Annual Report 2009

RAND PROJECT AIR FORCE

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About RAND Project AIR FORCE

The mission of RAND Project AIR FORCE (PAF), a division of the RAND Corporation and the Air Force's federally funded research and development center for studies and analyses, is to undertake an integrated program of objective, independent analysis on issues of enduring concern to Air Force leaders. PAF addresses far-reaching and interrelated questions: What will be the role of air and space power in the future security environment? How should the force be modernized to meet changing operational demands? What should be the size and characteristics of the workforce? How can that workforce be most effectively recruited, trained, and retained? How should sustainment, acquisition, and infrastructure be streamlined to control costs? PAF carries out its research agenda in four programs that represent core competencies:

Strategy and Doctrine seeks to increase knowledge and understanding of geopolitical and other problems in the national security environment that affect Air Force operations. PAF maintains expertise in defense strategy; regional analysis; the objectives and tasks of evolving joint operations; and the potential contributions of air and space power to joint operations, defense planning, and requirements for force development.

Force Modernization and Employment identifies and assesses ways in which technological advances and new operational concepts can improve the Air Force's ability to satisfy a range of future operational demands. This research involves assessments of technology feasibility, performance, cost, and risk. PAF assesses major force components needed in the future and the systems and infrastructure supporting their operations.

Manpower, Personnel, and Training concentrates on questions about workforce size and composition and about the best ways to recruit, train, develop, pay, promote, and retain personnel. PAF's research encompasses the total workforce: active-duty, guard, reserve, civilian, and contractor personnel.

Resource Management analyzes policies and practices in the areas of logistics and readiness; outsourcing, privatization, and contracting; the industrial base; planning, programming, and budgeting; infrastructure; and weapon-system cost estimating. The goal of this program is to maximize the efficiency and effectiveness of Air Force operations in a resource-constrained environment.

PAF also conducts research on topics that cut across all four programs, and its research staff regularly responds to Air Force requests for help on time-urgent problems.

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Message from the Director

Andrew R. Hoehn

Through 60 years of collaboration, RAND Project AIR FORCE (PAF) has acquired unparalleled insight into Air Force strategy, forces, policy, resources, and manpower. We have developed a body of expertise and intellectual capital and are uniquely poised to provide policy recommendations on critical national security challenges. Working with the Air Force to translate these recommendations into decisions that have lasting impact—that produce useful and enduring benefits for the service—remains our most important goal.

Whether we are successful in these efforts—and whether these efforts lead to lasting impact—depends in large measure on the objectivity and quality of our research. Independent, unbiased, empirical analyses are the foundation of RAND's reputation for objectivity. We strive to maintain that objectivity in all we do. Quality is the other standard against which RAND measures itself. High-quality research can take many forms but ideally leads to high-quality outcomes. Research that better informs sponsors; helps improve their decisions; and/or leads to tangible improvements in capabilities, performance, costs, or other important measures has helped produce higher-quality outcomes and therefore supplied the enduring value we seek to provide. Indeed, "impact" may be one of the most important measures of quality.

Impact can come in different forms. At times, we engage in fast-breaking efforts to support time-critical policy decisions. To provide a set of near-term recommendations to the Air Force leadership on irregular warfare, PAF formed a team of experts on the subject that developed recommendations in a little over a month to strengthen Air Force capabilities in this rapidly evolving mission area. The PAF team put forward a set of recommendations that soon became policy. The PAF team was able to respond quickly by drawing on nearly a decade's worth of analyses and Air Force investment.

It can sometimes be easy to identify an impact, one that leads to measurable change. For example, PAF pioneered concepts for consolidating

The impact of PAF's contributions can also be felt long after the original work is complete.

support functions to allow warfighting units to deploy with much less infrastructure and for fighting units to be scaled to the size needed for a given contingency. This work clearly led to measurable results. However, a contribution we might label as having impact is often less tangible—although nonetheless consequential—coming, for example, in the form of support on critical day-to-day operational decisions. For more than a year, military leaders in Iraq asked for weekly classified telephone conferences with senior RAND analysts to discuss the insurgency in Iraq and their approach to counterinsurgency operations. Senior Air Force leaders responsible for personnel policy also routinely interact with PAF personnel specialists on a wide range of personnel policy issues. They seek results from analysis, but they also seek judgment and advice.

The impact of PAF's contributions can also be felt long after the original work is complete. Such was the case with our analyses for the next-generation bomber. The recent cancellation of plans for a new bomber and ongoing discussions about future bomber requirements renewed interest in PAF's long-range strike analysis, which began a few years ago. The results highlighted the most important capability gaps that a new bomber would need to fill. Similarly, PAF's work on aging aircraft, which dates back more than a decade, has been especially helpful in highlighting known dangers and uncertainties surrounding existing aircraft fleets—important factors in the Air Force's recapitalization planning.

We provide analyses and recommendations that can help the Air Force make better decisions, but we are not the decisionmakers. If we want our work to contribute significantly, we need to ensure that our research is developed and presented in ways our sponsors can readily use. PAF's research staff is its most valuable resource for achieving relevant, actionable recommendations for the Air Force. Highly skilled and dedicated, the PAF team reflects a wide range of academic backgrounds and real-world work experience, a breadth and depth of expertise ideally suited to address the kind of complex, multidisciplinary issues the Air Force faces today and well into the future. Team members engage tirelessly with the Air Force in gathering data, presenting research findings, and (when needed) helping to implement recommendations.

In this annual report, we present the research of some of the PAF analysts who have made important contributions to Air Force decisionmaking during the past year by developing

- measures that could bolster the effectiveness of joint forces in the Asia-Pacific region through infrastructure enhancements, force modernization, and changes in posture
- a framework the Air Force can use to guide building the capacity of partner air forces to better prepare them to ensure their own security against threats
- a strategic planning tool and risk scorecard for senior Air Force leaders and their planning staffs to support them in making judgments about future threats
- a taxonomy for defining cross-cultural skills that is helping shape an emerging cultural education program at Air University
- a more-systematic alternative for making retain-or-retire decisions on the basis of an aircraft's remaining years of life
- a business-case analysis that will help the Air Force determine if and when it may be advantageous to install winglets on aerial tankers
- concepts for consolidating current wing-level maintenance activities for the F-16, KC-135, and C-130 fleets onto a network of centralized repair facilities that could yield millions of dollars in savings per year.

Together with the Air Force, we will continue to develop a research agenda that addresses the areas in which we can achieve high-quality outcomes and therefore have the greatest positive impact, focusing on both short- and long-term policy questions. We will continue to engage with the Air Force at all levels to understand its current challenges and will also work to anticipate the types of problems the Air Force will face in the future. Our research staff will stay focused on how the Air Force can make better decisions as a result of our efforts. With a focus on achieving the greatest possible impact, we can continue to be effective in helping Air Force leaders make better, more-informed decisions and maximize the return on the Air Force's investments.

Andrew R. Hoehn
Vice President, RAND Corporation
Director, Project AIR FORCE

Shared Visions

How PAF Is Helping Pacific Air Forces Extend Its View of Future Capabilities

In August 2008, leaders from Pacific Air Forces (PACAF) and analysts from RAND Project AIR FORCE (PAF) and other institutions gathered at Hickam Air Force Base in Hawaii for Pacific Vision, a war game designed to identify the capabilities PACAF will need to prevail against potential threats in the Asia-Pacific region through 2016. "Potential adversaries are putting a lot of effort into improving their military capabilities," says Jeff Hagen, a PAF senior engineer who led the team that assisted with the game and adjudicated the results. "We wanted to see what near- and mid-term improvements would have the greatest effect on the United States' ability to operate and fight in the region."

The game suggested that U.S. airpower could achieve its objectives effectively but that the United States would need to focus on a number of crucial improvements, including to forward infrastructure, to be more confident of success. These outcomes could have important implications for how PACAF plans its posture and deploys its forces in the event of a major conflict. The game also typifies the kind of direct support that PAF is able to provide the Air Force beyond the range of a formal research study. As Jeff puts it, "This was about spotting a need and structuring a game to help us think through the problems in real time."

Spotting the Need

PAF's involvement in Pacific Vision emerged from ongoing research and discussions between David Ochmanek, then director of PAF's Strategy and Doctrine program, and leaders at PACAF about emerging threats that deserve special attention in future force planning. In particular, they discussed concerns about the Air Force's ability to project power into the Asia-Pacific at a time when potential adversaries are improving their ability to hold assets at risk at greater distances.

PACAF is responsible for providing air and space power over an area covering more than 100 million square miles that is home to half the world's population. The region's potential threats range from ongoing insurgency and terrorist operations to major conflicts with near-peer adversaries. The United States must be able to deploy airpower rapidly and provide space-based capabilities to warfighters, such as positioning, navigation, and timing; intelligence, surveillance, and reconnaissance;

A KC-135 Stratotanker refuels a B-2 Spirit over the Pacific Ocean. The B-2 and KC-135 are deployed to Andersen Air Force Base, Guam, to support U.S. Pacific Command's continuous bomber presence and theater security operations in the Asia-Pacific region.

precision targeting; and command, control, and communications. Enemy attacks against bases and satellite communications could significantly undermine the ability of the United States to promote and protect its interests in this part of the world.

Pacific Vision was created to help PACAF address potential threats before they fully materialize. Jeff's view is that "War gaming allows us to test our assumptions against the worst an enemy could throw at us and to learn from potential mistakes before we make them for real."

War gaming allows us to test our assumptions against the worst an enemy could throw at us and to learn from potential mistakes before we make them for real.

Structuring the Game

The game was designed to be difficult for PACAF forces. Alan Vick, a senior political scientist at PAF who focuses on defense strategy, headed the Red team, which also included Roger Cliff, another PAF senior political scientist with expertise on the military capabilities and strategies of countries in the region, along with other regional experts. The Red team's job was to create a realistic, highly stressing scenario that would test the limits of PACAF's ability to deploy forces and wage an effective campaign.

PACAF was represented by two Blue teams made up of Air Force officers and other subject-matter experts. Each team operated independently of the other, but both developed approaches that reflected capabilities programmed to be available by 2016. The game focused not on the performance of specific weapon systems but on the strategies for deploying them to forward areas and the infrastructure needed to employ them effectively. PAF director Andrew Hoehn served as a senior mentor to both Blue teams by providing insights during the game and sharing his observations with the PACAF commander at the conclusion of the exercise.

A flightline ground crew prepares to tow a Global Hawk unmanned aircraft system to a secure hangar at Andersen Air Force Base, Guam. Sheltering aircraft and making base infrastructure more durable under attack are important elements of PACAF's future basing posture.

To facilitate learning, the teams played the game twice. At the end of the first two days, the clock was reset to the beginning of the scenario, and the Blue teams had the chance to adjust their strategies according to the outcomes of the first round. This time, each team could modify the Air Force's planned future forces and explore other options to see which ones might produce a more-effective force.

Thinking in Real Time

In addition to representing the Red forces, PAF's major role in the exercise was to assess the results of each move in the game and help identify overarching lessons. Jeff Hagen led the assessment team, which included several of his PAF colleagues: senior engineer Sherrill Lingel, senior physical scientist Tom Hamilton, and research programmer Barry Wilson. Each night, the assessment team convened to examine the moves the Red and Blue teams had made that day, calculate outcomes, and compile a briefing to deliver at the onset of play the next morning.

Jeff Hagen

This is the point at which PAF's modeling experience was most essential. The assessment team had to create operational models that would ordinarily have required weeks of research. However, because of their experience with long-term studies, the researchers were able to complete the task in a matter of hours. "This is one of the major reasons for having an ongoing analytic capability available to the Air Force," says Jeff. "The work we do year after year lays the groundwork for applications that the Air Force can tap on short notice."

Looking Forward

The exercise offered important lessons about dealing with a wide range of future challenges. As Jeff observes, "The U.S. military is the most advanced in the world, but that does not mean it is all-powerful. Thinking carefully about strategy, operations, and tactics could make the difference between victory and defeat."

The discussion Pacific Vision generated continues. Another version of the game, played in April 2009, considered the same set of concerns under a different type of scenario. "One of PAF's responsibilities is to help the Air Force focus attention on issues that are likely to become important down the road," says Jeff. Pacific Vision is a good example of how the long-standing Air Force–PAF partnership accomplishes that goal.

Partnerships with Foreign Air Forces

Enhancing the USAF's Approach to International Security Cooperation

The looming presence of terrorist and insurgent groups worldwide requires the United States to work with its allies to defeat these threats and strengthen national security. Constrained by aging weapon systems, high operational tempos (OPTEMPOs), and shrinking budgets, the U.S. military services nonetheless have an important option for meeting these ubiquitous demands: do more to work by, with, and through partners to accomplish their missions.

This thinking is reflected in the Department of Defense's (DoD's) *Quadrennial Defense Review Report* (February 6, 2006) and its *Building Partnership Capacity: QDR Execution Roadmap* (May 2006), which emphasize the importance of building the security and defense capabilities of partner countries to enable them to make valuable contributions to coalition operations and improve their indigenous capabilities.

The U.S. Air Force has a long history of working with foreign air forces to build partnerships. This global perspective is described in a document entitled *Air Force Global Partnerships Strategy* (2009). To enhance implementation of the strategy, the office of the Deputy Under Secretary of the Air Force for International Affairs (SAF/IA) asked a PAF research team led by Jennifer Moroney to identify ways to build on past and ongoing security cooperation efforts, define the key elements of a more-robust approach for meeting the new requirements, and recommend ways to integrate these elements into the larger plan.

Key Assumptions About Security Cooperation

Successful collaboration between the United States and its partners depends on the extent to which each is acting in its own national interest. When these interests align, cooperation is more likely to be fruitful and sustainable. Five key assumptions underpin the PAF study team's concept for an approach to security cooperation:

The U.S. Air Force has two major reasons for building partnerships, both of which reflect national- and department-level guidance. The first is to enable partners to address domestic and regional problems without direct U.S. military participation. The second is to integrate partners into ongoing and future U.S.-led coalition operations around the world.

A USAF search-and-rescue team jumps alongside Chilean airmen during Operation Southern Partner. This exercise was part of an in-depth exchange that emphasizes partnership, cooperation, and information-sharing with partner-nation Air Forces in Latin America.

Capt Jason Ward discusses C-17 Globemaster III capabilities with members of the Pacific Rim Airpower symposium. Held at Hickam Air Force Base, Hawaii, the symposium brought together representatives from Australia, Bangladesh, Brunei, Canada, India, Indonesia, Japan, Malaysia, Mongolia, Nepal, New Zealand, Philippines, South Korea, Singapore, Sri Lanka, Thailand, and the United States.

Security cooperation efforts can build the capabilities and capacity of partner air forces for domestic and regional purposes and for coalition operations. It can also shape the strategic environment in a way that can preclude the need for major direct U.S. military action.

Security cooperation activities that aim to build partnerships are more likely to succeed and to develop into lasting and sustainable capacity if the capabilities interest both the partner and the U.S. Air Force.

A partner will probably be more interested in developing capabilities that have domestic and reconstruction applications, increase its international prestige, or support its military transformation and modernization efforts. This higher level of interest increases the probability that the capabilities will be sustained over the long term and that ongoing capacity will be developed if the partner has the resources to do so.

The partner should not use its improved capacity to pursue negative outcomes. This includes taking action against the partner's own citizens, settling old scores with neighbors, or generally destabilizing the geographic area in question.

Finding Room for Improvement

U.S. security cooperation events and activities with allied and partner militaries can take many forms, including training and education, exercises, staff exchanges, and sales of U.S. weapon systems to foreign governments. For the U.S. Air Force, security cooperation activities include

- deployment of advisory teams to support the large-scale rebuilding and training of partner air forces, such as the Air Force advisers who are helping to reestablish the Afghan Air Corps
- missions to train, equip, and assist allies and partners in their counterterrorism efforts, such as capacity-building activities to support the Armed Forces of the Philippines; training exercises for countries in the Trans-Sahel region of Africa, primarily Chad, Niger, and Mali; and train-and-equip events for countries in the Horn of Africa region, particularly Djibouti, Ethiopia, and Yemen.
- sales of aircraft to allies and partners, such as the sale of ten F-16 fighters, along with spare parts and maintenance components, to Chile in 2002

Key Terminology

TERM	DEFINITION	EXAMPLES
Security cooperation	Activities conducted with allies and friendly nations to build relationships that promote specified U.S. interests, build the capabilities of these countries to carry out self-defense and coalition operations, and provide U.S. forces with peacetime and contingency access[a]	Training and combined exercises Operational meetings Contacts and exchanges Security assistance Medical and engineering team engagements Cooperative development acquisition and technical interchanges Scientific and technological collaboration
Security assistance	A group of programs authorized by law that allows the transfer of military articles and services to friendly foreign governments[b]	Foreign military sales Foreign military financing International military education and training Direct commercial sales
Building partnerships	Setting the conditions for interaction with partner, competitor, or adversary leaders, military forces, or relevant populations by developing and presenting information and conducting activities to affect their perceptions, will, behavior, and capabilities[c]	Defeating terrorist networks Preventing hostile states and nonstate actors from acquiring or using weapons of mass destruction Conducting irregular warfare Carrying out stabilization, security, transition, and reconstruction operations (such as those in Iraq and Afghanistan) Enabling host countries to provide good governance
Capability	The ability to perform a specific skill or function	Flying an F-16 fighter aircraft
Capacity	The extent to which a particular capability can be employed	Using F-16s to conduct a combat mission

[a] Derived from material on the Defense Security Cooperation Agency Web site (http://www.dsca.mil/pressreleases/faq.htm).
[b] Derived from material in the Security Assistance Management Manual (SAMM), DoD 5105.38-M (http://www.dsca.osd.mil/samm/).
[c] Modified from the definition in Joint Chiefs of Staff, "Joint Capability Areas, Framework Definitions," January 12, 2009 (http://www.dtic.mil/futurejointwarfare/cap_areas.htm).

As part of its analysis, the PAF research team provided a detailed description of historical and current Air Force efforts to build partnerships with foreign air forces. First, it assessed several major Air Force security cooperation cases from 1997 to 2007 to discern whether these cases were aligned with U.S. strategic interests and priorities. Next, the team analyzed six ongoing case studies from around the world that represent the breadth and variation of Air Force security cooperation approaches. Some of these can easily be linked to U.S. strategic interests, while others may have a strategic benefit to the United States but are more the result of international sales opportunities.

PAF found that many elements of Air Force security cooperation are responsive to U.S. security strategy. However, there is room for considerable improvement. In particular, the PAF team suggested five focus areas for enhancing the effectiveness of the Air Force's security cooperation efforts: visibility, planning, evaluation, resourcing, and institutionalization. Each focus area is briefly discussed below.

Increasing Visibility into Certain Activities

Even when Air Force security cooperation planners believe their actions are consistent with strategic guidance, they may base decisions on incomplete and inconsistent information, especially when they lack awareness of other, related security cooperation activities being conducted in the respective partner countries. Therefore, there is a need for greater visibility of all U.S. security cooperation efforts to tighten the linkages between DoD guidance and the Air Force's decisions about where, how, why, and with whom to build partnerships.

Instructor pilot Capt Jamie Riddle and a student at the Iraqi Flight Instructor School walk to the flightline before a mission at Kirkuk Air Base, Iraq. Helping to train Iraqi pilots is one of the security cooperation activities the U.S. Air Force conducts as part of its efforts to build the capabilities of partner air forces for domestic and regional purposes.

Air Force security cooperation data collection efforts have been improving, particularly since 2005, when SAF/IA's Knowledgebase—a centralized, useful repository of security cooperation data and guidance—came online. However, despite SAF/IA's concerted attempts to expand the data included in Knowledgebase, so many Air Force–related security cooperation activities are being conducted by so many actors, including other U.S. armed services and the National Guard, it is difficult for any one system to incorporate all the information.

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Strengthening Planning, Evaluation, and Resourcing Processes

Planning. Effective planning can be an important part of U.S. efforts to augment indigenous capacity and build relationships with partners. In cases involving foreign military sales to U.S. partners, follow-on sustainment can lead to long-lived relationships and long-term partnership activities. However, although the Air Force often makes significant efforts to encourage partner countries to purchase sustainment packages, these components are often missing from initial security assistance agreements. If included at the outset, sustainment and training agreements can help ensure the partner's long-term commitment to the relationship.

Evaluation. The effectiveness of security cooperation efforts is not routinely evaluated to identify best practices and lessons learned. Moreover, evaluations often are not coordinated with the host nation, thus limiting both the Air Force's ability to gain a complete and accurate understanding of any shortcomings and the host nation's ability to incorporate and sustain new capabilities. Air Force planners would benefit from regular assessments designed to ensure that security cooperation efforts focus on the most suitable or appropriate partner airpower capabilities, which are necessary for developing an effective training program.

Resourcing. Resource constraints can limit the effectiveness of Air Force security cooperation efforts. In particular, security cooperation budgets do not always include sustainment costs, which often leaves the partner to pay (or not) for such things as recurring training, replacement items, spares, and off-site maintenance. The affordability of training should be a key consideration when the Air Force develops a security cooperation effort. Foreign partners often forgo U.S.-based training simply because it is too expensive. In some cases, partners get more-affordable training from other countries. For instance, when Chile bought F-16s from the United States, it relied both on in-house trainers and on the Netherlands for pilot and maintenance training. Innovative solutions, such as training subsidies, may make U.S.-based training options more attractive to partners.

Institutionalizing Processes to Create a Foundation for Success

If Air Force security cooperation efforts are to achieve robust, lasting success, the Air Force needs to institutionalize processes that will enable effective security cooperation management and funding over the long term. By including security cooperation priorities in the regular Air Force planning, programming, and budgeting cycle, security cooperation

Jennifer Moroney

Since coming to RAND in 2003, senior political scientist Jennifer Moroney has made important contributions to RAND's growing body of work on U.S. security cooperation strategies. From the beginning of the war on terrorism, DoD and Air Force leaders have increasingly emphasized the importance of security cooperation and building the capacity of partner nations. "Although the Air Force has conducted these types of activities for decades, the national security benefits of their efforts have been underappreciated until relatively recently," she says. The United States gains by helping these countries better prepare to ensure their own security against internal or regional threats without depending on U.S. assistance. In many cases, allies and partners will also be capable of playing key roles in coalition operations—counterterrorism missions, stability operations, or disaster response contingencies—that serve the national security interests of all involved.

Over the past five years, Jennifer and her colleagues have broadened the scope of research in this area to include, for example, suggestions for improving management processes and tracking tools that increase awareness and visibility across the range of security cooperation activities. "By working with many of the key security cooperation players within DoD, we have begun to build bridges between organizations and create a stronger and more informed security cooperation community."

Jennifer both serves as associate director of Project AIR FORCE's Strategy and Doctrine Program and leads several research projects. One of these projects is developing a framework for assessing the effectiveness of Air Force security cooperation activities. Another is examining foreign military training methods and models to identify what U.S. airmen need to know to work effectively with foreign militaries. "Predeployment training for our service members is important to the success of many security cooperation activities," Jennifer explains. "It will help to better equip airmen for the train-and-advise activities that are a key component of U.S. efforts to build the capacity of our partners and allies."

To ensure that her research is informed by people who are directly involved in planning and carrying out U.S. security cooperation activities, Jennifer has traveled to more than 45 countries; met the senior leaders and strategic planners of each U.S. combatant command; and attended and observed security cooperation exercises, training, and military exchanges. "It's important to be there. You have to understand the challenges our forces face as they work with our partner militaries. By understanding their experiences and concerns, we can provide much more-informed recommendations on lessons learned and best practices for building partnerships." Likewise, she has consulted with many foreign officials in an effort to understand their concerns and solicit their suggestions for improving the effectiveness of U.S. security cooperation efforts.

> "It's important to be there. You have to understand the challenges our forces face as they work with our partner militaries."

Jennifer's success has not gone unrecognized. She is frequently asked to brief senior decisionmakers in DoD and other government agencies. In 2009 she received a RAND Merit Award for her leading role in establishing RAND as an expert organization on the subject of security cooperation.

Even as Jennifer strives to balance her research obligations, her PAF management responsibilities, and her frequent travels, she still finds time to get away for weekends with her husband, Kevin, and baby son, Ciarán, to Deep Creek Lake, a popular vacation area in Western Maryland. Growing up in that area, Jennifer spent summers boating, swimming, and waterskiing on the lake where for many years her father's family owned a boat company. Although her weekends at the lake now usually include a healthy dose of work as well as play, she doesn't mind. "I really enjoy the work that I do. And when I can be out on the boat in the sun and still get some research or writing done, it seems like the best of both worlds."

would operate more like other important Air Force initiatives, sharing a common decision cycle and building its activities on a time line shared with other Air Force initiatives and system acquisition programs. Institutionalized processes would also enable those engaged at all levels of security cooperation to assess requirements, compete for resources, evaluate performance and effectiveness, and modify security cooperation programs and activities as necessary.

Affordability should be a key consideration: Foreign partners often forgo U.S.-based training simply because it is too expensive.

Recommendations for the U.S. Air Force

The PAF study team proposed a number of measures that the Air Force could consider to enhance the effectiveness of its security cooperation efforts. Several of these options are highlighted here.

Near-Term Options

- Enhance Knowledgebase, the Air Force's security cooperation database, by adding information about the security cooperation–related programs of other organizations and by participating in their forums on this issue.
- Increase emphasis on security cooperation topics in discussions with allies and partners to improve understanding of the related activities they conduct with other countries.
- Assign responsibility for security cooperation programs to specific offices; identify "champions" for specific security cooperation programs.
- Consider holding an annual security cooperation conference with key Air Force stakeholders and the combatant commands; organize staff talks with other services to better leverage existing security cooperation resources.

Longer-Term Options

- Establish a more-systematic process for evaluating the effectiveness of security cooperation programs and activities and include it in the *Air Force Global Partnerships Strategy* and other appropriate plans and guidance documents.
- Take further steps to embed Air Force security cooperation programs in formal resource-allocation processes so that the programs can better compete in the planning and programming cycle.
- When conducting security cooperation planning conferences, consider including selected allies and partners.

The strong linkage to national security objectives and DoD guidance described in the *Air Force Global Partnerships Strategy* is a key element of an effective approach and a highly positive step forward for Air Force efforts to build partnerships. Combined with the enhancements PAF has suggested, such an approach will increase the Air Force's responsiveness to the broader community by improving coordination with other services, partners, and allies. It will also enable SAF/IA to use limited resources more efficiently and effectively now and in the future.

For more information, see

MG-790-AF, *International Cooperation with Partner Air Forces*, by Jennifer D. P. Moroney, Kim Cragin, Eric Gons, Beth Grill, John E. Peters, and Rachel M. Swanger. Online at http://www.rand.org/pubs/monographs/MG790/

Confronting the "Parade of Terribles"

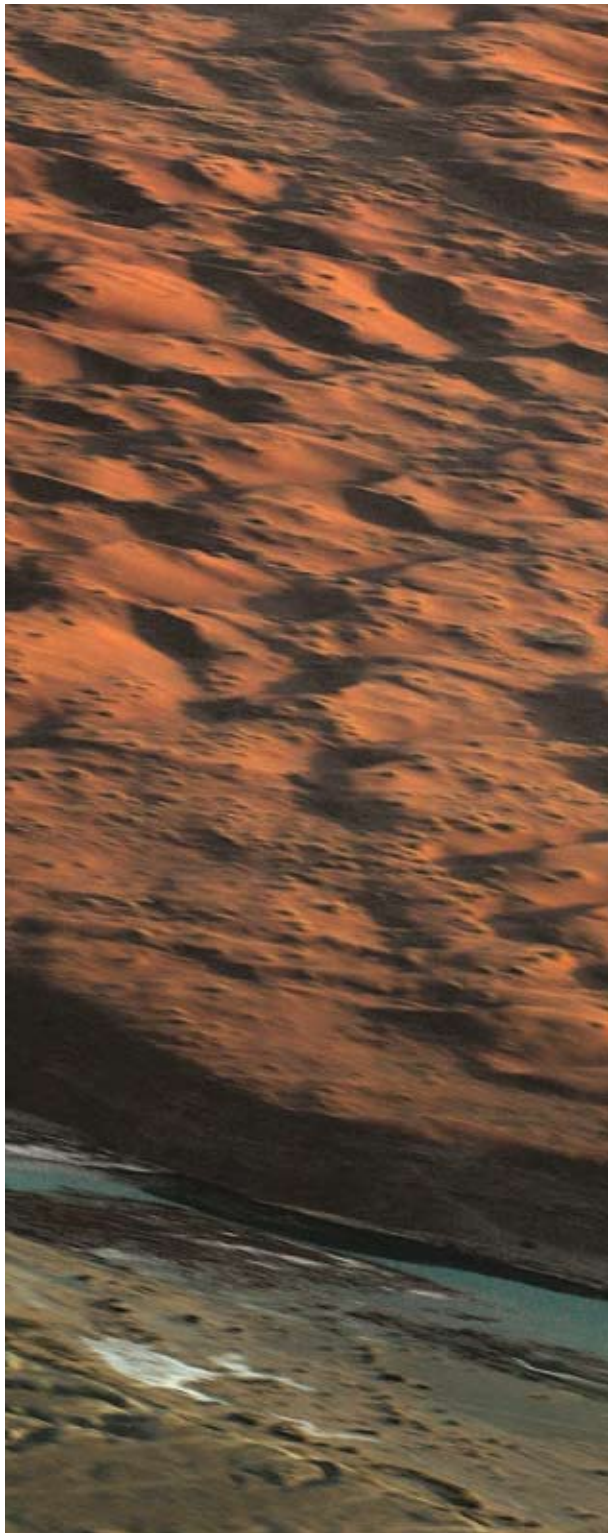
To respond to ever-tightening defense budgets, decisionmakers in DoD and the military services are shifting funding away from programs that address future challenges, such as potential nuclear-armed regional adversaries, the emergence of China as a great power, and continued unrest in the Middle East. Instead, they must allocate scarce financial resources to immediate and urgent priorities, including ongoing operations in Iraq and Afghanistan, global operations against radical Islamists, and looming recapitalization needs across DoD. Thus, short-term risk reduction requires trade-offs that may, in the long run, increase risks.

Managing Risk in USAF Force Planning, a monograph by Frank Camm and a team of PAF colleagues, describes a framework intended to guide senior leaders as they make necessarily subjective judgments about the probabilities and potential harm of various threats and weigh the relative benefits of alternative policy options. Application of the framework also functions as a consensus-building activity that allows decisionmakers and planners to gain insight into the underlying beliefs and assumptions that shape policy decisions.

Using a Simple Scorecard to Guide Deliberations

The approach centers on the step-by-step development of a risk-evaluation scorecard that reports the results of deliberations about a range of potential threats and the policy packages designed to address them. Table 1 is a notional sample of such a scorecard. Column 0 represents the currently programmed force, appropriately extended to cover any relevant planning horizon. Each of the remaining columns represents an alternative policy package applied over the same horizon. Each row provides information about outcomes associated with these policy packages in a different future.

To implement the scorecard, Air Force planners work with senior leaders to develop information about three things: which futures to focus on during a planning cycle, which policy packages to give particular attention to, and ways for senior leaders to identify and validate the likely



An MQ-1 Predator unmanned aircraft armed with AGM-114 Hellfire missiles flies a combat mission over southern Afghanistan. One of Predator's roles is to provide interdiction and armed reconnaissance against critical targets.

A New Approach for Assessing National Security Risk

Notional Policy Scorecard							
FUTURE DOMINATED BY THREAT LISTED	RISK MEASURE	ALTERNATIVE POLICY PACKAGES					
		0	1	2	3	4	5
		Current force	Operate from FOBs against antiaccess threats	Conduct large-scale COIN with U.S. forces	Build partner capacity for irregular warfare in many countries	Conduct air operations exclusively from long range	Operate from FOBs under nuclear attack
Natural disaster	Magnitude	2	2	2	2	2	2
	Probability (%)	15	15	15	15	15	15
State failure	Magnitude	4	4	2	4	3	4
	Probability (%)	7	7	7	6	7	7
High-loss terrorism	Magnitude	7	6	6	5	6	6
	Probability (%)	15	15	15	13	13	15
Major insurgency	Magnitude	3	3	2	1	3	3
	Probability (%)	45	45	45	30	45	45
Traditional conventional conflict	Magnitude	4	4	4	4	3	4
	Probability (%)	4	4	4	4	4	4
High-tech conventional conflict	Magnitude	8	4	8	8	5	4
	Probability (%)	7	5	7	7	5	5
State nuclear use or threat	Magnitude	20	16	20	20	13	10
	Probability (%)	7	6	7	7	6	5
Low-risk future	Magnitude	2	2	2	2	2	2
	Probability (%)	0	3	0	18	5	3

NOTES: The values presented in the table are subjective and notional and for illustration only. Probabilities sum to 100 percent for each policy package. Magnitudes reflect subjective judgments about relative levels of damage rated on a scale of 1 to 20.

probability and magnitude of damage to U.S. national security interests for each future and policy. Each of these three key elements is discussed briefly below.

Choosing Relevant Futures

To begin, PAF researchers sought to impose some degree of order on the "parade of terribles"—a distinctly challenging set of problems that could unfold over the next decade or so. To do this, they surveyed the unclassified literature on threats identified in recent years. Air Force strategic planners would, of course, examine classified sources as well.

Next, the PAF team identified the characteristics the potential threats share so that it could group the vast majority of them into what ultimately became seven generic categories (the rows in Table 1): natural disaster, state failure, high-loss terrorism, major insurgency, traditional conventional conflict, high-tech conventional conflict, and state nuclear use or threat of use. These categories are basic building blocks of the risk assessment regardless of the planning horizon. The threats in each category tended to have similar causes and effects, which suggested that defense planners could often counter them through similar strategies and forces.

Finally, the team identified a set of detailed scenarios associated with each threat type and asked which scenario would require the greatest U.S. effort for mitigation. The most stressful of these became the "most-salient threat," which was used to represent others that might arise within the category. Also taken into account were factors that could affect the likelihood and magnitude of damage to U.S. interests from each threat, as well as the adequacy of the Air Force's ability to address each, particularly its capacity to react effectively to potential surprises.

Choosing Relevant Policy Packages

In considering the risks relevant to Air Force–wide strategic force planning over the next 15 years, the PAF team found that alternative policy packages are most meaningful when each emphasizes a distinctly different major capability. Each should also offer concrete, qualitative alternatives that the Air Force might use to mitigate risks identified in relevant futures.

To sustain the engagement of senior leaders and to allow in-depth analysis of each package under serious consideration, planners should limit the number of options they examine using this approach. Within any planning cycle, package definition should evolve as leaders and planners identify hybrids that better match their beliefs and priorities about the future.

The PAF team identified five examples of policy packages that the Air Force might implement if it received resources beyond those available for the currently programmed force. These packages (columns 1–5 in Table 1) would provide the capability to operate from forward operating bases (FOBs) in the face of severe antiaccess threats, conduct large-scale

Alternative policy packages are most meaningful when each emphasizes a distinctly different major capability.

counterinsurgency (COIN) operations using U.S. forces, build partner capacity for irregular warfare in many nations simultaneously, conduct offensive air operations exclusively from long-range distances, and operate from FOBs that are under nuclear attack from a regional power.

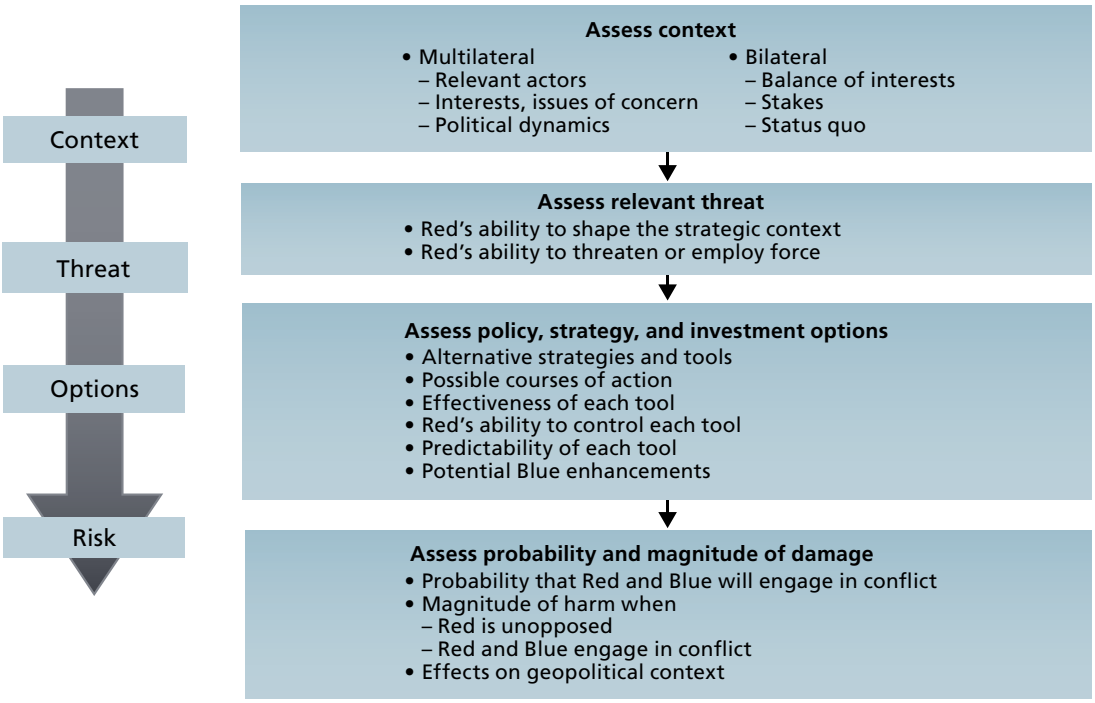
Assessing Probabilities and Magnitudes of Damage

Given a future threat and a chosen policy package, senior Air Force leaders and planners must address many questions: What is the likelihood that the threat will actually manifest itself over the planning period? How can the United States affect that likelihood? If the threat manifests itself, how likely is open conflict? What would be the consequences of conflict or of a U.S. decision not to respond to a manifest threat?

PAF's approach provides a disciplined way to ask these questions and derive answers to them that culminates in a subjective assessment of both probability and magnitude of damage. Figure 1 illustrates this process. It begins with an initial scoping step that places any most-salient threat of the type described above in both a regional and a global context, identifying the likely players and their primary interests. It also assesses the balance of interests relevant to the threat to determine what the benefits and costs of any potential conflict might be for the principal players.

Based on information from the first step, the next step in the approach is to assess what actions any potential opponent—referred to here as *Red*—might take. Action can take many forms, from efforts to persuade other relevant players to change their positions to direct use of force to secure Red's interests, including use of force against the United States and its allies—designated here as *Blue*.

Figure 1—Overview of Method for Assessing Probabilities and Magnitudes of Damage to U.S. National Interests



Airmen wearing Level A suits participate in one of the six scenarios conducted at the 2009 Chemical, Biological, Radiological, and Nuclear Challenge at Ramstein Air Base, Germany. Being prepared for nuclear attacks on forward operating bases is part of the Air Force's strategic approach for evaluating risks posed by a range of potential future threats.

The third step is to consider the options available to the United States to counter any Red action. Like Red, Blue has a broad set of actions it can use to shape the threat environment, try to deter Red from acting, and apply military force, if necessary. This step considers alternative courses of action and asks how effective each alternative is, how predictable its effects are, how much control Blue has over it, how changes in Blue capability or capacity might change the answers to these questions, and so on. (In this context, *capabilities* are sets of policies; human, physical, and information assets; and fungible resources that allow the Air Force to perform certain high-level tasks relevant to its mission. *Capacities* are measures of how much of any capability the Air Force can employ at any time.)

At this point, planners are able to assess the likely interaction between Red and Blue, each with specified options available, in the context of a particular most-salient threat. In each case, the analyst works through the Red and Blue options by considering a Red action, a Blue decision to respond or not to respond in a particular way, and the consequences for Red and Blue of each sequence. By using this approach, senior Air Force leaders and planners can reach consensus on a subjective assessment of the probability that the most-salient threat will become active during the planning period and, if it does, what damage it would do to U.S. interests.

Frank Camm

When Frank Camm was growing up in Arlington, Virginia, he never imagined that the fields where he played pick-up football games would eventually become the site of the Pentagon City complex, now the home of RAND's Washington Office. Frank, a senior RAND economist, finds it ironic that his former playground is now his workplace. During Frank's junior high years, his father, a senior Army officer serving at the Pentagon, worked in the Office of the Secretary of Defense's new Office of Systems Analysis along with several ex-RANDites. He sometimes brought home RAND reports that piqued Frank's curiosity about military organization and war-gaming. "I was hooked," he says. "From that time on, I knew I wanted to work at RAND, so I began to plan how I could make my career there."

During his 30-plus years at RAND, Frank has led or participated in dozens of studies across a wide range of topics in nearly every RAND research division. However, two projects stand out for him. The first came shortly after Frank returned to RAND in 1985 after a two-year stint at the American Petroleum Institute. He took over an ongoing study on stratospheric ozone depletion that RAND was conducting for the Environmental Protection Agency. "RAND had already compiled tons of background research, and I was asked to take the lead on translating that research into actionable policy terms." Frank and his team analyzed the costs of reducing chlorofluorocarbons and other chemicals that were shown to deplete ozone levels in the atmosphere. Their research led to several specific recommendations for reducing the use of chlorofluorocarbons and other chemicals.

As a result, Frank was invited to serve as a member of the official U.S. delegation to the United Nations conference on stratospheric ozone depletion. There, the delegates drafted the Montreal Protocol, which has been hailed as the most successful international environmental agreement to date. "It was a very rewarding effort, not only because of the success of the protocol, but also because I learned a lot about dealing with an uncertain future over a long time period."

That experience also served him well in 2001–2002, when he became a member of the congressionally mandated Commercial Activities Panel, chaired by the comptroller general of what is now the Government Accountability Office. The panel was tasked with developing recommendations for improving the way that the federal government decides what activities to outsource to contractors.

Given Frank's knowledge of resource management issues and RAND's reputation for objectivity, the chairman asked him to serve as an "honest broker" by balancing the entrenched interests of the union and industry representatives. "I was able to bring to bear ten years' of RAND analysis on these issues—not just mine, but other RAND work as well—and help them develop equitable and understandable recommendations," he explains. Remarkably, despite their differences, the panel members reached a consensus and unanimously endorsed a number of key federal government acquisition reforms, 90 percent of which were ultimately implemented.

> "For me, living in D.C. is like living at the county fair and having the rides change every week. New music, new art shows, new movies, in and around town."

Looking back over his long and successful research career, Frank remembers that, although working at RAND had been a childhood dream, he almost had to pass when the opportunity finally came. In 1976, after receiving his Ph.D. in economics from the University of Chicago, Frank was offered a position in the Santa Monica Office. To accept, however, he had to promise his wife, Nancy, that one day they would trade the urban sprawl of Los Angeles for a more manageable life in the Washington, D.C., area. In the mid-1980s they made the move and haven't looked back. "For me, living in D.C. is like living at the county fair and having the rides change every week. New music, new art shows, new movies, in and around town. I'm a music fan with broad interests. And when I retire, I have the ambition of taking a two-year training course at the National Gallery so that I can serve as a docent. We'll see."

In the aftermath of Hurricane Katrina, TSgt Lem Torres and a young boy are lifted to safety from the roof of the child's flooded home. Conducting search-and-rescue operations is part of the Air Force's ongoing capability to provide assistance to victims of natural disasters throughout the world.

Expected Benefits of PAF's Approach

The proposed PAF approach can enhance the Air Force's force-planning and resource-allocation efforts in three important ways. First, it gives Air Force decisionmakers a more-instinctive sense of the persistent presence of uncertainty and its implications for policy decisions. In particular, it highlights the range of risks that remain active after senior leaders have committed themselves to a preferred package of policies and resources. It also enables an active, structured interaction between the leaders and their support staffs that leads to a better mutual understanding of subjective beliefs about key uncertainties

Next, this approach filters future challenges so that decisionmakers can focus planning on the most-salient threats. As a result, planning against a few generic threats can potentially prepare the Air Force for dealing successfully with most of the "terribles" it might face.

Finally, the approach helps decisionmakers become more keenly aware of the policy-relevant consequences of taking risks when resource shortages occur. It also gives them more-precise language for discussing subjective beliefs about uncertainty. As they adopt this language, they should be able to communicate more clearly and convincingly—decisionmaker to staff, operator to planner, peer to peer, and Air Force advocate to any stakeholder outside the Air Force, particularly to DoD and Congress.

For more information, see

MG-827-AF, *Managing Risk in USAF Force Planning*, by Frank Camm, Lauren Caston, Alexander C. Hou, Forrest E. Morgan, and Alan J. Vick. Online at http://www.rand.org/pubs/monographs/MG827/

The Engineer Keeping PAF on the Right Track

PAF has a very close and strategic relationship with the leadership of the Air Force.

Richard Moore

Without good lines of communication to the Air Force and smoothly operating business processes, PAF research would come to a halt. One important way PAF maintains communication is through its Air Staff liaison, Rich Moore. In this role, Rich helps Air Force leaders understand PAF's capabilities and connects them to the PAF analysts who can best address their research interests. Rich also serves as PAF's director of operations, making sure that the division's day-to-day operations are cost effective and timely. This allows management and researchers to focus on doing high-quality work, rather than spending time on the policy, funding, compliance, and logistical issues that support research. An engineer who spent 22 years in the Air Force, Rich helps keep PAF's parts moving together in unison.

Connecting Air Force Leaders to PAF Experts

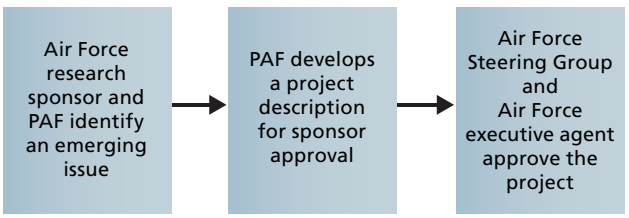
As Air Staff liaison, Rich is often the first person that senior Air Force leaders and their staffs contact when they need information or possibly a research study. Rich helps them understand how to work with PAF. He

arranges for subject-matter experts to brief them and sends them relevant publications. He discusses the types of studies PAF is especially good at and how PAF, a federally funded research and development center (FFRDC), differs from other organizations that conduct research.

Rich helps Air Force sponsors move proposed projects through official PAF and Air Force approval processes (Figures 2 and 3). Each PAF research project must have an Air Force sponsor who is either a general officer or member of the Senior Executive Service. Of this pool of senior Air Force leaders, some 20 percent are closely involved in PAF's research each year. "Given PAF's small size, it has an extraordinary level of senior leader involvement," Rich notes. "The reason is that, as the Air Force's only FFRDC for studies and analysis, PAF has a very close and strategic relationship with the leadership of the Air Force. We address major issues that the senior leaders have asked us to help them with. We work with the research sponsor throughout the course of each study so that we can be flexible when real-world events drive changes to study requirements. We keep the sponsors informed

Figure 2 (top)—Approval Process for PAF's Core Research Agenda. PAF and the Air Force collaborate annually in a multistep process to develop PAF's core research agenda.

Figure 3 (bottom)—Approval Process for Add-on Projects. To ensure that PAF's research agenda is flexible and responsive to the Air Force's needs, new research projects can be added throughout the year.



PAF requires the same business management capabilities that are necessary to operate any organization, but it also has unique operational needs.

of our preliminary findings so that they can make more-informed decisions while the research is under way." Rich likewise often represents PAF in interactions with other DoD organizations and defense contractors.

Rich also works closely with PAF's director to identify and implement ways to improve communications and enable PAF to be more responsive and relevant to the Air Force.

Capitalizing on Research Experience

Rich's liaison services are grounded in ten years of research and management experience at RAND. After joining RAND's research staff in 1999 as a senior engineer, he conducted research that focused primarily on the Air Force's development and employment of advanced technologies and weapon systems. In one landmark project—*Next-Generation Gunship Analysis of Alternatives* (AoA)—he co-led the team that conducted RAND's first AoA. The Chief of Staff of the Air Force, who wanted to explore options for providing the next generation of gunship in 2015 and beyond, had requested the work. "We explained that RAND had never done an AoA," Rich says, "but based on prior work, the Air Force believed we had a clear view of the way ahead. So we said, 'Okay, we'll do our best.'"

The project included more than 40 RAND researchers and 75 Air Force operators, intelligence specialists, engineers, cost experts, and logistics and maintenance experts. Together, they assessed the relative cost-effectiveness of alternatives for providing next-generation gunship capabilities. The study concluded that the most viable approach involved a common platform that could be modified to fly multiple missions, including gunship missions.

Walking in Air Force Shoes

Just as Rich's research background helps the Air Force better leverage its investment in PAF, his military background has often helped PAF researchers engage more constructively with their Air Force contacts.

The son of an Air Force pilot and engineer, Rich earned a B.S. in aeronautical engineering from the Air Force Academy, an M.S. in aeronautical engineering from the Air Force Institute of Technology, and a Ph.D. in mechanical engineering from Purdue University. He began his Air Force career by directing flight test programs for air-to-air and air-to-ground missiles, returning to the Air Force Academy to guide research programs and lead the aircraft propulsion curriculum cadre. He was called away from the academy to serve as chief of the Advanced Propulsion Division at Wright Laboratory, where he established and led a new effort, the Air Force's $120 million Hypersonic Technology Program. In his last assignment in the Air Force, he was a member of the staff of the Assistant Secretary of the Air Force for Acquisition.

This wealth of experience is now brought to bear on behalf of PAF. As research proposals are vetted and developed, Rich provides valuable perspectives on the engineering and programmatic aspects of proposed

An AC-130H gunship aircraft jettisons flares as an infrared countermeasure. Rich Moore's research on options for providing the next-generation gunship (2015 and beyond) concluded that the most viable approach involved a common platform that could be modified to fly multiple missions.

projects, as well as on how senior Air Force leaders, the major commands, the Air Force Research Laboratory, and weapon system program managers might view the proposals.

Providing the Business Capabilities That Support the Research

PAF requires the same business management capabilities that are necessary to operate any organization, but it also has unique operational needs. The business management capabilities that underpin PAF research have four essential legs:

Orchestrating the research agenda. PAF works closely with the Air Force to develop its annual research agenda. That agenda consists of core research projects that are supported by funds Congress appropriates specifically for PAF and by add-on projects that are funded by various Air Force organizations throughout the year and included in the research agenda. Figure 2 illustrates the process for defining and approving PAF projects.

The Air Force Steering Group, chaired by the vice chief of staff, guides the development of the research plan and approves its final form. PAF's director of operations works closely with the Air Force's executive agent for PAF and his staff to orchestrate a process that begins in June, when PAF's four program directors propose projects derived in large part from meetings conducted with Air Force leaders during the preceding months. These projects are then prioritized according to guidance from senior decisionmakers throughout the Air Force and are vetted in house to ensure that PAF has the expertise to address the key research issues. PAF

The director of operations develops and implements a transparent process for managing the day-to-day financial operations of PAF and addressing long-term financial management issues.

also aims for a good balance among the four program areas: Force Modernization and Employment; Manpower, Personnel, and Training; Resource Management; and Strategy and Doctrine. In July, the proposed agenda is given to the Air Force Working Group (senior leaders who report directly to the members of PAF's Air Force Steering Group), revised in response to their input, and submitted in the fall to the Steering Group for its refinement and approval. Subsequently, PAF's operations team develops a status report containing overviews of all the projects, which is sent twice yearly to each Air Force general officer and member of the Senior Executive Service.

Keeping the finances straight. The director of operations develops and implements a transparent process for managing the day-to-day financial operations of PAF and addressing long-term financial management issues. The majority of PAF's funding is appropriated by Congress as a line item in the Air Force's budget. Additional financial support comes from individual Air Force sponsors who request research. PAF's annual resources typically correspond to an FFRDC level-of-effort ceiling that is established by Congress and managed by OSD. The director of operations develops a budget and monitors project spending to control costs. Twice a year, he also conducts financial analyses and prepares an updated business plan designed to meet corporate financial goals, such as determining overhead rates.

Rich also works closely with contract specialists at RAND and in the Air Force to develop the five-year contracts under which PAF operates. During these renewal periods, Rich is in frequent touch with staff in the executive agent's office, to support their efforts to conduct a comprehensive review of the need for an FFRDC and PAF's ability to meet that need.

Ensuring compliance with contractual and regulatory requirements. The contract renewal and extension processes described above are required by law and, in turn, by the Federal Acquisition Regulations and DoD's FFRDC Management Plan. These documents, along with the Air Force–RAND Sponsoring Agreement for PAF and RAND's contract with the Air Force, officially define the FFRDC role and provide an excellent framework for the close and strategic working relationship between the Air Force and PAF. Many aspects of this relationship differ from those the Air Force has with for-profit defense contractors. For example, because FFRDCs have such close working relationships with their government sponsors, Congress limits their size. Rich works closely with the executive agent's office to ensure that all PAF's support to the Air Force complies with this guidance and to help professionals in the Air Force, at RAND, and elsewhere understand the uniquenesses of PAF as an FFRDC.

Managing distribution approval of PAF's publications. RAND has agreed that the distribution of any report resulting from Air Force–supported PAF research will be cleared by the Air Force. The Air Force and PAF have also

agreed that the Office of the Secretary of Defense (OSD) will approve the public release of unclassified documents because most of these reports have significant implications for DoD agencies beyond the Air Force. Rich and his team work with the Air Force and OSD to define the appropriate distribution of the 30-plus unclassified and the ten-plus classified, proprietary, or official-use reports that PAF publishes each year. With each document, different issues arise—for example, questions and comments about the findings can come from OSD reviewers who represent various defense agencies. Rich orchestrates PAF's responses to their input, which often leads to helpful interactions about the research and to further dissemination of PAF's findings.

Beyond choreography of the activities in the four areas described above, Rich works closely with PAF's director and the Air Force executive agent's staff to refine and sometimes reinvent processes that will make the PAF research organization more agile, efficient, and relevant to the Air Force's needs.

Everything comes together under Rich: Like all the individuals who have previously served as PAF's director of operations or Air Staff liaison, he is himself a researcher. But he is also a leader, one who guided a 70-person, $30 million-per-year Air Force program for high-Mach jet-engine technology development, and policy adviser, one who, in the Pentagon, supervised an investment strategy for a $130-million-per-year portfolio for human effectiveness technology development for the Assistant Secretary of the Air Force for Acquisition. This job takes someone who is a detail-oriented, problem-solving multitasker. But Rich stresses that it also requires someone who enjoys interacting and working closely with others. "It's all about good relationships," Rich says, "collaborating effectively, being transparent, communicating, and being as helpful as possible."

Cross-Cultural Competence and Mission Success

In the current security environment, U.S. forces increasingly find themselves in a wide range of situations in which language skills, regional expertise, and cultural sensitivity are crucial for achieving positive outcomes. To negotiate with local people for supplies, members of the U.S. military may have to use approaches different from those they would use at home. They may need to apply different rules of etiquette to interact with different groups within a culture—e.g., government officials and tradespeople—and constantly stay aware of protocol relating to gender differences. They may also have to apply factual information about the foreign relations of a given country—for example, whether a neighboring country is an ally or a foe—or identify which local people appear to be acting suspiciously and which do not.

In difficult circumstances that are further complicated by cultural differences, a misstep could impede mission success. DoD underscores the extent to which this is so, stating that language, culture, and regional expertise are core defense competencies that are as important as "critical weapons systems" (*DoD Language Transformation Roadmap,* 2005).

Senior Air Force leaders asked PAF to assist in conceptualizing the content of training programs aimed at helping members of the Air Force improve their cross-cultural skills. (In this context, *training* refers to any efforts to improve job performance, including education, experience, and professional development.) As an initial step in this direction, a team of PAF researchers developed a unique taxonomy of cross-cultural skills: a framework that describes the behaviors service members may need when they are deployed to a foreign country. Their findings highlight the importance of training personnel in cross-cultural behaviors for their deployed jobs, as well as the gap between the demand for particular types of skills and the limited number of cross-cultural training programs the Air Force currently offers.

Defining Cross-Cultural Job Skills

Without consensus on the nature of cross-cultural competence and the type of training needed, the Air Force could misdirect resources toward training programs that do not meet the needs of deployed airmen. Therefore, before PAF researchers could help the Air Force develop an effective

TSgt Sherry Burt dances and sings with people from the village of Damerjog, Djibouti, after performing with the U.S. Central Command Air Forces Expeditionary Band, the Desert Ramblers. Sharing a love of music and other art forms often becomes the first step in understanding and appreciating another culture.

Developing the Cross-Cultural Skills of Air Force Personnel

PAF researchers developed a unique taxonomy of cross-cultural skills: a framework that describes the behaviors service members may need when they are deployed to a foreign country.

program, they needed to define what personnel should be able to do during foreign deployments. The team's review of the research literature did not yield a comprehensive description or typology of the skills required to perform effectively during international assignments in either military or civilian settings, and neither could initial PAF–Air Force discussions resolve the problem.

To address this gap, researchers developed a framework that sought to cover all potentially relevant aspects of cross-cultural competence for deployed airmen. The framework comprises 14 skill categories (see box).

The team verified the importance of the 14 categories by conducting a survey between August and October 2007 of nearly 21,000 airmen who had been deployed during the 18 months prior to the survey's implementation. The sample was selected to allow analysis by occupational specialty, rank, grade, and deployed location. The most recent deployments of the respondents were varied, but the three most common were Iraq (36 percent), Qatar (18 percent), and Afghanistan (12 percent).

The Influence of Occupational Specialties on Perceptions of Skill Importance

Survey findings indicate that certain skills are more important than others in general, but all are important in some jobs (see Figure 4). Consequently, the research team concluded that no category should be rejected from inclusion in the final list of skill categories for Air Force cross-cultural skills training.

However, the survey results provided several surprises. For example, of all the categories, *foreign language skills* ranked third from the bottom in importance. To examine this result further, the team computed responses to a survey item that focused solely on speaking a foreign language. The importance rating increased but still remained lower than at least half the other skill categories. This finding runs counter to the pop-

Cross-Cultural Skills Important for Deployments to Foreign Countries	
Gathering and interpreting observed information	Negotiating with others
Respecting cultural differences	Applying regional knowledge
Applying appropriate social etiquette	Resolving conflict
Establishing credibility, trust, and respect	Engaging in self-initiated learning
Changing behavior to fit the cultural context	Speaking a foreign language
Using verbal and nonverbal communication	Influencing others
Managing stress in an unfamiliar cultural setting	Establishing authority

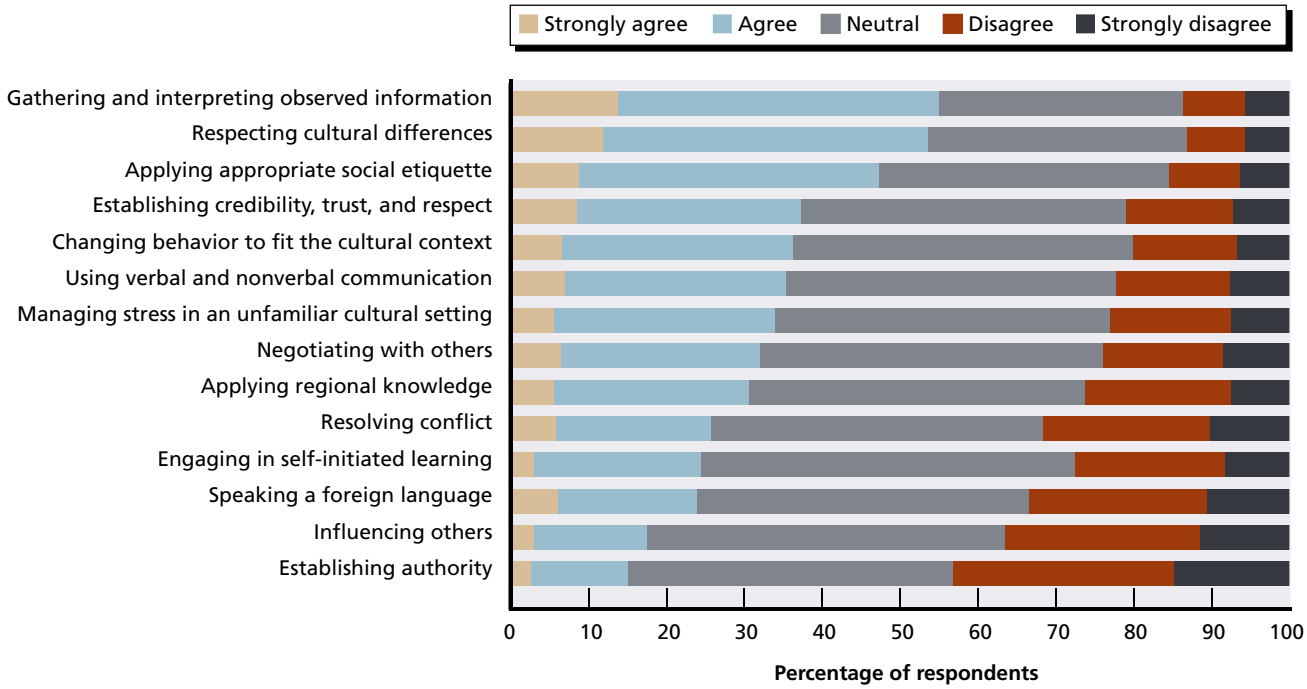


Figure 4—Perceived Importance of Skill Categories. About 21,000 airmen were asked to what extent they agreed or disagreed that the 14 cross-cultural skill categories are important. Responses differed across occupational specialties, but all categories received some degree of support.

ular idea that foreign language training efforts should outrank training efforts in all other categories, a position many Air Force trainers and instructors with whom the team met hold and that is also reflected in the bonuses the Air Force offers for having or acquiring language skills. The moderate importance assigned to the category of *managing stress in an unfamiliar cultural setting* was similarly surprising. During informal interviews, many training personnel considered this category the least relevant aspect of performance and rejected it as a skill that should be addressed in Air Force training.

Analyses indicate that the level-of-importance ratings differed across occupational specialties. Respondents in such specialties as security forces, foreign area officers, and contracting agreed or strongly agreed that nearly all categories were important. In contrast, respondents in such specialties as intelligence, aircrew protection, and aircraft maintenance only partially agreed that most categories were important. In some specialties—e.g., pilots and navigators—respondents tended either to be neutral or to disagree slightly that any categories were important. These differences led the PAF team to conclude that the amount of cross-cultural training should not be the same for all airmen.

Perceptions of Inadequate Levels of Training in Cross-Cultural Skills

Figure 5 shows the percentage of respondents who reported that they had received training in each of the 14 cross-cultural skills, either during the course of their Air Force careers or just prior to deployment. In the skill category with the highest importance rating—*gathering and interpreting observed information*—38 percent had not been trained prior to deploy-

ment, and 32 percent had not gotten this type of training at any time in their career. In a half dozen skill categories, as many as 40 to 60 percent of respondents had never received training.

The PAF team concluded that the amount of cross-cultural training should not be the same for all airmen.

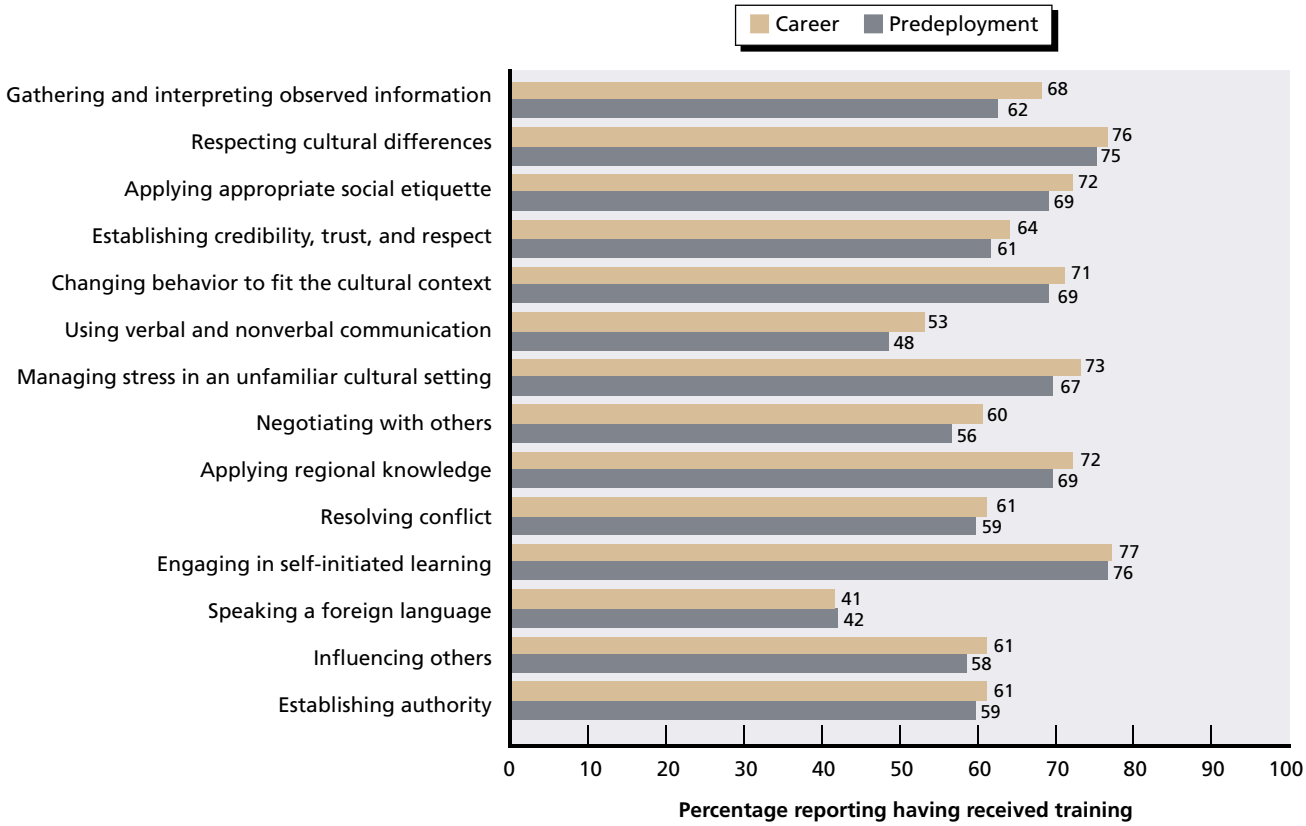
For nearly all the categories, the reported rates for career-long training were only slightly higher than those for predeployment training. This was surprising; one would expect personnel to receive much more training over the course of a career than they would just prior to deployments. It is possible that the survey participants were more likely to recall their predeployment training experiences because they were the more recent.

Generally, cross-cultural skills cannot be fully learned through predeployment training because they involve complex behavior, such as establishing credibility with local people. The PAF researchers caution that predeployment training works best as a refresher course rather than as a primary means of providing training. In addition, the benefits of cross-cultural training can easily be lost if such training is but one of many elements included in preparation for deployment.

Dissatisfaction with Cross-Cultural Training That Was Received

The survey was also designed to determine how helpful current Air Force training is perceived to be. Of those trained, 51 percent or fewer agreed that the training was helpful, depending on the skill category. Figure 6 shows the percentages of respondents agreeing or strongly agreeing that training they had received in the 14 skill categories had been helpful.

Figure 5—In Each Skill Category, Survey Results Showed That Many Respondents Had Not Received Any Training



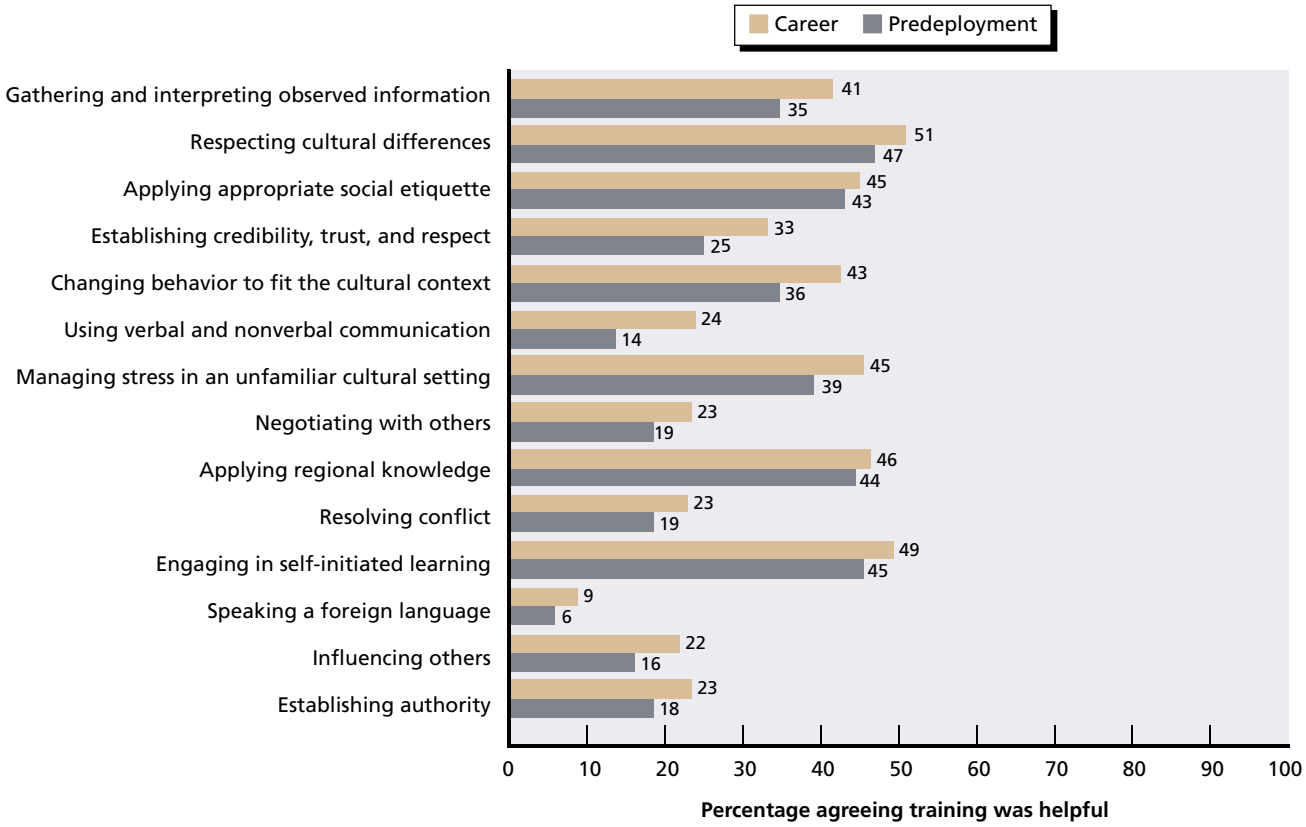


Figure 6—Among Respondents Who Received Training, 51 Percent or Fewer Considered It to Have Been Helpful

Recommendations

Given the variation in importance ratings across occupational specialties, PAF recommends that any comprehensive cross-cultural training program provide at least three graduated levels of training:

- All Air Force personnel need at least minimum training in all 14 categories of cross-cultural skills throughout their career and just prior to deployment. This will ensure that airmen have a basic foundation of cross-cultural behavior ready to apply if the need arises.
- The next, medium, level would provide cross-cultural behavior training of greater depth to airmen in the occupational specialties that indicated that all 14 categories were, on average, moderately important. As with the lower-level training, no category would be left out, but greater attention would be paid to categories generally rated as more important than the others.
- The final, highest level of training would provide expert-level training to airmen in the occupational specialties that indicated clear and strong agreement with the importance of a particular category.

Learning complex skills requires a comprehensive approach, and this assessment represents only the first step. Therefore, the study also recommends additional actions the Air Force should take to design a comprehensive cross-cultural training program. These include designing new curricula to address the 14 behavior categories where necessary, develop-

Chaitra Hardison

As an undergraduate at the University of California at Berkeley, Chaitra Hardison already knew that she wanted to study psychology. "I was very interested in testing and measurement procedures," she says, "especially when applied to work settings. I was fascinated not only with their ability to improve a business's bottom line or an employee's job satisfaction but also to affect the composition of a workforce in terms of gender and race. Effective testing and measurement procedures—along with well-designed training programs—can help ensure that a workplace is performing at its best."

Her interest was unexpectedly nurtured by a stint as a stockbroker at Merrill Lynch. "I was fascinated by Merrill Lynch's testing process—a personality test screening for sales ability, a statistics test screening for knowledge of economics—and I loved learning about the stock market and studying for my broker's license. But I realized the learning was going to stop eventually, so I went to graduate school. My coworkers thought I was nuts!"

After getting her Ph.D. from the University of Minnesota in 2005, she began to look for a place where she could develop a long-term career. "I had known about RAND for a long time, but it hadn't occurred to me that industrial and organizational psychologists worked there." Then, through one of her professors, she met Larry Hanser, a RAND senior behavioral scientist who has played a leading role in helping the Air Force develop better matches between senior leaders and the jobs they perform. He demonstrated by example that Chaitra didn't have to choose between her primary research interests in personnel employment and education. At RAND, she could pursue them both, so she joined the professional staff that same year.

In the short time since then, Chaitra has examined many facets of organizational behavior in the U.S. Air Force—subject matter of training programs, personnel selection methods, attrition, organizational climate, and diversity. In one of her first studies, she assisted in a project to develop training content for Air Force personnel in noncombat specialties to help them prepare for an expeditionary environment. She recently led a project that examined the validity, bias, fairness, racial group differences, and alternative measures for the Air Force Officer Qualifying Test, an aptitude measure used to select officers, pilots, and navigators. She is currently leading three studies, one on foreign language requirements for Air Force officers, another on the validity of the strength aptitude test for high-strength jobs and its affects on gender diversity, and a third on whether the occupational analysis needs of the Air Force are being met.

> "The level of diversity in DoD and the wide variety of perspectives that exist there have been eye-opening. And I'm still trying to break the code of defense jargon. That will be a work in progress for quite a while."

It's more than a bit ironic that, in conducting research on behalf of the Air Force, Chaitra experienced some cross-cultural challenges of her own: She had to learn the language and understand the behaviors she encountered in DoD. "The level of diversity in DoD and the wide variety of perspectives that exist there have been eye-opening," she says. "And I'm still trying to break the code of defense jargon. That will be a work in progress for quite a while."

However, no one is likely to argue that she didn't succeed. In addition to achieving recognition within the Air Force for her analysis of the importance of cross-cultural skills, in 2009 Chaitra received a RAND Merit Award for her leadership and intellectual contributions to this important topic.

In the Panjshir Province, Afghanistan, elders meet with Capt Glenn Little (left) and Maj Nicholas Dickson, representing two Air Force reconstruction teams, to discuss the protocol for a medical visit to a local village.

ing assessment tools for measuring skills in the 14 categories, setting standards for cross-cultural performance expectations, and tracking the skills and training received.

The results of this research are helping shape an emerging cultural education program at Air University and are also being used in the modification of predeployment training for Air Force personnel. The final report formed the basis of testimony that the Director of Force Development presented to the House Armed Services Committee's Subcommittee on Oversight and Investigations.

For more information, see

MG-811-AF, *Cross-Cultural Skills for Deployed Air Force Personnel: Defining Cross-Cultural Performance*, by Chaitra M. Hardison, Carra S. Sims, Farhana Ali, Andres Villamizar, Ben Mundell, and Paul Howe. Online at http://www.rand.org/pubs/monographs/MG811/

Retain or Retire?

Extending the Service Lives of Aircraft That Are Already Old

Over the next 20 years, the further aging of aircraft that are already old will introduce daunting challenges for aircraft operators, including the U.S. Air Force, which is one of the world's largest operators of old aircraft. Current sustainment approaches for older aircraft are a concern because they are not founded on a clear understanding of the structural health of the airframe and its systems. Generally, it appears that operators respond reactively to new aging or damage-related problems, often going into a crisis mode that focuses on each event in isolation.

Three factors have contributed to this situation: budgets that have reduced sustainment resources, especially for engineering support of long-term decisions; overwhelming numbers of older aircraft that continuously need additional capabilities to meet evolving threats and satisfy new mission requirements; and policy changes that have de-emphasized adherence to integrity principles and system-engineering processes. Unfortunately, the reactive mode of sustaining aircraft has affected availability and mission readiness and has also increased overall maintenance costs.

In 2001, the late Dr. John W. Lincoln, head of the Air Force's Aircraft Structural Integrity Program from 1980 to 2002, put the risks associated with aging fleets in stark perspective:

> The . . . USAF is keeping aircraft in their inventories longer than ever before. In many cases, aircraft are left in the inventory longer because they are still operationally effective; however, in most cases they remain . . . because the money is not available to replace them. These aircraft are seeing the effects of aging through corrosion, fatigue cracking, material degradation, and wear. These effects are causing operators to bear a significant economic burden to keep them operational with the potential for degradation of flight safety if they are not maintained properly. Consequently, the USAF is caught in a "death spiral" since aging aircraft funding requirements are inhibiting its ability to procure new systems.
>
> *Personal communication to an associate, 2002*

SrA Jeremy Lueth hand washes the centerline on the underbelly of a KC-135 Stratotanker at Royal Air Force Mildenhall, England. He spends 12 hours a day with a cleaning team that keeps the nearly 50-year-old aircraft corrosion free and looking its best.

Ironically, the Air Force's success in managing the single-crack problem has allowed some aircraft to stay in service for such long periods that they have become vulnerable to multiple small cracks throughout an aircraft.

To explore a range of sustainment issues for aging aircraft systematically, RAND senior engineer Jean Gebman examined a body of research conducted for the Air Force over the past fifteen years, including PAF's AoA for KC-135 recapitalization. He identified technical and institutional considerations that must be addressed in ways that contribute to effective life-cycle management of resources. He also developed related policy options intended to support the Air Force leadership in its deliberations about future resource-allocation decisions.

Technical Challenges: Obsolescence and Material Deterioration

Airframe Structure

For the aircraft of interest in this study, the primary structure of the airframe tends to be constructed predominantly of metal, with honeycomb or carbon fiber for some secondary structures—e.g., leading and trailing edges of wings and stabilizers, fairings between fuselages and wings, and control surfaces (flaps, ailerons, rudders, and elevators). The main technical challenges include single fatigue cracks, widespread fatigue damage, and various forms of corrosion.

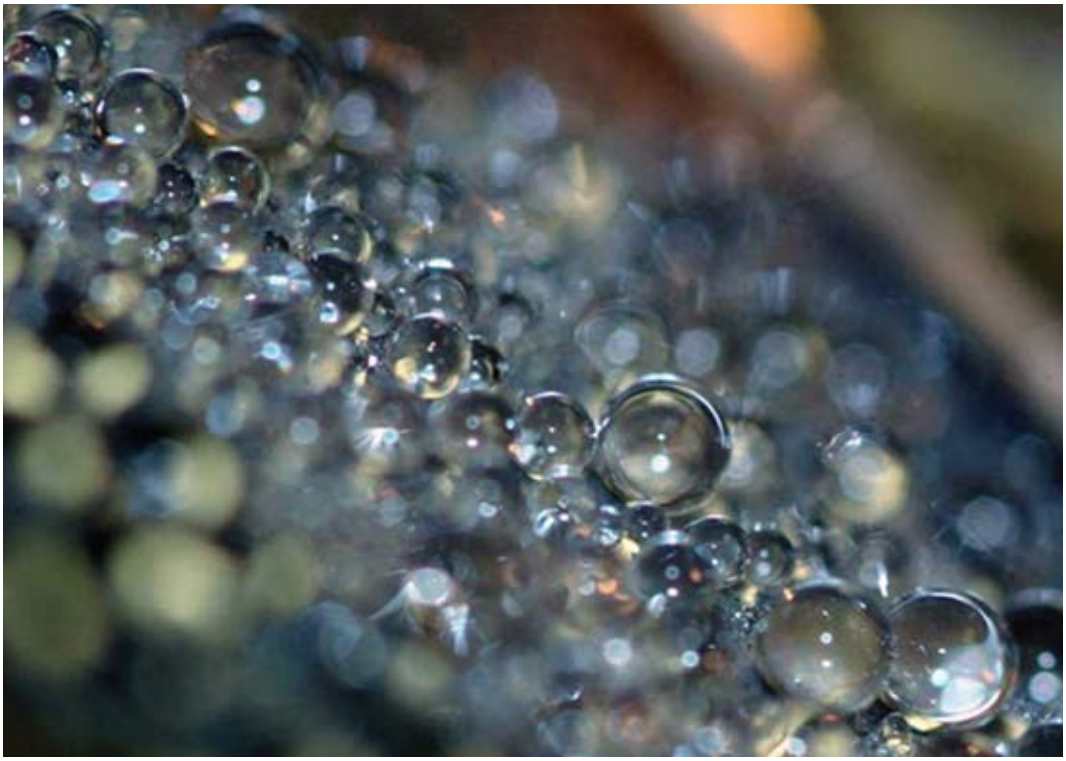
Ironically, the Air Force's success in managing the single-crack problem has allowed some aircraft to stay in service for such long periods that they have become vulnerable to multiple small cracks throughout an area or throughout an aircraft. Such generalized fatigue damage is proving to be far more difficult to detect than a single crack is. Moreover, as fatigue cracks reach significant sizes in multiple areas of a structure, the inspection burden increases, and the costs of maintenance and modifications rise.

The class of corrosion problems known as *stress corrosion cracking* can manifest in a wide variety of ways. The cause commonly includes both a corrosion process and a stress that is perpendicular to the material's direction of greatest strength. Such *transverse stress* can develop in a number of ways—for example, in the grains of the material or where parts have been clamped together to form joints. *Exfoliation corrosion* often occurs at fastener holes and is marked by bubbling up or flaking of material, similar to the way lumber that has been attacked by termites flakes. *Crevice corrosion* can develop at the interface between two adjoining parts if each part is corrosion-prone and if moisture makes contact with both surfaces. This can lead to pitting and can then advance to exfoliation, which can ultimately work its way through the entire thickness of the part.

Propulsion

The technical challenges of cost-effectively sustaining propulsion systems in 50- and 70-year-old airframes may be far more tractable than sustaining airframes fabricated from 1950s materials and 1950s technologies. Because engines endure far harsher environments and loads than airframes do, they are designed to be taken apart during the overhaul process. Airframes are not. Thus, it is usually much simpler to disassemble an engine and replace its parts during regular overhaul than it would be to do so with an airframe.

However, as engines age, the required scope of an overhaul increases. Meanwhile, sources of supply diminish, and the costs of producing parts



Shown here are the effects of a transparent coating that causes water to bead into drops and roll or bounce off a surface. This new technology will help protect and sustain Air Force systems by preventing corrosion and reducing ice formation on optical elements and aircraft.

using obsolete technologies rise, further increasing the upward pressure on maintenance costs. In these cases, the chief technical challenge lies in assessing whether an aircraft will remain in service long enough to justify the investment in a new engine.

Institutional Challenges: Getting Objective and Independent Assessments of Fleet Status

Objective assessments of current fleet status and future conditions that might affect that status are fundamental components of effective life-cycle management of resources. However, few operators seem to possess the technical expertise and resources for conducting their own in-depth assessments. Thus, they must depend on other sources, particularly on equipment manufacturers and sustainment providers, airworthiness authorities (e.g., the Federal Aviation Administration), and independent-assessment authorities for airworthiness and fleet viability (e.g., the U.S. National Transportation and Safety Board and the Air Force's independent Fleet Viability Board).

Members of the first group may have interests that do not align well with those of the operators. For example, a maintenance center will have an interest in creating repeat business. An aircraft manufacturer will have an interest in manufacturing new aircraft to recover its investment costs and to earn a return on that investment. Thus, for both civil and military aviation, expecting manufacturers and service providers to offer objective assessments would seem to entail some obvious risks.

Airworthiness authorities have limited visibility of the current condition of an operator's fleets and are generally not highly involved in fore-

To find cracks, SrA Rebeca Hill paints fluorescent fluid on the engine exhaust cover of an F-16 Fighting Falcon at Balad Air Base, Iraq.

casting future fleet condition. Rather, their focus is on issuing guidelines and directives related to sustaining current airworthiness and on verifying compliance with these directives.

A "Holistic" Policy Approach to Sustainment Planning

Managing limited resources so that an aircraft fleet that is already old can be sustained for another 20 years requires careful consideration of difficult questions:

- Could cuts in sustainment resources increase resources available for procuring new aircraft?
- At what point would cutting back on sustainment resources become counterproductive to effective life-cycle management of resources?
- Might increasing investments in sustainment activities make life-cycle management of resources more cost-effective?
- What risks does a strategy that favors modification in lieu of procurement entail?
- What is the least-risk schedule for replacing fleets in a mission area?

There are several policy options that could help the Air Force resolve these questions and the resource-management issues they imply. These options are briefly described below.

Comprehensive Sustainment Master Plans

In addition to developing an aircraft structural integrity plan for each airframe, which has been a preferred Air Force practice since 1958, PAF's research suggests that there should also be a comprehensive sustainment master plan for each aircraft model. Besides defining future operations, such a plan would describe the work, schedule, and resources needed over the model's remaining life. Its implementation would include routine surveillance and analysis of damage observed in aircraft components; routine upgrading of life-forecasting models and supporting engineering analyses of individual airframes and systems; use of data and models to provide engineering assessment; and periodic, rigorous engineering assessments to determine the ability of aircraft to meet mission requirements.

Sustainment master plans would help solve anticipated safety problems, mitigate knowable risks, and produce more-accurate estimates of the costs and risks associated with alternative service-life goals and alternative sustainment strategies. Moreover, the plans would improve the transparency and increase the credibility of the Air Force's preferred allocation of resources and help make the case to senior DoD policymakers and to Congress more compelling.

Managing limited resources so that an aircraft fleet that is already old can be sustained for another 20 years requires careful consideration of difficult questions.

Coordinated Remaining-Life Investments

Because a large number of widely dispersed organizations participate in making decisions that influence the resource-planning and resource-allocation processes, coordination is essential for effective life-cycle management of resources to become a reality. Without it, the effectiveness of even the most complete and accurate sustainment master plan can be undercut. Coordination of interdependent activities should involve operators and sustainment organizations and encompass a range of research and development, resource-allocation, and sustainment processes. Coordination across fleets within a mission area and across mission areas would also be highly desirable.

Meaningful Service-Life Goals

Finally, establishing meaningful goals for fleet service limits is essential. Setting these goals would require, among other things, technical knowledge and a comprehensive plan for future operations—including a sustainment master plan, a coordinated investment plan, and meaningful measures of fleet conditions. Setting limits on future use should also be considered, as should identification of process enhancements and technological advancements that may be required to realize a service-life goal.

Although the Air Force's immediate problems are with the sustainment and retirement of its aging aircraft, these policy options could apply to all U.S. Air Force aircraft. Their broad applicability is a consequence of the fact that effective preparation for quality service during a fleet's golden years is a function of how the fleet is used, managed, and sustained throughout its service life.

Jean Gebman

April 1968 was a big month for Jean Gebman. He finished work on his master's degree in aerospace engineering at the University of Michigan, interviewed for a job at RAND, was hired, and reported for work—all in the space of a few days. The pace hasn't changed a lot since then. He has participated in or led an impressive array of research studies for PAF in such areas as weapon system acquisition, force structure, aircraft reliability and maintainability, and the entire spectrum of problems that affect aging aircraft. By 1974, he had also found time for a Ph.D. in engineering at the University of California at Los Angeles (UCLA).

Jean's research career has many highlights. His early work on finding the right mix of military and civil airlift resources supported decisions both to strengthen the Civil Reserve Air Fleet and to acquire the KC-10 as a dual-role tanker and transport. Later, he led research that encouraged DoD to procure several dozen transport aircraft to provide the Air Force an efficient means of moving large amounts of bulk cargo and troops.

He designed a major data-collection and engineering-analysis program to identify ways to improve reliability and maintainability for mission-critical radars on the F-15 and F-16 fighters and explored ways to improve the avionics acquisition process for modern weapon systems, such as the F-22. For the last fourteen years, he has been PAF's senior technical point man on aging aircraft.

Jean has also served as an associate program director and an associate department head at RAND. As a teacher, he has lectured on systems engineering, systems management, and mission analysis at UCLA, the University of Southern California, and the Pardee RAND Graduate School. His teaching duties haven't been confined to classrooms, however. He and his wife, Sheila, have three children—Ryan, Michael, and Heather—all of whom are engineers. Jean points out that, "In addition to standard engineering curricula, they've had a healthy dose of home schooling in the systems approach."

"Part of what I've tried to pass on to the kids is what I'd call my philosophy of engineering, which has evolved from my academic and research experiences." He is a firm believer that, in addition to the pure and deep technical knowledge that an engineer requires, it's important to have a broader view of the world. "When I was a college freshman at Syracuse University," he says, "we were taught that the definition of engineering was the wise application of scarce resources to the important needs of society. That has been a guiding principle in my work."

Jean admits that he sometimes gets kidded about expressing his views via what some colleagues call the Gebman Manifesto, which puts that principle in an Air Force context: "If you buy an airplane, there are certain universal values that come into play: You want it ready when you need it. When you use it, you want it to be trustworthy. You want it to be a cost-effective use of resources. Anything else is a subsidiary or a combination of those three basics."

> "If you buy an airplane, . . . You want it ready when you need it. When you use it, you want it to be trustworthy. You want it to be a cost-effective use of resources. Anything else is a subsidiary or a combination of those three basics."

Jean's broader view of the world also includes a 25-year history of civic involvement in his home city of Santa Monica, California. He has been honored for many of his efforts, including promotion of Little League baseball, oversight of a $90 million school-construction project, and establishment of financial oversight policies for the school district. Since 1998, he has served as a city airport commissioner. Clearly, the lessons he learned at Syracuse have served their purpose.

At Travis Air Force Base, California, TSgt Christopher Thompson hydraulically opens the cowlings on the number 2 engine of a KC-10 Extender so that he can make a necessary repair. Because engines are designed to be disassembled, it is much easier to replace their parts during an overhaul than it is to renovate an airframe.

Concluding Thoughts

Uncertainties will always be associated with aging systems and about the consequences of errors in estimates of longevity and future costs. Thus, an important role of sustainment processes is to help operators conserve resources while protecting their essential interests from surprises. Cost-effectively sustaining a fleet of aging aircraft requires an operator to accomplish two objectives: First, make the right investments in aircraft sustainment. Second, make the right decisions about when to replace the aircraft. Although getting it right can allow a user to defer replacement costs, getting it wrong can ultimately cost more, yield less capability, and disrupt the capacity to complete important missions.

For more information, see

TR-560-AF, *Challenges and Issues with the Further Aging of U.S. Air Force Aircraft: Policy Options for Effective Life-Cycle Management of Resources*, by Jean R. Gebman. Online at http://www.rand.org/pubs/technical_reports/TR560/

Adding Winglets to Air Force Tanker Fleets

Would Fuel Efficiency Go Up and Operating Costs Go Down?

Since the late 1980s, commercial airlines and cargo carriers have added structures called *winglets* to the wingtips of their aircraft to reduce drag and thus make the aircraft more fuel efficient (see Figure 6). Most commercial aircraft and some military aircraft, such as the C-17A, come equipped with winglets or similar devices. Moreover, increasing jet fuel costs have prompted commercial operators to retrofit existing aircraft with winglets to increase fuel efficiency and lower costs.

In the 2009 National Defense Authorization Act, Congress asked the Air Force to have an FFRDC assess whether adding winglets to portions of the KC-135R/T and KC-10A tanker fleets would be cost-effective. Would the reduction in operating expenses over the lives of the aircraft produce a positive return on investment? How would the future price of jet fuel affect the savings? Would adding winglets affect maintenance and flight operations? Are there investment strategies that could minimize the Air Force's capital expenditure and maximize return? The Air Force chose PAF to help answer these questions.

To perform the analysis, PAF used a combination of high-resolution flight simulations, cost-estimation methods, technical and operational expertise, and interviews with contractors and operators. PAF researchers calculated the range of fuel-consumption savings that could be achieved in the course of actual tanker missions. They also examined the potential return on investment under a wide range of assumptions about future fuel prices, the remaining service lives of the aircraft, OPTEMPOs, and the total cost of developing and installing the winglets.

The Cost-Effectiveness of Adding Winglets to Tankers

The PAF team found, in the majority of potential futures examined, neither tanker fleet achieved a net cost savings, even when acquisition costs for winglets were at the low end of the estimates. The business case for adding winglets to the KC-135R/T and KC-10A became more persuasive as fuel prices rose and the aircraft were flown at higher OPTEMPOs over longer service lives. However, the option is currently not attractive for several reasons.

A C-17 Globemaster III moves into position to refuel from a KC-10A Extender over the Black Sea. The winglets on the wingtips of these aircraft help reduce drag and increase fuel efficiency.

PAF's analysis suggests that jet fuel would have to average $4 to $6 per gallon for two to four decades to justify the cost of adding winglets.

To make winglets cost-effective, the average price of jet fuel would have to be much higher than is currently projected. The spike in the price of jet fuel to over $3 per gallon in 2008 spurred interest in making aircraft more fuel efficient. Even so, PAF's analysis suggests that jet fuel would have to average $4 to $6 per gallon for two to four decades to justify the cost of adding winglets in most circumstances. The Department of Energy projects that jet fuel prices may remain close to $3.00 per gallon for nearly 20 years. That is well short of the value needed to generate a positive return on investment under most of the cases the researchers examined.

Tankers do not operate at a sufficiently high utilization rate to warrant the addition of winglets. Researchers looked at a range of OPTEMPOs, from planned peacetime usage to slightly above the level of current contingency operations. However, even the high estimate falls below usage rates for commercial passenger and cargo aircraft. Because savings are a function of the number of hours an aircraft is flown, the decision to add winglets makes sense for many commercial operators but not for the Air Force.

The acquisition cost for winglets could be relatively high. PAF researchers estimated a range of acquisition costs for each proposed winglet program based on both the commercial experience with winglets and military acquisition programs. Many of the Air Force's KC-135R/T aircraft are over 50 years old. Modifying these aircraft could require extensive structural work, thus increasing the cost. At the high end of the cost estimates, adding winglets would produce a negative return on investment in every case the researchers examined. While the KC-10 fleet is much younger, and its structure is generally considered to be in good condition, the relatively high potential research and development cost could push overall program costs to the high end of the range and thus

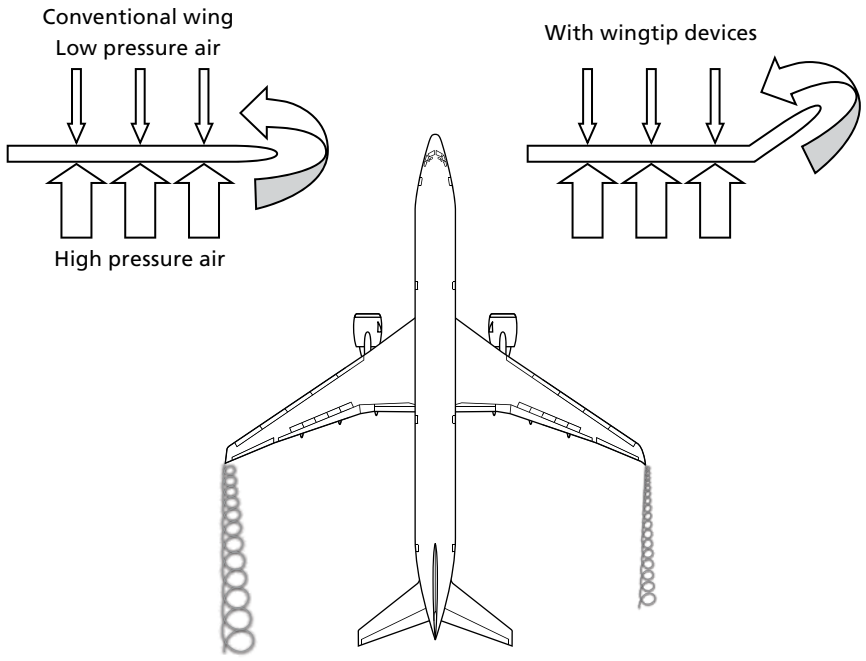


Figure 7— Winglets Improve Aerodynamic Performance. The differential between low-pressure, high-velocity air above the wing and high-pressure, low-velocity air below the wing creates lift, which enables the aircraft to fly. Winglets improve aerodynamic performance by reducing the amount of high-pressure air that flows up and around the wingtip during flight. This flow has an adverse effect on the low-pressure air distribution above the wing, thus increasing drag.

A KC-135R undergoes a full maintenance overhaul at the Oklahoma Air Logistics Center. There are concerns that the KC-135R/Ts may require extensive maintenance to remain in service long enough to justify the cost of adding winglets.

make the return on investment negative for every combination of flying hours, fuel price, and service life examined.

The use of competition in certain phases might help reduce costs, although existing contractual arrangements may limit these opportunities in the development and production phases. PAF found that options for reducing capital expenditure—such as leasing winglets or sharing acquisition costs with partners—are not promising.

Other Possible Problems with Adding Winglets

Adding winglets to tanker fleets could require altering the ground infrastructures of the air bases at which the tankers are permanently stationed. This could also reduce the number of aircraft that could operate from contingency bases. Winglets would increase the KC-135R/T's wingspan by 12 feet, thus demanding changes in taxiways, parking aprons, and fuel hydrants at some bases. The extra six feet of wingspan on KC-10As would have less effect because these aircraft operate at bases that already accommodate the much larger C-17A transport aircraft.

An examination of the operational effects of winglets on takeoff and landing indicated that winglets would minimally influence flight operations. For instance, winglets can have a minor adverse effect on crosswind sensitivity. Conversely, when operating at high-altitude runways and/or in hot temperatures, winglets may improve the aircraft's climb performance and shorten the runway length required. The study found that winglets would not affect training and routine maintenance.

Potential for Future Addition of Winglets if Circumstances Change

While the business case for adding winglets to the KC-135R/T and KC-10A is not currently attractive, that could change if fuel prices increase significantly. Commercial experience suggests that winglets can be installed relatively quickly once the design is developed. Although such a strategy would shorten the period during which savings could be realized, it would also defer the modification costs. If the business case did not improve, the winglets need not be installed. The analytic framework the PAF team developed, along with the findings documented in the report, will help the Air Force determine if and when it may be advantageous to install winglets.

Alternative Strategies for Saving Fuel

The Air Force should consider fuel-saving alternatives to winglets. These might include new structural design features on the aircraft surface, such as aerodynamic fairings, fillets, and seals, and new ways of using flight control surfaces, such as rudders and flaps. Several of these systems have already been implemented on commercial airliners of sizes similar to Air Force tankers. Although these options would not reduce fuel consumption as much as winglets would, they could be less expensive and easier to implement and may offer a better return on investment. Further analysis is needed to better determine the possible costs, savings, and risks of these modifications.

"I was fascinated with foreign policy and aviation," Dan recalls. "I read *Jane's All the World's Aircraft* to keep up with new aircraft programs the way kids in Santa Monica read the *L.A. Times* to keep up with the Dodgers."

Donald Stevens and Daniel Norton

Donald Stevens directs PAF's Force Modernization and Employment program. As he sees it, "The Air Force is the most technologically sophisticated U.S. military service, but this makes strategic and programmatic decisions all the more complex. Smart policy choices about costly programs must be based on highly technical information. The decision about whether or not to add winglets to tankers is a good example because, on the surface, it seems like a promising approach to improving fuel efficiency. However, when we considered the technical requirements and limitations in a military operational context, we found that there is reason to be cautious."

PAF combines technical knowledge and scientific methodologies with an appreciation for the policy decisions the Air Force must make. Maintaining this skill set requires a continuing focus on identifying and developing staff who can understand and respond to Air Force needs. Donald says that he prefers to hire people who are in the early stages of their careers and to help them grow as RAND researchers. "I don't just look at their education and work experience. I look for a genuine personal interest and curiosity about the subject. What are their hobbies and other activities? If they're going to air shows and technical expos in their spare time, it suggests that they like to keep pushing beyond what they already know."

Donald has always been an avid learner with passionate interest in a variety of subjects. "My father worked at Northrop, so at my kitchen table, we talked about aerodynamics and aircraft engineering," he says. "At a very early age, I became very interested in how birds fly." By the time Donald entered college at the University of Southern California, where he majored in mechanical engineering, he had become adept at computer modeling. A summer internship at Northrop put his skills to work and even prepared him for work he would do decades later at RAND. "Some of the same models I used that summer are still being used at RAND today," he says. "Those were very good models!"

But Donald brought more than modeling experience to RAND, where he began working in 1987. He also recruited senior staff from the aerospace industry to help mentor junior colleagues. Today, in his current management role, Donald has an even greater appreciation of the value of continuous mentoring. "Up-and-coming researchers require direction so they can learn what they need to learn in order to become leaders themselves." This applies not only to new hires, but to staff who have been at RAND for many years. "When I assign individuals to projects, it's because I think they have the right skills for the job, and the job poses interesting challenges that will extend their abilities. That way, people keep getting better and better."

One such assignment was the choice of Dan Norton to co-lead the winglets study with him. Dan is a senior management systems analyst who has spent more than 20 years at RAND studying mobility, modernization, and strategic planning issues for the Air Force and other U.S. military services. Dan's professional interests reflect the diversity of his background. As an American who was brought up in Saudi Arabia, he traveled extensively in Europe and Asia. By the time he was 18, he had visited 40 countries. His interests were correspondingly eclectic: "I was fascinated with foreign policy and aviation," he recalls. "I read *Jane's All the World's Aircraft* to keep up with new aircraft programs the way kids in Santa Monica read the *L.A. Times* to keep up with the Dodgers." After he returned to the United States as an undergraduate at Occidental College, his path presented itself naturally: While double-majoring in political science and economics, he took a class in national security studies from a professor who was also a RAND analyst. When the professor took the class on a tour of RAND, Dan was hooked. "I knew immediately that that was the kind of place where I could learn and grow," he says.

Dan's career illustrates the kind of continuous learning that Donald values in the Force Modernization and Employment program. Starting out as a research assistant at RAND in 1987, Dan used high-resolution simulations to analyze the effectiveness of ground combat systems. After a few years his focus shifted to the strategic mobility of Army units.

To expand his skill set and broaden his experience base, Dan went back to school in 1994 to earn a master's degree in business administration from the University of California at Berkeley. Shortly after returning to RAND, he co-led a study of the affordability of the Air Force's modernization plans. The methodology developed for this project was later adopted by the Air Force. He then worked on large force-effectiveness assessments, such as the Next-Generation Gunship and KC-135 Recapitalization AoAs. Dan's combination of operational and business expertise provided an excellent match for the demands of the winglet study, which focused primarily on whether the proposed program would make business sense for the Air Force.

Dan says that the Air Force has used the winglet study to address questions from Congress. "Even though the idea of adding winglets to tankers does not look promising today, the parties are confident that the question has been given a thorough and rigorous examination. We've also pointed out some other avenues for cost savings that the Air Force should consider. "This is the kind of technically based policy analysis the Air Force relies on us to do."

Centralized Repair Networks

Improving Support for F-16 and KC-135 Aircraft

In 2007, senior Air Force logisticians asked RAND to undertake a strategic reassessment of the Air Force's logistics enterprise. The objective was to identify alternatives for appropriately rebalancing logistics resources and capabilities between operating units and support network nodes across the total force, including the active-duty forces, the Air Force Reserve Command, and the Air National Guard.

Using projections for the future operating environment, a PAF research team led by Ron McGarvey and Bob Tripp identified alternative ways to reallocate maintenance workloads and resources between that provided at the aircraft operating locations and that provided by a robust network of centralized repair facilities (CRFs). The alternatives the team identified offer equal or greater capability than the current system does and require equal or fewer resources. Thus, the Air Force could use these repair network concepts to increase its operational capability at no additional cost or to achieve the same capability at less cost, then to use the savings to support other mission areas that are more stressed than aircraft maintenance.

Potential Operational Effectiveness and/or System Efficiency Improvements from a CRF Network

For this study, PAF chose to examine F-16 fighters and KC-135 tankers because of their dissimilarities—both in their logistical support requirements and in their projected levels of use in future deployment scenarios. The research focused on wing-level maintenance tasks, including sortie launch-and-recovery workloads and removal and replacement of failed aircraft components—collectively referred to as mission-generation (MG) workloads—along with shop repair of failed components and aircraft inspections, which have been historically performed on site, in the unit's "backshops."

Currently, individual operational units perform both MG and backshop maintenance. The analysis examined a network-based alternative in which MG workloads are retained at each operational unit and a network of CRFs handles major aircraft inspections and component repair. Consolidation of CRF workloads could reduce manpower through economies

An airman tightens down an Fj-16 Fighting Falcon canopy after a periodic inspection at Nellis Air Force Base, Nevada.

Shuttle costs for aircraft inspections—those associated with aircraft movement between the operating locations and the CRFs—are very small compared to manpower costs.

of scale. But moving maintenance tasks away from the aircraft's operating location would require investments in transportation and facility construction. The key question was whether the potential savings from economies of scale would offset the additional transportation and facility costs.

Figure 8 illustrates the manpower economies of scale that consolidating CRF workloads can provide. The left endpoint of the curve demonstrates that a relatively small backshop facility supporting a comparably small amount of flying required approximately ten CRF manpower authorizations per 1,000 annual flying hours.

The rightmost portion of the curve indicates that a CRF supporting a much larger workload volume is able to achieve the same levels of performance (measured in maintenance production rates) with significantly less manpower than the equivalent backshops. This suggests that implementing a repair network consisting of a few relatively large CRFs could significantly reduce the total manpower requirement for non-MG workloads.

The research team developed a mathematical model that considers the full range of CRF network alternatives, from fully decentralized solutions that retain CRF maintenance capabilities at all operating locations to fully centralized alternatives that consolidate all CRF capabilities at one site. The model identifies the alternative that minimizes the total cost.

Results Using a CRF Network for F-16 Fighters

Take, for example, a case in which the goal is to provide maintenance support for a steady-state deployment of 10 percent of the combat-coded

TSgt Nathan Bechdolt inspects the leading edge flap of an Fj-16 Fighting Falcon at Misawa Air Base, Japan. Sergeant Bechdolt, an F-16 crew chief, is one of 31 airmen deployed from the Air National Guard, Fort Wayne, Indiana, to help during a low-manning period.

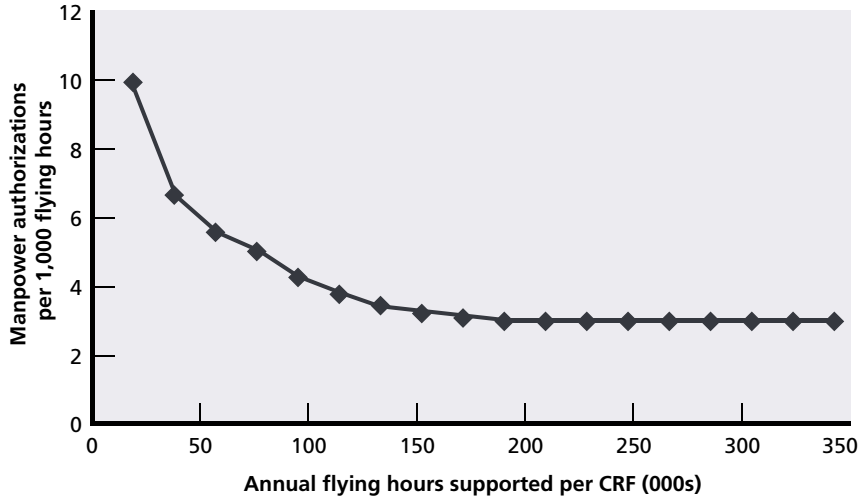


Figure 8—Moving Away from Small F-16 Backshops Toward Large CRFs Can Reduce Manpower Requirements

F-16 fleet into two theaters for an indefinite duration, while retaining the capacity for a surge deployment of 80 percent of the same fleet into two theaters. PAF identified an alternative that maintains the overall maintenance manpower level while enhancing the capability of F-16 MG units by consolidating CRF workloads and transferring the resulting reduction of 1,900 backshop manpower positions into MG maintenance. This would allow each combat-coded squadron to have sufficient MG capabilities to conduct split operations, in which some fraction of the primary authorized aircraft deployed, and the rest operated from the home station. PAF found that the cost of the CRF network was relatively insensitive to the specific network design. Alternatives containing between three and four CRFs worldwide, with considerable latitude regarding the specific CRF locations, all achieved total system costs very close to the minimum achievable cost.

However, if the Air Force concluded that its current F-16 maintenance operational capabilities were sufficient, it has the potential to realize an annual savings of nearly $90 million by centralizing the CRF workloads across the total force without creating any new split operations (see Figure 9). The Air Force might decide that, even though F-16 maintenance capabilities were stressed, the 1,900 backshop positions could be more effectively applied to a different career field.

The bar on the left side of the figure represents the annual manpower costs associated with the current system ($345 million). The bar on the right shows the total system costs for the total force CRF network alternative, again without added split operations ($257 million).

Shuttle costs for aircraft inspections—those associated with aircraft movement between the operating locations and the CRFs—are very small compared to manpower costs. However, large fluctuations in the price of aviation jet fuel led the PAF team to conduct additional analyses to determine how sensitive the alternative CRF network strategies would be to variations in shuttle cost. For the F-16C, aviation fuel constitutes 26 percent of the total cost per flying hour. PAF's calculations indicated

In all the cases they examined, PAF researchers observed an economic rationale for repair network centralization.

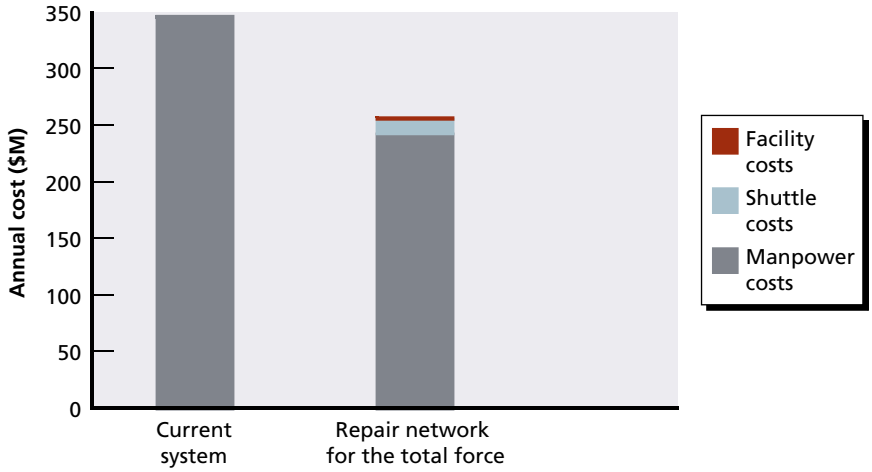


Figure 9—F-16: Potential Cost Savings Can Be Achieved Through CRF Efficiencies. The costs here do not include aircraft maintenance squadron manpower. Because their manpower levels were not modified in the repair network alternative, these individuals perform MG tasks only.

that the total force CRF network would be less expensive than the current system, even if the cost of aviation fuel increased by a figure up to 28 times that used in this analysis. The results indicate similar insensitivity for the facility costs: Even if the facility costs computed in this analysis were understated by a factor of ten, they would not be large enough to materially affect the outcomes.

Results Using a CRF Network for KC-135 Tankers

The analysis for the KC-135 identified similar potential for increased effectiveness and efficiency through consolidation of certain backshop maintenance workloads into a flexible maintenance network support concept. Extending current Air Mobility Command (AMC) maintenance support concepts for deployed aircraft to home station operations, PAF assumed, for purposes of illustration, that the goal was to sustain a steady-state deployment of 40 percent of the combat direct support KC-135 into two theaters for an indefinite duration, with a surge deployment of 100 percent of the same fleet into two theaters.

In this case, the team found that centralizing CRF workloads could allow transfer of 2,400 positions from backshop maintenance to MG

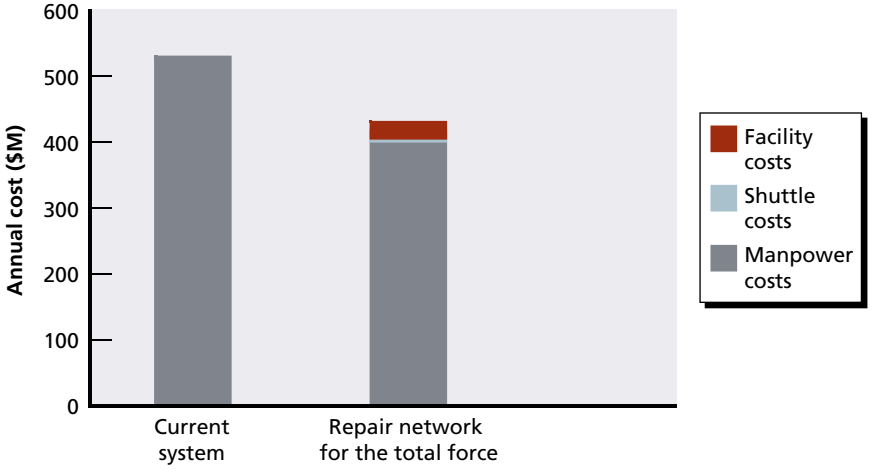


Figure 10—KC-135: Potential Cost Savings Can Be Achieved Through CRF Efficiencies. The costs include aircraft maintenance squadron manpower because its level was increased by roughly 200 positions in the repair network alternative.

SSgt Greg Thompson uses a cable tension meter to check an aileron cable inside the main landing gear wheel well on a KC-135 Stratotanker at March Air Reserve Base, California.

maintenance, giving each combat direct-support squadron the ability to conduct split operations. Again, the CRF network design demonstrated considerable flexibility. Options containing between one and three CRFs worldwide, with relative insensitivity to the specific CRF locations employed, all cost approximately the same as the optimized minimum cost. If the Air Force concluded that its current KC-135 maintenance operational capabilities were sufficient, it could realize an annual savings of $100 million by centralizing these backshop workloads across the total force but creating no new split operations (see Figure 10).

The bar on the left side of Figure 10 shows the annual manpower costs for the current system ($531 million). The bar on the right represents the total system costs for the total force CRF network alternative without split-operations manpower ($429 million).

As with the F-16, the research team conducted additional analyses to determine how sensitive the alternative KC-135 strategies were to variations in the shuttle cost. The total force CRF network would be less expensive than the current system, even if the price of aviation fuel increased by a figure up to 43 times that assumed for the fiscal year 2008 cost per flying hour. Facility construction costs again constituted a very small fraction of total system costs.

Ron McGarvey

When Ron McGarvey was studying for his doctorate in industrial engineering and operations research (OR) at Pennsylvania State University, he already knew he wanted to work at RAND. "In my field, RAND is extremely well known because in many respects the genesis of OR was here," he explains. When you're talking about the history of OR in your course work, the RAND name keeps popping up—where these things were first developed, first tested. So in 2002, when I was ready to start my career, I didn't seriously consider any other position."

Ron feels doubly fortunate because he was hired into a team that for many years has been led by Bob Tripp, a well-known figure in logistics research. "One of the best things about working at RAND is the team emphasis," Ron says, "in contrast to a university where junior people tend to compete against each other for tenure. Here we do our best to set personal egos aside and work for the good of the team and the good of the project."

Ron's research for PAF already reveals a great deal of breadth. He has developed optimization models that have been used to evaluate strategies for integrating theater airlift assets into multimodal distribution systems. He has also developed network design models for a PAF analysis recommending ways the Air Force can improve the maintenance structure that supports fighter aircraft in the continental United States.

As project leader, he and his PAF colleagues examined the organizational effects of centralizing the management of USAF war reserve materiel under a single organization and developed new modeling approaches for allocating war reserve materiel across storage sites to ensure that USAF deployment requirements are satisfied even when access to a site is lost. He also led a research effort to identify alternatives for better managing strategic airlift assets. Currently, he and Bob are leading a 15-member team that has been tasked with developing new logistics strategies to improve support to Air Force operations in the current and OSD-projected future security environments.

In January 2008, Ron assumed some very new responsibilities. During its 63-year partnership with the Air Force, PAF has established relationships with various major commands, including having on-site representatives at Air Force headquarters in the United States, Europe, and the Pacific. "PAF management asked if I would consider accepting a fixed-term position within AMC at Scott Air Force Base, Illinois. When I spoke to my wife, she was interested in seeing another part of the United States and experiencing small-town life, so I said, 'Sure.'"

What does Ron do at Scott? "Basically I'm a RAND guy doing RAND project work about 95 percent of the time. But I act as a liaison and provide administrative support when people visit the site. A nice development this year is that PAF is about to start an AMC-focused project to study ways that the Air Force uses commercial carriers for short-haul intratheater airlift. We want to help the Air Force think about a more-formal strategy than it now has for using these assets and how such a strategy might affect future USAF requirements. I'm looking forward to leading that project. It will tie RAND more closely into the interests and concerns of the command."

"It's pretty difficult to complete an entire analysis, start to finish, in 30 minutes. In a half hour of cooking, you can go from a collection of raw ingredients to a really good dinner. It's a nice contrast."

When he leaves his office at Scott, Ron has another type of interest that he pursues with enthusiasm: gourmet cooking. "My wife, Emmanuelle, is from France, and I began by learning about French cooking from her. But then I got hooked and took some classes. Now I do most of the cooking at home for us and our two little boys, Pierre and Felix. What I enjoy about it most is that it's an immediately gratifying activity. Research is gratifying, too. However, it's pretty difficult to complete an entire analysis, start to finish, in 30 minutes. In a half hour of cooking, you can go from a collection of raw ingredients to a really good dinner. It's a nice contrast."

Conclusions

For both the F-16 and the KC-135, PAF's analyses suggest the potential for improvements in operational effectiveness and/or system efficiency across various CRF alternatives. In all the cases they examined, PAF researchers observed an economic rationale for repair network centralization.

But a broader view should also consider options for rebalancing resources across mission design series to meet the most pressing needs of the future security environment. Rebalancing options should further take into account the reprogramming of resources between maintenance and other career fields if OSD guidance and other projections suggest that those fields will be more stressed in likely future scenarios.

At an air base in Southwest Asia, SSgts Ruben Mariscal (left) and Frank Veres with A1C Abigail Smith prepare to install a new wheel on a KC-135 Stratotanker. A PAF research team found that, for both the F-16 and the KC-135 aircraft fleets, a network of centralized repair facilities would help increase operational capability at no additional cost. Alternatively, the current capability could be achieved at less cost, and the Air Force could use the resulting savings to support other mission areas.

For more information, see

MG-872-AF, *Analysis of the Air Force Logistics Enterprise: Evaluation of Global Repair Network Options for Supporting the F-16 and KC-135*, by Ronald G. McGarvey, Manuel Carrillo, Douglas C. Cato, Jr., John G. Drew, Thomas Lang, Kristin F. Lynch, Amy L. Maletic, Hugh G. Massey, James M. Masters, Raymond A. Pyles, Ricardo Sanchez, Jerry M. Sollinger, Brent Thomas, Robert S. Tripp, and Ben D. Van Roo. Online at http://www.rand.org/pubs/monographs/MG872/

Project AIR FORCE Research Excellence Award

In 2008, Project AIR FORCE (PAF) instituted an award to honor researchers who, year after year, have achieved the highest degree of excellence in their work. Winners receive support for professional development and a plaque recognizing their outstanding contributions. The selection committee includes the unit director, Andrew Hoehn, the associate director, Carl Rhodes, and the director of staff development, Michael Kennedy. PAF congratulates the 2009 Research Excellence Award winners, Jean Gebman, Nelson Lim, and Kristin Lynch, on their record of outstanding accomplishments.

Jean Gebman

Jean Gebman is being honored for his extraordinary body of work, which has helped the Air Force understand the processes that affect the readiness, trustworthiness, and cost-effectiveness of its aging aircraft. His research in this area has focused on such topics as analyzing fatigue failure in aircraft structures and reducing the cost of aircraft maintenance while still supporting critical programs.

He was a major contributor to RAND's AoA for recapitalizing the KC-135 fleet and has supported the efforts of commander of the Air Force Materiel Command to strengthen the Air Force's process for setting and justifying life limits for aging aircraft.

Jean has helped the Air Force make important decisions about managing the F-16 fighter and KC-135 tanker fleets, which are expected to have very long service lives. His technical expertise led to his participation in the investigations of the Columbia Space Shuttle disaster and, more recently, the loss of an F-15C whose fuselage broke apart during basic fighter maneuvers.

Jean received his B.S. in aerospace engineering from Syracuse University, his M.S. in aerospace engineering from the University of Michigan, and his Ph.D. in engineering from the University of California at Los Angeles.

Nelson Lim

Nelson Lim is being honored for his contribution to the solution of a complex problem: whether bias in promotion selections has been responsible for lower representation of gender and ethnic minorities at higher grades in the Air Force's military and civilian workforces.

Some have been tempted to approach this issue simplistically. But as a specialist in diversity management, Nelson Lim was aware that other issues might be complicating the problem. So, instead, he tackled it using a sophisticated analysis called *propensity scoring* to frame the issue in a way that would, first, help determine whether there was even a basis for concern about discrimination. PAF's statisticians then were able to use his techniques to show that the representation problem is not a function of the promotion system itself but rather of such other factors as the quality of initial accessions and the occupations minorities tend to enter.

In recognition of his expertise in this area, Nelson has also been selected to head an Office of the Secretary of Defense study group next year that will be responding to a congressional requirement for a commission on diversity.

Nelson received his B.A. and M.A. in economics and his Ph.D. in sociology, all from the University of California at Los Angeles.

Kristin Lynch

Kristin Lynch is being honored for her ongoing contributions to publishing PAF's logistics research, year after year: getting research documented, through review, and out as final products.

As an integral part of PAF's agile combat support research team, Kristin has focused on ways to enhance the Air Force's ability to support its deployed operations, including lessons from several recent operations. For the Air Force's air and space operations center and Air Force forces, she related resources to operational capabilities to evaluate how the Air Force might best posture its command and control capabilities for potential future operational requirements. Kristin has also worked toward a future vision for Air Force logistics, evaluating current Air Force initiatives to support it. She is currently updating and expanding an operational architecture for integrated global enterprise combat support planning, execution, and control to improve warfighter support during steady-state, training, and contingency operations. Kristin is very good at digging into the details of Air Force organizations and processes and using her detailed knowledge to enhance PAF's research.

Majoring in mathematics, Kristin received her B.S. from Syracuse University and her M.S. from Virginia Polytechnic Institute and State University.

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