likelihood and impact of failure. As an example, consider the assumption that a JFACC located in reachback has robust means of communicating with forward forces. This may be a critical assumption if failure could adversely affect the ability to control these forces. The assumption may be likely to fail if an adversary has, say, cybercapabilities that are designed to disrupt such communications. Hence, robust communications between the JFACC and forward forces may be a risk factor in some scenarios. We report the number of risks identified and a qualitative description of each as metrics. These may be compared and contrasted for alternative C2 concepts within the same scenario.

Resiliency

Here, *resiliency* is the inherent resistance to impact, flexibility, adaptability, and recoverability of the C2 concept. The wargaming design for evaluating C2 risk was also designed to evaluate C2 resiliency. For each risk, TTX participants were asked to identify resiliency measures. There are three types of resiliency measures: signposts, shaping actions, and hedging actions. A *signpost* is something that can be monitored to know whether an assumption

[12] National Institute of Standards and Technology, "Guide for Conducting Risk Assessments: Information Security," September 2012, p. 6.

[13] See James A. Dewar, *Assumption-Based Planning: A Tool for Reducing Avoidable Surprises*, Cambridge, U.K.: Cambridge University Press, 2002.

[14] JP 5-0, 2011.

[15] More specifically, an assumption is deemed critical if it is both load bearing and vulnerable. An assumption is said to be load bearing if failure of the assumption would have adverse impact on performance against the goals, regardless of the likelihood of failure. A load-bearing assumption is said to be vulnerable if there is plausible likelihood of failure. Hence, C2 risk is defined in terms of impact and likelihood of failure, which is consistent with the National Institute of Standards definition of risk.

is going to fail. A *shaping action* is one that can be taken to help prevent an assumption from failing. A *hedging action* is one that can be taken in the event an assumption fails. For instance, employing a cyber protection team to protect communications between a JFACC and its forward forces would be an example of a shaping action. Developing alternative communication means, such as a joint aerial layer network, would be an example of a hedging action.

Versatility

Versatility of a given C2 concept refers to its applicability to a range of scenarios. We do not offer a specific metric for versatility. Instead, we suggest that versatility be assessed by viewing the resource, performance, risk, and resiliency metrics in an alternative way: Rather than comparing and contrasting alternative concepts in a given scenario, compare and contrast a given concept in alternative scenarios.

Trade-Offs

Note that C2 concepts for a given scenario do not form an ordered set. That is, when comparing and contrasting alternative C2 concepts for a given scenario or operation, there is never one clear winner. There are only preferences based on the metrics. To see this, consider that the resources for a given C2 concept can always be reduced, which is in some sense a favorable outcome because it would likely reduce financial costs. However, at some point, the reduction of resources will adversely affect C2 performance, risk, or resiliency, which is not favorable. Hence, there are trade-offs among the metrics when comparing and contrasting alternative C2 concepts for a given scenario or operation.

How Do Recently Proposed C2 Concepts Compare and Contrast in Relevant Pacific Scenarios?

In consultation with the sponsor, we compared and contrasted two alternative C2 concepts in two different scenarios using the methods just described. The first was a major war scenario that involved Phase II and Phase III operations with a near-peer competitor in the Pacific and was loosely based on the Unified Engagement 2014 scenario, with a few modifications.[16] The second scenario was an HA/DR operation set in the Philippines and was based on historical precedents from similar operations. The appendixes provide information about the scenarios, including how they were selected and developed.

For the two C2 concepts, we first considered having the GCC commander directly lead the operation with his or her components, including the theater JFACC, colocated in Hawaii. As an alternative, we considered having the GCC commander establish one or more JTFs to lead the operation. Each JTF was provided its own forward-based air, land, sea, and special operations

[16] For instance, our sponsor requested a new-near evaluation so we modified the Unified Engagement scenario from a 2024 to a 2020 time frame.

components, separate from the theater-level components. For instance, each JTF had its own JFACC that coordinated joint air operations through a single JAOC for the entire theater. For the major war scenario, we assumed the GCC stood up two JTFs for the operation, each with its own geographic area of responsibility, one led by the Navy and one led by the Air Force. For the HA/DR scenario, we assumed just one JTF, which was led by the Marine Corps. In both scenarios, we also assumed that there were other theater security concerns besides the operation. Chapter 3 provides details on the C2 concepts, including organizational diagrams.

We evaluated the metrics for each C2 concept in the two different scenarios, then compared and contrasted the results.

Table S.l is a side-by-side comparison of the metrics related to manpower resources, performance, risk, and resiliency in the major war scenario (we discuss versatility later in this summary). Manpower resource requirements are about double for the JTF-led operation. It could be very stressful for the total force to provide the necessary manpower. In terms of performance, key takeaways are that standing up JTFs may have increased the GCC commander's options and flexibility at the theater level but at the expense of increased organizational height. These factors could improve effectiveness of C2 (by increasing options) at the theater level, but the increased height may also slow decisions related to theater-level support to the operation or to amassing forces at the theater level. Also note that the JTF commanders, and the JAOC, have many relationships (both direct and indirect) that they must manage under a JTF-concept, which may be detrimental to C2 efficiency. Perhaps most significant is that ten C2 risks are related to the JTF-led operation but only four for the GCC-led operation. Participants in the C2 risk-and-resiliency (C2R2) TTX ranked the importance of the risks they identified; the table describes the most important risks and the associated resiliency measures.

Table S.2 compares the metrics for the two concepts in an HA/DR scenario side by side. As with the results for the major war scenario, the manpower resource requirements are greater for a JTF-led operation than for a GCC-led operation. However, the distinction is somewhat less pronounced for HA/DR than for a major war because there is only one JTF for the HA/DR operation. The performance implications of having a JTF, rather than the GCC commander, lead the HA/DR operation are similar to those for the major war scenario. In particular, standing up a JTF to lead the operation may increase the theater commander's options and flexibility for C2 at the theater level, but this again increases the height of the organizational structure, which may slow C2 decisionmaking at the theater level. Each concept in HA/DR (ten total) had an equal number of risks.

To examine the versatility of the concepts, we looked at the metrics associated with the two scenarios for a given concept. Table S.3 compares and contrasts the GCC-led C2 concept for the major war and HA/DR scenarios side by side. The manpower resource requirements are much higher for the major war scenario. The performance metrics are identical. However, this C2 concept had far more risks for the HA/DR scenario than for the major war scenario. For the HA/DR scenario, the most important unique risk is related to responsiveness of the operation to

Table S.1. Comparison and Contrast of the GCC-Led and JTF-Led C2 Concepts in a Major War Scenario

Category and Metric	Major War Scenario: GCC-Led	Major War Scenario: JTF-Led
Resources		
Total Air Force manpower	447	944
Total JAOC manpower	317	591
Performance		
Span of control at theater level	5	7
Span of control at JTF level	N/A	5
Connectivity index at theater level	10.7	5.1
Connectivity index at JTF level	N/A	21.4
Height at theater level	4	5
Height at JTF level	N/A	4
Number of JAOC relationships	1	3
Risk and resiliency		
Number of unique risks	2	8
Number of common risks	2	
Total number of risks	4	10
Most important unique risk	Ability to maintain battlespace awareness of forward operations from reachback at USPACOM	Ability to task air assets under JTF control in a timely manner
Associated resiliency measures	Implement user-defined operating picture (UDOP) concept (hedging action)	Monitor the timing of air operations (signpost) Train and exercise with multiple JFACCs using a single JAOC (shaping action) Stand up a coordination cell for each JFACC within the JAOC (hedging action)
Most important common risk	U.S. forces have sufficient time to plan and execute force flow	
Associated resiliency measures	Implement adaptive basing operational concepts (shaping action) Prepositioning (shaping action) Mobility exercises (shaping action)	

what is happening in the joint operational area (JOA). For the major war scenario, it is related to the ability of maintaining battlespace awareness of forward operations.

Table S.4 compares and contrasts the C2 concept for a JTF-led operation in the same scenarios. Again, the manpower resource estimates are substantially higher for the major war scenario. Unlike the GCC-led operation, the performance metrics vary across the two scenarios because the two scenarios have different numbers of JTFs (two JTFs for the major war scenario and one JTF for the HA/DR operation scenario). Each of the two scenarios had ten risks, and the most important risks for each are related, both having to do with the ability of the JTF commander to task assets in a timely manner.

Table S.2. Comparison and Contrast of the GCC-Led and JTF-Led C2 Concepts in an HA/DR Scenario

Category and Metric	HA/DR	
	GCC-Led	JTF-Led
Resources		
Total Air Force manpower	253	444
Total JAOC manpower	147	220
Performance		
Span of control at theater level	5	6
Span of control at JTF level	N/A	5
Connectivity index at theater level	10.7	6.67
Connectivity index at JTF level	N/A	17.90
Height at theater level	4	5
Height at JTF level	N/A	4
Number of JAOC relationships	1	2
Risk and resiliency		
Number of unique risks	6	6
Number of common risks	4	
Total number of risks	10	10
Most important unique risk	The orchestration of the operation is responsive to what is happening in the JOA	The JTF commander has the authorities (operational control [OPCON], tactical control [TACON]) established for the operation and can conduct operations in a timely manner
Associated resiliency measures	Have the JAOC run a separate air tasking order (ATO) cycle for the HA/DR operation (shaping action)[a]	Develop a Pacific Air Force (PACAF) checklist of needed authorities and processes to use and work with USPACOM to update Concept Plan (CONPLAN) 5001 (shaping action) Send requests for forces and authorities as needed (hedging action)
Most important common risk	Deployable communications packages either do not exist or are not available	
Associated resiliency measures	Continue to build out and unit type code the requirements for deployable communication packages and incorporate them into command post and field-training exercise events (shaping action) Leverage host-nation infrastructure if available (hedging)	

[a] This would mean that the 613th JAOC would be running two separate ATO cycles, one for air operations to support the HA/DR operation and synched to its battle rhythm and a second for air operations not supporting that operation and synchronized to the battle rhythm of the GCC.

Table S.3. Versatility of GCC-Led C2 Concept in Major War and HA/DR Scenarios

	GCC-Led Operation	
Category and Metric	**Major War**	**HA/DR**
Resources		
Total Air Force manpower	447	253
Total JAOC manpower	317	147
Performance		
Span of control at theater level	5	5
Connectivity index at theater level	10.7	10.7
Height at theater level	4	4
Number of JAOC relationships	1	1
Risk and resiliency		
Total number of risks	4	10
Most important unique risk	Ability to maintain battlespace awareness of forward operations from reachback at USPACOM	The orchestration of the operation is responsive to what is happening in the JOA
Associated resiliency measures	Implement UDOP concept (hedging action)	Have the JAOC run a separate ATO cycle for the HA/DR operation (shaping action)

The manpower resource estimates for the C2 concepts in the scenarios vary significantly, and providing the needed manpower may stress the total force. The methods for comparing and contrasting alternative C2 concepts in a given scenario should be applicable to other theaters in addition to the Pacific; however, we caution against generalizing the results of the comparison and contrast of the C2 concepts for GCC-led and JTF-led operations in Pacific scenarios. The results would likely vary if the details of the concepts are changed or in different scenarios.

Recommendations

Our recommendations are based on the methods we developed for comparing and contrasting alternative C2 concepts and on resiliency measures associated with the most important risks during the C2R2 TTX. We recommend that the Air Force

- Evaluate manpower resource needs and span of control–related performance metrics for C2 concepts recently proposed for the Pacific area of responsibility and expand analysis to include additional scenarios of interest.
- Implement the C2R2 TTX methodology in upcoming exercises and wargames with Air Force participation. A C2R2 TTX could be conducted as a parallel workshop for exercises including Pacific Sentry, Plan Blue, Unified Engagement, and Futures Game.
- Prioritize and continue to build out unit type code requirements for deployable communications packages. Availability of deployable communications was identified as a common C2-related risk for the HA/DR scenario.

Table S.4. Versatility of JTF-Led C2 Concepts in Major War and HA/DR Scenarios

	JTF-Led Operation	
Category and Metric	**Major War**	**HA/DR**
Resources		
Total Air Force manpower	944	444
Total JAOC manpower	591	220
Performance		
Span of control at theater level	7	6
Span of control at JTF level	5	5
Connectivity index at theater Level	5.1	6.67
Connectivity index at JTF Level	21.4	17.90
Height at theater level	4	4
Height at JTF level	4	4
Number of JAOC relationships	3	2
Risk and resiliency		
Total number of risks	10	10
Most important unique risk	Ability to task air assets under JTF control in a timely manner	The JTF commander has the authorities (OPCON/TACON) established for the operation and can conduct operations in a timely manner
Associated resiliency measures	Monitor the timing of air operations (signpost) Train and exercise with multiple JFACCs using a single JAOC (shaping action) Stand-up a coordination cell for each JFACC within the JAOC (hedging action)	Develop a PACAF checklist of needed authorities and processes to use and work with USPACOM to update CONPLAN 5001 (shaping action) Send requests for forces and authorities as needed (hedging action)

- Continue to develop the UDOP concept because it may be a resiliency measure to address the risk of maintaining battlespace awareness in a major war scenario with the GCC-led concept.
- Train and exercise production of an ATO for multiple JFACCs at the 613th JAOC. This could help improve the efficiency of ATO production in an operation led by one or more JTFs.
- Train and exercise parallel ATO production cycles at the 613th JAOC. This could help ensure that air operations are responsive to JOA needs in an operation where time is of the essence, such as an HA/DR operation.
- Given the risk assessment for the HA/DR operation, PACAF should add additional details to the joint air component portion of CONPLAN 5001:[17]
  - Identify the likely Air Force staff needed for joint field office(s).

[17] Headquarters U.S. Pacific Command, "USPACOM CONPLAN 5001-13: Defense Support of Civil Authorities (DSCA)," December 20, 2013.

- Develop a checklist of possible needed authorities and coordination processes for the joint air component (JTF-subordinate JFACC).
- Expand the command, control, and coordination portion of the CONPLAN to include details for the joint air component.

We also suggest two future areas of research for the C2 community on this topic. The first is to develop techniques that capture the dynamic nature of C2 organizations, since the organizational structures tend to vary over time. The second is to continue efforts to evaluate the contributions of C2 organizations to achieving operational outcomes. M&S techniques may play a role in these proposed areas of future research.

Acknowledgments

We would like to thank the project sponsor, Brig Gen Dirk Smith, Headquarters (HQ) Pacific Air Force (PACAF) Director of Air and Cyberspace Operations (A3/6) for the opportunity to conduct this research. We would also like to thank the project cosponsor, Mark (Tap) Tapper, defense intelligence senior leader, HQ U.S. Air Force intelligence directorate (A2). The project benefited from the help provided by many individuals across the U.S. Air Force, but we would like to specifically acknowledge the help they received from Col Max Marosko, HQ PACAF/A3/6D; Col David Moeller, then 613rd Air and Space Operations Center (AOC) commander; Col David Kirkendall, then 613 AOC vice commander; Lt Col Christopher Hoskins, Command and Control Working Group lead at HQ PACAF/A3/6; Lt Col Christopher Forrest, 613 AOC; Steven Diamond, command historian, HQ PACAF. We thank Lt Gen (ret.) Robert Elder for the feedback and guidance he provided on our midterm briefing. We thank David Ochmanek, John Yurchak, LTC Sherry Oehler, Joslyn Hemler, Beth Waina, and Lt Col Mark Coggins for the joint perspectives they provided. We would like to acknowledge the important contributions of our colleagues, C. Ryan Henry, Gary Briggs, James Dewar, and Dara Gold. The authors would like to thank the editor, Phyllis Gilmore, for greatly improving the readability of the report. We appreciate the thorough peer reviews of the draft version of this report by Michael Spirtas and Dan Gonzales. The manuscript is much improved as a result of their reviews. The authors alone are responsible for any errors or shortcomings.

Abbreviations

A2/AD	anti-access and area-denial
AADC	area air defense commander
ABP	assumption-based planning
ACA	airspace control authority
AEW	air expeditionary wing
AFI	Air Force Instruction
AOC	air and space operations center
AOD	air operations directive
AOR	area of responsibility
ASEAN	Association of Southeast Asian Nations
ATO	air tasking order
BDA	battle damage assessment
C2	command and control
C2R2	C2 risk-and-resiliency
C3	command, control, and communications
CCC	combined coordination center
C-Day	commencement day, which refers to the day deployment for an operation commences (when the time-phased force deployment begins)
CFACC	combined forces air component commander
CFSOCC	combined forces special operations component commander
CJTF	combined joint task force
COMAFFOR	commander Air Force forces
CONOP	concept of operation
CONPLAN	concept plan
CPX	command post exercise
CSF	combined support force
D-Day	the day an operation commences
DIRMOBFOR	Director of Mobility Forces
DIRSPACEFOR	Director of Space Forces
DoD	U.S. Department of Defense
DRAT	disaster relief assessment team
FTX	field training exercise
GCC	geographic combatant command
HA/DR	humanitarian assistance and disaster relief
H-Hour	the hour an operation commences

HQ	headquarters
HUM	humanitarian
IGO	intergovernmental organization
ISR	intelligence, surveillance, and reconnaissance
JACCE	joint air component coordination element
JAG	judge advocate general
JAOC	joint air and space operations center
JFACC	joint forces air component commander
JFC	joint forces commander
JFLCC	joint forces land component commander
JFMCC	joint forces maritime component commander
JFSOCC	joint forces special operations component commander
JIPTL	joint integrated prioritized target list
JOA	joint operational area
JP	Joint Publication
JTCB	joint targeting coordination board
JTF	joint task force
LNO	liaison officer
LO	liaison officer (Air Force)
M&S	modeling and simulation
MAAP	master air attack plan
MEF	marine expeditionary force
MNC-I	Multi-National Corps–Iraq
MND	multinational division
MND-C	Multi-National Division–Central
MND-N	Multi-National Division–North
MNF	multinational force
MNF-I	Multinational Force—Iraq
MTO	mission type order
NCA	National Command Authorities
NDRRMC	National Disaster Risk Reduction and Management Council
NGO	nongovernmental organization
OODA	observe, orient, decide, and act
OPCON	operational control
PACAF	Pacific Air Force
PAF	Project AIR FORCE
SCI	structural control intensity
SOF	special operations forces
TACON	tactical control

TALCE	tanker airlift control element
TET	target effects team
TJFACC	theater joint forces air component commander
TTX	tabletop exercise
UDOP	user-defined operating picture
UN	United Nations
USAID	U.S. Agency for International Development
USCENTCOM	U.S. Central Command
USPACOM	U.S. Pacific Command
UTC	unit type code

1. Introduction

Background

Command and control (C2) in a military context has been defined as "the means by which a JFC [joint forces commander] synchronizes and/or integrates joint force activities."[1] C2—supported by information, communication, and sensing technologies—enabled the United States to achieve quick victories, with minimal casualties, in recent military campaigns. For instance, C2 allowed U.S. and coalition partners to closely integrate their air, land, and maritime forces and operate with speed, maneuverability, flexibility, and surprise during Operation Desert Storm and in swift defeats of Afghanistan and Iraq.[2] It has been argued that effective means of C2 of U.S. forces may help deter future conflicts.[3]

The observe, orient, decide, and act (OODA) loop C2 concept was first proposed in a 1987 briefing.[4] Boyd suggested that operating with a faster OODA loop than an adversary would enmesh the adversary "in a world of uncertainty, doubt, mistrust, confusion, disorder, fear, panic chaos . . . and/or fold adversary back inside himself so that he cannot cope with events/efforts as they unfold."[5] In the observe and orient stages, individuals with different skills and abilities are exposed to their external environment so that they might develop "implicit communications and trust" and thereby "diminish friction and compress time" to gain quickness and security.[6] Boyd further suggested that the orient stage is the most important because it shapes the way C2 decisionmakers observe, decide, and act.[7] He concluded that operating inside an adversary's OODA loop means the same thing as operating inside its C2 loop.[8]

Effective C2 to support joint operations depends on well-defined command arrangements and authorities. C2 is also dependent on leading-edge technologies in a variety of ways: Technology facilitates the timely delivery of data, intelligence products, and other information planners need; processes that information to aid in plan development; facilitates the delivery of orders; enables

[1] Joint Publication (JP) 1, *Doctrine for the Armed Forces of the United States*, Washington, D.C.: Joint Staff, March 25, 2013, pp. xxii–xxiii.

[2] Max Boot, "The New American Way of War," *Foreign Affairs*, August 2003.

[3] Yoichi Kato, "Interview: Herbert 'Hawk' Carlisle: Strong U.S.-Japan Alliance Deterring China from Provocative Actions," *Asahi Shimbun*, April 22, 2014.

[4] John R. Boyd, "Organic Design for Command and Control," briefing presented at the Defense and the National Interest, May 1987.

[5] Boyd, 1987, slide 7.

[6] Boyd, 1987, slide 18.

[7] Boyd, 1987, slide 26.

[8] Boyd, 1987, slide 26.

forces to synchronize and integrate their operations; and delivers intelligence and other information that is needed to rapidly assess the outcome of operations across all domains. Assured communications are especially crucial for C2 of forces in the Pacific, where forces may span vast distances, and when communication capacity is limited, such as the capacity provided by satellite communications and fiber links.

The geography of the Pacific creates potential challenges for C2 of air operations: C2 elements may have to communicate with forces over long distances; forces may have to operate over large areas; and forces may be widely dispersed because of the low density of available basing. The anti-access and area-denial (A2/AD) strategies and capabilities of near-peer competitors present another set of challenges for C2 of air operations: The pace and intensity of operations in A2/AD may compress C2 decision timelines, affecting battle rhythm and the C2 OODA loop; force protection may be challenged by the missile capabilities and capacities of near-peer competitors; and cyber and countercommunication capabilities may disrupt the flow or integrity of C2 information. Alternative paths for the flow of information and other technologies may help mitigate the geographic and A2/AD challenges, but effective mitigation may also require developing alternative C2 concepts that incorporate new tactics, techniques, and procedures and implement changes to roles, rules, responsibilities, and authorities.

Command and Control Concepts

Many alternative organizational structures for C2 have been used in past operations or proposed for use in future operations. We define a *C2 concept* as an organizational structure for C2, along with the associated roles, rules, responsibilities, and authorities.

For example, Figure 1.1 depicts an example organizational structure that may be used for C2 at the operational level. In this example, the geographic combatant command (GCC) commander is designated by the National Command Authorities (NCA) as the joint forces commander (JFC) for a joint operation. The JFC will have support from traditional components: the joint forces air component commander (JFACC), joint forces land component commander (JFLCC), joint forces maritime component commander (JFMCC), and joint forces special operations component commander (JFSOCC). The joint air and space operations center (JAOC) is the primary weapon system for operational-level C2 of joint air operations. Figure 1.1 depicts the joint air component coordination element (JACCE) staffs that may reside with the JFLCC, JFMCC, and JFSOCC for coordinating joint operations with the JFACC.[9]

Figure 1.2 shows an alternative C2 concept. In this alternative, the GCC commander establishes a joint task force (JTF) and designates the JTF commander as the JFC for the operation, rather than leading the operation directly. This enables the GCC commander to focus on other security concerns in the theater and on political-to-military engagements. In fact, the

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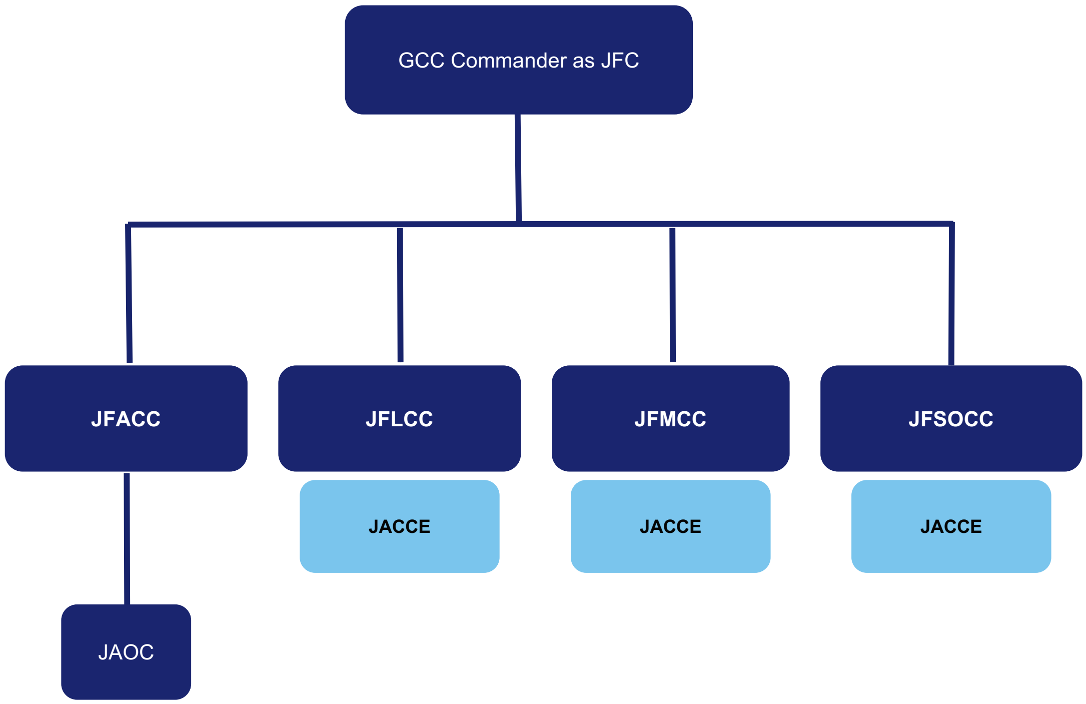
[9] Note that JACCE staffs are liaisons only and do not have the authority to make decisions.

Figure 1.1. GCC Commander as Joint Forces Commander



SOURCE: Based on JP 3-0, *Joint Operations*, Washington, D.C.: Joint Staff, August 11, 2011, Ch. IV.

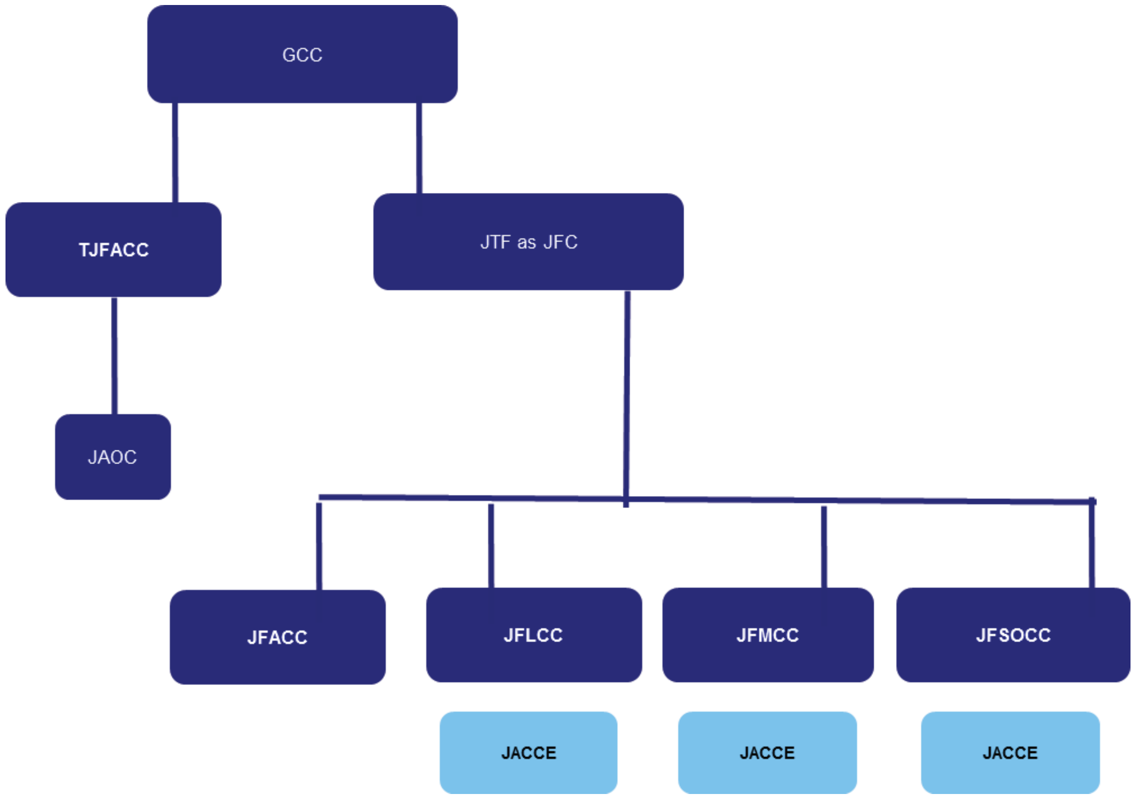
GCC commander may establish multiple JTFs for different security concerns within the theater or even divide the C2 roles, rules, responsibilities, and authorities for a single operation among multiple JTFs.[10] In Figure 1.2, each JTF may have his or her own components for the operation, separate from those at the theater level. For instance, in the figure, the JTF has a JFACC that is separate from the theater-level JFACC, which we designate as the theater JFACC (TJFACC) (for simplicity, the figure does not depict the other components at the theater level). The JTF-subordinate JFACC may have his or her own JAOC, or the TJFACC and JTF-subordinate JFACCs may have to use a single JAOC (as the figure implies).[11]

Many additional elements are not depicted in Figures 1.1 and 1.2. For instance, Strategic Command may designate the Joint Forces Component Command for Space to support the JFC for the operation; U.S. Cyber Command might do something similar. The Director of the

[10] If JTFs are located forward, one potential advantage of delegating certain authorities from the GCC to subordinate JTFs is that doing so could allow them to make independent decisions when circumstances preclude a centralized C2 approach.

[11] Given today's fiscally constrained environment, it is unlikely that each JTF would have its own AOC, but it is theoretically possible.

Figure 1.2. Joint Task Force Commander as Joint Forces Commander



SOURCE: Based on JP 3-0, 2011, Ch. IV.

National Security Agency may delegate signals intelligence operational tasking authority for the operation to the JFC. The JFC may designate any one of the individual component commanders as supported commander for a particular mission. Also, the figures do not depict C2 elements at the tactical level of war, which would include battle management elements, such as the Joint Surveillance and Target Attack Radar System.

Detailed and up-to-date discussions of the roles, rules, authorities, and responsibilities of a JFACC and of the JAOC and its associated tactics, techniques, and procedures, including those used in the air tasking order (ATO) cycle, are beyond the scope of this report.[12] However, the following is a high-level summary of a typical ATO cycle for convenience.[13] The JAOC is the primary weapon system a JFC uses for operational-level C2 of air operations. The ATO is the vehicle used to command and execute air operations. Typically, an ATO is produced every 24

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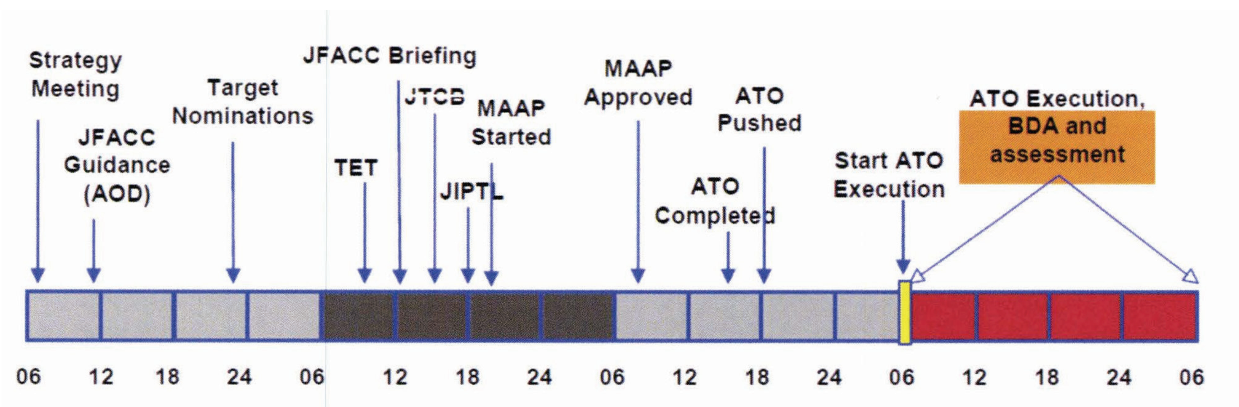
[12] For this information, see joint and Air Force doctrine, in particular, JP 3-30, *Command and Control of Joint Air Operations*, Washington, D.C.: Joint Staff, February 10, 2014, and Secretary of the Air Force, "Operational Employment: Air Operations Center," Air Force Tactics, Techniques and Procedures, March 12, 2012, Not available to the general public.

[13] This summary was adapted from Kevin Conner, Paul Lambertson, and Matthew Roberson, "Analyzing the Air Operations Center (AOC) Air Tasking Order (ATO) Process Using Theory of Constraints," Master's Thesis, Wright-Patterson Air Force Base, Ohio: Air Force Institute of Technology, June 13, 2005.

hours using a process that takes 72 hours from initial conceptualization to execution (Figure 1.3).[14] The process begins with broad guidance from the JAOC Strategy Division in the form of an air operations directive (AOD), matures through the intermediate-level joint integrated prioritized target list (JIPTL) and master air attack plan (MAAP), and ends with a fully developed and finalized ATO.

Figure 1.3 indicates major milestones in the cycle; numbers along the horizontal axis denote hours of the day. The cycle begins at 0600 on the first day, with the AOD being produced around hour 12 the same day with input from the Strategy Division and with guidance from each JFACC. Next come target nominations and development. The target effects team (TET) coordinates with each JFACC and joint targeting coordination board (JTCB) to produce and finalize the JIPTL by around 1800 hours on the second day of the cycle. This kicks off development of the MAAP, which would be approved early on the third day of the cycle, and the ATO would be finalized in the afternoon and pushed by around 1800 on the third day of the cycle. Execution of that ATO would typically begin 12 hours later, and battle damage assessment (BDA) would be concurrent with execution. The JAOC would coordinate the air operations represented in the ATO with other air operations being conducted within the same area of responsibility (AOR). For instance, the JAOC would likely coordinate with intratheater and theater refueling operations.[15] This is a simplified and generic representation of the complex and sometimes varied ATO cycle, but it should clarify the major milestones involved in the cycle.

Figure 1.3. Doctrinal 72-Hour ATO Timeline



SOURCE: Conner, Lambertson, and Roberson, 2005, p. 6.

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14 Conner et al., 2005, p. 3. Note that the ATO cycle could be shorter or longer than 72 hours. For instance, during peacetime it may be as long as a week. During combat operations, there are mechanisms such as a time-sensitive targeting cell that can shorten the tasking of air assets.

15 JP 3-30, 2014, p. xiii.

Alternative C2 concepts may respond differently to the C2 challenges associated with geography and to the A2/AD strategies and capabilities of potential adversaries. For instance, the area of operations may be divided into distinct joint operational areas (JOAs), each with its own JTF, to reduce the geographic expanse over which any one commander must control C2 of operations (obviously, careful coordination is needed between each JTF and the GCC). A JTF headquarters (HQ) that is based forward, as opposed to at a reachback facility, can operate on the same battle rhythm as the operation and can perhaps have improved situational awareness of the local environment, which in theory could improve the speed of the C2 OODA loop. The HQ may also be less dependent on long-haul communications for the C2 of forces it controls. On the other hand, a forward-based JTF HQ may operate on a different battle rhythm from that of the theater commander to whom it reports and may be within striking distance of an adversary's missile capability. Also, the forward-based JTF would require coordination through additional layers of the organizational structure for cross-JOA operations and for requesting theater-level support, which could slow the C2 decision OODA loop for cross-JOA operations and theater-level support.

For a given theater security concern, what C2 concept is preferred and why?[16] If history is a lesson, the C2 wiring diagram for a real-world operation may change continuously and not be complete until the operation has ended, and decisions about the C2 structure may be based on such factors as the personalities of the decisionmakers.[17] However, a clearer understanding of the strengths and weaknesses of alternative C2 concepts for specific types of security concerns can aid selection of a C2 concept and help the services that train, organize, and equip the joint C2 components leverage the strengths and mitigate the weaknesses of a given concept.

Research Questions and Scope

This project addressed two research questions:

1. What methods should be used to compare and contrast alternative concepts for C2 of joint air operations in the Pacific?[18]
2. How do recently proposed C2 concepts compare and contrast in relevant Pacific scenarios?

In consultation with the project sponsor, we limited the scope of the project to a study of concepts for operational-level (as opposed to tactical-level) C2 of joint operations (as opposed to

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[16] By *theater security concern*, we mean a potential or existing operation that may obtain military support from the theater combatant command. If we interpret *command* as meaning the combatant command or NCA intent, there is no difference between the example C2 concepts with regard to command. The only differences are with regard to the *control* element. However, we will continue to refer to comparing and contrasting alternative C2 because of common usage of the term.

[17] Personal communication with PACAF Historian, April 2016.

[18] By *compare and contrast*, we mean comparing the similarities and contrasting the differences.

bilateral C2 or C2 of combined force operations) in the Pacific. Particular attention was given to implications for the air component. The research focused on C2 as opposed to command, control, and communications (C3), for example. As a result, the research did not include a detailed look at communication systems and other C3-related systems and their support to C2. These decisions were made to ensure there were adequate resources to execute the project and to help ensure that the results are relevant to the Pacific Air Force (PACAF) sponsor, who would likely have a key role in joint air component operations for security concerns in that region.

Past Work and Where This Project Fits In

We conducted an extensive literature review as part of this effort (see the bibliography). This section summarizes a few highlights of that review to set the context for the project.

A U.S. Army review of C2 models and theory in 1990 examined five categories of models: implementation (e.g., Army field manuals that describe C2 doctrine), organizational theory, behavioral models, system-oriented models, and information network models.[19] The authors concluded that research conducted from organizational or management theory perspectives was more productive than research that evolved from other perspectives. They claimed that no extant model was sufficiently well developed and supported by data to be used in a predictive or analytic fashion. They recommend that models should deal with specific organizational structures.[20]

In 2001, a group of colleagues used an agent-based model to assess the impact of a commander obtaining information more rapidly than an adversary commander on operational outcome and ground warfare.[21] In this case, the commanders had the ability to deploy reserve forces to defend and counterattack. Their work demonstrated that a commander with superior communications and the ability to quickly recognize the main attack of an adversary could defeat that adversary, even if it had a force advantage. However, that method has not been scaled up to reflect all the intricacies of large-scale air campaign planning.

A 2003 U.S. Department of Defense (DoD) report argues for a new organizational form, called the *edge organization*, for military organizations to improve their efficiency and

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[19] Lloyd M. Crumley and Mitchell B. Sherman, *Review of Command and Control Models and Theory*, U.S. Army Research Institute for the Behavioral and Social Sciences, Technical Report 915, 1990.

[20] Crumley and Sherman, 1990, p. 6.

[21] Dan Gonzales, Louis R. Moore, Christopher G. Pernin, David M. Matonick, and Paul Dreyer, *Assessing the Value of Information Superiority for Ground Forces—Proof of Concept*, Santa Monica, Calif.: RAND Corporation, DB-339-OSD, 2001.

effectiveness.[22] In 2006, the same authors described the problems that C2 is designed to solve and argued that traditional approaches to C2 lack the agility needed for 21st century problems.[23]

A 2007 journal article describes progress on modeling and simulation (M&S) of human decisionmaking for tactical-level C2. In this approach, the simulated decisionmaker chooses a tactical decision to maximize some utility function, averaged over his or her beliefs about different outcomes and their utilities. The article discusses the need to balance deliberate planning, which is based on strategic considerations, with rapid planning to react fast to local circumstances.[24]

A U.S. Army War College paper from 2008 applies principles of organizational science and complexity theory to the analysis of DoD organizations. It argues that DoD organizations in the information age need agility, which has six attributes: robustness, resilience, responsiveness, flexibility, innovation, and adaptation. It compares and contrasts the military C2 needs in the industrial and information ages in terms of agility.[25]

A 2009 paper describes insights and best practices for achieving synergy with the joint force air component when a U.S. Air Force–led TJFACC is supporting an established JTF in an irregular warfare, land-centric environment. The authors also addressed considerations for the use of JTF-subordinate JFACCs. Their findings are based on operational experience from the conflicts in Iraq and Afghanistan. While their focus was on the use of JTFs in irregular warfare, the authors also provide some first-order thoughts on the use of JTF concepts in other types of conflicts.[26]

A 2009 RAND report provides a historical overview of JTFs for C2 of military operations and argues that the U.S. Air Force should be considered to lead JTFs for operations in which force is dominated by use of land-based aircraft or that take place over long distances. The report recommends steps the U.S. Air Force should take so that it is prepared to lead a JTF.[27]

A journal article from 2010 acknowledges that it would be useful to have M&S models for examining how communications affect C2 as measured by operational outcomes. However, it claimed that this was beyond the state of the art because the C2 ontology was not yet sufficiently

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[22] David S. Alberts and Richard E. Hayes, *Power to the Edge: Command . . . Control . . . in the Information Age*, Washington, D.C.: DoD Command and Control Research Program, 2003.

[23] David S. Alberts and Richard E. Hayes, *Understanding Command and Control*, Washington, D.C.: DoD Command and Control Research Program, 2006.

[24] James Moffat, "Modelling Human Decision-Making in Simulation Models of Conflict," *International C2 Journal*, Vol. 1, No. 1, 2007.

[25] Christopher E. Hicks, "Understanding and Designing Military Organizations for a Complex Dynamic Environment," paper, Carlisle, Pa.: U.S. Army War College, March 15, 2008.

[26] Gary Luck and Mike Findlay, "Air Component Integration in the Joint Force," Joint Warfighting Center, U.S. Joint Forces Command, Insights and Best Practices Focus Paper 6, March 20, 2009.

[27] Michael Spirtas, Thomas-Durell Young, and S. Rebecca Zimmerman, *What It Takes: Air Force Command of Joint Operations*, Santa Monica, Calif.: RAND Corporation, MG-777-AF, 2009.

developed.[28] Instead, the article presents results on a more modest goal, of using agent-based M&S to evaluate the extent to which information technology supports a commander's accurate evaluation of measures of performance.[29]

Several reports on lessons and lessons learned from military operations provide relevant insights on aspects of C2. One of these in particular contrasts conventional and irregular warfare and talks about differences in the C2 for them.[30] It argues that flexibility and empowerment at the lowest appropriate level promoted success in irregular warfare operations.

The U.S. Air Force's Unified Engagement 2014 tabletop exercise (TTX) examined two concepts that were developed to support military operations in which communications were contested or denied. The first, the combined forces information component command, is a cross-domain component that would have responsibilities for aspects of cyber, space, and information operations, including electronic warfare and strategic messaging. The second, distributed control, is a flexible C2 mechanism for delegating tactical control (TACON) and elements of operational control (OPCON) to a forward regional element if reachback communications are severely degraded or denied. A RAND report details observations from the wargame about these concepts.[31]

The central tenet of the 2015 Air Force Future Operating Concept is that operational agility will enable the U.S. Air Force to provide global vigilance, global reach, and global power in the future environment.[32] It argues that C2 in 2015 focused on large-scale, conventional air operations, augmented by space and cyberspace operations with domain-specific tasking orders centered on the ATO. By 2035, it argues that U.S. forces will need the ability to self-synchronize and adapt to fulfill commander's intent.[33] This would permit fluid transitions between supported or supporting roles and between centralized control and distributed coordination. The concept calls for an evolution from air-centric to multidomain C2 and for the AOC to evolve to a multidomain operation center.[34]

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[28] Note that the meaning and relevance of a C2 ontology is not clear to the authors of this report.

[29] Jim Davison and Alex Pogel, "Tactical Agent Model Requirements for M&S-Based IT→C2 Assessments," *The International C2 Journal*, Vol. 4, No. 1, 2010.

[30] Joint Staff J7, Joint and Coalition Operational Analysis Division, *Decade of War*, Vol. I: *Enduring Lessons from the Past Decade of Operations*, Suffolk, Va., June 15, 2012, Ch. 2.

[31] Brien Alkire, Lillian Ablon, and Ryan Henry, *Observations on Cross-Domain Integration, Cyber Operations and Flexible Command and Control from Unified Engagement 2014*, Santa Monica, Calif.: RAND Corporation, 2016, Not available to the general public.

[32] U.S. Air Force, "Air Force Future Operating Concept: A View of the Air Force in 2035," September 2015.

[33] We interpret *self-synchronization* to mean that a subordinate commander would have the authority and capability to synchronize the planning and execution of operations to a battle rhythm that is different from that of his or her commander under prescribed circumstances.

[34] *Multidomain operations* may be defined as operations involving the exploitation of asymmetric advantage across multiple domains to achieve the freedom of action required by the mission (see Jeffrey M. Reilly, "Multidomain

RAND research conducted in 2015 provides a survey of recent wargaming approaches and M&S capabilities for C2. It argues that M&S capabilities are not sufficiently mature for modeling human decisionmaking aspects of C2, and recommends that wargaming and M&S are used in complementary ways.[35] Another RAND project conducted in 2015 developed an interface between a combat simulation tool and a communication network analysis tool that may be useful for future research into how the availability and accuracy of information for C2 can affect operational outcomes. The results of these two RAND efforts are not published yet.[36]

The results of our literature review suggest that M&S alone is not sufficiently mature for comparing and contrasting alternative C2 concepts. Historical experience may be useful for doing so, but there is little historical experience with C2 concepts in certain scenarios. For instance, the United States has, arguably, not conducted Phase II and III operations with a near-peer competitor since World War II. The joint community has experimented and continues to do so with alternative C2 concepts in TTXs, command post exercises (CPXs), and field training exercises (FTXs). However, many of these exercises have other objectives in addition to C2, and the format is usually optimized for participants to practice the planning of operations with a given C2 concept, rather than narrowly focusing on comparing and contrasting C2 concepts. There is a body of work on military C2 from an organizational theory perspective, but that research tends to have a broad focus rather than focusing on specific C2 concepts in specific scenarios of interest. This project seeks to fill a void by focusing attention on specific C2 concepts and scenarios of interest and providing a more rigorous approach than is typical of recent exercises. It is primarily based on methods from organizational theory.

Research Approach

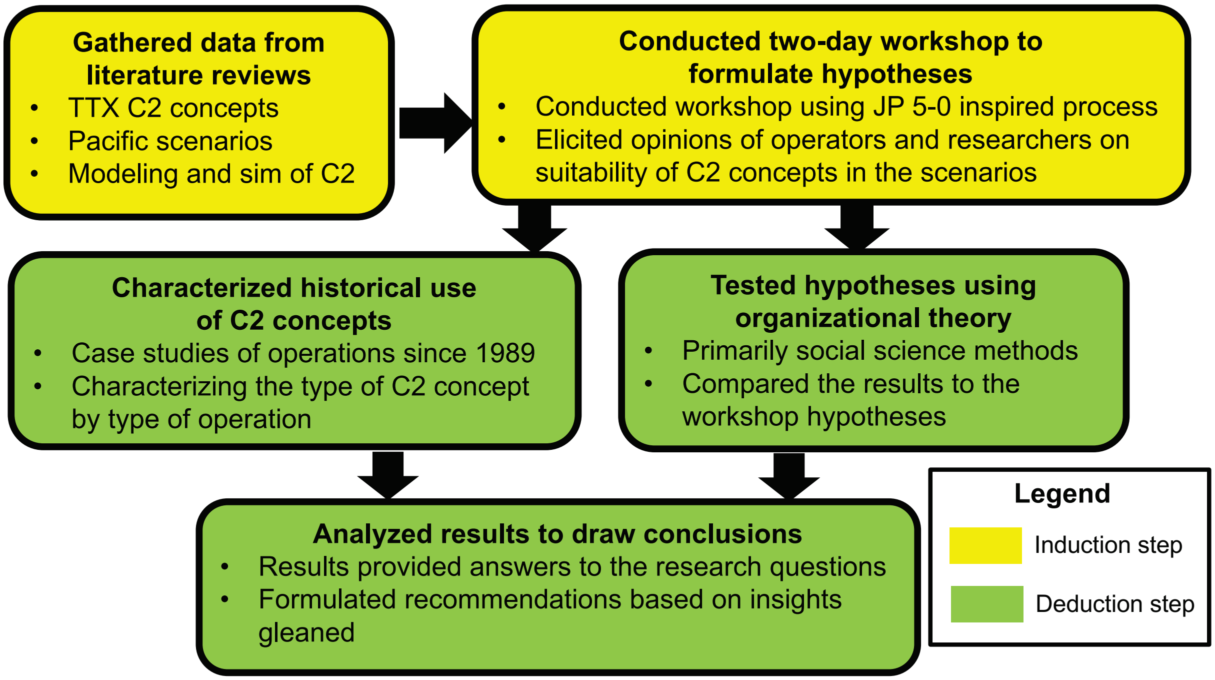
The research was conducted in two phases: the induction and the deduction phase (see Figure 1.4). During the induction phase, we conducted extensive literature reviews to identify relevant C2 concepts and scenarios; on C2 doctrine; on recent exercises conducted at U.S. Pacific Command (USPACOM) HQ on C2; on past research on C2 from a variety of fields; on the state of the art in M&S for C2 research. We then conducted a two-day workshop in January 2016 to elicit subject-matter expert input on the research questions. Participants were primarily C2 researchers and military operators, including former and current aviators from the Air Force and Navy. Participants role-played as the JFC and JFACC in a selection of scenarios set in the Pacific and considered the pros and cons of alternative C2 concepts for each. We adapted the

Operations: A Subtle but Significant Transition in Military Thought," *Air and Space Power Journal,* Spring 2016, p. 71, fn. 2). Therefore, multidomain C2 may be interpreted as C2 of multidomain operations.

35 Ryan Henry, Sherrill Lingel, Sarah Soliman, and Matthew Carroll, "Operational Command and Control: Analytic Roadmap for Contested Environments," unpublished RAND research, September 2015.

36 Bradley Wilson, "Interfacing Force on Force and Communications Models: MANA and JNE," unpublished RAND research, October 2015.

Figure 1.4. Research Approach



method for the workshop from the joint planning process, treating each alternative C2 concept as a course of action for C2 of forces.[37] We developed a set of goals for the C2 of air operations, adapted from joint doctrine, and reviewed these with the participants to help ensure that C2 of joint air operations was adequately emphasized.[38] Scenarios included major war scenarios and lesser contingencies. Participants were asked for input on what kinds of metrics would be useful for comparing and contrasting alternative C2 concepts and on which C2 concept they preferred for each scenario, given their own qualitative assessment of the metrics. The results of the induction phase provided initial hypotheses on the answers to the two research questions.

The second phase of the research was the deduction phase, which tested each hypothesis. Evidence to support each hypothesis or its alternative was drawn from two sources independent of those for the induction phase: additional literature reviews, including a historical review to examine the consistency of the hypothesized results with use of C2 concepts in past operations, and evaluation of C2 metrics, primarily using methods we adapted from organizational theory.

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[37] The joint planning process is described in JP 5-0, *Joint Operation Planning*, Washington, D.C.: Joint Staff, August 11, 2011.

[38] We derived five operative goals for C2 of air operations from the JFACC tasks described in JP 3-30: (1) allocate and task air capabilities to accomplish individual missions, (2) evaluate priorities and recommend an apportionment that meets the operational objectives, (3) deconflict the airspace through airspace control authority (ACA), (4) protect forces through the area air defense commander (AADC) role, and (5) support space superiority and force enhancement missions through space coordination authority. See JP 3-30, 2014, pp. x and II-2.

The deduction phase led to our findings, and insights we gleaned from the findings were the basis for our recommendations.

Report Outline

Chapters 2 and 3 address the first and second research questions, respectively. Chapter 4 describes the findings and recommendations. Appendix A summarizes our historical review of C2 in past operations. Appendix B describes a humanitarian assistance and disaster relief (HA/DR) scenario we used in our evaluation of metrics. A separate appendix, not publicly available, describes a major war scenario we used in our evaluation of metrics.

2. What Methods Should Be Used to Compare and Contrast Alternative Concepts for Command and Control of Joint Air Operations in the Pacific?

As described in Chapter 1, our research approach included a literature review of C2 concepts that the U.S. Air Force has examined recently, the JP 5-0 planning process, possible Pacific theater scenarios that need C2 of joint air forces, and M&S tools that explore C3 relationships and processes. Using the results of that effort, we convened a two-day C2 workshop that applied the JP 5-0 planning process to two potential C2 concepts for Pacific-theater scenarios. The format of the workshop provided the opportunity to elicit opinions from operators and C2 researchers on the suitability of the two C2 concepts in the scenarios. Participants were asked what kind of metrics they felt would be useful for comparing and contrasting alternative C2 concepts for a given scenario, regardless of whether methods were available for evaluating them. While many potential metrics were suggested, the participants concluded that they tended to fall into broad categories. Their conclusion was that C2 concepts could be adequately compared and contrasted in terms of the resources they require, their relative performance, and the risks associated with them.

As described in Chapter 1, we then conducted further literature reviews to seek evidence to support the hypothesis workshop participants offered and to refine the result. In organizational theory, it is common to assess organizational effectiveness in terms of the goals of the organization.[1] So, we adapted five operative goals for C2 of joint air operations from the tasks of the JFACC that are described in JP 3-30:[2]

1. Allocate and task air capabilities to accomplish individual missions.
2. Evaluate priorities and recommend an apportionment that meets the operational objectives.
3. Deconflict the airspace through ACA.
4. Protect forces through an AADC.
5. Support space superiority and force enhancement missions through a space coordination authority.

The participants at the two-day C2 workshop did not rigorously define the categories of resource, performance, and risk that they had identified, so we conducted literature reviews to try to identify suitable definitions in the context of the C2 organizational goals. Albert and Hayes sought to characterize C2 agility and defined agility in terms of robustness, resilience,

[1] See Richard L. Daft, *Organization Theory and Design*, 10th ed., Mason, Ohio: Cengage Learning, 2008, p. 75.

[2] See JP 3-30, 2014, pp. x and II-2.

responsiveness, innovation, and adaptation.[3] They defined each of those terms as well. The Air Force Future Operating concept discusses C2 agility in similar terms.[4] We decided that what the two-day workshop participants had referred to as *risk* could be divided into two categories: one capturing the risk of adverse conditions affecting the organization's ability to reach its goals and another capturing the inherent resiliency of the C2 organization to these adverse conditions.[5]

RAND researchers recently completed a project on how to compare the relative strengths and weaknesses of aggregated and disaggregated mission architectures.[6] The researchers concluded that these mission architectures could be evaluated in terms of five criteria categories: cost, effectiveness, risk, resiliency, and versatility. While these categories were developed for comparing and contrasting mission architectures, rather than C2 organizational structures, we recognized that the categories very closely mirrored the categories of resources, performance, risk, and resiliency that were identified by the participants at the two-day workshop, except they included an additional category, versatility. We therefore concluded that the following five categories of metrics are useful for comparing and contrasting alternative C2 concepts:

1. *resources*—the resource needs associated with a C2 concept
2. *performance*—the efficiency and effectiveness in achieving the C2 organizational goals
3. *risk*—the likelihood and impact of adverse conditions on performance
4. *resiliency*—impact resistance, flexibility, adaptability, and recoverability
5. *versatility*—the applicability of the C2 concept to a range of scenarios.

Once the categories had been identified and defined, we sought methods of evaluating metrics associated with them.

Evaluating Resource Metrics

The number of personnel required to staff the C2 concept will be based on the type and magnitude of the contingency.[7] The direct staffing levels determine the dedicated capability each element of the concept will have to perform its assigned responsibilities before it must resort to reachback capabilities. The staffing specialties supporting each concept element are based on information in JPs and Air Force instructions (AFIs). We selected Air Force personnel to directly

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[3] Alberts and Hayes, 2006, pp. 189–190.

[4] U.S. Air Force, 2015.

[5] The National Institute of Standards and Technology defines *risk* as "a measure of the extent to which an entity is threatened by a potential circumstance or event, and is typically a function of the adverse impacts that would arise if the circumstance or event occurs; and the likelihood of occurrence" (National Institute of Standards and Technology, "Guide for Conducting Risk Assessments: Information Security," September 2012, p. 6).

[6] Bart E. Bennett, Elliot Axelband, Mel Eisman, Lance Menthe, Michael Nixon, Daniel M. Norton, Steven Trochlil, and James Williams, *Strengths and Weaknesses of Aggregated Versus Disaggregated Mission Architectures*, Santa Monica, Calif.: RAND Corporation, forthcoming, Not available to the general public.

[7] Other factors, such as the number of nations involved, may affect the size as well. Also, a separate command structure could be set up for specific purposes, such as the C2 of U.S. stealth aircraft in the case of JTF Noble Anvil.

staff the air component elements. These staffing quantity estimates should be able to support 24-hour coverage with some on-call time for selected element staff and provide a starting posture that might be proved effective when evaluated during a C2 exercise or game. During a contingency the quantities would be monitored and adjusted as the contingency develops.

We will refer to an individual or a suborganization appearing in the depiction of a C2 organizational structure as a *C2 element*. Each C2 element in a concept is generally staffed with experienced personnel who support and advise the element commander or otherwise monitor, assess, plan, or execute operations. These personnel help their commander make informed decisions and develop specific air asset tasking products. The direct staffs also act as the commanders' subject-matter experts within their areas of functional expertise and recommend courses of action, given the mission and available resources. They are also liaisons, managing the flow of information to and from the commander and determine its accuracy, filtering out any unnecessary information. Other staff, such as in the JAOC, monitor, assess, plan, or execute operations. All can rely on reachback to subordinate organizations, which is critical to keep dedicated staffing levels reasonable.

We took several steps to determine the numbers of staff per concept and scenario. We began by developing an understanding of each staffing position's responsibilities based on JPs and AFIs.[8] We then formulated a baseline number of staff for a given C2 concept–scenario pairing from an understanding of personnel responsibilities, adding to compensate for 24-hour operations. For example, a major war, which we assumed to be more intense than an HA/DR operation, requires more staff. These values do not include the personnel potentially required from allies or partners, other representatives of U.S. government organizations and sister services, or other Air Force organizations that would provide reachback support services to each element's direct staff.

Evaluating Performance Metrics

As discussed in Chapter 1, C2 organizations contribute to the success of operational outcomes. But in the literature reviews for this research, we found methods of quantitatively assessing the contributions of human decisionmaking in C2 organizations to operational outcomes to be elusive. One journal article concludes that "[w]hatever contribution C2 may make is generally masked by the contribution made by other component systems . . . . While no solutions have been offered as a way around this . . . the approach taken by the behavioral or soft sciences may warrant investigation."[9] In 2010, a group of researchers concluded that M&S

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[8] A key source of information for the resource metric evaluation was the Pacific Air Force Forces Supplement to AFI 13-103, *Pacific Air Force Forces Supplement: Command and Control, AFFOR Staff Operations, Readiness and Structures*, May 1, 2015.

[9] Noel Sproles, "The Difficult Problem of Establishing Measures of Effectiveness for Command and Control: A Systems Engineering Perspective," *Systems Engineering*, Vol. 4, No. 2, 2001, p. 154.

techniques for assessing C2 based on force outcomes remain elusive because the C2 "ontology is not yet sufficiently developed."[10] However, it is important to distinguish between the performance of forces in meeting the objectives of an operation and the efficiency and effectiveness of C2 organizations for enabling success in that operation. For these reasons, our research applied measures of efficiency and effectiveness from organizational theory to the comparison of C2 concept performance in a given operational scenario.

It is fundamental to modern Air Force doctrine that C2 and organization "are inextricably linked."[11] Traditionally, the literature on organizational theory depicts the C2 concept within an organization as a tree or pyramid, with the chief executive or commander at the apex.[12] More recent works recognize that organizations are also social networks with informal lines of reporting and peer-to-peer collaboration.[13] In this section, we look at traditional and modern metrics in relation to the standard "boxes-and-lines" organizational chart to understand how the structural dimensions of a C2 concept may enhance or impede its performance.[14]

A handful of metrics can provide useful insights into the potential advantages and disadvantages of C2 concepts, which we introduce in the next section. As to which particular values of these metrics are best, however, the answer is all too often, "it depends."[15] Structural metrics like these are likely therefore best viewed as warning flags rather than simple objectives for optimization. The idea is not necessarily that a given C2 concept should score "well" on any particular metric but that this structure should not deviate too far from accepted norms without an intelligible reason.

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[10] Davison and Pogel, 2010, p. 4.

[11] Air Force Doctrine Annex 3-30, *Command and Control*, Washington, D.C.: Headquarters U.S. Air Force, November 7, 2014.

[12] Henry Mintzberg, *The Structuring of Organizations*, Englewood Cliffs, N.J.: Prentice Hall, 1979.

[13] Ricky W. Griffin and Gregory Moorhead, *Organizational Behavior*, 10th ed., Boston: Cengage Learning, 2011.

[14] There is no agreement in the literature as to the distinction between *metrics* and *measures*. In this chapter, we use particular convention in which metrics are indicators that can be directly observed, while measures are broader indicators derived from interpretations of one or metrics. See John Cugini, Laurie Damianos, Lynette Hirschman, Robyn Kozierok, Jeff Kurtz, Sharon Laskowski, and Jean Scholtz, *Methodology for Evaluation of Collaboration Systems*, Evaluation Working Group, DARPA Intelligent Collaboration and Visualization Program, April 12, 1999.

[15] There is similarly a lengthy debate over the taxonomy of organizational structures, which we do not delve into here. A useful recent summary of these issues may be found in Don Snyder, Bernard Fox, Kristin F. Lynch, Raymond E. Conley, John A. Ausink, Laura Werber, William Shelton, Sarah A. Nowak, Michael R. Thirtle, and Albert A. Robbert, *Assessment of the Air Force Materiel Command Reorganization: Report for Congress*, Santa Monica, Calif.: RAND Corporation, RR-389-AF, 2013.

Span of Control

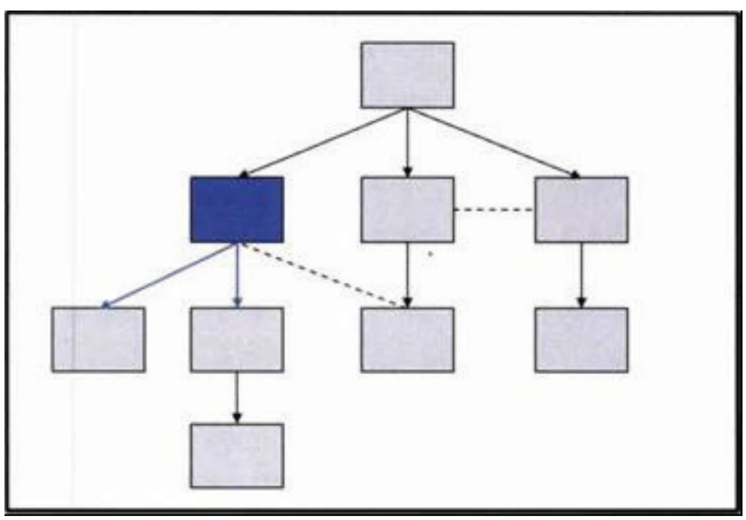
Twenty-five years ago, the concept of a commander's span of control was mentioned sparingly in service doctrines and nowhere in formal JPs.[16] JP 1 lists this concept as one of the four key organizational principles to consider when designing joint C2 structures.[17] Span of control is also discussed specifically in the JP concerning C2 for joint air operations.[18] These publications do not provide a particular mathematical definition for this metric, however, noting only that

> [s]pan of control is based on the number of subordinates, number of activities, range of weapon systems, force capabilities, and the size and complexity of the operational area.[19]

In this report, we adopt the standard definition from modern organizational theory that a commander's span of control is simply the number of people (or organizational heads) that directly report to him or her. This is also sometimes expressed as a ratio of supervisors to subordinates. We consider the other attributes mentioned above—resources and operational areas, which are also important to performance—elsewhere in this report.

Figure 2.1 shows an example of the span of control metric for the notional C2 concept. Here, the span of control of the blue-highlighted commander is two, because two organizations

Figure 2.1. Span of Control



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[16] William G. Pierce, "Span of Control and the Operational Commander: Is It More Than Just a Number?" Fort Leavenworth, Kan.: U.S. Army Command and General Staff College, School of Advanced Military Studies, January 5, 1991.

[17] The other three principles are simplicity, interoperability, and unit integrity. See JP 1, 2013.

[18] JP 3-30, 2014.

[19] JP 3-30, 2014.

report directly to him or her. Other commanders in this structure would have different values for their spans of control (ranging from one to three in this simple example). Note that neither the dashed lines nor the second-level subordinates (the subordinate of a subordinate) count toward the span of control. Note also that we refer here to OPCON or TACON, but not to administrative control. The concept is technically applicable to administrative control, but almost all examples in the literature deal with span of control in terms of the structure of the decisionmaking processes.

Span of control is a useful metric because it is easy to describe and because the implications of extreme values are often intuitive. If the span of control is too narrow, the C2 concept may be inefficient because the structure is "top heavy" with managers. On the other hand, if the span of control is too wide, the concept may be ineffective because a single person is being asked to manage too much at once. We discuss what values may characterize "too narrow" and "too wide" in the section on performance later in this chapter.

Empirically, the span of control has been found to vary at different levels of the organization. In her seminal work on the subject, Woodward found the span of control of chief executive officers to have a median of six, while the span at the lowest levels was often 30 or more.[20] At the upper levels, however—which are the most relevant to the analysis of C2 concepts—the average span of control is more constant. From the 1980s through 2000s, chief executive officers typically had spans of control that varied more widely, from five to ten, but the trend today is that supervisors, "typically consolidate direct reports to six or so."[21] A recent overview of The Coca-Cola Company, which claims nearly 100,000 employees worldwide, reported spans of control between six and eight at the upper echelons.[22] A summary of the organizational structures of U.S. state and local government agencies found that the span of control ranged largely between five and 13, with the most common values being between six and seven.[23]

Other metrics may be built out of the span of control metric by considering the distribution of spans of control across the entire organization. The most commonly discussed span-of-control metric, in fact, is the average span of control for all supervisors in the concept. (Note that, in this measure, only those who actually have people reporting directly to them are usually included in the average.) So in Figure 2.1, for example, there are five commanders with subordinates who report to them directly. The distribution of spans of control is (1, 1, 1, 2, 3), giving an average of 1.6 and a standard deviation for the population of 0.8. Note that the average value of this notional structure is very low compared to the norm.

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[20] Joan Woodward, *Industrial Organization: Theory and Practice*, Oxford, U.K.: Oxford University Press, 1965.

[21] Gary L. Neilson and Julie Wulf, "How Many Direct Reports?" *Harvard Business Review*, April 2012.

[22] Vicky Narayan, "Organizational Structure of The Coca-Cola Company," 2010.

[23] Jennifer Glazer-Moon, "FY 2010 Span of Control Analysis," Miami-Dade County: Office of Strategic Business Management, September 21, 2010.

The total span of control is also sometimes defined to describe a larger slice of the hierarchy. This metric counts subordinates, not only direct reports but second-level subordinates and so on—everyone in the structure who ultimately falls under the purview of a given commander, whether directly or through an intermediary. In Figure 2.1, for example, the total span of control of the blue-highlighted commander is three, while the total span of control of the commander at the apex is eight.

Height

Unlike the span of control, which may vary across an organization, the height of a C2 concept is a property of the organization as a whole. The height is simply the maximum number of echelons in the hierarchy—the longest chain from top to bottom in the C2 structure. In Figure 2.1, the height is four. Note that the average length of the chain may vary, but it is standard practice to take the maximum.[24] (So, in Figure 2.1, the height is four even though there is only one branch with four elements and the characteristic length of the command chain is only three.)

This statistic varies among similarly sized organizations, although within a narrower range than the span of control. One study of companies of between 200 and 4,000 employees found an average height of 6.1 ±1.2.[25] Generally speaking, of course, for organizations of the same size, the height and span of control must be inversely related: Tall implies narrow, and flat implies wide. Indeed, if the span of control is identical at each echelon, the relationship between this average span of control (<S>), the height (*h*), and the total number of personnel (*n*) is given directly by the following:[26]

$$n = \frac{\langle S \rangle^{h} - 1}{\langle S \rangle - 1}.$$

Because the height metric is simple, there have been various attempts to generalize it or combine it with the span of control to build more-complicated measures. One approach is to describe where the organizational structure falls between the most extreme cases of height possible. These two extremes are illustrated in Figure 2.2. If the organizational structure is purely hierarchical, the result is the maximally tall tower shown on the left, in which everyone (except the lowest) has exactly one subordinate. If the organizational structure is such that all subordinates report directly to the commander without intermediaries, the result is the "flat" diagram shown on the right.

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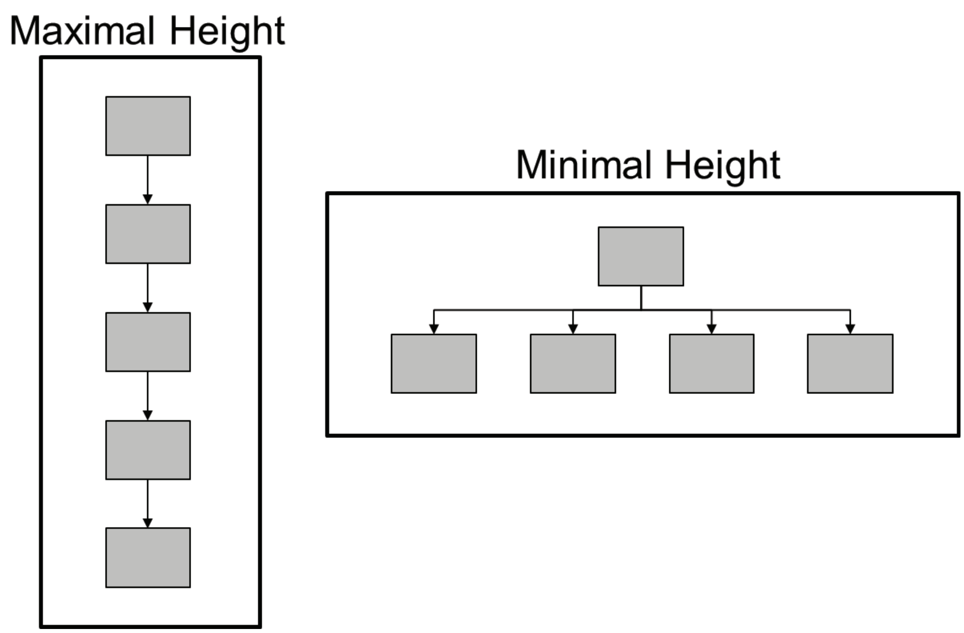
[24] Mintzberg, 1979.

[25] Bernard C. Reimann, "On the Dimensions of Bureaucratic Structure: An Empirical Reappraisal," *Administrative Science Quarterly*, Vol. 18, No. 4, December 1973.

[26] The number of personnel will be lower if there is significant deviation from the norm.

Figure 2.2. Height Variation



An example of such a metric is the hierarchical control index or structural control intensity (SCI).[27] For the maximal height tower on the left of Figure 2.2, the SCI would be 1; for the minimal height case on the right, it would be 0. (Note that this holds no matter how many entities are involved, which is the purpose of this formulation.) For comparison, the C2 concept shown in Figure 2.1 scores a value of 0.21 on this particular index. The main factor in the SCI is the *sum* of the *total* spans of control of all members, C:

$$SCI = \frac{C - C_{min}}{C_{max} - C_{min}}.$$

The minimal and maximal cases are included in the numerator and denominator to ensure that the SCI varies from 0 to 1. For the nine entities in Figure 2.1, $C_{max} = n(n-1)/2 = 36$; $C_{min} = (n-1) = 8$; and $C = 14$. Thus, the SCI is 0.214.[28]

Despite the potential appeal of such combined metrics, however, their analytic value remains unproven. One study that attempted to apply this particular index to a range of actual companies found it was useful as a descriptive measure of what they termed “administrative density” or “top-heaviness” but found no clear correlation between the SCI and the amount of decentralized decisionmaking within the organization, which is of particular importance to understanding military operations.[29]

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[27] See Yitzhak Samuel and Bilha F. Mannheim, “A Multi-Dimensional Approach Toward a Typology of Bureaucracy,” *Administrative Science Quarterly*, Vol. 15, No. 2, June 1970.

[28] For the derivation, see Samuel, 1970.

[29] Reimann, 1973.

Connectivity

The final category of metrics considers the C2 concept as a network and looks at connectivity. Unlike previous categories, this one attempts to incorporate some of the indirect reporting relationships in these structures because, in modern organizational theory, whether someone falls within a commander's total span of control is not always a binary question. As Mintzberg put it,

> Who should be counted as a subordinate. . . those whose work is reviewed by the manager even though they do not formally report to him? What about the nonsupervisory aspects . . . collecting information, developing liaison contacts. . . . Control—that is, direct supervision—is only one factor among many in deciding how many positions to group into one unit, or how many units to group in one larger unit, in both cases under a single manager.[30]

Network-related metrics are also an attempt to account for the reality that "[a]ctual communication patterns are quite different from the reporting relationships shown on the organizational chart."[31] Indeed, where communications are unrestricted, all units within a C2 concept are likely to be connected to one another in some way.

For our purposes, when we say that a C2 concept has a higher degree of connectedness, what we mean is that there are more instances in which commanders within the concept are connected to one another through formal and informal reporting relationships by multiple paths. The analysis here is somewhat similar to looking at connectivity in communications networks, except that unlike communications networks, where we are often concerned with assuring a high degree of redundancy, in a C2 concept, we may seek instead to eliminate it.

One approach to measuring the connectivity of a C2 concept is to consider the maximum number of reporting links, direct or indirect, that could be removed from the structure before it would be split into two or more disconnected parts.[32] In the notional C2 concept in Figure 2.1, for example, this number would be two. (Note that the minimum number required to break the structure, while often used for communications network analysis, is not as interesting for C2 concepts because, in every case presented so far, that number would be one.) Unfortunately, however, this simple metric alone does not rescale with the size of the structure, which makes comparisons between structures of dissimilar size opaque.

Another option is to consider the organizational diagram as analogous to a road network. The link-to-node ratio is the most common metric used in this case.[33] By this metric, both structures

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[30] Mintzberg, 1979.

[31] Griffin and Moorhead, 2011.

[32] Adapted from Gregory S. Hornsby, "Modularity, Reuse, and Hierarchy: Measuring Complexity by Measuring Structure and Organization," *Complexity*, Vol. 13, No. 2, December 2007.

[33] For example, see Wesley E. Marshall and Norman W. Garrick, "The Effect of Street Network Design on Walking and Biking," in *Proceedings of the 89th Annual Meeting of Transportation Research Board*, Washington D.C., January 2010.

in Figure 2.2 would rate 0.8, while the structure in Figure 2.1 would rate 1.1. However, some analysts specifically caution against using this metric for C2 concepts because "the link-to- node ratio metric cannot discriminate between alternative network organizations that have the same numbers of nodes and links but differ in their arrangement. The mere counting of a link does not account for its significance."[34] (Far-more-complicated metrics have also been proposed to measure network connectivity but are designed to analyze much larger networks and go far beyond our needs here.[35])

Instead, we have borrowed the approach of the SCI metric mentioned in the previous section and measure the connectivity of a C2 concept by comparing the actual number of direct and indirect reporting links (C) between all members in the structure with the maximum and minimum number of connections possible. The connectivity index (CI) is thus as follows:[36]

$$CI = \frac{C - C_{min}}{C_{max} - C_{min}}.$$

The utility of this metric may be understood by comparing the results to the previous case. Even though the two canonical organizational structures depicted in Figure 2.2 could not be more different in shape, they both have CI = 0, because they are both simply connected. The more complicated C2 concept shown in Figure 2.1, however, has a few additional indirect connections, and therefore scores CI = 0.07. Interestingly, there is more than just a formulaic resemblance to the SCI mentioned in the previous section in this definition we propose: here, C_{max} and C_{min} prove to be precisely the same mathematical quantities as in the SCI (see previous footnote) but they are derived in completely different ways.[37] This suggests a deeper connection between the two metrics. Most important, however, is that the CI captures in a normalized way the third element of the C2 concept—informal reporting and peer-to-peer relationships—that the height and span of control do not.[38]

The means and robustness of communications between members are important topics in an evaluation of military C2 but were beyond the scope of this research. Other related metrics that

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[34] T. J. Grant, *Network Topology in Command and Control: Organization, Operation, and Evolution*, IGI Global, May 31, 2014.

[35] For example, see the Perron-Frobeneius Eigenvalue introduced by Sanjay Jain and Sandeep Krishna, "Graph Theory and the Evolution of Autocatalytic Networks," in S. Bornholdt and H. G. Schuster, eds., *Handbook of Graphs and Networks: From the Genome to the Internet*, Berlin: Wiley, 2003, pp. 355–395. These were applied to the military C2 context by Jeffrey R. Cares, *Distributed Networked Operations: The Foundations of Network Centric Warfare*, New York: iUniverse, 2005.

[36] Note that the connectivity index figures reported in the executive summary, Chapter 4, and Chapter 5 have been multiplied by ten so that they are represented on a scale of 0–100.

[37] The sum of total spans of control is not identical to the actual number of connections, only the maximum and minimum values of those quantities are the same. In other words, C_{max} and C_{min} are the same, but C is not.

[38] It is also quite similar (although not identical) to the clustering coefficient (see Cares, 2005).

may be useful but that we did not evaluate involve degrees of separation and reachability between members. Examples of these can be found in prior research.[39]

Optimality

Fifty years ago, management scientists and efficiency experts widely believed that there was an optimal height and span of control for all organizations. This is no longer the case.[40] Optimal values for these metrics are now believed to vary with the type and purpose of the organization,[41] and one size does not fit all. The fundamental Air Force doctrinal tenet of "centralized command with decentralized execution" is clearly broad enough to encompass a wide range of C2 concepts; in this context, the JP on C2 for joint air operations explicitly states that

> [t]he C2 system for joint air operations will vary depending on the operational area and specific missions. Given the flexibility of modern C2 capabilities, geographic considerations have less of an impact on organizational structure today than in the past. The entire C2 system may be spread across the operational area or concentrated in a specific location, either in close proximity to the fight or far from it. *Ultimately, there is no standard template for C2 design*.[42]

Nevertheless, there are still norms for the span of control for analogous organizations that are useful to consider. The U.S. Army, for example, holds that "[p]lanners should not exceed the allocated HQ span of control. Generally, an HQ controls at least two subordinate maneuver units, but not more than five."[43] The U.S. Marine Corps writes that, "[a]lthough a reasonable span of control varies with the situation, as a rule of thumb an individual can effectively command at least three and as many as seven subordinates. Within this situation-dependent range, a greater number means greater flexibility."[44] Similarly, the Department of Homeland Security has established the standard Incident Command System (ICS), which emphasizes maintaining a span of control in the same range:

> Span of control is key to effective and efficient incident management. Supervisors must be able to adequately supervise and control their subordinates, as well as communicate with and manage all resources under their supervision. . . . In ICS, the span of control of any individual with incident

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[39] See Dan Gonzales, Michael Johnson, Jimmie McEver, Dennis Leedom, Gina Kingston, and Michael S. Tseng, *Network-Centric Operations Case Study: The Stryker Brigade Combat Team*, Santa Monica, Calif.: RAND Corporation, MG-267-1-OSD, 2005.

[40] Mintzberg, 1979.

[41] Griffin and Moorhead, 2011.

[42] JP 3-30, 2014, emphasis added.

[43] Field Manual 101-5, *Staff Organization and Operations*, Washington, D.C.: Headquarters, Department of the Army, May 31, 1997.

[44] Marine Corps Doctrinal Publication 6, *Command and Control*, Department of the Navy, October 4, 1996.

> management supervisory responsibility should range from 3 to 7 subordinates, with 5 being optimal.[45]

The ICS also notes that "[t]he use of Task Forces and Strike Teams is encouraged . . . to optimize the use of resources, *reduce the span of control* over a large number of single resources, and reduce the complexity of incident management coordination and communications"[46] and that

> Area Commands are particularly relevant to incidents that . . . are geographically dispersed, and evolve over longer periods of time . . . [or] when a number of incidents of the same type in the same area are competing for the same resources, such as multiple hazardous material incidents, spills, or fires.[47]

So for the average span of control, then, it appears that a range of three to seven (average of five) is usually recommended for military and police organizations. Also, as indicated in the earlier section, this is also fairly typical of midsized organizations, if slightly narrower than in the business world. Interestingly, this is not inconsistent with the estimates 50 years ago that five to six subordinates with interlocking work was the maximum size that admitted of effective management.[48]

As for the height of a C2 concept, we found no clear preference other than that it not be too dissimilar from the norms shown earlier and that it be consistent with the desired average span of control. Anywhere between four and six is thus reasonable for a midsized organization of the types we are considering. Unfortunately, we identified no literature on the preferred value of connectivity commercial enterprises or military C2 concepts, so this remains a descriptive, rather than normative, statistic for our purposes. The only clear suggestion is that some degree of greater connectedness than a simple tree is now preferred, so the CI should be at least somewhat greater than zero.

Evaluating Risk and Resiliency Metrics

In broad terms, the C2 risk and resiliency methodology that we developed is an adaptation of an existing methodology, assumption-based planning (ABP), that RAND originally developed for the U.S. Army in the 1990s as a means of identifying weaknesses in an existing strategic plan so that the plan could be made more robust.[49] It is a deliberative framework for identifying the underlying assumptions of an existing plan, assessing their weaknesses, and developing actions

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[45] Department of Homeland Security, *National Incident Management System*, December 2008, p. 47. The document also notes that "During a large-scale law enforcement operation, 8 to 10 subordinates may be optimal" (DHS, 2008, p. 47).

[46] DHS, 2008, p. 55, emphasis added.

[47] DHS, 2008, p. 62.

[48] For example, see Lyndall F. Urwick, "The Manager's Span of Control," *Harvard Business Review*, Vol. 34, No. 3, May–June 1956.

[49] James A. Dewar, *Assumption-Based Planning: A Tool for Reducing Avoidable Surprises*, Cambridge, U.K.: Cambridge University Press, 2002.

to make them more robust. It has similarities to the risk identification and mitigation processes for operational planning that are described in JP 5-0 and requires planners to periodically reassess assumptions and develop courses of action, branches, and sequels based on the assessment. For the purposes of our research, we applied this methodology in a TTX format and incorporated concepts from retrospective futurology.[50] To adapt ABP to C2 risk and resiliency, we treated the C2 concepts as "plans" for C2 of operations in a given scenario. One objective for the TTX was to compare and contrast the risk and resiliency of alternative C2 concepts for a given scenario while keeping performance in terms of operational outcomes fixed.[51] For this reason, TTX participants were presented with each operational scenario as if it had already occurred. That is, the individual missions conducted as part of the operation were presented in past tense, with the understanding that whichever C2 concept was employed was capable of enabling success of each individual mission and therefore the operation. Rather than plan operations, participants were guided through the details of each individual mission and asked to identify the underlying C2 assumptions that must have held for success. In this regard, the TTX is described as having a retrospective futurology format.

Akin to the ABP method, which has five methodological steps, our C2 risk-and-resiliency (C2R2) TTX methodology also walks the players through five interdependent steps (Figure 2.3). As a preliminary, the candidate C2 concepts are described to the TTX participants after the scenario has been described. Some participant discussion of the pros and cons of each C2 concept is useful but is not the basis for the results of the TTX. Instead, such discussion is used as preparation for identifying risks and resiliency.[52]

The first step, after reviewing the concept under discussion, is identifying all assumptions that undergird the effective operations of that concept. According to Dewar, an *assumption* is "an assertion about some characteristic of the future that underlies the current operations or plans of an organization."[53] Assumption identification can be difficult because it depends on the ability to uncover both explicit and implicit assumptions. In this step, players identify what are referred to as *load-bearing assumptions*, that is, the assumptions on which a critical function of the C2 concept under discussion rests.

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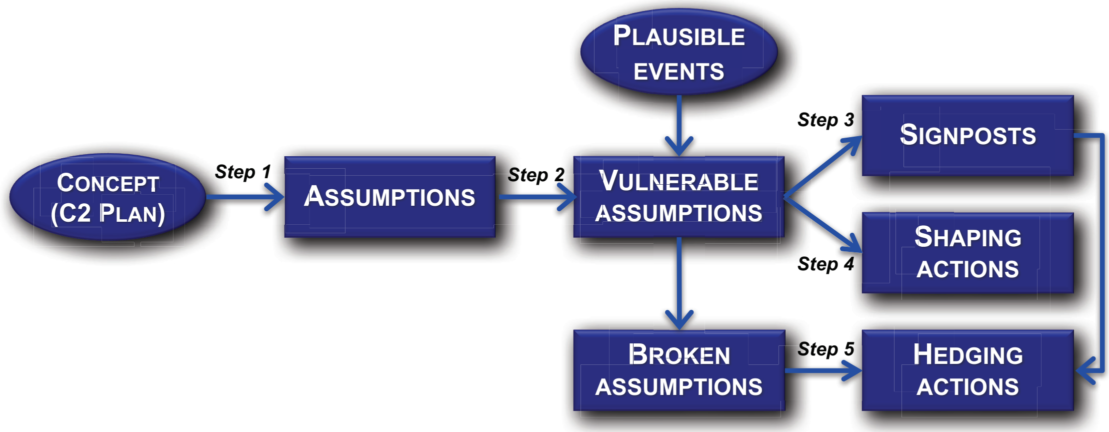
[50] To clarify, the sole purpose of the TTX and its "retrospective futurology" approach was to assess risk and resiliency not to assess performance.

[51] As discussed earlier, there is an important distinction between the performance of an operation, which could be assessed in terms of operational objectives being met, and the performance of the underlying C2, which could be measured in terms of efficiency and effectiveness of the C2 actions that enable operations.

[52] We briefed the TTX facilitators and participants on types of biases that could affect results and the methods for mitigating them.

[53] Dewar, 2002, p. 5.

Figure 2.3. The Five Steps of the C2 Risk-and-Resiliency Tabletop Exercise Methodology as Adapted from ABP



SOURCE: Based on Dewar, 2002.

The second step is to refine the load-bearing assumptions identified in the first step and determine which would be classified as vulnerable. According to the ABP methodology, a *vulnerable assumption* is one that could fail owing to plausible events within the time horizon of the plan.

The third step determines how to measure whether or not these events will come to pass—that is, having identified which assumptions are vulnerable, we next determine how vulnerable they are. *Signposts*, in the ABP schema, are "indicators, or warning signals, that the vulnerability of an assumption may be changing."[54] Pursuant to the retrospective futurology characteristic of the TTX methodology, identifying these signposts depends on a sober assessment of the most likely things to have happened in that past scenario to which the C2 concept has been applied. This is facilitated by the "events" within each scenario that give the players a sense of the temporal distance between operational milestones.

Working from the signposts identified in the third step, the fourth step identifies *shaping actions* that enable a player to "control the vulnerability of an important assumption."[55] This is another way to assess the strength of an assumption. In some cases, the vulnerability of certain identified assumptions cannot be controlled, and these end up as *broken assumptions*.

For assumptions that have broken, the fifth identifies *hedging actions* to assesses whether there is a way around the failure. Steps four and five combine to provide an assessment of the resiliency of the C2 concept.

It is important to note that ABP is traditionally a forward-looking methodology, applied to assess the strengths and weaknesses of future plans. For this TTX, RAND applied it in reverse. To weigh the strengths and weaknesses of the two C2 concepts, the participants seek to

[54] Dewar, 2002, p. 25.

[55] Dewar, 2002, p. 31.

determine the things that had to have happened for operational milestones to have been reached. This obviated the all-but-inevitable "scenario fighting" that occurs during war games and TTXs, and also allowed for some valuable creative freedom.

Assessing the Relative Importance of Risks

After using the C2R2 TTX methodology to identify risks and their associated resiliency measures, it was helpful to come to consensus about the order of importance of the risks. As distinct from identifying differences among physical measurements of things, such as the relative loudness of sound from several sources measured in decibels, the law of comparative judgment was used for comparing perceptions of abstract concepts. For example, given a set of identified moral values, what is their relative importance for guiding human behavior? In this case, we wished to identify the relative importance of risks associated with a selection of C2 concepts in a selection of scenarios.

The essential process used to assess the relative importance of the risks followed the paired comparison method first outlined in 1927.[56] In this method, judgments are made on the relative importance of each pair of risks. The tasks of judging all pairs of risks can be daunting, as the number of pairs grows rapidly with the number of risks (e.g., with 14 risks, there are 91 pairs to judge). To reduce the burden of judging pairs, the total number of judgments required was divided among the TTX participants so that each pair of risks is judged by at least one participant. We elicited the judgments from participants in writing after the conclusion of the TTX.

The result is a ranking of the most important risks. We used an online comparative judgment engine to generate the importance scores.[57] A guide for using the engine for mathematics assessments is available,[58] along with a guide for administering the application (Wheadon, 2016).[59]

Evaluating Versatility Metrics

In this section, we explore the versatility or applicability of a given C2 concept to a range of scenarios. Versatility is based on assessments of the other metric categories of performance, resources, risk, and resiliency.

As mentioned earlier, GCC commanders may find themselves facing a broad range of possible scenarios. Understanding the extensibility of a given C2 concept across a broad range of

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[56] L. L. Thurstone, "A Law of Comparative Judgment," *Psychological Review*, Vol. 34, 1927.

[57] See No More Marking, website, 2017.

[58] Ian Jones and Matthew Inglis, *Comparative Judgement for Mathematics Assessment*, NoMoreMarking Ltd., undated.

[59] Chris Wheadon, *No More Marking: The Guide*, NoMoreMarking Ltd., March 22, 2016.

scenarios is important, given today's tight budgets and fixed resource pool for manning, training, and exercises. Commanders cannot tailor each C2 concept for each possible scenario; this is simply not practical. Perhaps it is more useful to ask to what other scenarios a given C2 concept is well suited and why.

An important means of measuring a given C2 concept's versatility is to examine the same metrics across a broader range of scenarios. We did not intent to analyze this extensively here, but rather to demonstrate a way to compare and contrast alternative C2 concepts and to present an approach for thinking about the problem. Thus, in Chapter 3, we take a narrower look at two C2 concepts and present a method to extend our approach for considering alternative scenarios.

Conclusions

Our research approach included a literature review of C2 concepts that the U.S. Air Force has recently examined, the JP 5-0 planning process, possible Pacific theater scenarios that need C2 of joint air forces, and M&S tools that explore C3 relationships and processes. Based on this effort, we convened a two-day C2 workshop in which a list of C2 metrics were distilled into three categories for evaluating C2 concepts: risk, resources, and performance. Further research added two metrics—resiliency and versatility.

The chapter described how we evaluated the five metrics for comparing and contrasting alternative C2 concepts. Evaluating the manning resources leverages JPs and AFIs for C2. Performance metrics include span-of-control, height, and connectivity index metrics from organizational theory. To evaluate risk and resiliency for different C2 concepts, we developed the C2R2 TTX methodology, which we adapted from ABP. Finally, to understand the versatility of each candidate C2 concept, we evaluated the previous four metrics across a broad set of scenarios.

In the next chapter, we apply these approaches to comparing and contrasting two C2 concepts in the context of an HA/DR operation and major war scenario.

3. How Do Recently Proposed Command-and-Control Concepts Compare and Contrast in Relevant Pacific Scenarios?

C2 Concepts and How We Selected Them

In the first, or "baseline," concept, the GCC commander is the operational lead for the joint operation. That is, the USPACOM commander is the JFC. The GCC maintains operational oversight of theater-level JFACC, theater-level JFMCC, and theater-level JFSOCC. For joint air operations, the GCC depends on the TJFACC to execute the joint air component of the mission. The TJFACC is dual-hatted as the commander, Air Force forces (COMAFFOR). We developed this C2 concept in collaboration with the research sponsor, and the concept is representative of concepts that may be used in operations today. It was represented graphically in Figure 1.1. The JFACC, JFMCC, and JFSOCC each have a JACCE, staffed by personnel from the TJFACC. The JACCE represents the TJFACC for the purposes of coordinating cross-domain efforts. This is a more centralized organizational concept than the alternative, which we describe next.

The second concept has almost twice as many nodes as the baseline. In this concept, the GCC designates one or more JTF commanders, who each have their own components for the operation, including a JTF-subordinate JFACC. This is a more dispersed organizational concept. Concepts similar to this have been used in many recent operations, including the wars in Iraq and Afghanistan, and for HA/DR operations in the Pacific and elsewhere. The concept was represented graphically in Figure 1.2. As in the baseline C2 concept, each of the components under the JTF has a JACCE, which consists of personnel provided by the TJFACC, but whose role is coordination between the JTF-subordinate JFACC and the other JTF components.

Scenarios and How We Selected Them

The scenarios provide an operational context for comparing and contrasting alternative C2 concepts in terms of the five metric categories we established in Chapter 2: resources, performance, risk, resiliency, and versatility. The scenarios are especially useful for the C2R2 TTX methodology developed and applied in this research project.

The guidance from the PACAF sponsor was to select scenarios that are set in the Pacific theater, set them in a near-term time frame (no later than 2020), and emphasize joint operations (as opposed to coalition). This would help ensure that the results are relevant to the sponsor and complementary with other efforts that are examining operational C2 for bilateral or coalition operations. There was also a desire to have the scenarios collectively span multiple phases of conflict, in case the phases made important differences, and to incorporate multiple theater concerns into the scenarios for realism.

We researched scenarios that have recently been examined at TTXs and CPXs, many of them conducted by PACAF and USPACOM. We developed a list of potential C2 stressors and characterized each candidate scenario in terms of the stressors based on our judgment. C2 stressors included such things as center of gravity, geographic dispersion, and likelihood of escalation to include major combat operations. The rows of Table 3.1 correspond to C2 stressors, and the columns correspond to the candidate scenarios.

We estimated that we had the resources and time available to assess the metrics for two concepts in two different scenarios and so had to select only two. The U.S. military has not engaged in Phase II or Phase III operations with a near peer since World War II, so there is no historical information on modern C2 concepts in such conflicts. As a substitute, we selected the Unified Engagement scenario. While other scenarios involve these types of operations and competitor, we had participated in Unified Engagement and had ready access to the details of the scenario.

For the second scenario, we decided to choose the Philippine HA/DR scenario to have sharp contrast in C2 stressors with the Unified Engagement scenario. Another rationale for the choice is that PACAF and USPACOM have conducted and supported many HA/DR operations in

Table 3.1. Candidate Scenarios and C2 Stressors

C2 Stressor	Phase I: Homeland Defense	Phase I: Shipping Lanes	Phase II/III: Unified Engagement	Phase II/III: Philippine Counter-insurgency	Phase IV: Thailand Security Force Assistance	Phase IV: Timor Peacekeeping	Phase V: Philippine HA/DR
Center of gravity	Military forces	Irregular forces	Military forces	Population	Population	Population	Population
Force size	Small	Medium	Large	Medium	Medium	Medium	Large
Joint or interagency	Joint	Joint	Joint	Joint	Joint	Joint	Interagency
Geographic dispersion	Wide dispersion	Mostly grouped	Wide dispersion	Mostly grouped	Medium dispersion	Mostly grouped	Wide dispersion
Reaction time	Rapid	Moderate	Rapid	Moderate	Slow	Slow	Moderate
Combatant command info requirements	Immediate	Daily	Immediate	Daily	As required	As required	Daily
Force dissimilarity	Largely dissimilar	Mostly similar	Largely dissimilar	Mostly similar	Mostly similar	Mostly similar	Widely varied
Implementation time	Short	Medium	Short	Medium	Medium	Medium	Short
Permissive environment	Yes	Yes	No	No	Mixed	Mixed	Yes
Logistics security	Yes	No	No	No	Mixed	Mixed	Yes
Mission vulnerable to failure	Yes	No	Yes	Yes	Yes	No	No
Likelihood of major combat operations	Yes	No	Yes	No	No	No	No

recent years, and so this type of scenario is highly relevant. We drew on historical information from these operations in the development of our scenario.[1] Our research team included a licensed medical doctor with research experience in HA/DR, and we leveraged her experience to incorporate details on the ways in which the U.S. military would need to interact with host-nation emergency services for C2 of the HA/DR operation. The next two paragraphs summarize each scenario.

The first scenario was a major war in the Pacific, which was based on the scenario used in Unified Engagement 2014.[2] In this scenario, a state actor uses military force to seize control of a contested island that is occupied by another nation, with the objective of expanding sovereignty in the region. The U.S. objectives are to deter further aggression and to restore control of the island so that the dispute over it can be resolved peacefully. There are horizontal and vertical escalations, and the scenario evolves to a fast-moving campaign involving Phase 0, I, II, and III operations. The conflict primarily involves air and naval forces, as well as some land forces for amphibious assault of disputed islands and for force protection. When we evaluated the C2 concept for a JTF-led operation in this scenario, we assumed that there would be two JTFs: one geographically focused on the south and led by the Navy and the other geographically focused on the north and led by the Air Force. Each JTF had its own components. The center of gravity for the conflict was in the south, and the commander of the JTF based in the southern portion of the operational area was the supported commander for operations that crossed geographic boundaries.[3]

The second scenario was an HA/DR operation. In this scenario, a magnitude 9.0 earthquake struck the Philippines and created a tsunami that caused extensive land damage to the island archipelago. The U.S. objectives were to enable relief operations to mitigate further loss of life, minimize additional suffering, and reduce the scope of the disaster. To meet these objectives, the USPACOM commander and the U.S. ambassador to the Philippines coordinated to deliver humanitarian assistance in support of the U.S. Agency for International Development (USAID) and the Office of Foreign Development Aid. In addition, and as required, the commander was to provide military-to-military support to the Armed Forces of the Philippines. The U.S. military assisted with seven major tasks during the operation: (1) situation assessment, (2) search and rescue, (3) transportation of personnel and supplies, (4) medical care, (5) water purification, (6) reestablishing communications, and (7) repair and reconstruction of roads and bridges. As is typical in HA/DR operations, the U.S. military was engaged for roughly one month. The scenario

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[1] See Appendix A for historical information on C2 in past operations, including HA/DR operations.

[2] U.S. Air Force, Headquarters, A5SW, "Unified Engagement 14: Wargame Report," October 2015, Not available to the general public; U.S. Air Force, "Unified Engagement," briefing, undated.

[3] This scenario is described in more detail in a separate appendix volume (Brien Alkire, Sherrill Lingel, Caroline Baxter, Christopher Carson, Christine Chen, David Gordon, Lawrence M. Hanser, Lance Menthe, and Daniel M. Romano, *Command and Control of Joint Air Operations in the Pacific: Appendix C, Major War Scenario*, Santa Monica, Calif.: RAND Corporation, forthcoming, Not available to the general public).

involved air and naval forces for transport of personnel and supplies and land and special operations forces (SOF) for force protection. When we evaluated the C2 concept for a JTF-led operation for this scenario, we assumed just one JTF that is based in the Philippines.[4]

How Resources Compare and Contrast

In this section, we evaluate manning resources needed for the two C2 concepts for two scenarios: HA/DR and a major war. In the Pacific theater, the GCC (PACOM commander) may choose to be the JFC, and we assume that this individual is a Navy warfighter and that the deputy GCC commander is an airman. However, if the GCC commander were an Air Force officer, the JFC staff would likely have a large representation of airmen.

The two C2 cases we examined are the GCC-led and JTF-led concepts. Both cases have a TJFACC who handles the employment of joint airpower at the theater level. However, in the second case, the JTF is supported by a JFACC for his or her JOA, and the TJFACC then focuses on everything outside the JOA. In the second concept, the JTF-subordinate JFACC communicates with and informs the TJFACC, and both rely on the 613th JAOC to develop their part of the overall ATO. This multiple JFACC concept, with a JFACC supporting the JTF and sharing the theater JAOC, can be a typical arrangement, driven by unforeseen, short-term incidents outside the scope of the original JAOC establishment.[5] We consider the HA/DR to be unforeseen and the major war to be large enough that the GCC determined a JTF-subordinate JFACC was required. We begin our manning resource analysis with the TJFACC.

Theater Joint Forces Air Component Commander or Commander Air Force Forces

The two sets of responsibilities for the TJFACC/COMAFFOR are distinctly different, and different staffs have traditionally executed each set.[6] In the JFACC role, the commander establishes unity of command and unity of effort for joint air operations using the JAOC and TJFACC staffs; in the COMAFFOR role, the commander executes control of Air Force forces through the COMAFFOR staff, which traditionally consists of PACAF A-staff.[7] The TJFACC/COMAFFOR staff amounts to about 70 personnel (Table 3.2).

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[4] Appendix B describes this scenario in more detail.

[5] JP 3-30, 2014.

[6] AFI 13-1 AOC V 3, 2012, and JP 3-33, *Joint Task Force Headquarters*, Washington, D.C.: Joint Staff, July 30, 2012.

[7] AFI 13-1 AOC V 3, 2012, and JP 3-33, 2012.

Table 3.2. TJFACC/COMAFFOR and JFACC (under JTF) Air Force Staff During an HA/DR or a Major War

TJFACC/COMAFFOR Staff		TJFACC	COMAFFOR	JFACC (under JTF)
	Commander		1	1
	Deputy Commander	0	1	0
Leadership	Chief of Staff	1	1	1
	Senior Enlisted	1	1	1
	Support Staff	2	2	2
	1 – Manpower and Personnel	2	2	2
	2 – Intelligence	2	2	2
	3 – Operations	2	2	2
	4 – Logistics	2	2	2
J-Staff & A-Staff	5 – Plans	2	2	2
	6 – Communications	2	2	2
	7 – Installations & Mission Support	0	2	0
	8 – Strategic Plans & Programs	0	2	0
	9 – Analyses, Assessments, and Lessons Learned	0	2	1
Special	Director of Space Forces	1	0	1
Staff	Director of Mobility Forces	1	0	1
	Public Affairs	1	1	1
	JAG	1	1	1
	Surgeon General	1	1	1
	Inspector General	1	1	1
	Finance (contracting)	1	1	1
	Provost Marshal	1	1	1
	Chaplin	1	1	1
	HQ Commandant	1	1	1
	Historian	1	1	1
	Safety	1	1	1
	Linguists	3	3	3
	NGO/IGO Liaisons	1	1	1
TOTAL		32	37	34

NOTE: JAG = Judge Advocate General; IGO = intergovernmental organization.

The TJFACC has a staff of 32, while COMAFFOR has a staff of 37 supporting the commander. Each group has similar requirements for functional staff, but the COMAFFOR staff may also include A-7, A-8, and A-9 staff when needed. We assumed that the TJFACC staff would operate from the JAOC for operational-level C2 of air operations,[8] and the COMAFFOR

[8] This is typical. See JP 3-30, 2014.

staff from the PACAF Operations Support Center in the PACAF HQ building. The TJFACC staff in communication with the JAOC informs the commander of air operations and ensures that appropriate joint air operations and ATOs are developed and executable. The COMAFFOR staff helps the commander maintain the Air Force portion of operations in the theater and reaches back to additional staffs that are not necessarily directly assigned to the COMAFFOR but that would support it, as needed, during contingency operations. The staff works closely with these components across the Air Force to ensure adequate support of joint operations. We assumed that the deputy commander would come from a different service. Also, we assigned the theater's directors of mobility operations and space forces to the TJFACC staff, which is representing their function to the commander. These commanders would also have their own staffs and would reach back to their own communities for assistance, which is not part of this analysis.

Table 3.2 also shows the 34 JTF-subordinate JFACC staff in the second concept. We assumed that the JTF-subordinate JFACC would operate from a different location, that the TJFACC staff would not be shared, and that the JTF-subordinate JFACC would require a staff with skills and functions similar to those of the TJFACC staff. This JTF-subordinate JFACC staff could be tailored to meet the JTF mission as needed and would rely on the COMAFFOR for Air Force forces issues. Again, we assumed that the deputy commander would come from a different service. For the major war scenario, there are two JTFs, so the total staff for the JTF-subordinate JFACCs would be 68.

TJFACC Staff: 613th Air Operations Center

The JAOC provides operational-level C2 of air, space, and cyberspace operations. It is the focal point for planning, directing, and assessing air, space, and cyberspace operations to meet the TJFACC's (and, in the second concept, the JTF-subordinate JFACC's) operational objectives and guidance.[9] The five divisions of the JAOC are strategy; combat plans; combat operations; intelligence, surveillance, and reconnaissance (ISR); and air mobility. The manning levels for each division will vary for the two scenarios and two C2 concepts. Finally, the JAOC commander has staff and specialty teams that help the flow of information and coordination across the AOC enterprise. The overall structure of the JAOC is illustrated in Figure 3.1.[10]

To determine staffing levels for each subelement in the JAOC, we began by deriving each position's responsibilities from JPs and AFIs. For example, the commander's direct staff (e.g., ATO coordinators or weapon system managers) generally translates JFC and JFACC guidance to the JAOC and coordinates all air, space, and cyber operations with the subelements in the JAOC. The JAOC commander has a staff of 27 to 33 (Table 3.3). So, we used JPs and AFIs to

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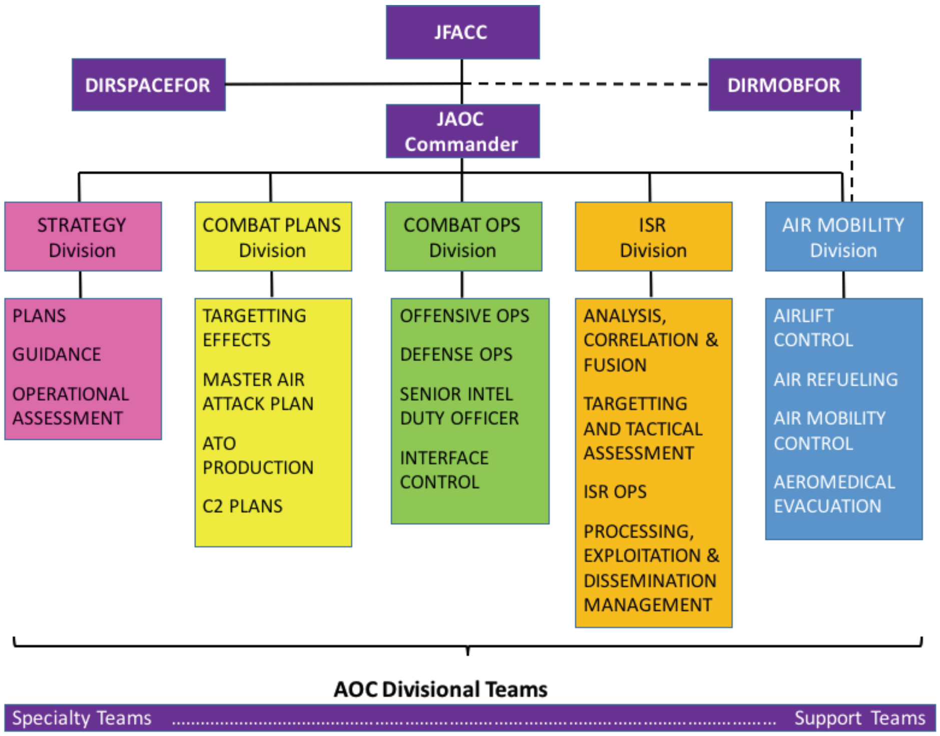
[9] AFI 13-1 AOC V 3, 2012.

[10] AFI 13-1 AOC V 3, 2012. This AFI writes extensively about each division's responsibilities, which will not be explained in any detail in this document.

Figure 3.1. JAOC Organizational and Functional Teams



NOTE: DIRSPACEFOR = Director of Space Forces; DIRMOBFOR = Director of Mobility Forces.

understand the responsibilities of the staff for the GCC-led concept for an HA/DR and used this understanding to formulate baseline staffing levels. We then added to this baseline to determine the staff for a major war, a more intense scenario, and for the additional JFACCs under the JTF-led concept as applicable. For the commander's staff, we assumed that this level of intensity of operations would be similar for either scenario within a concept, except that the JAOC staff in the JTF-led concept supports more than one JFACC and thus requires a few more personnel. These values can seem limited and may require some on-call time or cross-utilization for short periods.

The Strategy Division develops short-term and long-range planning for air, space, and cyber operations to achieve theater objectives. While strategies differ between scenarios, the air, space, and cyberspace missions will exist for both. Table 3.4 shows the division staff, which ranges from 21 to 62 staff. The GCC-led concept adds staff to compensate for the likely increase in intensity with a major war. Staffing for the JTF-led concept increases because this division supports multiple JFACCs (two for the HA/DR scenario and three for the major war); intensity also increases during a major war.

Table 3.3. JAOC Commander Staff

	GCC-Led		JTF-Led	
	HA/DR	Major War	HA/DR	Major War
Commander	1	1	1	1
ATO coordinators	3	3	6	9
Weapon system managers	3	3	3	3
Configuration managers	3	3	3	3
Information assurance team	3	3	3	3
Process improvement team	14	14	14	14
Total	27	27	30	33

NOTES: *Configuration managers* administer and facilitate AOC weapon system configuration management; help resolve AOC weapon system site security and accreditation issues; and ensure that the system of record's configuration management plans and processes address all weapon system configuration changes to impose configuration control and security consistent with established AOC, Air Force, and DoD information assurance requirements. The *information assurance team* establishes, implements, and maintains the information assurance program for a DoD information system or organization, ensuring that the protection and detection capabilities meet DoD architecture requirements, tracking compliance, and mitigating system vulnerabilities. *The process improvement team* evaluates the overall effectiveness of the AOC weapon system, focusing on AOC processes and data and on information flows within the AOC and recommends changes that will improve these flows. This team develops the data management platform portion of the knowledge operations plan. Other staff categories are self-explanatory. See AFI 13-1AOC V3, *Operational Procedures, Air Operations Center (AOC)*, Vol. 3, November 2, 2011, inc. Change 1, May 18, 2012, for more details.

Table 3.4. JAOC Strategy Division Staff

	GCC-Led		JTF-Led	
	HA/DR	Major War	HA/DR	Major War
Chief	1	1	1	1
Planning team	5	8	8	16
Guidance team	6	9	9	17
Operational assessment team	9	14	14	28
Total	21	32	32	62

The Combat Plans Division is responsible for the near-term JAOC planning. Table 3.5 shows the division staff, which ranges from one to 110. Responsibilities seem to center on combat missions during wartime operations (e.g., determine targets and air attack plan), which are not applicable in an HA/DR but imperative in a major war, which is the basis for the staffing values shown in the table. Staffing increases between concepts for a major war because this division supports three JFACCs in the JTF-led concept.

The Combat Operations Division executes the ATO developed by the Combat Plans Division. Table 3.6 shows the division staff, which ranges from one to 92. These individuals monitor battlefield air and missile defense operations and modify the combat air mission as

Table 3.5. JAOC Combat Plans Division Staff

	GCC-Led		JTF-Led	
	HA/DR	Major War	HA/DR	Major War
Chief	1	4	1	4
Target team	0	9	0	19
Master air attack planning team	0	24	0	48
C2 planning team	0	11	0	23
ATO production team	0	8	0	16
Total	1	56	1	110

Table 3.6. JAOC Combat Operations Division Staff

	GCC-Led		JTF-Led	
	HA/DR	Major War	HA/DR	Major War
Chief	1	1	1	1
Offensive operations team	0	12	0	24
Defensive operations team	0	8	0	16
Senior intelligence team	0	17	0	35
Interface control team	0	8	0	16
Total	1	46	1	92

needed. As with the Combat Plans Division, these functions are not applicable in an HA/DR but are imperative in a major war, which is the basis of the staffing values shown in the table. Staffing increases between concepts for a major war because this division supports three JFACCs in the JTF-led concept.

The ISR Division provides the JFACC, JAOC, and the other divisions with intelligence, ISR operations, and targeting to help develop accurate ATOs. Table 3.7 shows the division staff, which ranges from 44 to 135. While the scenario will dictate this division's operation, both scenarios will require ISR and assume a major war scenario to be more intense than an HA/DR, which leads to the staffing differences between scenarios within each concept. Staffing differs between concepts because this division supports two JFACCs.

The Air Mobility Division plans, coordinates, and executes air mobility in the theater with input from the director of mobility forces. Table 3.8 shows the division staff, which ranges from 33 to 97. Both scenarios will have an enormous lift requirement and a potential evacuation mission. However, during a major war, the refueling mission is likely more intense because of

Table 3.7. JAOC ISR Division Staff

	GCC-Led		JTF-Led	
	HA/DR	**Major War**	**HA/DR**	**Major War**
Chief	1	1	1	1
Analysis, correlation, and fusion	8	12	12	24
Target and tactical assessment	8	12	12	24
ISR operations	8	12	12	24
Processing, exploitation, and dissemination	6	9	9	19
Imagery support element	5	8	8	16
National tactical integration	5	8	8	16
Personnel embedded in other divisions	3	5	5	11
Total	44	67	67	135

Table 3.8. JAOC Air Mobility Division Staff

	GCC-Led		JTF-Led	
	HA/DR	**Major War**	**HA/DR**	**Major War**
Chief	1	1	1	1
Airlift control team	8	12	12	24
Air refueling control team	8	12	12	24
Air mobility control team	8	12	12	24
Air evacuation control team	8	12	12	24
Total	33	49	49	97

the combat mission, which leads to the staffing differences between scenarios within each concept. Staffing differs between concepts because this division supports more than one JFACC.

The JAOC special and support teams consist of personnel from ally, joint, and other DoD and civilian organizations not included in this Air Force manpower requirement. There is an extensive number of other Air Force functions, some similar to the special staff at the JFACC level and many not listed.[11] Following an approach similar to the one we used earlier, we gained an understanding of the numerous agencies that might be involved from JPs and AFIs, determined a baseline amount of 20 for the GCC-led HA/DR, then added to this baseline for a major war and the larger JTF-led concept as applicable. These personnel would also reach back into their communities for assistance as needed, which is not included in this analysis.

The JAOC is the most manpower-intensive organization in both concepts, ranging from 147 to 589 personnel. Here, we found the first significant differences in staffing requirements,

[11] See AFI 13-1 AOC V 3, 2012.

depending on the concept and type of contingency. For the GCC-led concept, the JAOC requires more than twice as many staff members for the major war as for the HA/DR scenario (see Table 3.9). Several factors contribute to this significant range in direct staff requirements:

- The JAOC is required to be fully functional 24 hours a day, seven days a week, with little to no on-call time.
- Some of the functions play more or less of a role during certain scenarios than others (e.g., combat plans or combat operations are less important in HA/DR scenarios than in major war scenarios).
- In the GCC-led concept, the JAOC supports one JFACC; in the JTF-led concept the JAOC supports more than one (for the major war scenario we examined, there were two JTFs, each with its own JFACC). The JAOC manning for a JTF-led major war inflates because the staff must support multiple JFACCs (one for each JTF-subordinate JFACC and the TJFACC).

JTF

The JTF maintains C2 over the four subelements (JFACC, JFACC, JFMCC, and JFSOCC) and assigns missions, priorities, and guidance necessary to meet operational objectives. We examined the most demanding case for the Air Force, in which the JTF commander is an airman. The JTF therefore requires dedicated staffing of about 35 personnel (Table 3.10). Should the JTF be led by a sister service, the Air Force staffing demand would likely decrease to one, the deputy commander.

Table 3.9. JAOC Staffing

	GCC-Led		JTF-Led	
	HA/DR	Major War	HA/DR	Major War
Commander staff	27	27	30	33
Strategy Division	21	32	32	64
Combat Plans Division	1	56	1	110
Combat Operations Division	1	46	1	92
ISR Division	44	67	67	135
Air Mobility Division	33	49	49	97
Specialty and support teams	20	40	40	60
Total	147	317	220	589

Table 3.10. JTF Air Force Staff for an HA/DR or a Major War

JTF Staff		USAF Staff
Leadership	Commander	1
	Deputy commander	0
	Chief of staff	1
	Senior enlisted	1
	Personal/support	2
J-staff	J-1—Manpower and Personnel	3
	J-2—Intelligence	3
	J-3—Operations	3
	J-4—Logistics	3
	J-5—Plans	3
	J-6—Communications	3
Special staff	Public Affairs	1
	JAG	1
	Surgeon General	1
	Finance (contracting)	1
	Provost marshal	1
	Chaplin	1
	HQ commandant	1
	Historian	1
	Safety	1
	Linguists	1
	NGO/IGO liaisons	1
Total		35

The JTF would be in theater, closer to the operational area, and the dedicated airmen members would reach back for additional support as required. It would also have a contingent of joint staff, which would reach back to the other services respectively. We assumed that the four JTF subelements would also be in theater with the JTF. We added three dedicated personnel to the J-staff to help with the JTF's span of control.

Joint Air Component Coordination Element

In these concepts, the JACCEs are established at land, maritime, and special operations component commanders' HQ to better integrate air, space, and cyberspace operations with land and sea operations. They act as the JFACC/COMAFFOR's liaison and primary representative to the other commanders. As shown in Table 3.11 each JACCE staff is generally a liaison element of the JFACC, and the numbers range from 12 to 20. Within each concept, the increase in staffing for a major war compensates for the additional communication likely required to coordinate a more complicated air, land, and sea war taking place in multiple locations. During an HA/DR, the area of operations is generally more focused, smaller. The JACCE element staff in the JTF-led concept is the same as in the GCC-led concept because the staff members directly represent their JTF-subordinate JFACC.

Summary

Each of the two concepts in this analysis has a slightly different organizational structure, as illustrated in Figures 1.1 and 1.2. The range of numbers of direct Air Force staff required to support each concept for the two scenarios can seem extensive. Table 3.12 summarizes the manpower resource requirements.

Table 3.11. Individual JACCE Staffing

	GCC-Led		JTF-Led	
	HA/DR	**Major War**	**HA/DR**	**Major War**
Leadership				
Director	1	1	1	1
Deputy director	1	1	1	1
Operations	1	2	2	2
Liaison officer (LNO)	1	2	2	2
Other support	2	2	2	2
Divisions				
Plans	1	2	2	2
Intelligence	1	2	2	2
Operations	1	2	2	2
Air and Space	1	2	2	2
Logistics	1	2	2	2
Air Mobility	1	2	2	2
Total	12	20	10	10

Table 3.12. Total Staffing Requirement for Each Concept and Scenario

	GCC-Led		JTF-Led	
	HA/DR	**Major War**	**HA/DR**	**Major War**
TJFACC/COMAFFOR	69	69	69	69
613 JAOC	147	317	220	591
JTF	—	—	35	70
JTF-subordinate JFACC	—	—	34	68
JACCE	36	60	120	180
Total	253	447	489	979

How Performances Compare and Contrast

We next applied the three metrics—span of control, height, and connectivity index—to the two C2 concepts and two scenarios. We also applied a fourth measure, the number of relationships the JAOC must manage in each combination. Table 3.13 lists the performance metrics for the major war and HA/DR scenarios. Recall that, under the JTF-led concept, it is possible to evaluate several of the metrics from the theater-level perspective and from the operational-level perspective. Table 3.13 provides the metrics for both perspectives.

In the major war scenario led by the GCC commander, the span of control is 5. The contributions are 1 for each component, plus 1 for the GCC staff. The height of the organization is 4 and the connectivity index is 10.7 from the perspective of the GCC. The JAOC has just one relationship to manage, that with the TJFACC. Now consider what happens in this scenario if the GCC commander stands up two JTFs to lead the operation instead of leading it directly. While the span of control increases from 5 to 7, the number of informal relationships the GCC commander has to manage relative to the size of the organization drops significantly. This can be seen with the decrease of the connectivity index from 10.7 to 5.1. These two effects could increase options and flexibility for the GCC commander, potentially enhancing performance of C2 at the theater level. However, these changes come at the expense of increased organizational height from the theater perspective (5 versus 4). This could result in delays of C2 decisions made about the operation at the theater level. For instance, this could slow theater-level support to the operation or slow the ability to amass forces at the theater level.

We also have to consider these metrics from the operation perspective of the JTF commander, whose span of control is 5 (1 for each JTF-subordinate component plus 1 for the JTF staff), and the height is 4. However, the JTF commander has a relatively large number of informal relationships to manage. Again, this is evidenced by the connectivity index of 21.4 (compared to 10.7 for the GCC commander under the GCC-led operation). This could adversely affect C2 efficiency for the JTF commander. Finally, the number of JAOC relationships increases from 1, for the GCC-led option, to 3, for the JTF-led option, because the single JAOC

Table 3.13. Performance Metrics

Metric	Major War			HA/DR		
		JTF-Led			JTF-Led	
	GCC-Led	Theater Perspective	Operation Perspective	GCC-Led	Theater Perspective	Operation Perspective
Span of control	5	7	5	5	6	5
Height	4	5	4	4	5	4
Connectivity index (0–100)	10.7	5.1	21.4	10.7	6.67	17.9
Number of JAOC relationships	1	3		1	2	

must now produce an ATO with inputs from three separate JFACCs: the TJFACC and the two JTF-subordinate JFACCs. This increase in the number of relationships could adversely affect JAOC efficiency.

Comparing and contrasting the two C2 concepts for the HA/DR scenario produces similar, but somewhat less pronounced, results because there is only one JTF in the HA/DR scenario (as opposed to the two in the major war scenario). Standing up a JTF can increase options and flexibility for the GCC commander by increasing the span of control and decreasing the connectivity index. But doing so increases the organizational height, which could adversely affect the efficiency of theater-level support to the operation.

The performance metrics presented here appear to fall within established norms. It is important to remember that modern organizational theory holds that these metrics alone are not sufficient in themselves to determine that one C2 concept is necessarily better than another. Indeed, our intuitive ideas about which aspects of C2 structures are preferable are not always borne out by the data either.

For example, it is evident having a flatter C2 structure requires fewer "hops" for information to flow from the lowest echelons to the highest. So, one might expect this would speed up the OODA loop. Indeed, the U.S. Marine Corps asserts that, "Narrowing span of control . . . [means] adding layers of command. But the more layers of command an organization has, the longer it takes for information to move up or down. Consequently, the organization becomes slower and less responsive."[12]

However, in early experiments, the authors were surprised to find that this expected disadvantage did not always appear. Sometimes it was outweighed by the opposite disadvantage of having to manage resources across a wider span of control. Narrower structures, at times, displayed superior performance; as one researcher explained, "[f]reed from the burdens that arise

[12] USMC, 1996.

from having many subordinates, decisionmakers appeared to be able to develop a better understanding of the problem."[13]

This tension between the height and span of control of an organization mirrors the tension in the basic doctrine of centralized command with decentralized execution. As early as World War I, decentralization was seen as necessary to "ensure the commander's span of control did not exceed his ability to effectively employ available air assets in support of ground operations on the Western Front."[14] Yet too much decentralization can lead to the opposite problem—it can place too much of a decisionmaking burden on the lower echelons. As one analyst writes,

> [i]n general, centralized command with decentralized execution is ideal for situations where the JFACC will have a large span of control and the battle space is relatively fixed. Centralized control allows the assignment of tasks, apportionment of aircraft, and synchronization of an incredibly complex plan while delegating detailed planning to the tactical level. However, a significant workload is placed on lower echelons to build flexibility into the execution when fluid situations erupt.[15]

It is important also not to assume modern technology can solve these age-old organizational conundrums. Air Force basic doctrine warns that

> [m]odern communications technology may tempt commanders to take direct control of distant events and override the decisions of forward leaders. . . . [But] despite impressive gains in data exploitation and automated decision aids, a single person cannot, with confidence, achieve and maintain detailed situational awareness over individual missions when fighting a conflict involving many simultaneous engagements taking place throughout a large area, or over individual missions conducted in locally fluid and complex environments.[16]

The performance metrics are important because they can help illuminate whether a C2 structure is unusual or unbalanced. Making more-refined assessments beyond this requires understanding the specific missions and situations involved. Exercises and experiments remain essential to test C2 concepts and determine the most desirable values for these metrics. Finally, no C2 concept, however well designed for a specific purpose, can substitute for leadership: "Because people are the first and most important element of our command and control system, strong and effective leadership is of essential importance to our command and control."[17]

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[13] Rocco Carzo Jr. and John N. Yanouzas, "Effects of Flat and Tall Organization Structure," *Administrative Science Quarterly*, Vol. 14, No. 2, June 1969.

[14] Travis Hallen, "Flawed Doctrine: The Problem with Centralised Command and Decentralised Execution," Kingston ACT, Australia: The Sir Richard Williams Foundation Inc., 2012.

[15] Daniel F. Baltrusaitis "Centralized Control with Decentralized Execution: Never Divide the Fleet?" Maxwell Air Force Base, Ala.: Center for Strategy and Technology, Air War College, Air University, June 2004.

[16] Air Force Doctrine Document 1, *Air Force Basic Doctrine*, Washington, D.C.: Headquarters U.S. Air Force, February 27, 2015. This quote from Air Force doctrine seems to be talking about the role of communications in current operations and may not be applicable to communications in the context of planning.

[17] USMC, 1996.

How Risk and Resiliency Compare and Contrast

We conducted a C2R2 TTX to test the methodology and to evaluate the risk and resiliency of the two C2 concepts in the two scenarios. The TTX took place over two-and- a-half days. Eleven participants of varying backgrounds formed a representative sample of the U.S. armed forces. The group remained together throughout both days without breaking into smaller teams, and any necessary adjudication occurred in front of the players. The names of participants will not be made available since participation was voluntary, but participants had the following backgrounds and affiliations:

- Rated, air battle manager, U.S. Air Force
- rated A-10 pilot, U.S. Air Force
- meteorologist
- rated C-17 pilot, U.S. Air Force
- intelligence analyst, National Air and Space Intelligence Center
- signals officer, U.S. Army
- logistician, U.S. Marine Corps
- rated E2-C pilot, U.S. Navy
- former Deputy Assistant Secretary of Defense
- industrial and organizational psychologist
- war gamer, logistician, and cost analyst.

Over the course of each morning, we identified the load-bearing assumptions for the two concepts simultaneously, on the belief that any load-bearing assumption will hold true for both concepts (the results seem to support this belief).[18] Each loading-bearing assumption was captured in real time in an Excel spreadsheet and projected onto a screen to enable brainstorming and dialogue.

In the afternoon, we determined which of the load-bearing assumptions were vulnerable under each concept, and those that were load bearing and vulnerable were deemed to be risks. For each risk, we then identified signposts that could be monitored to determine whether the associated load-bearing and vulnerable assumption (risk) was failing. Finally, the participants walked through the list of risks to identify hedging or shaping actions that could provide resiliency measures. These were also captured live as they were developed.

We will now examine the risk and resiliency results for the two concepts in the two scenarios. We first consider the HA/DR operation (Tables 3.14–3.16). Taking the total number of vulnerable assumptions identified and combining the results that delineated a concept to be fully vulnerable (coded as *yes* rather than *no*) or relatively vulnerable (*more* versus *less*), neither

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[18] To reiterate, a *load-bearing assumption* is one that would adversely affect operational outcomes, regardless of the likelihood of the assumption failing. As an example, in a some scenarios, the assumption that the JFACC has robust communications with forward forces might be "load-bearing" in the sense that operations could be adversely affected if the communications were degraded. However, this is not a risk unless the assumption is both load-bearing and vulnerable. Vulnerability is an assessment of the likelihood of failure.

Table 3.14. Comparison of Risk and Resiliency of GCC-Led and JTF-Led Concepts in an HA/DR Scenario

	GCC-led	JTF-led
Total Number of Load-bearing Assumptions	19	19
Number of Risks (Load-Bearing & Vulnerable Assumptions)	10	10
Number of Risk With No Associated Resiliency Measure (hedging or shaping action)	0	0
Key Observations	72-hour ATO cycle may not be responsive to needs	

Table 3.15. Unique Risk and Resiliency Measures of the GCC-Led HA/DR Operation

Risk Identified Under Concept for GCC-Led Operation	Importance Score	Resiliency Measures	
		Shaping Action	Hedging Action
The orchestration of the operation is responsive to what is happening in the JOA	70.62	AOC runs a separate ATO cycle for HA/DR	
Means of sharing information with partners	62.54	Advance multilateral information-sharing agreements and arrangements	
Span of control: scale of disaster reflects extant plan or experience (has the scope the operation had been planned for)	55.39	Embed military LNOs with the nongovernmental organizations (NGOs) to assess scope	
In-transit visibility of all relief assets (know what is going where and to whom)	51.16	Embed LNOs at transit and receiving sites to provide feedback	
United Nations (UN) and Republic of Philippines have sufficient assets to maintain mission or take over operation	39.91	Extend duration of operation until there is sufficient confidence	
Command element operating on same battle rhythm	29.71	Set up a cell on the Philippine battle rhythm	

C2 concept seemed overly more suited to the HA/DR operation at first blush. Of the 19 load-bearing assumptions, we identified an equal number of risks (ten) for each C2 concept.[19] (This belied the views some participants expressed during the TTX "hot wash": Because the nature of an HA/DR mission is operationally dispersed and administratively and logistically complex, some participants believed this would favor the C2 concept for a JTF-led HA/DR operation in

[19] This adds together the vulnerable assumptions that were identified to definitely be vulnerable (*yes*), as well as those identified on a soft scale of vulnerability (*more*). Additionally, one more assumption was identified for the alternative C2 concept, which we coded as *N/A* for the baseline because it did not pertain. This was, in effect, the exception that proved the rule that scenario-based vulnerabilities translate across C2 concepts.

Table 3.16. Unique Risk and Resiliency Measures of the JTF-Led HA/DR Operation

Risk Identified Under JTF Concept	Importance Score	Resiliency Measures: Shaping Action	Resiliency Measures: Hedging Action
Commander has authorities established for operation (tasking, OPCON) and can establish operations in a timely manner	72.86	Developed a PACAF-level checklist, or perhaps a USPACOM-level concept plan (CONPLAN) for HA/DR	Requests for forces and authorities
Commanders at all levels understand roles, responsibilities, and processes	60.71	Put the right person in place; CPXs	
Opportunity cost of HADR response is acceptable with respect to other USPACOM commander missions and responsibilities	57.59	Increase engagements with organizations on the ground, including embassy and NGOs, to improve fidelity of assessment	
Taskable ISR assets are available to provide common operational picture	51.09	Send an ISR LNO to represent JTF equities at the Joint Collection Management Board (This board coordinates intelligence collection at the Joint Intelligence Operations Center and adjudicates ISR requests at the USPACOM level.)	JTF commander requests TACON of needed ISR
Commanders at all levels understand capacity and capability of the resources at their disposal	47.74	Put the right person in place; hold CPXs	Leverage informal and peer-to-peer relationship
Joint forces commander has situational awareness prior to event, including preestablished C2 relationships (military-military, political-military, civilian-military)	24.11	Standing JTF (assumes significant associated training)	GCC connects JTF in early phases

which more nodes would ostensibly allow more flexibility, which was deemed crucial for mission success.)

However, a closer examination provides some instructive nuance. While the organization of the JTF-led operation would be responsive to events in the JOA, the 72-hour ATO cycle of the GCC-led concept put this at risk. Crucially, although both C2 concepts had ten risks, the risks for the GCC-led HA/DR operation yielded no obvious hedging actions. As stated earlier, a hedging action is one taken in the event a particular risk is incurred. This essentially means that without a hedging action, there is no recourse if the shaping actions fail. It is possible that, with more time, the TTX participants might have devised hedging actions for some, if not all, of these risks. Regardless, this outcome certainly emphasizes the benefit of identifying both shaping (preventative) and hedging (postevent) actions.

By contrast, participants identified hedging actions for all but two of the risks associated with a JTF-led HA/DR operation. This may suggest that the C2 concept for the JTF-led HA/DR operation is more resilient.

The C2 concept for the JTF-led HA/DR operation also had six unique risks. The most important risk was that the commander had to have authorities established for mission tasking and OPCON. Participants identified shaping and hedging resiliency measures that could be applied to mitigate this risk.

Table 3.17 lists the four risks that the C2 concepts for a GCC-led and JTF-led HA/DR operation had in common. The most important common risk is that deployable communications packages either do not exist or are not available when needed. Shaping and hedging actions are available as resiliency measures for this risk.

In contrast with the numerical equivalency of risks for the C2 concepts for the HA/DR mission, the results for the major war scenario were mirror images of each other (Table 3.18).[20] Of the 14 load-bearing assumptions, only four were deemed vulnerable and, hence, considered risks for the GCC-led major war scenario. In contrast, ten load-bearing assumptions were determined to be vulnerable and, hence, were risks for the JTF-led major war scenario. Most interestingly, far fewer assumptions were deemed to be fully vulnerable in this scenario—only about 35 percent, compared with the more than 50 percent for the HA/DR scenario.[21] This seemed to reflect the greater difficulty of achieving mission success in a major war, perhaps especially one against a near-peer competitor.

Table 3.17. Common Risk and Resiliency Measures Between the Two C2 Concepts in the HA/DR Scenario

Common Risk Identified	Importance Score	Resiliency Measures: Shaping Action	Resiliency Measures: Hedging Action
Deployable communications packages either do not exist or are not available when needed	73.58	Continue to build out unit type code (UTC) requirements for deployable communications packages and incorporate them into CPXs and FTXs	Leverage host-nation infrastructure (if available)
Taskable mobility assets available to transport critical materiel	60.92		PACOM commander requests support from U.S. Transportation Command commander
Republic of the Philippines government provides permission for JFLCC to conduct force protection	43.24		Request force protection from host nation
Releasability protocols in place	18.84	Establish and practice the protocols	

[20] GCC-led concept results: two *more*, seven *less*, two *yes*, three *no*. JTF-led concept results: seven *more*, two *less*, three *yes*, two *no*.

[21] In the HA/DR scenario, 11 assumptions out of 20 (55 percent) were coded as *no*. In the major war scenario, five out of 14 (35.7 percent) were coded as *no*.

Table 3.19 lists the two risks that were unique to the GCC-led major war scenario. The risk of higher importance was the ability of maintaining battlespace awareness of forward operations from reachback. Both risks identified have hedging actions as resiliency measures.

By contrast, eight risks were identified for the JTF-led major war scenario (Table 3.20). TTX participants identified hedging actions for only three of the eight risks. As with the HA/DR mission, the lack of hedging actions does not point to a definitive conclusion about the weakness of the JTF-led C2 concept in the major war scenario; these results are the product of a single two-day TTX. However, participants had difficulty determining hedging actions for this scenario than for others, which is a trend worth recognizing.

Table 3.18. Comparison of Risk and Resiliency of GCC-Led and JTF-Led Major War Scenario

	GCC-led	JTF-led
Total Number of Load-bearing Assumptions	17	17
Number of Risks (Load-Bearing & Vulnerable Assumptions)	4	10
Number of Risk Factors With No Associated Resiliency Measure (hedging or shaping action)	0	0
Key Observations	72-hour ATO cycle may not be responsive to needs	

Table 3.19. Unique Risk and Resiliency Measures of GCC-Led Effort in the Major War Scenario

Risk Identified Under GCC Concept	Importance Score	Resiliency Measures: Shaping Action	Resiliency Measures: Hedging Action
Able to maintain battlespace awareness	73.37		User-defined operating picture (UDOP)[a] (can leverage Japan's common operating pictures if in Japan)
Able to maintain sufficient OPCON	48.75	Wideband high frequency, alternative paths, mission type orders (MTOs)[b]	Joint Aerial Layer Network, Smart T terminals, delegated authorities, lease more communications

[a] According to the Future Operation Concept (U.S. Air Force, "Air Force Future Operating Concept: A View of the Air Force in 2035," September 2015), UDOPs allow users to distill the common operating pictures' immense trove of information to comprehensible formats that suit their immediate needs (p. 14). Users can subscribe to certain types of information, and the information can periodically synchronize with the common operating picture. See U.S. Air Force, 2015.

[b] An MTO allows subordinate commanders to adapt to a changing situation given their commander's intent. In essence, an MTO directs a unit to conduct an operation without specifying how. It is intended to enhance flexibility to help overcome the fog and friction of war (Robert W. Peterman, "Mission-Type Orders: An Employment Concept for the Future," Maxwell Air Force Base, Ala.: Air War College, Air University, March 1990, p. iii). ISR MTOs have been used in operations Enduring Freedom and New Dawn (Jason D. Green, "Integrating Mission Type Orders into Operational Level Intelligence Collection," master's thesis, Norfolk, Va.: National Defense University, May 27, 2011, p. 12).

Table 3.20. Unique Risk and Resiliency Measures of JTF-Led Effort in the Major War Scenario

Risk Identified Under JTF Concept	Importance Score	Resiliency Measures	
		Shaping Action	Hedging Action
Able to task air assets	76.11	Training and exercises	Stand up coordination cell[a]
NCA authorizes strikes on critical targets and conduct of offensive space and cyber operations	65.92	Cyber JACCE/JACCE–like concepts for expertise	
Sufficient interservice planning and coordination to enable joint schemes of maneuver	63.65	Training; exercises	
Targeting synchronized for cross-domain operations	50.91	Each JTF's resident joint targeting cycle	
Logistics train sufficient for adaptive basing	44.85	Preposition resources, agile combat, use of C2 systems, war reserve materials	Lean on coalition/host nation relationships[b]
Force protection adequate	42.56	Organic protection; use of ISR assets; and P-8s, if not needed for antisubmarine warfare	
Sufficient time to stand up C2 apparatus such that the operation is not impeded	37.26	Improved indications and warning; messaging	Standing JTF (assumes significant associated training)[c]
Successfully conduct defensive and offensive cyberoperations	25.63	Cyber effects teams located at the JTF with necessary authorities, especially with respect to host nation; ensuring resilient communications	

[a] TTX participants recommended standing up a coordination cell for each JTF-subordinate JFACC within the centralized JAOC as a hedging action. The cells would operate on the same battle rhythm as the JAOC and could coordinate the needs of the JTF-subordinate JFACC in the preparation of the ATO.
[b] TTX participants recommended that U.S. forces lean on coalition and/or host-nation relationships for assistance in ensuring a sufficient logistics and training for adaptive basing as a hedging action.
[c] TTX participants recommended establishing a standing JTF as a hedge to ensure that the operation is not impeded. Significant training needs are associated with this hedge.

TTX participants noted that the dispersed nature of the C2 concept for the JTF-led major war scenario did not easily lend itself to sufficient levels of coordination, synchronization, and direct reachback to the theater to enable executing the mission with all due speed. The three hedging actions identified all deal with some kind of coordination—either buttressing the level of coordination or leaning on coordination mechanisms already in place—to enable mission-critical actions, such as tasking air assets, ensuring a sufficient logistics train, and a ensuring a robust C2 apparatus.

Table 3.21 lists the two risks the C2 concepts had in common for the major war scenario. No hedging actions were identified for them. The most important common risk is having sufficient time to plan and execute force flow. Participants suggested that using adaptive basing operational concepts (CONOPs), prepositioning forces and posturing, and mobility exercises would offer shaping actions.

Table 3.21. Common Risk and Resiliency Measures Between C2 Concepts in the Major War Scenario

Common Risk Identified	Importance Score	Resiliency Measure	
		Shaping Action	Hedging Action
Sufficient time to plan and execute force flow	43.31	Adaptive basing CONOPs,[a] prepositioning resources, mobility exercises, posturing	
Able to maintain sufficient TACOM	34.35	Local commander can give verbal commands	

[a] *Adaptive basing* refers to evolving techniques for air bases to absorb adversary attacks, then rapidly reconstitute operations at current or backup locations. This may include techniques used in most major wars since World War I, including camouflage, concealment and deception, hardening of facilities, dispersal of aircraft on airfields away from airfields and across multiple airfields, and postattack recovery. It may also include newer capabilities, such as more-integrated joint force approaches to protecting forward locations and concepts for more-dispersed and more-resilient operations (see Alan J. Vick, *Air Base Attacks and Defensive Counters: Historical Lessons and Future Challenges*, Santa Monica, Calif.: RAND Corporation, RR-968-AF, 2015, p. 59).

After the conclusion of the TTX, we elicited input from the participants on which C2 concept they would prefer relative to each risk identified at the TTX. The results in Table 3.22 suggest that participants felt that the C2 concept for a GCC-led operation was generally more resilient for the two scenarios the TTX considered.

Note that the TTX identified many C3 systems that could mitigate risks in the scenarios. A detailed evaluation of communication and other C3 systems that support C2, including a baseline of C3 systems supporting each concept, would be useful but was beyond the scope of this project.

How Versatility Compares and Contrasts

Appendix A presents a review of C2 structures implemented in military operations from 1989 until 2015. The historical review shows that GCC commanders have used four C2 concepts: service and functional components, subordinate unified commands, single-service forces, and JTFs. Our examination focused on the use of JTF and service and functional component leads across a range of missions that included engagements, security cooperation, deterrence, crisis response and limited contingency operations, and major operations and campaigns.

This review also shows that crisis and deterrence operations tend to rely on JTF-led concepts. Operations with a major operations component tend to strike a balance between JTF and service or functional component leads. Two influencing factors trend toward service- and functional-led (GCC) operations: (1) situations in which political ramifications are significant and (2) scenarios in which the expected timeline is short or the response time is tight. Analysis of versatility of the two C2 concepts across a range of scenarios was not within the scope of our analysis. However, the methodology in this chapter would be a useful exercise moving forward. What might that analysis look like? For each C2 concept, we suggest examining the four metrics across a

Table 3.22. Survey Results of Preferred C2 Concept for Each Identified Risk

Risk	GCC-Led	JTF-Led
Able to maintain sufficient TACON		X
Able to maintain sufficient OPCON	X	
Able to maintain battlespace awareness	X	
Sufficient time to stand up C2 apparatus such that the operation is not impeded	X	
Sufficient time to plan and execute force flow	X	
Able to task air assets	X	
Targeting synchronized for cross-domain operations	X	
Rules of engagement formulated and disseminated to forces	X	
Logistics train sufficient for adaptive basing	X	
Force protection adequate		X
Successfully conduct defensive and offensive cyberoperations	X	
NCA authorization to strike critical targets and conduct offensive space and cyber operations	X	
Sufficient interservice planning and coordination to enable joint schemes of maneuver	X	
Sufficient spectrum deconfliction and frequency allocation to support operations	X	
Joint forces commander has situational awareness prior to the event	X	
Preestablished C2 relationships (military-military, political-military, civilian-military)	X	
Taskable ISR assets are available to provide common operational picture	X	
Units ready and nearby to respond (e.g., 82nd within 18 hours, crisis response force)	X	
Commanders at all levels understand capacity and capability of the resources at their disposal	X	
Commanders at all levels understand roles, responsibilities, and processes	X	
Commander has authorities for operation and can establish operations in a timely manner	X	
Taskable mobility assets available to transport critical material	X	
Funds available	X	
Span of control: scale of disaster reflects extant plan and experience		X
Means of sharing information with partners		X
Deployable communications packages either do not exist or are not available	X	
Releasability protocols in place	X	
Opportunity cost of HA/DR response is acceptable with respect to other USPACOM commander missions and responsibilities	X	
Republic of Philippines government provides permission for JFLCC to conduct force protection	X	
Interservice request for forces for force protection mission is possible	X	
In-transit visibility of all relief assets	X	
ACA in terminal area sufficient to manage all air assets		X
Command element operating on same battle rhythm		X
UN and Republic of Philippines have sufficient assets to maintain mission, take over operation		X
The orchestration of the operation is responsive to what is happening in the JOA		X

range of scenarios. Tables 3.23 and 3.24 summarize the results of the two scenarios for the JTF-led and GCC-led concepts, respectively. While this report looks at only two scenarios, additional scenarios would aid understanding of the versatility of each concept. One useful approach would be to examine the various Pacific theater operational plans. Each plan would likely entail different risks and different alternative resiliency measures to consider. Some scenarios may indicate that the resources needed are just too great to implement or that the span of control may be too broad. However, operational plans are combat operations and will not fully represent the range of situations we found ourselves in for this theater. One can draw on real-world situations (HA/DR, noncombatant evacuation operations, etc.) that have occurred in the Pacific to examine the versatility of the C2 concepts under consideration.

For the GCC-led concept, the most important unique risk was the responsiveness and situational awareness of a high HQ located on Oahu. This concept may be unsupportable in some of the Pacific scenarios. Furthermore, looking across a range of situations may reveal additional risks and potential resiliency measures.

Table 3.23. Initial Look at Versatility of JTF-Led Concept

	JTF-Led Operation	
Category and Metric	**Major War**	**HA/DR**
Resources		
Total Air Force manpower	929	482
Total JAOC manpower	464	220
Performance		
Span of control at the theater level	7	6
Span of control at the JTF level	5	5
Connectivity index at the theater level	5.1	6.67
Connectivity index at the JTF level	21.4	17.9
Height at the theater level	4	4
Height at the JTF level	4	4
Number of JAOC relationships	3	2
Risk and resiliency		
Total number of risks	10	10
Most important unique risk	Ability to task air assets under JTF control in a timely manner	The JTF commander has the authorities (OPCON/TACON) for the operation and can conduct operations in a timely manner
Associated resiliency measures	Monitor the timing of air operations (signpost) Train and exercise with multiple JFACCs using a single JAOC (shaping action) Stand up a coordination cell for each JFACC within the JAOC (hedging action)	Develop a PACAF checklist of needed authorities and processes to use or work with USPACOM to develop a CONPLAN for HA/DR (shaping action) Send requests for forces and authorities as needed (hedging action)

Table 3.24. Initial Look at Versatility of GCC-Led Concept

Category and Metric	GCC-Led Operation	
	Major War	HA/DR
Resources		
Total Air Force manpower	466	254
Total JAOC manpower	317	147
Performance		
Span of control at the theater level	5	5
Connectivity index at the theater level	10.7	10.7
Height at the theater level	4	4
Number of JAOC relationships	1	1
Risk and resiliency		
Total number of risks	4	10
Most important unique risk	Ability to maintain battlespace awareness of forward operations from reachback at USPACOM	The orchestration of the operation responsive to what is happening in the JOA
Associated resiliency measures	Implement UDOP concept (hedging action)	Have the JAOC run a separate ATO cycle for the HA/DR operation (shaping action)

4. Findings and Recommendations

Findings

What Methods Should Be Used to Compare and Contrast Alternative Concepts for C2 of Joint Air Operations in the Pacific?

The research results suggest that alternative concepts for C2 of joint air operations in the Pacific should be compared and contrasted in terms of five metrics:

1. **Resources.** In particular, comparing and contrasting the concepts in terms of their manpower requirements is useful for capturing the "costs" of alternative concepts.
2. **Performance.** Methods for directly assessing the operational outcomes of human decisionmaking as a function of an organizational structure remain elusive. However, there are methods for comparing and contrasting C2 concept performance in terms of efficiency and effectiveness, for instance, assessing span-of-control metrics.
3. **C2 Risk.** We developed a unique TTX approach to assessing C2-related risk metrics that is based on ABP. C2 risk is associated with assumptions that have a likelihood of failure and that could adversely affect the outcome of operations. Signposts can monitor the situation to determine whether an assumption is likely to fail.
4. **C2 Resiliency.** Similarly, the C2R2 TTX methodology can be used to identify two types of resiliency measures associated with each risk: a shaping action that can be taken to prevent failure and a hedging action that can be taken in the event an assumption fails.
5. **Versatility.** For versatility, we suggest comparing and contrasting a given C2 concept in terms of resources, performance, risk, and resiliency across a range of scenarios (rather than comparing alternative C2 concepts against a given scenario). This may provide insights into the versatility of a given C2 concept in addressing a range of operational needs.

There is no optimal or correct choice of a C2 concept for a given operation, only preferences in terms of the metrics. To demonstrate this in simple terms, consider that it is always possible to cut resources from a given C2 concept, which would be beneficial in terms of resource requirements. But reducing them too much may adversely affect the performance and risk metrics, which is detrimental. Hence, there are trade-offs among these metrics.

How Do Recently Proposed C2 Concepts Compare and Contrast in Relevant Pacific Scenarios?

Table 4.1 compares and contrasts the C2 concepts for a GCC-led and a JTF-led major war operation that includes Phase II and Phase III operations with a near-peer competitor. In terms of resources, the JTF-led C2 concept requires about twice the manpower as the GCC-led C2

Table 4.1. Comparison and Contrast of the GCC-Led and JTF-Led C2 Concepts in a Major War Scenario

	Major War Scenario	
Category and Metric	GCC-Led	JTF-Led
Resources		
Total Air Force manpower	447	944
Total JAOC manpower	317	591
Performance		
Span of control at the theater level	5	7
Span of control at the JTF level	N/A	5
Connectivity index at the theater level	10.7	5.1
Connectivity index at the JTF level	N/A	21.4
Height at the theater level	4	5
Height at the JTF level	N/A	4
Number of JAOC relationships	1	3
Risk and resiliency		
Number of unique risks	2	8
Number of common risks	2	
Total number of risks	4	10
Most important unique risk	Ability to maintain battlespace awareness of forward operations from reach-back at USPACOM	Ability to task air assets under JTF control in a timely manner
Associated resiliency measures	Implement UDOP concept (hedging action)	Monitor the timing of air operations (signpost) Train and exercise with multiple JFACCs utilizing a single JAOC (shaping action) Stand up a coordination cell for each JFACC within the JAOC (hedging action)
Most important common risk	U.S. forces have sufficient time to plan and execute force flow	
Associated resiliency measures	Implement adaptive basing operational concepts (shaping action) Prepositioning (shaping action) Mobility exercises (shaping action)	

concept (944 versus 447). The difference is in the additional manpower needed for the JTF-subordinate JFACCs, the additional JACCE staffs, and augmentation at the JAOC.[1]

For performance, we will first compare and contrast the numerical values of the metrics for the two concepts, and then offer an interpretation of the result. If the GCC commander directly leads an operation, the span of control at the theater is 5. This is because there are five direct

[1] Our evaluation of staffing levels did not consider how the staffs would be resourced or take into consideration possible resource constraints. Our evaluation also assumed that the U.S. Air Force would be tasked to lead one of the JTFs. This might be the case for an operation in which the preponderance of forces are air forces.

reports to the GCC commander (the GCC staff and the four components). However, if the GCC commander instead decides to stand up two JTFs to lead the operation, the span of control at the theater level increases from 5 to 7 (since each JTF commander is also a direct report), but the number of indirect relationships that the GCC commander must manage relative to the size of the organization drops, as measured by the connectivity index, which goes from 10.7 to 5.1. Note that the span of control of each JTF commander is 5, but that the connectivity index is very high at the operational level, in contrast to the theater level (21.4 as compared to 5.1). The height of the organization at the theater level increases from 4 to 5 in a JTF-led operation, and the number of relationships that the JAOC must manage increases from 1 in a GCC-led operation to 3 in a JTF-led operation (one relationship for each JFACC).

Our interpretation is that the GCC commander may improve the effectiveness of C2 at the theater level by standing up JTFs because this gives the commander more options (enabled by expanded span of control) and reduces the number of indirect relationships he or she must manage relative to the size of the organization. However, JTF commanders have a large number of indirect relationships to manage relative to the size of the organization (as measured by the connectivity index), which could be detrimental to C2 efficiency for the operation. Similarly, the JAOC only has a relationship to a single TJFACC in the case of a GCC-led operation but must also manage relationships to the JTF-subordinate JFACCs for a JTF-led operation, which could be detrimental to C2 efficiency at the JAOC. Of course, one means of making up for this efficiency strain is to augment the JAOC staff to respond to a more complicated situation. And finally, the increased height in the organization, as seen from the theater level (5 versus 4), could slow theater-level C2 decisionmaking related to the operation. For instance, this could slow decisions related to theater-level assets supporting the operation or could slow the ability to amass forces from across the theater.

In terms of C2 risk, the C2 concept for a GCC-led operation in a major war scenario appears to be less risky than that for the JTF-led operation; the TTX identified fewer risks here, four for a GCC-led operation and ten for a JTF-led operation. The two concepts had two risks in common. The most important common risk is that U.S. forces must have sufficient time to plan and execute the force flow. The TTX participants suggested that the use of adaptive-basing concepts, prepositioning of forces and equipment, and additional mobility exercises could provide resiliency measures to mitigate this risk. Among the risks that are unique to a GCC-led operation, the most important was judged to be the risk to maintaining battlespace awareness of forward operations from reachback at USPACOM. Participants identified implementation of the UDOP concept as a potential resiliency measure.[2] As for the unique risks associated with the C2 concept for a JTF-led operation, the most important was judged to be the ability to task assets under JTF control in a timely manner. Participants suggested monitoring the timing of operations to determine the timeliness, conducting training and exercises for the JAOC to work with

[2] For details about the UDOP concept, see U.S. Air Force, 2015, p. 9.

multiple JFACCs, and standing up a coordination cell for each JFACC within the JAOC as potential resiliency measures for mitigating the risk.

Table 4.2 compares and contrasts the two C2 concepts in the HA/DR scenario. While the major scenario involved two JTFs, the HA/DR scenario only involves one JTF. Still, the JTF-led operation requires almost twice the total Air Force manpower as the GCC-led operation, including significantly more personnel at the JAOC. The effects on performance are similar to

Table 4.2. Comparison and Contrast of the GCC-Led and JTF-Led C2 Concepts in an HA/DR Scenario

	HA/DR	
Category and Metric	**GCC-Led**	**JTF-Led**
Resources		
Total Air Force manpower	253	444
Total JAOC manpower	147	220
Performance		
Span of control at the theater level	5	6
Span of control at the JTF level	N/A	5
Connectivity Index at the theater level	10.7	6.67
Connectivity Index at the JTF level	N/A	17.9
Height at the theater level	4	5
Height at the JTF level	N/A	4
Number of JAOC relationships	1	2
Risk and resiliency		
Number of unique risks	6	6
Number of common risks	4	
Total number of risks	10	10
Most important unique risk	The orchestration of the operation is responsive to what is happening in the JOA	The JTF commander has the authorities (OPCON/TACON) established for the operation and can conduct operations in a timely manner
Associated resiliency measures	Have the JAOC run a separate ATO cycle for the HA/DR operation (shaping action)	Develop a PACAF checklist of needed authorities and processes to use and work with USPACOM to update CONPLAN 5001 (shaping action) Send requests for forces and authorities as needed (hedging action)
Most important common risk	Deployable communications packages either do not exist or are not available	
Associated resiliency measures	Continue to build out and UTC the requirements for deployable communication packages and incorporate them into CPX and FTX events (shaping action) Leverage host nation infrastructure if available (hedging action)	

those for the major war scenario. Standing up a JTF may increase the number of options and flexibility at the theater level, as measured by the increase in theater-level span of control and the decrease in indirect relationships. The height of the organization as seen from the theater level also increases, which may slow theater-level support to the operation. The TTX identified ten risks for each C2 concept. Participants judged the most important common risk to be to the existence and availability of deployable communication payloads. As a resiliency measure, participants suggested continuing to build out the UTC the requirements for deployable communication packages and incorporating them into exercise events. In the event that packages are not available, participants suggested that U.S. forces should leverage host-nation infrastructure for communications to the extent available. The most important unique risk associated with the GCC-led concept is keeping the orchestration of the operation responsive to what is happening in the JOA. As an associated resiliency measure, participants suggested running separate ATO cycles for the HA/DR operation and the other theater-level concerns. The most important unique risk for the JTF-led concept is to the JTF commander having established OPCON and TACON for the operation and being able to conduct operations in a timely manner. Resiliency measures may include developing a PACAF checklist of needed authorities and processes to use or working with USPACOM to develop a CONPLAN for HA/DR.

For versatility, we would compare and contrast the resource, performance, risk, and resiliency metrics for a given C2 concept across scenarios (rather than C2 concepts for a given scenario). Table 4.3 shows the for GCC-led operations for the major war and HA/DR scenarios side by side. The manpower resource requirements are substantially greater for a major war than for an HA/DR operation. The performance metrics do not change between the two scenarios. The most important risks are those related to maintaining battlespace awareness of forward operations from reachback at USPACOM in the case of the major war scenario and responsiveness of operations in the JOA in the case of HA/DR.[3]

Table 4.4 compares the JTF-led concept in the two scenarios. Again, the manpower resource requirements are much greater for the major war than for the HA/DR operation. Unlike the concept for a GCC-led operation, here there are some differences in the performance metrics in the two scenarios. This is because there are two JTFs for the major war but only one for the HA/DR operation. Ten risks were identified for each scenario. In the major war case, the most important risk is related to the ability of the JTF to task air assets in a timely fashion. In the case of HA/DR, it is related to having authorities to conduct operations in a timely manner.

[3] For this concept in the major war scenario, the implication for the Air Force is the challenge of maintaining battlespace awareness for the TJFACC operating from PACAF HQ.

Table 4.3. Versatility of GCC-Led C2 Concept in Major War and HA/DR Scenarios

	GCC-Led Operation	
Category and Metric	**Major War**	**HA/DR**
Resources		
Total Air Force manpower	447	253
Total JAOC manpower	317	147
Performance		
Span of control at the theater level	5	5
Connectivity index at the theater level	10.7	10.7
Height at the theater level	4	4
Number of JAOC relationships	1	1
Risk and resiliency		
Total number of risks	4	10
Most important unique risk	Ability to maintain battlespace awareness of forward operations from reachback at USPACOM	The orchestration of the operation is responsive to what is happening in the JOA
Associated resiliency measures	Implement UDOP concept (hedging action)	Have the JAOC run a separate ATO cycle for the HA/DR operation (shaping action)[a]

[a] To clarify, this shaping action would have the 613th JAOC run two separate ATO cycles: one for air operations to support the HA/DR operation and synched to its battle rhythm and a second for air operations other than those to support the HA/DR operation and synchronized to the battle rhythm of the GCC.

Discussion

We observe that the manpower resource estimates for the selected concepts and scenarios vary over a significant range. For instance, the total Air Force C2 manpower estimate ranges from a low of 253 for a GCC-led HA/DR operation to a high of 944 for a JTF-led major war scenario. Similarly, the manpower estimates for the JAOC vary from a low of 147 to a high of 591. Providing manpower resources for these C2 concepts could strain the total force.

The methods developed in this research for comparing and contrasting C2 concepts in a scenario should be applicable to other theaters besides the Pacific. However, because our results are for select scenarios in the Pacific and because results can vary if concept details are changed or applied to different scenarios, our results should not simply be generalized.

While the results of the metric evaluations are narrowly focused on joint air operations in the Pacific in specific scenarios and with specific concepts, we believe that the methodologies could be applied to evaluations of a broader range of operations, theaters, scenarios, and concepts. In hindsight, we do recognize two key shortcomings of the methodologies that the C2 community could address in future research. The first is that we assumed that the C2 concepts are static. In real-world operations, the C2 concepts tend to be very dynamic. New methods might need to be developed to compare and contrast alternative C2 concepts that change over time. The second

Table 4.4. Versatility of JTF-Led C2 Concepts in Major War and HA/DR Scenario

	JTF-Led Operation	
Category and Metric	**Major War**	**HA/DR**
Resources		
Total Air Force manpower	944	444
Total JAOC manpower	591	220
Performance		
Span of control at the theater level	7	6
Span of control at the JTF level	5	5
Connectivity index at the theater level	5.1	6.67
Connectivity index at the JTF level	21.4	17.9
Height at the theater level	4	4
Height at the JTF level	4	4
Number of JAOC relationships	3	2
Risk and resiliency		
Total number of risks	10	10
Most important unique risk	Ability to task air assets under JTF control in a timely manner	The JTF commander has the authorities (OPCON/TACON) established for the operation and can conduct operations in a timely manner
Associated resiliency measures	Monitor the timing of air operations (signpost) Train and exercise with multiple JFACCs using a single JAOC (shaping action) Stand up a coordination cell for each JFACC within the JAOC (hedging action)	Develop a PACAF checklist of needed authorities and processes and work with USPACOM to update CONPLAN 5001 (shaping action) Send requests for forces and authorities as needed (hedging action)

is that our performance metrics evaluate the efficiency and efficacy of C2 in enabling operations, as opposed to evaluating the contributions of C2 concepts to achieving operational outcomes. M&S techniques for C2 may provide methods for overcoming these shortfalls, but more progress is needed.

Recommendations

The recommendations are based on the five metrics and associated methods for comparing and contrasting alternative C2 concepts in a given scenario developed as part of this research. The recommendations also include insights gleaned from the C2 risk and resiliency metrics judged to be most important from the C2R2 TTX conducted in July 2016. Specifically, we recommend that the Air Force do the following:

- Evaluate manpower resource needs and span-of-control–related performance metrics for C2 concepts recently proposed for the Pacific AOR. Expand the analysis to include additional scenarios of interest.
- Implement the C2R2 TTX methodology in upcoming exercises and wargames with Air Force participation. A C2R2 TTX could be conducted as a parallel workshop for exercises, including Pacific Sentry, Plan Blue, Unified Engagement, and Futures Game.
- Prioritize and continue to build out UTC requirements for deployable communications packages. Availability of deployable communications was identified as a common C2-related risk for the HA/DR scenario.
- Continue to develop the UDOP concept; it may be a resiliency measure to address the risk of maintaining battlespace awareness in a major war scenario with the GCC-led concept.
- Train and exercise production of an ATO for multiple JFACCs at the 613th JAOC. This could help improve the efficiency of ATO production in an operation led by one or more JTFs.
- Train and exercise parallel ATO production cycles at the 613th JAOC. This could help ensure that air operations are responsive to JOA needs when time is of the essence, such as in an HA/DR operation.
- Based on the risk assessment for the HA/DR operation, we recommend that PACAF add additional details to the joint air component portion of CONPLAN 5001:[4]
  - Identify the likely Air Force staff needed for joint field office(s)
  - Develop a checklist of possible needed authorities and coordination processes for the joint air component (JTF-subordinate JFACC)
  - Expand the command, control, and coordination portion of the CONPLAN to include details for the joint air component.

[4] Headquarters U.S. Pacific Command, "USPACOM CONPLAN 5001-13: Defense Support of Civil Authorities (DSCA)," December 20, 2013.

Appendix A. Historical Review

Objectives and Scope

In January 2016, a two-day workshop on C2 was held at RAND. The participants had the opportunity to determine how they would want to have C2 in place to complete a potential scenario in the PACAF AOR. When participants role-played as the GCC, they unanimously preferred to directly lead operations that could involve combat with a near-peer adversary rather than delegate leadership responsibility for those operations to a subordinate JTF. When asked why, they said it had to do with risk to U.S. forces and political risks associated with the prospect of failing to meet U.S. objectives. They also expressed that the GCC would be better able than a JTF to amass forces from across the theater to bring to bear against adversary centers of gravity. In contrast, many of the participants felt that JTF leadership would be preferred for other operations not involving combat with a near-peer adversary, especially those that require smaller-scale, rapid responses to localized environmental effects.

The objective of this appendix is to describe a historical review we conducted with a low level of effort to determine whether recent history reflects the preferences of the participants in the 2016 workshop and to gain insights into potential drivers of these preferences or their alternatives. The results of the review also provide a useful context for the project, and during the course of the review, we became aware of a few less-tangible considerations for C2 concepts that did not arise in the development of the metrics.

The review examined C2 in operations from 1989 to 2015. We derived the initial list of operations from two editions of a chronicle of the use of U.S. armed forces abroad.[1] These sources were augmented with information gathered from additional literature reviews, as well as from interviews with military historians and personnel who participated in C2 organizations of recent operations. We chose 1989 as the starting year because it marked the year of the first test of the Goldwater-Nichols Act of 1986: Operation Just Cause (the U.S. invasion of Panama). The Goldwater-Nichols Act streamlined the military chain of command from the President to the Secretary of Defense, and from the Secretary of Defense directly to the GCCs, bypassing the service chiefs.[2] That was also the year the Berlin Wall came down, essentially ending the Cold War, which had significant implications for how the U.S. military trained and equipped for the future.

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[1] Richard F. Grimmett, *Instances of Use of United States Armed Forces Abroad, 1798–2004*, Washington, D.C.: Congressional Research Service, October 5, 2004; Barbara Salazar Torreon, *Instances of Use of United States Armed Forces Abroad, 1798–2015*, Washington, D.C.: Congressional Research Service, R42738, October 15, 2015.

[2] Goldwater-Nichols Department of Defense Reorganization Act of 1986, 99th Cong., October 1, 1986.

We begin by describing some of the characteristics of C2 used in recent operations, go on to describe our findings on C2 leadership by the type of operation to see whether history reflects the preferences of the workshop participants, and end with our findings on some of the less tangible considerations for C2 concepts.

Characteristics of C2 in Recent Operations

On November 9, 1989, the world changed forever. The wall separating the free world from the Communist bloc had fallen. With little notice, the Cold War had ended. The large two-front war that countless American soldiers, sailors, airmen, and marines had been preparing to fight would never come. The impending fight with the Soviet Union never happened, and our military planners shifted focus onto less threatening but more diverse military endeavors.

Military operations over this period varied greatly in the number of forces used, the purpose of the operations, the extent of hostilities, geographic locations, and the C2 concepts used. GCCs often had numerous, concurrent missions, including peacetime engagements working with the many U.S. ambassadors, nations, and other stakeholders in their AORs.[3] GCC commanders have a unique challenge in that they have broad theatre responsibilities, shaping and defining how to respond to crises within the AOR.[4] It would appear that no single C2 concept is optimal for all operations. This is likely a result of the diversity of requirements in the AORs. Also, C2 concepts have tended to evolve over the course of an operation, rather than remain static.

Defining the C2 concept is not simple and involves one of several key design and planning decisions. A 2013 best-practices focus paper concludes that the essential tasks in determining the optimal C2 structure are developing an understanding of the environment, framing the problem, providing a range of options to national leadership, developing a strategy to support the plan of action the NCA desires, determining an operational approach, defining the mission, and gaining the necessary forces.[5]

JP 1 states the following:

> Component and supporting commands' organizations and capabilities must be integrated into a joint organization that enables effective and efficient joint C2. The C2 structure is centered on the JFC's mission and CONOPS; available forces and capabilities; and joint force staff composition, capabilities, location, and facilities. The JFC should be guided in this effort by the following principles: simplicity . . . span of control, . . . unit integrity, . . . interoperability.[6]

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[3] Gary Luck and Deployable Training Division, Joint Staff J-7, "Mission Command and Cross-Domain Synergy," focus paper, March 2013.

[4] Deployable Training Division, Joint Staff J-7, "Joint Operations," focus paper, March 2013a.

[5] Deployable Training Division, Joint Staff J-7, "Design and Planning," focus paper, July 2013b.

[6] JP 1, 2013, p. V-18.

GCC commanders have employed four different C2 structures in recent operations to meet the intent of the quote from JP 1, including basing the structure on functional and service components, subordinate unified commands, single-service forces, and JTFs.

In 2003, the U.S. Central Command (USCENTCOM) combined forces land component commander was called on as the coalition functional component to support the attack north into Iraq. This is an example of a GCC commander employing a functional component as the basis for a C2 structure. The response to Typhoon Haiyan in 2013 is an example of a GCC commander using a service component as the basis for C2. In particular, U.S. Marine Corps Forces, Pacific was the supported commander for foreign humanitarian assistance support to the Philippines.

A subordinate unified command, or subunified command, is an established joint organization subordinate to a GCC. A subunified command may be established on a geographical area or functional basis to conduct continuing operations.[7] For instance, an example of the use of a geographic subunified command as the basis for C2 would be the political and military roles U.S. Forces Japan played in support of the 2011 tsunami and nuclear relief efforts in Japan during Operation Tomodachi. An example of a functional subunified command for this would be the support that Special Operations Command, Pacific and Joint Special Operations Task Force (JSOTF) provided to Operation Enduring Freedom–Philippines from 2002 to 2015.

Single-service or specific operational forces have provided the basis for C2 in crises or operations that were limited in duration or scope. For instance, the 3rd Marine Expeditionary Brigade was assigned to support USAID and the Office of Foreign Disaster Assistance in assisting the government of the Philippines after Typhoon Haiyan in 2013. The brigade was subordinate to III Marine Expeditionary Force (MEF) and U.S. Marine Corps Forces, Pacific. As the operation continued to unfold, the GCC commander established JTF 505 with III MEF as the lead service. An example of a specific operational force as a basis for C2 is Task Force Dagger. This JSOTF was established at the beginning of operations in Afghanistan in 2001 and was subordinate to Special Operations Command, Central but reported directly to USCENTCOM. This JSOTF was supported by the USCENTCOM TJFACC.[8]

The final option we have seen GCC commanders use for a C2 structure is the JTF. It has been argued that a major benefit of the JTF option is that it is likely to focus on a single mission and can direct close integration of mission forces in the objective area.[9] The following are examples of JTF-based C2 structures:

- JTF-South in 1989 for Operation Just Cause. The core of JTF HQ was the XVIII Airborne Corps operating directly under U.S. Southern Command.

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[7] Deployable Training Division, Joint Staff J-7, "Geographic Combatant Commanders (GCC) Command and Control Organizational Options," focus paper, 2nd ed., August 2016.

[8] Deployable Training Division, 2016.

[9] Deployable Training Division, 2016.

- JTF Somalia in December 1992 for Operation Restore Hope. The JTF was established by U.S. Commander in Chief, Central. The core JTF HQ was assigned to the I MEF.
- Combined JTF (CJTF) Inherent Resolve in October 2014 for defeating the Islamic State in Iraq. It was established by USCENTCOM. The U.S. 3rd Army and U.S. Army Central was designated as the CJTF commander.

U.S. military commanders have had to coordinate their efforts with numerous state and nonstate partners during recent operations. This has included host-nation governments, foreign militaries, and intergovernmental organizations and NGOs. The military usually experiences fewer challenges in working with foreign military counterparts than with other, nonmilitary partners. For instance, coordination with partners during HA/DR operations can be challenging if there is little mutual understanding between the two parties in terms of organizational culture and ways of working.[10] Nonmilitary organizations may be perceived to deviate from impartiality and independence when working with military organizations.

Furthermore, humanitarian actors' safety can be at risk if their military partners are not perceived as a friendly presence in the service region. Depending on the nature of the disaster and the political environment in the affected nation(s), civil-military relations can range from cooperation to sheer coexistence. The UN developed four strategies to facilitate civil-military coordination in different contexts (see Figure A.l):[11]

- **Colocation.** During peacetime, it is most efficient for military and humanitarian actors to colocate in the same facility; this arrangement allows real-time interaction and communication with low organizational and technical constraints.
- **Liaison exchange.** Unilateral or bilateral exchange of LNOs is common when colocation is not feasible for logistical or security considerations.
- **Liaison visits.** In more complex disasters, when military actors are party to the conflict or are perceived as belligerent, humanitarian actors would prefer to minimize visible contacts to secure personnel safety and access to the affected population. In this case, LNOs from both sides will only interact in relevant meetings and activities.
- **Interlocutor.** As the complexity of the disaster escalates, working with a third party is the only way for military and humanitarian actors to interact.

C2 During Operation Iraqi Freedom

In November 2002, President George W. Bush announced that Iraqi President Saddam Hussein must disarm or face the consequences at the hands of a U.S.-led "coalition of the willing."[12]

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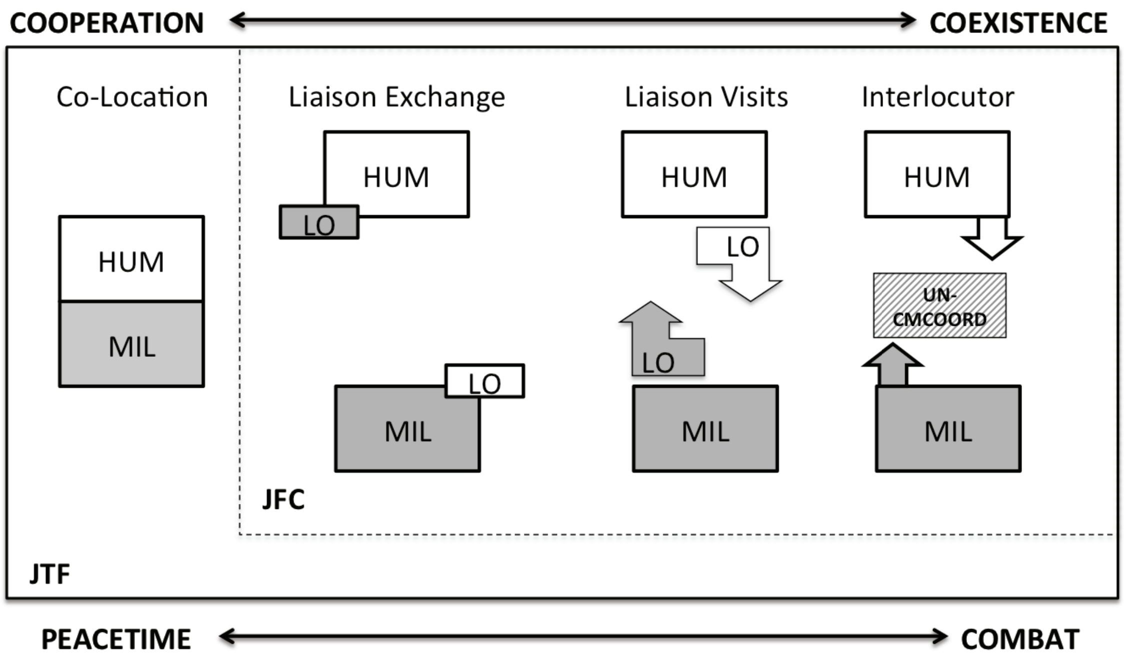
[10] L. K. Wentz, "Lessons from Kosovo: The KFOR Experience," Washington, D.C.: Command and Control Research Program, 2002.

[11] United Nations General Assembly, "Implementation of the International Strategy for Disaster Reduction," August 4, 2015.

[12] Stephen A. Carney, *Allied Participation in Operation Iraqi Freedom* Washington, D.C.: U.S. Government Printing Office, 2012.

Figure A.1. Potential Civil-Military Liaison Arrangements Under Each C2 Concept



SOURCE: Adapted from United Nations Office for the Coordination of Humanitarian Affairs, *Country/Situation-Specific Guidelines and Guidance on Humanitarian Civil-Military Coordination and the Use of Military and Civil Defense Assets: Humanitarian Civil-Military Coordination—A Guide for the Military*, 2014.
NOTE: HUM = humanitarian; LO = liaison officer.

Iraq was not a new place for the U.S. military. Since the end of operations Desert Shield and Desert Storm, USCENTCOM had been conducting Phase 0 and Phase I operations (shaping and deterring actions):[13]

- Following the end of the Gulf War, Operation Provide Comfort began with the use of JTF Provide Comfort—and later CTF Provide Comfort—to ensure security and provide aid to the Kurds in northern Iraq and institute a no-fly zone north of latitude 36N (1991–1996).
- In Operation Southern Watch, JTF Southern Watch reported to USCENTCOM and installed a no-fly zone south of latitude 33N (1991–2003).
- Operation Desert Strike was a joint U.S. Navy and U.S. Air Force strike on air defenses in southern Iraq (1996).
- The CTF for Operation Northern Watch reported to U.S. European Command and installed and maintained a no-fly zone, again north of latitude 36N (1997–2003).
- In Operation Desert Fox, CENTCOM commanded strikes on targets in Iraq in response to a continual failure to comply with UN Security Council resolutions (1998).

When the decision to invade Iraq in 2003 was made (Phase II and Phase III operations), GEN Tommy Franks—then USCENTCOM commander—elected not to create a CJTF to fight the war. He would have the service component commanders conduct combat operations. The

[13] The phase numbers refer to military operations as defined in Section E of JP 3-0, 2011, Fig. V-3.

component commanders served as the force providers for the regional commander, USCENTCOM. In Operation Iraqi Freedom, the combined forces air component commander (CFACC) assumed OPCON over all land forces, except SOF. The SOF were controlled by the combined forces special operations component commander (CFSOCC). The CFACC controlled all air operations in the Iraqi AOR through the combined air operations center. The combined forces maritime combatant commander controlled all naval forces.[14]

The U.S. Army Central commander was appointed as the CFACC and commander of all Army forces in the AOR. He had OPCON of all ground forces in the AOR, including British forces and U.S. Marines, but not U.S. and coalition SOF.[15]

The commander of U.S. Air Force Central Command was selected as the CFACC and commander of all U.S. and coalition air forces (AFFOR) in the AOR. He was granted OPCON and TACON over any U.S. European Command aircraft participating in Operation Northern Watch.[16] The CFACC was located at Prince Sultan Air Base in Saudi Arabia (later, Al Udeid Air Base in Qatar), where he was responsible for directing air operations in the area through the combined air operations center. The CFACC was also designated as the ACA and the AADC, so he was responsible not only for the conduct of all air operations but also for defense of the airspace in the area of operations. Because air operations in the north could potentially involve Turkey, the CFACC was charged with coordinating airspace control with Turkey.[17]

The commander of U.S. Naval Forces Central Command was designated the combined forces maritime component commander and the commander of all naval forces in the area of operations. He was responsible for the conduct of maritime operations in the area and was granted coordinating authority with the U.S. Navy European Command commander to execute Tomahawk Land Attack Missile tasking for U.S. Navy European Command naval forces operating in the eastern Mediterranean in support of operations in Iraq.[18]

The commander of Special Operations Command, Central was designated the CFSOCC. CFSOCC was granted C2 of coalition SOF.[19] CFSOCC created three combined joint special operations task forces, one to operate in northern Iraq; another for western Iraq; and a third, naval, task force to work the southern coast.[20]

The commander of Marine Corps Forces, Pacific was designated commander of U.S. Marine Forces, Central Command. He was responsible to the commander of USCENTCOM for

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[14] Walter L. Perry, Richard E. Darilek, Laurinda L. Rohn, and Jerry Sollinger, eds., *Operation Iraqi Freedom: Decisive War, Elusive Peace*, Santa Monica, Calif.: RAND Corporation, RR-1214-A, 2015.

[15] Patrecia S. Hollis, "CENTCOM: Targeting in a Unified Command," *Field Artillery,* Vol. 4, No. 3, 2014.

[16] Hollis, 2014.

[17] Perry et al., 2015.

[18] Hollis, 2014.

[19] Hollis, 2014.

[20] Carney, 2012.

providing all Marine Corps forces in the area. These forces were placed under the OPCON of the combined forces land component commander.[21]

On June 14, 2003, after the declared end of major combat operations (Phase II and Phase III), CJTF-7 replaced the combined forces land component commander as the commander for all ground forces in theater (Iraq and Kuwait). The primary element of CJTF-7, the U.S. Army's V Corps, was commanded first by LTG William Wallace and then, beginning in July, by LTG Ricardo Sanchez.[22]

At the beginning of Phase IV operations, the main task of CJTF-7 was to provide stability for the establishment of an interim Iraqi government, the Iraqi Governing Council, and the Coalition Provisional Authority.[23] CJTF-7 assumed responsibility for organizing, training, and certifying a newly created Iraqi security force after all the Iraqi armed forces had been disbanded on May 23, 2003.[24]

For C2 purposes, CJTF-7 divided Iraq into six divisional areas of responsibility: Multi-National Division (MND)–North, MND–North Central, MND–Baghdad, MND–West, MND–Center South, and MND–Southeast. Later, in 2004, MND-North split into Multi-National Force (MNF)–Northwest and MND–Northeast.[25]

Future changes to the MNDs included the following: In 2006 MND–North Central merged with MND-North. In 2007, with the surge of forces, MND-Center formed. In 2008 MND-Northeast merged with MND-North, and MND–Center South merged with MND-Center. In 2009, MND-Center merged with MND-Southeast, with the latter becoming MND-South later that year. In January 2010, MNDs North, Baghdad, and South transitioned to U.S. Divisions North, Center, and South.[26]

On May 15, 2003, USCENTCOM replaced CJTF-7 with two new commands: MNF–Iraq (MNF-I) and Multi-National Corps–Iraq (MNC-I). The commander of CJTF-7 led MNF-I and LTG Thomas Metz commanded MNC-I.[27]

In 2007, President Bush decided to increase U.S. troop levels in Iraq. The military "surge" included sending five additional Army brigades, approximately 20,000 troops. In response to the "surge," MNF-I created a new AOR, MND-Center, which maintained responsibility from the outskirts of Baghdad to the Kuwait border and relieved MND-Baghdad forces of their role outside the city.[28]

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[21] Perry et al., 2015.

[22] Carney, 2012.

[23] Carney, 2012.

[24] Carney, 2012.

[25] Carney, 2012.

[26] Carney, 2012.

[27] Carney, 2012.

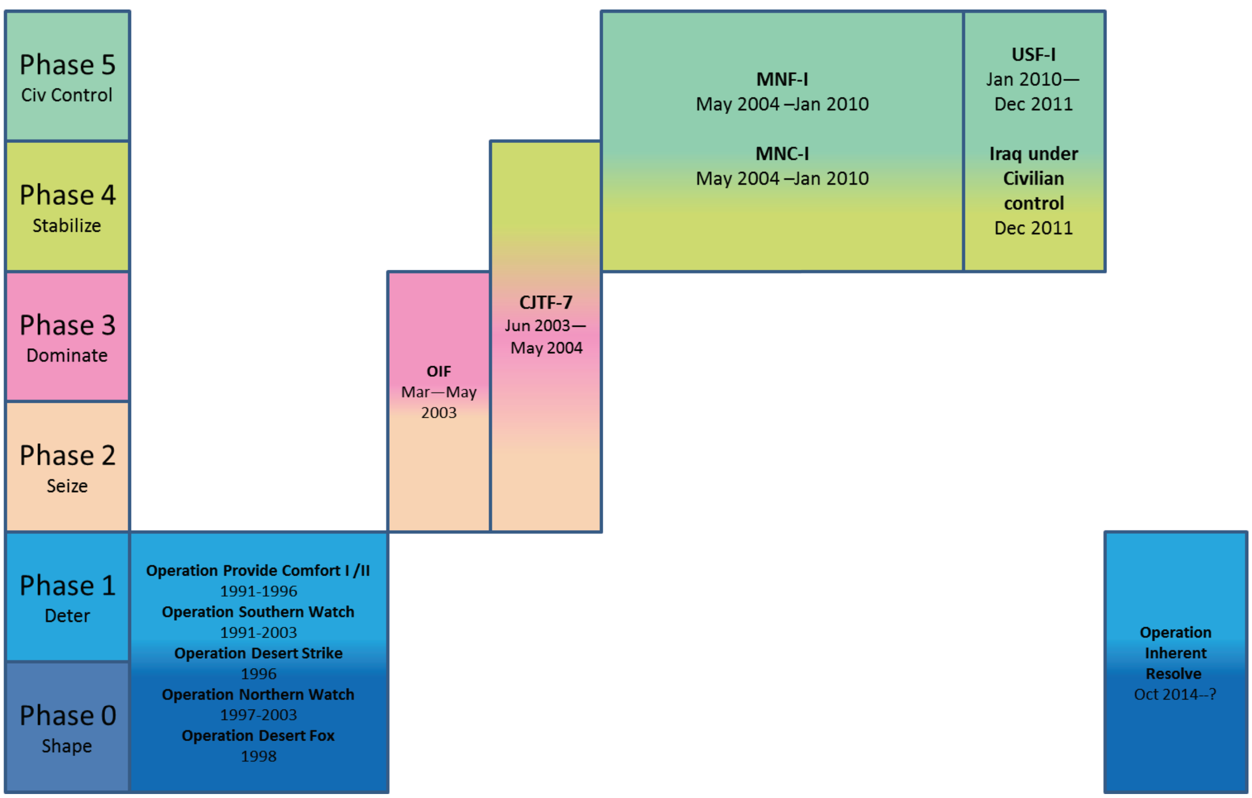
[28] Carney, 2012.

To support the ground forces during the Phase IV operations, the CFACC established the air component coordination element to facilitate interaction among the subordinate commands' staffs. This element did not have command authority and, initially, could not make commitments on behalf of the CFACC.[29]

In 2009, the Iraqi government decided against retaining allied forces in the country past July 31, 2009. In January 2010, MNF-I and MNC-I were combined and designated U.S. Forces–Iraq (USF-I). By December 2011, U.S. military forces had drawn down, and Iraq was under civilian control.

Figure A.2 illustrates these organizational changes, illustrating how military forces may transition between different C2 concepts significantly as operations unfold. The next subsection provides more details about C2 during an exemplar HA/DR operation that was conducted over the period of interest.

Figure A.2. Phasing and C2 in Iraq, 1991–2011



[29] 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 University, 2012.

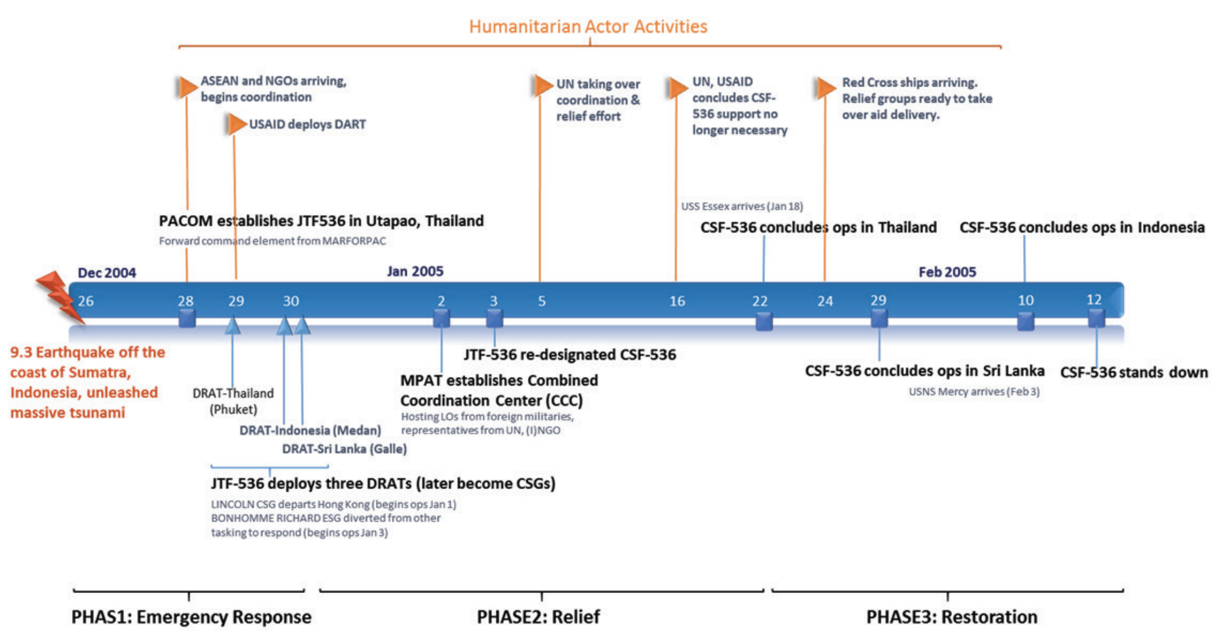
C2 During Operation Unified Assistance

On December 26, 2004, a 9.3 magnitude earthquake struck off the coast of the Indonesian island of Sumatra. The subsequent tsunami struck 11 nations, killed more than 225,000 people, and displaced 1.7 million in Southeast Asia and East Africa.

In response, USPACOM stood up JTF-536, under the command of Marine Corps LtGen Robert Blackman. After obtaining the Thai government's approval, JTF-536 quickly established its massive HQ in Utapao,[30] Thailand, and deployed three disaster relief assessment teams (DRATs) to Thailand, Sri Lanka, and Indonesia. (See Figure A.3.)

Given the scope of the earthquake and tsunami, USPACOM realized early on that Operation Unified Assistance required a multinational approach. Its multinational planning augmentation team thus set up the combined coordination center (CCC) in Utapao, hosting liaison officers from Australia, Britain, Japan, Thailand, and Singapore; representatives from USAID and several UN agencies; and NGOs and international NGOs. The CCC was recognized as the heart of the civil-military integration in the operation, not only providing a common venue for real-time coordination but also facilitating accurate needs assessments and helping avoid duplication of effort among a plethora of responders.

Figure A.3. Timeline of Operation Unified Assistance



[30] The HQ was massive in the sense that 11 foreign militaries were present along with representatives from various UN agencies and the U.S. Country Teams from the affected area. See Charles Daly, "Humanitarian Assistance and Disaster Relief Communications for the 21st Century," Newport, R.I.: U.S. Naval War College, October 5, 2007, p. 7.

However, not all civil-military coordination in the operation went as smoothly. Due to the longstanding conflict between a separatist group, the Free Aceh Movement, and the Indonesian military, the government of Indonesia placed considerable restrictions on all humanitarian actors, including foreign militaries, in the Aceh region. While the UN was able to establish a humanitarian information center, that did not occur not until several weeks after the earthquake, and the military assets were entirely under Indonesian military's coordination rather than conventional civilian coordination.[31]

Findings

C2 Leadership by Operation Type

Participants at the January workshop expressed their preference for the GCC commander to lead operations involving combat with a near-peer adversary but also indicated that delegating responsibility for an operation to a JTF might be preferable for other kinds of operations not involving combat with a near-peer adversary. We analyzed the C2 concepts used in recent operations to see if they reflected the preferences of the workshop participants.

To do this, we gathered data on 36 instances of the use of the U.S. military abroad during the period of 1989 to 2015 that involved a C2 concept led by a GCC commander or a JTF.[32] We then categorized each instance in terms of the types of operations involved. For this purpose, we used the following three categories of operations that are defined in joint doctrine:[33]

1. **Military Engagement, Security Cooperation, and Deterrence.** These ongoing activities establish, shape, maintain, and refine relations with other nations and domestic civil authorities (e.g., state governors or local law enforcement). The general strategic and operational objective is to protect US interests at home and abroad.
2. **Crisis Response and Limited Contingency Operations.** A crisis response or limited contingency operation can be a single small-scale, limited-duration operation or a significant part of a major operation of extended duration involving combat. The associated general strategic and operational objectives are to protect US interests and/or prevent surprise attack or further conflict.
3. **Major Operations and Campaigns.** When required to achieve national strategic objectives or protect national interests, the US national leadership may decide to conduct a major operation or campaign normally involving large-scale combat. During major operations, joint force actions are conducted simultaneously or sequentially in accordance with a common plan and are controlled by

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[31] Carsten Völz, "Humanitarian Coordination in Indonesia: An NG Viewpoint," *Forced Migration Review*, special issue, July 2005.

[32] Our primary sources were Torreon, 2015, and Grimmett, 2004. An additional 27 instances of the use of the U.S. military abroad did not involve a C2 concept led by a GCC commander or JTF.

[33] The category descriptions are direct quotes from JP 3-0, 2011, pp. I-4 to I-5.

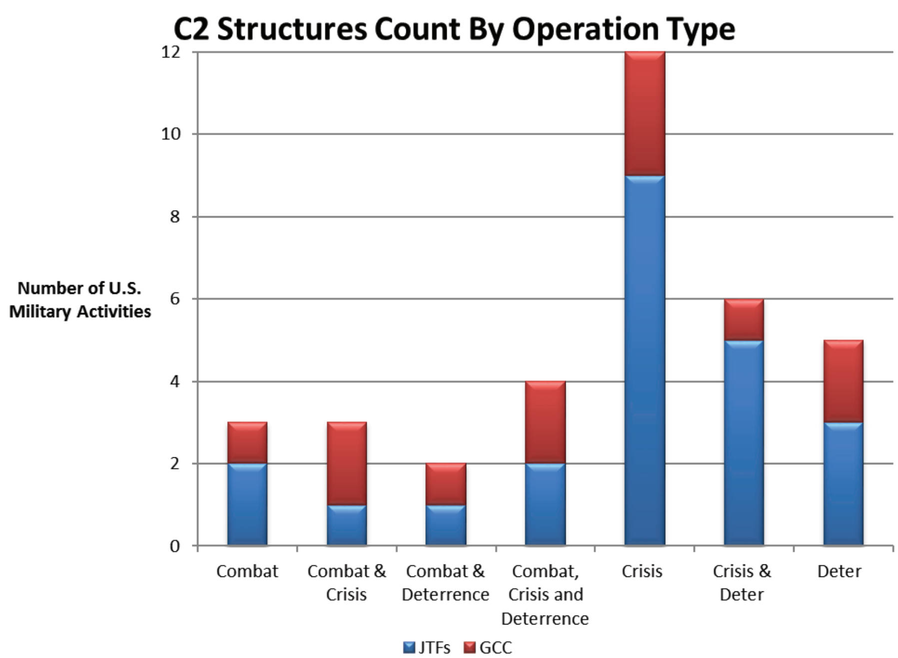
a single commander. A campaign is a series of related major operations aimed at achieving strategic and operational objectives within a given time and space.

Note that only the last category involves large-scale combat. For brevity, we refer to these three categories as deterrence, crisis, and combat operations, respectively. The member of our team who had primary responsibility for the historical analysis, who is an active-duty officer of the U.S. Air Force, applied his judgment to the list of instances to match each with the category definitions. The results were reviewed and refined with aid from other members of our team, which also included former and current active-duty U.S. military officers and consultations with additional sources. This allowed us to link U.S. military activities led by a GCC commander or a JTF to categories of operations.

Figure A.4 shows the results of this analysis. From left to right, the figure shows the number of military activities that involved only combat operations, both combat and crisis, both combat and deterrence, all three categories, only crisis, both crisis and deterrence, and only deterrence. Each bar further shows how many activities were led by JTF and GCC commanders.

The figure shows comparable usage of JTF and GCC concepts when large-scale combat is involved. This may provide evidence to contradict the preferences of the workshop participants. However, none of the combat operations during the period of analysis involved a near-peer adversary. Arguably, the United States has not conducted large-scale combat with a near-peer adversary since World War II. Hence, the historical evidence for the workshop hypothesis regarding combat operations is inconclusive.

Figure A.4. Command-and-Control Structures by Operation Type



A second observation is that military activities involving crisis and deterrence but not involving combat rely more heavily on C2 concepts led by a JTF. This may provide some evidence to support the preference of workshop participants for using JTF concepts in operations not likely to involve combat operations with a near peer.

Less-Tangible Considerations for C2 Concepts

The historical analysis also provided us with opportunities to examine issues affecting C2 concepts that did not arise during the development of metrics. The first consideration is that trust may play a significant role in the efficiency and effectiveness of a given C2 concept, specifically, trust between individuals, between individuals and organizations, or between different organizations in a C2 concept. Boyd credited trust as one of the key factors diminishing friction in the performance of C2 OODA loops.[34] Luck and Findlay credited trust as "a prerequisite to decentralization, delegation of authority and speed."[35]

While the research described in this report argues that C2 concepts for a given operation should be compared and contrasted in terms of five metric categories, history suggests that less-tangible factors, including personal bonds of trust between leaders, may play important roles in selecting a C2 concept and in choosing who to lead it. Being at the right place at the right time may play a role in selection of a C2 concept and leadership positions. These points were suggested by a subject-matter expert who had prior leadership experience in the C2 of recent operations.[36]

A third consideration is that C2 concepts, like the operations they are conducting, may evolve significantly and unpredictably over time. Indeed, much of the metric evaluation described in this report may give the illusion that C2 concepts are static. In fact, they have historically been very dynamic. As one historian noted during an interview, "the C2 wiring diagram is often not completed until the operation is over."

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[34] See Boyd, 1987, slide 9. Specifically, he says that a key point is that "Friction is diminished by implicit understanding, trust, cooperation, simplicity, focus, etc."

[35] See Luck and Findlay, 2009, p. 6.

[36] The subject-matter experts we interviewed for this research are anonymous.

Appendix B. Humanitarian Assistance and Disaster Relief Scenario

The scenarios provided context for all the metric evaluations. The scenarios were especially important for the evaluation of C2 risk and resiliency metrics, which used a unique TTX design. In many TTXs, participants are given a description of an evolving security concern. They plan operations over a sequence of moves, which are adjudicated to determine how missions and events unfold. However, this is not the format we used for the C2R2 TTX. Instead, participants were presented with an operation as if it had already been completed. The operation was described in terms of a sequence of events, which typically included individual missions. The description focused attention on the timing and outcome of operations, and C2 was initially described in generic terms. In this sense, the performance of the operation was fixed and held constant. Once the scenario had been described, participants were provided a C2 concept for it, were walked through the individual events, and were asked to identify key C2-related assumptions that must have held. In both scenarios, we assumed that other concurrent theater concerns required the attention of the joint force.

This appendix describes the HA/DR scenario and its key events.

Overview of Scenario

In this fictional account, a magnitude 9.0 earthquake struck the Philippines on May 31, 2020. A tsunami resulted from the earthquake.[1] Figure B.1 depicts the epicenter and the extent of the damage. In the figure, major features of the Philippines are not clearly discernable because they are depicted as covered with water due to the tsunami.

The USPACOM commander, in coordination with the U.S. ambassador, was directed to conduct foreign humanitarian assistance operations in support of USAID and the Office of Foreign Disaster Assistance. The commander's intent was to enable relief operations to mitigate further loss of life, forestall additional suffering, and reduce the scope of the disaster and, as required, to provide military-to-military support to the Armed Forces of the Philippines.

The U.S. military was asked to help with situation assessment, search and rescue, transportation of personnel and supplies, medical care, water purification, reestablishing communications, and repair and reconstruction of roads and bridges. The operation could be described in terms of three events: an initial response, an effort to sustain relief, and a transition and redeployment (Table B.l).

[1] We used an online tsunami damage estimation and mapping tool in developing this scenario (Tsunami Mapper website, undated).

Figure B.1. Epicenter of Fictional Earthquake and Extent of Tsunami Damage

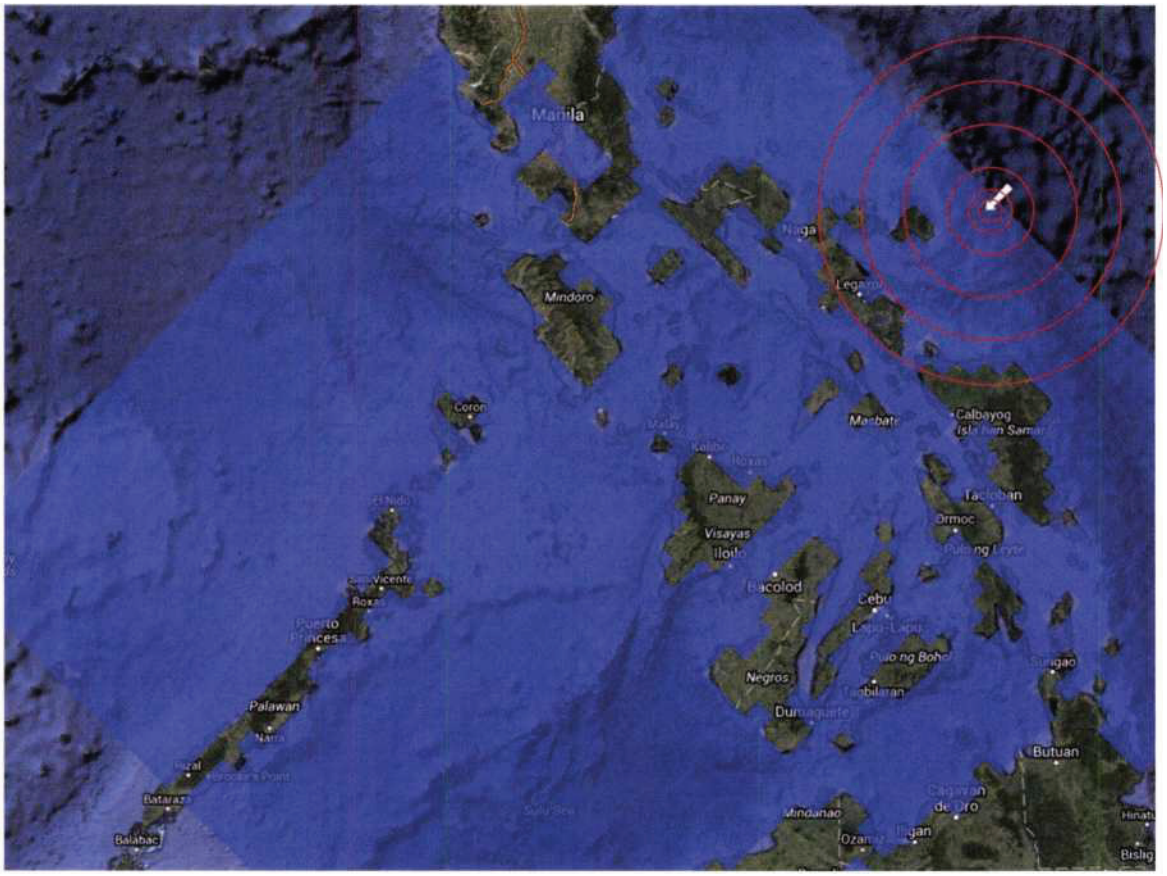

Table B.1. Three Key Events in the HA/DR Operation

Event Title:	Initial Response	Sustain Relief	Transition/Redeploy
Description:	• Earthquake struck • US forces deployed and aid began to arrive • SAR options concluded, focus shifted to rebuilding and relief	• Airlift of relief cargo • Selective redeployment of U.S. forces	• Philippine armed forces and the UN continued relief operations without US military support • Operation stood-down
Calendar Start Date of Event:	May 31	June 11	June 23
C-/D-Day:	C-2/D+0	C+9/D+11	D+21/D+23
Phases:	4 (Stabilization)	4 (Stabilization)	5 (Enable Civil Authority)

The operation required the U.S. military to coordinate with many actors, including the following:

- U.S. actors
  - DoD: humanitarian assistance survey team and humanitarian assistance rapid response team
  - Department of State: USAID disaster assistance response team and the U.S. embassy in Manila
  - PACOM: JFACC and director, Mobility Forces
  - U.S. Transportation Command: intertheater airlift, contingency response group, and tanker airlift control element
- Philippine actors
  - National Disaster Risk Reduction and Management Council (NDRRMC): Office of Civil Defense and such member agencies as the Armed Forces of the Philippines, the Department of Health, and the Philippines Red Cross
  - regional, provincial, municipal, and other risk reduction and management offices
  - local NGOs, such as the National Secretariat for Social Action
- international and regional actors
  - UN agencies: World Food Program (logistics), World Health Organization (health), United Nations Children's Fund (water, sanitation, and hygiene), United Nations High Commissioner for Refugees, United Nations Population Fund, etc.
  - other international organizations: World Bank, International Organization for Migration
  - Association of Southeast Asian Nations (ASEAN):
    - ASEAN Humanitarian Assistance Centre–Jakarta
    - ASEAN member states: Brunei, Darussalam, Cambodia, Indonesia, Laosc, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam
  - other countries: Japan, China, United Kingdom, Canada, Australia, etc.
  - civilian organizations:
    - International Committee of the Red Cross, International Federation of Red Cross and Red Crescent Societies
    - international NGOs: World Vision, Agency for Technical Cooperation and Development, Action contre La Faim [Action Against Hunger], Catholic Relief Services, PLAN, Handicap Int'l, etc.

Key humanitarian aid centers included Ninoy Aquino International Airport and are depicted in Figure B.2.

Figure B.2. Key Humanitarian Aid Centers

Event 1: Initial Response

The earthquake struck on May 31. One day later, on June 1, the government of the Philippines established the NDRRMC in Metro Manila. The Armed Forces of the Philippines began search and rescue operations across the affected islands. The same day, USPACOM issued planning and warning orders to provide C2 of intratheater airlift and reconnaissance to support regional HA/DR operations in the Philippines. The same order directs Commander, Marine Forces Pacific to prepare to deploy DRATs.

On June 2, the TJFACC at the 613 JAOC made a request that Air Mobility Command deploy a tanker airlift control element, and the associated support personnel, and provide OPCON for relief efforts. PACAF activates the Pacific Air Expeditionary Task Force Manila as a provision unit attached to PACAF for administrative control. The warning order from the Chairman of the Joint Chiefs directed USPACOM to provide, by July 4, a commander's estimate, alternative courses of action, and a contingency plan that would outline options for providing HA/DR to Southeast Asia.

On June 3, USPACOM established priorities: damage assessment and posturing all available theater airlift assets to provide support. Development of a logistics concept of operations was also in progress to ensure expeditious movement of relief supplies as they arrived in theater. Australian sources indicated that Ninoy Aquino International Airport was fully operational, with military and civilian flights operating from separate sides of the airstrip. Legazpi and Southern Luzon airports were closed. Cebu and Roxas City airports were crowded but serviceable. The government of the Philippines authorized overflight of Philippine airspace for two weeks in support of HA/DR operations. The authorization included the possibility of further extensions on coordination with the U.S. embassy and Indonesian government. Furthermore, a status of forces agreement was coordinated. A civil-military operations center was established in Manila. The UN activated health; logistic; shelter; water, sanitation, and hygiene; and telecommunication clusters to coordinate relief activities. Another three humanitarian coordination centers were being established in Roxas, Cebu, and Tacloban cities.

On June 4, international aid continued to arrive. A medical team from the Singapore Armed Forces was operating near Legazpi city, Albey. Military resources from Japan and Australia were on the way. DRATs deployed to the Philippines to determine the extent of damage, level of support, and the capacity of commands to support tsunami relief. PACAF deployed contracting officers to support HA/DR. The JFACC was assigned TACON of all military fixed and rotary-wing aircraft associated with HA/DR to establish a unified and integrated air relief distribution system. This arrangement—in keeping with joint doctrine—was intended to facilitate seamless coordination between intertheater and intratheater fixed- and rotary-wing aircraft by placing all scheduling and tasking authority under one functional joint air commander to ensure full integration of air operations.

On June 5, the JFACC for the operation requested USPACOM assistance in obtaining additional forces needed to augment the Pacific air expeditionary task force. Airlifting supplies were C-130s and C-17s from the United States and C-130s and helicopters from Australia, Singapore, Malaysia, Tunisia, and the Czech Republic.

On June 6, the Joint Staff approved P-3 crisis management reconnaissance operations in support of tsunami disaster relief operations.

On June 7, the aircraft carrier USS *Abraham Lincoln* took up station off the east coast of the Philippines and commenced helicopter operations, picking up supplies and personnel and shuttling them to the hardest hit parts of the countries. PACAF activated the 374th Air Expeditionary Wing (AEW) as a provisional unit assigned to the Pacific Air Expeditionary Task Force. The Philippine government agreed to allow the U.S. military to use international airport as a hub for humanitarian relief supplies.

By June 8, 1 million pounds of relief cargo had been moved by airlift since the start of the operation.

On June 9, the Pacific Rescue Coordination Center assumed responsibility for coordinating all personnel recovery (this would be different for a JFC or JTF because the JTF would have its own joint rescue coordination center). USPACOM established the boundaries of its own relief operations area for Operation Unified Assistance encompassing the area in and around the Philippines.

On June 10, the Armed Forces of the Philippines completed search and rescue. The estimated death toll reached 158,990, and more than 1 million residents were displaced. Meanwhile, 61 percent of medical clinics in the affected area were damaged.

Event 2: Sustain Relief

By June 13, 5 million pounds of relief cargo had been moved by airlift since the start of the operation. One week later, that total had increased to 10 million pounds.

By June 21, World Food Program, USAID, and UN logistics representatives concluded that the U.S. military no longer needed to requisition HA/DR supplies. Delivery of items already purchased or en route continued until on-hand supplies were exhausted. USPACOM issued an order canceling future HA/DR requisitions.

By June 22, USPACOM reported that planning order finalization was under way to allow formal transition planning and enable the selective redeployment of U.S. forces.

Event 3: Transition and Redeploy

By June 24, the UN had scaled down immediate relief efforts and transitioned to the buildup of food, water, and medical stocks.

On June 25, USPACOM issued a warning order to transition and redeploy.

On June 27, the Department of State's Philippine Country Team declared the mission complete and stated that the embassy would coordinate remaining relief efforts.

By June 28, 15 million pounds of relief cargo had been moved by airlift since the start of the operation.

On June 29, USPACOM reported that the UN would most likely assume responsibility for fixed-wing and helicopter operations in Philippines not later than the first week of July. The World Health Organization (WHO) finalized the death toll at 289,754 and estimated that there were 1.5 million internally displaced persons.

On June 30, the 374 AEW reported that its mission was complete and that it was ready to redeploy.

On July 2, the 374 AEW reported that all U.S. Air Force personnel had left the operational area. The Philippine armed forces and the UN were ready to continue relief operations without U.S. military support.

On July 3, military HADR operations stood down. Airlift had moved 25 million pounds of relief cargo over the duration of the operation.

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The geography of the Pacific region can present challenges for command and control (C2) of air operations; distances can be long and operational areas vast. Furthermore, regional competitors may seek to degrade, deny, or disrupt the content and flow of information needed for C2. Multiple organizational structures can be used to manage C2 in such environments. This report recommends methods for comparing and contrasting alternative concepts for C2 of joint air operations in the Pacific. A concept that is suitable for one type of operation, such as humanitarian and disaster relief, may be less suitable for another type of operation, such as a major war with a near-peer competitor. For this reason, the report also applies these methods to a selection of concepts and scenarios.

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