

# DISSERTATION

**RAND**

## *Blunting the Talons*

*The Impact of Peace Operations  
Deployments on USAF Fighter Crew  
Combat Skills*

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**RAND Graduate School**

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## PREFACE

This report is submitted as a dissertation to the RAND Graduate School in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Policy Analysis. It was produced as part of a larger project sponsored by the Deputy Chief of Staff for Air and Space Operations, HQ USAF. The larger project investigated the creation of a new, integrated readiness assessment and management system for the Air Force under the Resource Management and System Acquisition program within Project AIR FORCE.

This larger project is designed to provide an analytic structure and support to the Air Force in developing its own, improved system for reporting and managing readiness information for near term readiness assessment. One of its goals is to provide a structure and implement a system that can use the best available information and models to provide readiness assessments for internal Air Force use and for external reporting on the status of the Air Force. Continuing complex operational requirements and tight budgets demand improved readiness assessment and management. Because air power is so effective and flexible, because it can be used quickly and at great distances, and because these attributes are so important to U.S. national interests, the Air Force should stand out in its ability to assess its readiness quickly and accurately.

The new readiness system needs to provide decision makers with the opportunity to address proactively the policy implications of changes in specific parameters such as:

- Manning levels and experience mix
- Key resources such as flying hours and range/airspace availability
- Unit taskings to include deployment, exercise and contingency requirements

This report investigates how a particular type of contingency requirement - peace operations deployments - impacts the air-to-ground and air-to-air combat skills of USAF fighter crews.

#### **Project AIR FORCE**

<sup>f</sup> Project AIR FORCE, a division of RAND, is the Air Force federally  
<sup>l</sup> funded research and development center (FFRDC) for studies and analysis.  
<sup>e</sup> It provides the Air Force with independent analyses of policy  
<sup>e</sup> alternatives affecting the development, employment, combat readiness,  
<sup>f</sup> and support of current and future aerospace forces. Research is  
<sup>e</sup> performed in four programs: Aerospace Force Development; Manpower,  
Personnel, and Training; Resource Management; and Strategy and Doctrine.

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## SUMMARY

This document presents an analysis of the impact of peace operations deployments on USAF fighter crew combat skills. Peace operations deployments, and especially fighter crew involvement in these "stability enhancing" activities, are a relatively new phenomenon. Prior to the end of the Cold War in the early 1990s virtually all of the time USAF fighter crews spent in the air was devoted to tactical training that served two purposes. First, it prepared them to be as effective as possible in the event of war with the Soviet Union, Warsaw Pact or other communist adversaries of the US. Second, the very high state of combat readiness intensive training promoted acted as a deterrent that reduced the chances war would occur - enhancing global stability. Thus, for the first 40 years of the Air Force's existence there was a synergistic relationship between combat training and stability enhancing activities - at least as far as fighter crews were concerned.

This synergy came to an end with the emergence of the "new world disorder" of the early 1990s. Instead of training for and thereby helping to deter major war, USAF fighter crews were called upon to help promote global stability by deploying to various troubled regions and continuously occupying no-fly zones over Bosnia and Iraq to deter aggressive air or ground action by one or more parties in the region. Instead of practicing air-to-air and air-to-ground combat skills, pilots involved in these deployments found themselves engaged in missions that consist largely of left hand turns and are described variously as "converting jet fuel into noise" or "boring holes in the sky".

It quickly became apparent to the crews and their supervisors that peace operations' deployments - some lasting up to 120 days - were having a detrimental impact on their air-to-air and air-to-ground combat skill. But how big was the impact? Chapters Five and Six of this document present statistical analyses of data obtained from the 335<sup>th</sup> Fighter Squadron, 4<sup>th</sup> Fighter Wing (F-15Es) and the 4<sup>th</sup> Fighter Squadron,

388<sup>th</sup> Fighter Wing (F-16Cs) to shed some light on this question. The analyses lead to the following conclusions:

#### SHORT TERM IMPACT

- Proxy measures for important Major Theater War (MTW) air-to-ground and air-to-air combat skills show a rapid and marked decline during peace operations deployments.
- The probability of missing a target with a low level bomb delivery increases dramatically during deployments for non-instructors and for squadrons as a whole.
  - Probability of miss for F-15E visual and radar bomb deliveries increases, on average, by 20 to 25 percent.
  - Probability of miss for F-16C visual bomb deliveries increases, on average, by 25 percent.
- The probability of launching an invalid air-to-air missile shot during a peace operations deployment doubles compared to normal non-deployed training.
- Proficiency returns within a matter of weeks for both air-to-air and air-to-ground combat skills once normal training resumes.
- These skill losses are almost certainly associated with decreased proficiency in other important MTW combat skills, so the overall combat effectiveness of USAF fighter crews performing peace operations missions probably declines more, and perhaps much more, than these measures indicate.

#### LONG TERM IMPACT

- Anecdotal accounts, backed up by some exit survey evidence, suggest peace operations deployments are significant contributors to a disturbing decline in average USAF fighter crew tactical experience levels. They contribute in two ways:
  - First, the long family separations and lack of compelling rationale for personal sacrifice contribute to extremely low retention rates for experienced fighter pilots and WSOs.
  - Second, the near zero tactical training value of the sorties significantly decreases the amount of tactical training crews accomplish over the long term - forcing the USAF leadership to

choose between a shortage of instructors and flight leads brought on by increased upgrade times, or a de facto lowering of standards for these important positions.

There are a variety of ways these problems could be addressed. US national leaders could decide to eliminate one or more of the existing no-fly zone commitments. Alternatively, changes could be made to the nature of the deployments to minimize the detrimental impact they have on USAF fighter crew combat skills. These measures include policies that would alter who deploys, how long they are gone, how many crews and aircraft deploy, various options for increasing training for deployed units and new operational concepts for conducting peace operations. Most of these possible solutions have either already been adopted, or are unattractive for political, financial, or safety reasons.

With effective solutions unattractive, dangerous, unlikely, or years away the USAF finds itself on the horns of a real dilemma. On the one hand, there seems to be no slackening of demand for USAF fighter crew participation in stability enhancing peace operations. These operations are an important part of the environment shaping aspects of the current national security strategy and are therefore certainly a part of the "real mission" of the Air Force and other services. On the other hand, these operations have real, non-trivial negative consequences for both the long- and short- term combat readiness of fighter crews who participate in them. These negative effects will almost certainly impact the USAF's ability to effectively defend US national interests the next time it is called on to conduct a MTW air campaign. In short, there seems to be an inherent conflict between two important USAF missions that did not exist to anything like the same extent during the Cold War, and especially from 1975 to 1990.

This research shows that current commitments exceed the USAF fighter forces capacity to simultaneously conduct peace operations and maintain the same training and readiness standards developed during the last 15 years of the Cold War. These training standards are the result of lessons learned and relearned, sometimes the hard way, in combat during World War II, Korea and Vietnam. Crews trained to these

standards achieved outstanding results during Operation Desert Storm and the public, political leaders, and many in the military have accepted Desert Storm as the standard of performance they expect from American armed forces. With few attractive technological or operational solutions available it seems clear that sooner or later US national leaders must do one of the following:

- 1) Decrease the commitments USAF fighter forces currently face by bringing one or more of the current peace operations to an end through diplomatic or other means.

- 2) Increase the capacity of USAF fighter forces to simultaneously conduct peace operations deployments and high quality.

OR . . .

- 3) Continue to accept decreased, and declining, levels of USAF fighter crew MTW combat readiness and the attendant risks of casualties and operational reversals.

These are not attractive choices. The first two options have relatively high short term political or fiscal costs. However, it is important to remember that any delay or decision not to decide is in reality a choice to continue to stick with option three - the option that clearly has the highest long run cost.

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## GLOSSARY

| Symbol    | Definition                                                                                                                                                                                                                                |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| C4I       | Command, Control, Communications,<br>Computers and Intelligence                                                                                                                                                                           |
| CEA       | Circular Error Achieved                                                                                                                                                                                                                   |
| CONOPS    | Concepts of Operation                                                                                                                                                                                                                     |
| BVR       | Beyond Visual Range                                                                                                                                                                                                                       |
| EC        | Electronic Combat                                                                                                                                                                                                                         |
| F-15E     | Two seat long range multi-role fighter<br>aircraft.                                                                                                                                                                                       |
| F-16C     | Single seat multi-role fighter aircraft.                                                                                                                                                                                                  |
| JSF       | Joint Strike Fighter                                                                                                                                                                                                                      |
| LALD/HD   | Low Angle Low Drag/High Drag - A type of<br>visual bomb delivery                                                                                                                                                                          |
| LGB       | Laser Guided Bomb                                                                                                                                                                                                                         |
| Loft      | A type of radar bomb delivery.                                                                                                                                                                                                            |
| MOOTW     | Military Operations Other Than War                                                                                                                                                                                                        |
| MTW       | Major Theater War                                                                                                                                                                                                                         |
| PERSTEMPO | Personnel Tempo - Just as operational<br>tempo refers to the pace of military<br>operations personnel tempo refers to the<br>pace or frequency of personnel<br>deployments and TDY assignments.                                           |
| TDY       | Temporary Duty - A term used to describe<br>the status of military personnel or<br>units temporarily operating from or<br>assigned to bases or units other than<br>their home units or bases - as during<br>peace operations deployments. |
| USAF      | United States Air Force                                                                                                                                                                                                                   |

WSO    Weapon Systems Officer - Second crew member in two seat fighters such as the F-15E responsible for operating navigation, electronic countermeasures, and other sophisticated systems.

## 1. INTRODUCTION

### PURPOSE

The objective of this document is to help improve the understanding of the true cost of peace operations deployments by examining the relationship between these deployments and the combat skills United States Air Force (USAF) fighter pilots need to successfully conduct combat operations. The document is organized around the following questions:

- How do peace operations deployments fit into post Cold War US national security objectives?
- What part do USAF fighter crews play in peace operations designed to enhance stability in volatile regions?
- Are the skills USAF fighter crews use during peace operations deployments the same skills they would need during the opening phases of a MTW?
- How do USAF fighter crews' objectives during peace operations deployments impact the long term and short term combat effectiveness of USAF fighter crews and units?
- If there are negative effects of peace operations deployments on fighter crew combat readiness, what measures can US national leaders and USAF leadership take to address them?

### APPROACH AND METHODOLOGY

The analysis that forms the heart of this document relies on data collected from USAF fighter squadrons equipped with F-15E and F-16C aircraft. The analysis uses standard statistical methods, such as multiple regression analysis, to investigate the relationship between measures of aircrew experience, recent practice and proxy measures of air-to-air and air-to-ground combat skill performance. An example of the type of analysis conducted is a regression equation that postulates

visual bombing accuracy is a function of the number of practice bomb deliveries a particular pilot has performed in the past 30 days and whether or not he or she is an instructor. Standard statistical methods are also used to evaluate the statistical and practical significance of the regression results.

## **ORGANIZATION**

This report is divided into seven chapters. Chapter Two presents an overview of the major challenges facing the US as it attempts to enhance order and stability in the post Cold War world and how these new challenges have changed both the nature and training value of USAF stability enhancing tasks. Chapter Three presents an overview of the magnitude of the USAF peace operations commitment, and explains how the nature of no-fly zone enforcement sorties offers little opportunity for USAF fighter crews to practice important MTW combat skills. It presents a summary of current psychological research on human skill acquisition and expert task performance. Finally, it reviews previous work on the relationship between fighter crew practice and skill proficiency. Chapter Four presents an overview of previous research on statistical modeling of learning and skill acquisition, and offers some hypotheses about how peace operations deployments might effect the MTW combat skills of USAF pilots. Chapters Five and Six offer an analysis of data obtained from F-15E and F-16C squadrons that confirms the hypotheses set out at the end of Chapter Four. Finally, Chapter Seven discusses various options for addressing the combat readiness problems associated with USAF fighter crew participation in peace operations and concludes with a summary of the dilemma facing USAF and US national decision makers as they attempt to address the questions listed above.

## 2. RESEARCH CONTEXT

### THE MILITARY CHALLENGE IN THE POST-COLD WAR ERA

The end of the Cold War has also created a more chaotic international security environment where ethnic and regional conflicts previously suppressed by the US-Soviet competition of the Cold War flair from southern Europe to the Caucasus, to the Indian sub-continent, throughout Africa, the Taiwan straits and elsewhere. As the only global military power and chief guardian of the international system, the US is often called upon to act to suppress these conflicts and enhance international peace and stability. The US military, 40 percent smaller than its mid-1980s peak, now has three to five times as many people deployed on operational missions such as Operations Southern Watch and Deny Flight.

However, even with its large and capable military forces and huge economy, there are limits on what the US is able to do. American leaders must choose judiciously where and when to intervene in regional or ethnic conflicts. In addition, when they decide to intervene with military force they must deploy and employ forces in an efficient manner.

Efficiency is important in "stability enhancing" actions like the no-fly/no-drive zones in Bosnia and Iraq due to the unrelenting nature of the task. These operations are not designed to, nor are they capable of, quickly imposing US terms on the target parties. As a result, deploying and operating overwhelming military force in such operations is pointless and wasteful. Instead, a force large enough to establish and maintain US "presence" is deployed. These forces are powerful enough to make regional factions or trouble makers think twice (or more) before they act, but would require quick and substantial reinforcement to conduct major offensive operations.<sup>1</sup> This level of involvement is

---

<sup>1</sup> This requirement was demonstrated in February 1998 when the US deployed considerable air and naval reinforcements to the Persian Gulf region in anticipation of the need to conduct offensive air operations against Iraq during the UN weapons inspection crisis.

appropriate as the goal of these operations is not to eliminate or settle conflicts, but to suppress them.

However, these conflicts are not tractable in the short-term, they are open-ended commitments. USAF aircraft have been patrolling the no-fly/no-drive zones in Iraq for over 7 years with no end in sight. USAF commitment to the no-fly zone in Bosnia began in 1994, and US ground forces initially committed for 12 months in December 1995 have no planned exit date nearly two and a half years later. The early and continuing involvement of US air power assets and USAF units in particular in these stability enhancing operations is of particular interest.

#### **Airpower and International Stability Enhancement**

The remarkable performance of US air power - led by the USAF - in the 1991 Gulf War has led many analysts, commentators, and politicians to view air power as an extremely effective - some would even argue decisive - instrument of national power.<sup>2</sup> Airpower's enhanced lethality, highlighted by a seemingly endless stream of images depicting precise laser guided bomb (LGB) deliveries and ruined Iraqi armor on CNN, combined with the relatively small number of pilots sent in harm's way, make air power particularly attractive for stability enhancing operations where efficiency is an important consideration, or "virtue".

The similarity between many of the tasks combat aircrews performed during most of Operation Desert Storm and those that they perform during peace operations further enhances the belief that air power is an efficient way to address the need for US military presence. During peace operations missions USAF fighter pilots patrol the skies in search of prohibited military aircraft flights or ground activity just as their

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<sup>2</sup> The USAF flew 58 percent of all coalition sorties during the 1991 Gulf War. It flew 63 percent of the interdiction, and 60 percent of the offensive counter air missions. It flew almost four times as many sorties as the US Navy (the next largest contribution of sorties by service component or allied nation) and over ten times as many sorties as the Saudi Air Force (the sortie leader among allied nations). Source: Elliot A. Cohen, Gulf War Air Power Survey Vol. V, US Government Printing Office, Washington DC, 1993 pp. 232-233.

counterparts circled over Iraq searching for Iraqi fighters or Scuds during the Gulf War. Attack aircraft fly long missions at medium altitude and even practice designating targets on the ground with the laser targeting systems they would use to guide their weapons in the event they were needed.

So, on the surface it may seem that by engaging in stability enhancing missions, like no-fly/no-drive zone enforcement, the USAF is both enhancing the prospects for peace and preparing for the worst if the peace operations fail or if an unexpected crisis breaks out elsewhere in the world. In short, USAF involvement in peace operations seems to be an efficient way of reducing the cost of world stability because it allows crews to practice their combat skills while simultaneously deterring or suppressing conflict. However, as the analysis presented in subsequent chapters will show, the surface appearance of congruity between peace operations and combat skill maintenance quickly fades as one digs deeper.

#### The Cold War

This is a familiar situation for the Air Force. Throughout the Cold War, with tensions high and deterrence the order of the day, the USAF decided the best way to both ensure peace and prepare for the demanding combat tasks anticipated for World War Three, was to build and maintain capable conventional and nuclear forces at a high state of readiness.

This was not always done. During the 1950s and 1960s the USAF (and the other services) placed so much emphasis on nuclear war-fighting that conventional air-to-ground and air-to-air combat skills were neglected to a large extent. This was most clearly illustrated by the impact the US Navy's Top Gun air-to-air combat training program had on USAF and Navy air-to-air kill ratios during the Vietnam War. During operation Rolling Thunder from 1965 through 1968 the USAF and Navy used similar tactics, formations and almost identical aircraft (the F-4C and F-4B respectively) in air-to-air combat over North Vietnam. They had almost identical kill ratios against North Vietnamese MiGs: 2.25 to 1 for the Air Force and 2.42 to 1 for the Navy. These kill ratios compared very

badly with the 10 to 1 kill ratio achieved by USAF F-86 pilots against MiG-15s during the Korean War.<sup>3</sup>

Both services reacted to this situation. The USAF focused primarily on technological solutions (such as improving radar guided missiles and long range radar identification techniques) while the Navy launched an intensive air-to-air combat training program that included new formations and very realistic training for F-4 crews and developed a new version of the short range Sidewinder heat seeking missile better suited to maneuvering air combat. Known as Top Gun, the Navy's school was designed to dramatically improve F-4 crews' air-to-air combat skills.

When air combat resumed over North Vietnam from 1970-1973 the Navy's new emphasis on training and skill proficiency paid big dividends. The Navy's kill ration rose to 13 to 1 while the USAF - still using the outmoded tactics and with the same lack of emphasis on air combat skill training that both services entered the Vietnam conflict with, but with improved missiles and radar - saw its kill ratio decline to 1.92 to 1.<sup>4</sup> While the higher combat loss rate for the USAF was bad, it was accompanied by lower mission success rates for surviving fighters because the relative ineffectiveness of USAF fighters escorts in air-to-air combat led to increased MiG attacks on bomb laden strike aircraft - forcing them to jettison their bombs in order to maneuver against their attackers.

However, after the Vietnam War the USAF saw the error of its ways. The Air Force adopted the Navy's clearly superior formations and began its own realistic air-to-air training programs. Meanwhile, the advent of strategic nuclear parity and the consequent emphasis by first the Carter, and especially the Reagan administrations, on building the capability to successfully defend western Europe without relying on nuclear escalation caused the USAF (and the other services) to place increasing importance on all types of conventional combat skills.<sup>5</sup>

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<sup>3</sup> Marshall L. Michel III, Clashes: Air Combat over North Vietnam 1965-1972, Naval Institute Press, Annapolis MD, 1997 Chapter 9.

<sup>4</sup> This is just one example of how proper training can have a huge impact on the combat effectiveness of military forces.

<sup>5</sup> For an excellent discussion of US air operations over North Vietnam and their impact on the subsequent development of US air power see Mitchel, Clashes, Chapter 9.

Prevailing in a conventional confrontation with the Soviet Union was such a demanding mission that most Western planners hoped only to be able to successfully defend Western Europe. Even this limited goal was so demanding and the stakes so high that successful exploitation of a favorable outcome would cost little more than a successful defense, and was therefore usually considered a "lesser included case". During the last 15 years of the Cold War there was tremendous overlap between the sorts of tasks USAF aircrew engaged in to enhance deterrence and enhance stability in the bi-polar global competition and the tasks they would need to perform in the event a global or regional conflict actually occurred.<sup>6</sup>

#### The post-Cold War

The appearance of continued synergy between stability enhancing and MTW tasks for USAF fighter crews is deceptive. Unlike their Cold War counterparts, current USAF fighter crew face a trade-off when engaging directly in stability enhancing operations. While these operations take on the form of the missions flown for most of the 1991 Gulf War - medium altitude search and simulated laser guided bomb (LGB) deliveries - they are very different from the missions most USAF and other coalition aircrew engaged in for the first several days of Operation Desert Storm and do not allow the crews to exercise the skills they would need to survive and fight effectively during the opening "engagement phase" of a future major regional conflict.

During the engagement phase - before enemy defenses are eliminated - crews of non-stealthy attack aircraft will probably need to employ their aircraft, at least some of the time, on demanding day and night low altitude missions in order to take advantage of terrain masking and the curvature of the earth to reduce warning time to enemy radar guided surface to air missiles (SAMs). They will probably also face opposition from enemy fighters early in a future war that could require them, or

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<sup>6</sup> It is important to note that these military measures were coordinated with systematic economic (e.g. the Marshall Plan) and diplomatic (e.g. the system of interlocking alliances ringing the Soviet Union and China) initiatives that laid the foundation for sustained US military presence in critical regions of the world.

their specialized air-to-air colleagues in F-15Cs or F-22s, to engage in high-G maneuvering in a confusing multi-aircraft environment.

The typical no-fly/no-drive zone sortie does not allow USAF crews to practice the sets of skills they need to effectively employ their aircraft on the demanding mission profiles just described. In other words, engaging in these stability enhancing activities, while reducing the probability of a crisis in a particular country or region, probably reduces the survivability and combat effectiveness of crews during the most difficult and dangerous phase of a conflict should stability enhancing fail, or an unexpected crisis develop elsewhere. Table 2.1 below summarizes the argument presented above.

| A<br>i<br>r<br><br>F<br>o<br>r<br>c<br>e<br><br>M<br>i<br>s<br>s<br>i<br>o<br>n<br>s | Military Tasks                                              |                                                                                                                                                                                                                                         |                                                                                                      |                                                                                          |
|--------------------------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
|                                                                                      | C<br>O<br>L<br>D<br><br>W<br>a<br>r                         | Stability Maintenance                                                                                                                                                                                                                   | Warfighting                                                                                          |                                                                                          |
|                                                                                      |                                                             |                                                                                                                                                                                                                                         | Engagement Phase                                                                                     | Exploitation Phase                                                                       |
|                                                                                      |                                                             |                                                                                                                                                                                                                                         |                                                                                                      |                                                                                          |
|                                                                                      |                                                             | Deter global war by equipping and training large over-continental and nuclear forces for high-intensity combat operations.                                                                                                              |                                                                                                      |                                                                                          |
|                                                                                      | P<br>O<br>S<br>T<br><br>C<br>O<br>L<br>D<br><br>W<br>a<br>r | Deploy conventional forces quickly to crisis zones to neutralize the global and engage in on-going "preemptive" or humanitarian relief as means designed to decrease the probability of a crisis will escalate into regional conflicts. | Employ highly trained conventional and nuclear forces in global or regional high intensity conflict. | Exploit victory gained in engagement phase as quickly as it becomes militarily possible. |
|                                                                                      |                                                             | Deter regional conflicts by equipping and training over-continental, and to a lesser extent, nuclear forces for high-intensity combat operations.                                                                                       |                                                                                                      |                                                                                          |

Table 2.1 - Military tasks and Air Force missions Cold War and post Cold War

A final point on this table. The most recent, and therefore most often sighted, model of a major theater war (MTW) - the 1991 Persian Gulf War - had a very brief engagement phase and a prolonged exploitation phase. By the third day of the air war, coalition air power had largely eliminated Iraqi radar SAM defenses, creating a medium

altitude threat free zone or "sanctuary". For the next 36 days - until the start of the ground war - coalition air forces operated largely from this medium altitude sanctuary to attack Iraqi infrastructure and attrit Iraqi ground forces in the field. As a result, the bulk of USAF combat sorties were flown during the exploitation phase of the war where efficiency was the measure of effectiveness. This produces a tendency among some analysts - reinforced by CNN images of LGBs striking point targets from medium altitude - to believe that most future conflicts will consist almost exclusively of the sort of medium altitude missions USAF crews engaged in during the exploitation phase of Desert Storm and during ongoing peace operations. As a result, there is a tendency to underestimate the negative impact - and the potential implications - of peace operations on the combat readiness and effectiveness of USAF forces during what is likely to be the most dangerous and crucial part of a future major theater war: the engagement phase. In short, peace operations may appear much cheaper for USAF combat units in terms of combat readiness than they actually are.

If the US is to successfully minimize the impact of its global responsibilities on its economy and military readiness, decision makers must better understand the readiness implications for US forces engaging in stability maintaining peace operations. For reasons outlined above this is particularly true for USAF fighter crews.

#### CONCLUSION

The United States is currently the world's preeminent military and economic power. The key international security challenge facing US leaders as we move into the next century will be to execute the overall national strategy of "engagement and enlargement" while avoiding three dangers. First, the US must intervene - with military forces when necessary - to prevent various ethnic and regional struggles from expanding to threaten global security. Second, these stability enhancing interventions can not be allowed to erode US military capability to the point that US forces would perform poorly, or even suffer major reverses, in a MTW if stability enhancing operations prove ineffective. Both of these dangers could be avoided if the US devoted a larger share of its GDP to military expenditures. With more resources

available, the US military could maintain large stability enhancing commitments and still have plenty of highly trained and capable forces for MTW operations. However, the third danger is that in devoting a large share of its GDP to military expenditures, the US will weaken its economic competitiveness, and therefor its ability to stabilize the world economy and ultimately its ability to maintain its super-power status.

In order to avoid these dangers, or at least balance the risks between them, US national policy makers must have a good understanding of how military expenditures effect economic competitiveness, AND how military operations designed to enhance international stability impact combat readiness. The first relationship has been the subject of a long and voluminous discussion and is beyond the scope of this document. The second relationship is the general topic under consideration here. Figure 2.1 below illustrates the goals, instruments, missions and means of US national power, and where the research presented in this document fits into the whole.

## Research Context

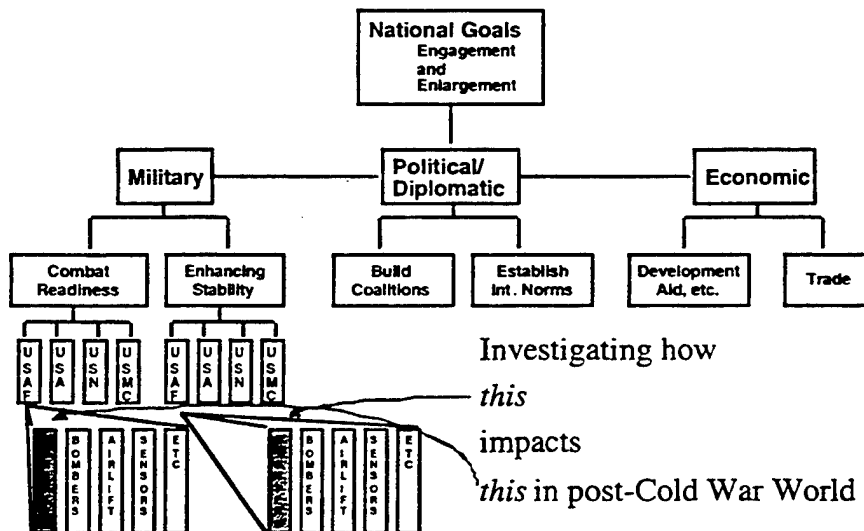


Figure 2.1 - Schematic of Research Context

Specifically, this document is concerned with what happens to the MTW combat skills of USAF fighter pilots when they engage in operations - like enforcing no-fly zones - designed to enhance international stability. The remainder of this report will be an attempt to quantify both the scope and intensity of the readiness impact of peace operations on USAF fighter crew combat skills.

### 3. BACKGROUND

#### PEACE OPERATIONS AND MAJOR THEATER WAR READINESS

Over the past six years USAF fighter aircraft have devoted hundreds of thousands of hours to conducting peace operations missions in the no-fly-zones over Bosnia and Iraq. While it might seem reasonable to assume that fighter pilots engaged in peace operations practice a wide range of tactical skills the discussion that follows reveals that this is not the case. During these sorties crews are unable to practice many of the skills they would need in the opening days and weeks of a MTW. As a result there is wide speculation inside and outside the military that the combat skill proficiency and MTW combat readiness of these crews suffers. Since the beginning of these operations there has been no systematic attempt to analyze the available data to determine what, if any, relationship exists between the number and frequency of training events crews accomplish and their ability to perform critical combat tasks.

The postulated negative relationship between peace operations participation and MTW combat readiness does not mean peace operations are not important, are not part of the "real mission" of the USAF, or should not be conducted. If a negative relationship it may mean that while peace operations are an integral part of the US national security strategy of enlargement and engagement, the more resources the USAF devotes to these "stability enhancing" activities the worse position it will be in if they fail and a major war occurs. In other words, the challenge facing the USAF, and the other military services, is how to strike a balance between operations designed to reduce and prevent international conflict, and operations designed to prepare the USAF (other services) to prevail if and when conflict occurs. In order to strike this balance USAF leaders need to better understand how engaging in peace operations impacts units' ability to successfully carry out their assigned MTW mission swiftly and with minimal losses.

### The Rise of Peace Operations

Prior to 1991 when USAF tactical aircrew took to the skies they were almost always engaged in either high quality peacetime training, or actual combat missions. Following the 1991 Gulf War they began to participate in a significant way in enforcing no-fly-zones over Iraq, and after 1993 over Bosnia. Figure 3.1 below, derived from USAF Reliability and Maintainability Information System (REMIS) data clearly illustrates the dramatic increase in the amount of time USAF fighter crews spent on peace operations in the first half of the 1990's. Additional analysis of this data indicates that on any given day the USAF has about 2 of its 14 active fighter wings orbiting over either Bosnia or Iraq enforcing no-fly-zones.<sup>1</sup>

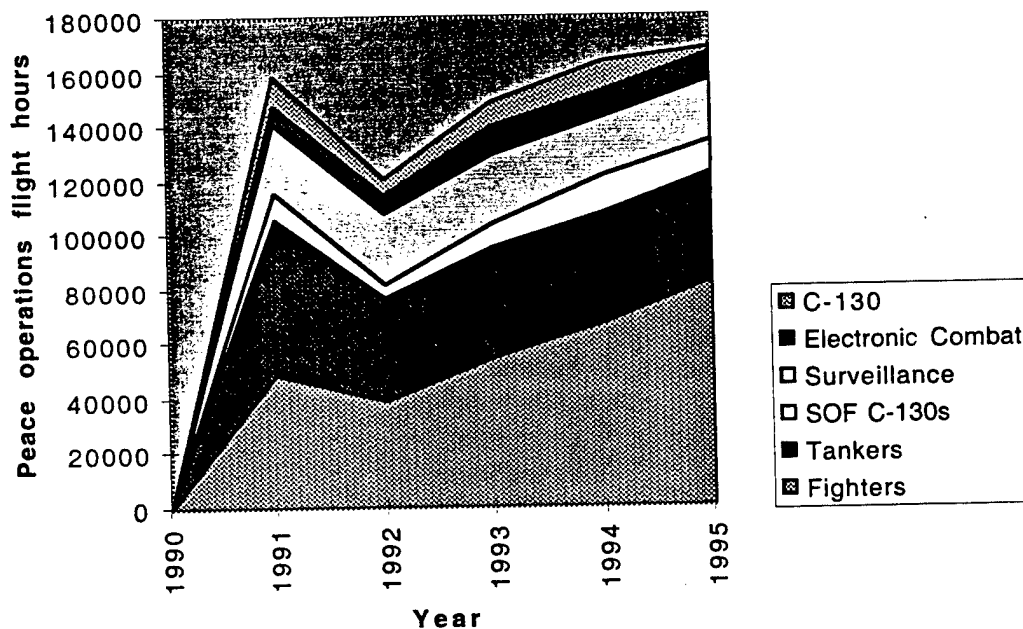


Figure 3.1. USAF Peace Operation Flight Hours per Year 1990-1995

<sup>1</sup>Much of this section is adapted from: Alan Vick, David T. Orletsky, Abram N. Shulsky and John Stillion, Preparing the USAF for Military Operations Other Than War, MR-842-AF, RAND, Santa Monica, CA, 1997, Chapter Three. In addition, this document presents a complete discussion of past USAF Military Operations Other Than War (MOOTW) involvement, and an expanded analysis of the extent of current USAF peace operations commitments.

### Training Value of Peace Operations Sorties

Over 50 percent of the sorties and hours flown in support of peace operations are flown by fighter or attack aircraft. For these crews there is a tremendous difference between the sort of skills they practice on peace operations missions and the combat skills (low level navigation and weapons delivery, air-to-air combat, missile breaks, etc.) they practice on almost all peacetime training sorties.

Figure 3.2 rank orders the tasks required to successfully accomplish various combat missions from the easiest to the most difficult. The tasks listed are not all-inclusive and some experienced practitioners of the tactical aircrew's art would probably rank some of the tasks in a slightly different order. However, in general the list depicts the easiest, safest and most routine tasks near the bottom and the most difficult, dangerous and demanding tasks toward the top.<sup>2</sup> What is most striking is that virtually all of the MTW combat related tasks are toward the top of the list and none of them are part of the typical fighter peace operations sortie.

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<sup>2</sup> This ranking of tasks is also consistent with the findings of studies by Tactical Air Command and the Institute for Defense Analysis of USAF and Navy tactical aircrew conducted in the late 1980s to investigate the optimal level of training in various skills. A discussion of these studies is presented in the next section.

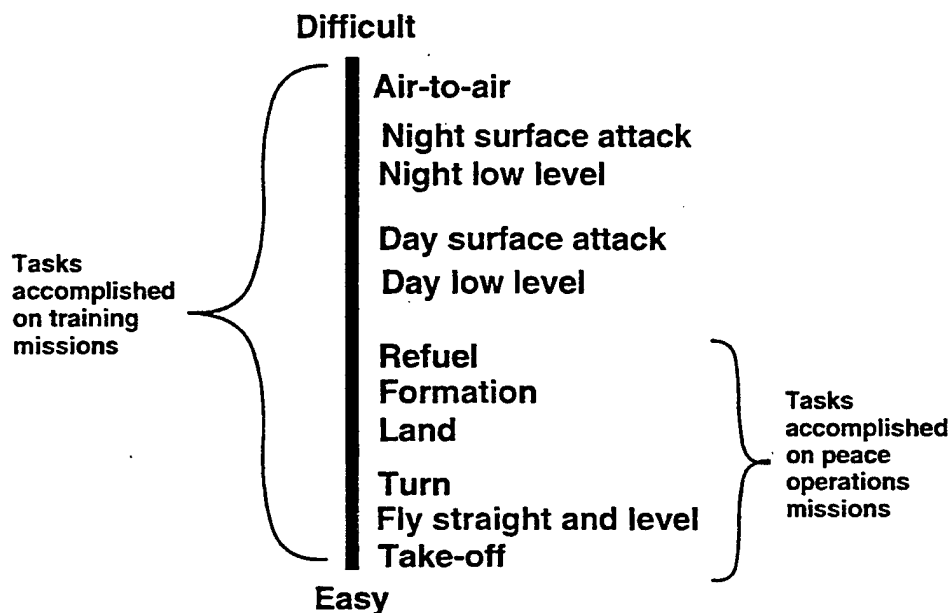


**Figure 3.2--Fighter Crew Training Opportunities During Peace Operations**

In sharp contrast to typical peacetime training sorties where crews practice low level navigation, weapons delivery and/or air-to-air combat skills, peace operations missions usually offer the opportunity to practice only the most routine tasks. Calling skills like formation flying and landing routine does not mean they are unimportant, or that there is not a certain level of danger or difficulty associated with them. Crews must take-off, land and often refuel and fly in formation to successfully accomplish many combat missions. They must also acquire targets, employ electronic countermeasures to reach them and return home, outmaneuver missiles, engage in air-to-air combat, aim and guide their weapons to impact, while simultaneously maintaining their situational awareness and avoiding collisions with other aircraft or the ground. Peace operations sorties provide fighter crews with virtually no opportunity to maintain their proficiency in many of their most important and perishable combat skills. This is primarily because of the nature of peace operations missions.

As Figure 3.2 illustrates, peace operations sorties for fighter crews consist almost entirely of relatively simple and routine tasks.

They take-off, fly in formation to an orbit point, loiter for a specified time, perhaps rendezvous with a tanker and then return to base. They may get to practice some combat skills, such as coordinating air-to-air radar searches, or medium altitude precision guided munition target acquisition but engaging in the same constant activity day after day with no adversary reaction quickly becomes so mind numbing that crews resort to asking each other movie trivia questions to pass the time while on station.<sup>3</sup>

There is mounting evidence of concern on the part of USAF leadership that peace operations deployments have negatively impacted fighter crew MTW combat skills exactly as described here. The following quotes illustrate these concerns:

At the Air Force Fighter Weapons School, officials reported a drop in proficiency of incoming students. They could fly medium-altitude tactics, skills used in no-fly zone operations, but were less proficient in low-level tactics needed for high-intensity conflict.<sup>4</sup>

In 1995, the bust rate for BFM (Basic Fighter Maneuvers) sorties at the (Fighter) Weapons School was 21 percent. In 1996, the rate almost doubled, to 37 percent. The principal reason, said instructors, is simple: Many pilots have spent long tours flying dozens of sorties over Bosnia-Herzegovina or Iraq in support of Air Force contingency operations. These patrol flights, while important to the execution of US global strategy, actually provide poor training.<sup>5</sup>

But training is constantly interrupted by long overseas deployments, most commonly to Saudi Arabia, home base for squadrons that patrol the no-fly zones in northern and southern Iraq. On these three-month deployments no training in air-to-air combat takes place. 'All you're doing is making left-hand turns all day' said Lt. Col. Ted Kresge, who commands the 27th Fighter Squadron. Pilots deride this duty as 'boring holes in the sky' or 'turning jet fuel into noise.'<sup>6</sup>

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<sup>3</sup>Interviews with F-15E crewmembers who took part in numerous sorties in support of Operation Provide Comfort and Operation Deny Flight indicate this was a widespread, and popular, way to pass the time while on station over Northern Iraq or Bosnia.

<sup>4</sup> "Stretched to the 'breaking point,'" *Air Force Times*, April 21, 1997, p. 3-4.

<sup>5</sup> "Readiness at the Edge," *Air Force Magazine*, June 1997, p. 58.

<sup>6</sup> "Air Force battles pilot burnout, steep dive in numbers", *The San Diego Union-Tribune*, Saturday, June 7, 1997, p. A-21.

It is the advanced combat skills that suffer as a result of these deployments, and it takes a significant but essential training effort to regain them...<sup>7</sup>

The logical arguments and expert opinion presented above make it clear that there is reason to believe fighter crews who spend large fractions of their flight time engaged in peace operations are less proficient at many MTW combat tasks than those who do not. But how much less proficient are they? Is there a way to quantify how much their combat skills are degraded and if so, to estimate how long it takes to regain them?

#### PSYCHOLOGICAL STUDIES OF EXPERT SKILL ACQUISITION AND TASK PERFORMANCE<sup>8</sup>

Before addressing the specific questions posed above it is appropriate to examine more general evidence of how deliberate, focused practice affects human skill acquisition, task performance and long-term working memory. Modern psychological investigations of the relationship between task performance (skill) and experience can be traced to de Groot's studies of the role of talent, or individual invariant characteristics unaffected by training, and practice in the performance of chess players.<sup>9</sup>

In work published in 1946, de Groot concluded that chess experts' knowledge and chess-specific reactions were acquired through extensive experience playing chess over a number of years rather than the result of some superior innate ability. At the time de Groot conducted his research many psychologists believed that superior ability in chess, and many other fields of human expertise, was the result of experts'

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<sup>7</sup> Col. William D Carpenter, Vice Commander, 1st Fighter Wing quoted in "Readiness at the Edge," *Air Force Magazine*, June 1997, p. 61

<sup>8</sup> This section relies heavily on material reviewed in K. Anders. Ericsson and A. C. Lehmann, "Expert and Exceptional Performance: Evidence of Maximal Adaptation to Task Constraints", in Annual Review of Psychology, ed. J. T. Spence et al, 47: pp. 273-305, Annual Reviews Inc., Palo Alto CA, 1996.

<sup>9</sup> See A. D. de Groot, Thought and Choice and Chess, The Hague, Netherlands, Mouton Press, 1946/1978.

superior intellectual capacity for extensive and exhaustive search for superior chess moves. However, de Groot found that expert chess players routinely accessed the best chess moves when they were initially presented with a chess position rather than after an extensive search of all possible moves. This finding indicates that much human expert performance is the result of pattern-based retrieval of superior alternatives from memory. His findings were confirmed and extended by Chase and Simon in a classic 1973 article where they showed that pattern-based retrieval accounts for superior performance in selecting chess moves and proposed that expertise in many other fields - ranging from music to football - was the result of vast amounts of knowledge and the ability to perform pattern-based retrieval attained through many years of experience in an area of specialization.<sup>10</sup> Chase and Simon's hypothesis was confirmed in subsequent research comparing novice and expert performance in analyzing problems in physics<sup>11</sup> and political science<sup>12</sup>, medical diagnosis and other fields. Chase and Simon's theory of knowledge based expertise is consistent with prevailing theories of skill acquisition in which knowledge is acquired through experience and then organized into responses (or sets of responses) that become automatic actions with sufficient practice.<sup>13</sup>

Practice is the key to attaining high levels of skill in almost any field of human endeavor. Research has shown that simply exposing people to a task environment for extended periods of time does not significantly increase task performance.<sup>14</sup> Exposure to a task should

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<sup>10</sup> W.G. Chase and H.A. Simon, "The Minds Eye in Chess", in Visual Information Processing, ed. W.G. Chase, pp. 215-281, Academic Press, New York, 1973.

<sup>11</sup> See M.T.H. Chi, R. Glaser and M. Rees E. 1982, "Expertise in Problem Solving", in Advances in the Psychology of Human Intelligence, ed. R. S. Sternberg, pp 1-75. Erlbaum, Hillsdale, NJ, 1982.

<sup>12</sup> See J. F. Voss, T. R. Greene, T. A. Post, B.C. Penner, "Problem-Solving Skill in the Social Sciences", in The Psychology of Learning and Motivation: Advances in Research and Theory, ed, G. H. Bower, 17:165-213, Academic Press, New York, 1983.

<sup>13</sup> See R.W. Proctor and A. Dutta Skill Acquisition and Human Performance, Sage, Thousand Oaks, CA, 1995 for a review of laboratory studies of skill acquisition.

<sup>14</sup> General experience in a particular domain is only weakly related to task performance for skills ranging from auditing to chess to

not be confused with the amount of time spent on focused activities specifically designed to improve task performance. Psychologists refer to such focused activities as "deliberate practice." There is considerable evidence that the amount of time people spend on deliberate practice is closely related to their level of expertise in a given task or set of tasks. The amount of time spent in deliberate practice activities has been shown to directly effect the level of performance attained by expert musicians, athletes and chess players.<sup>15</sup>

The reason for the weak link between measures of general exposure to a task and skill level is that most activities we encounter in our daily lives - in our jobs, in sports competitions, playing games, etc. - are not structured to allow for the detailed feedback and focused examination of performance necessary for effective learning and skill improvement to take place. In contrast, deliberate practice activities are specifically designed by coaches, managers, instructors, etc. to evaluate and improve particular individual skills through repetition, feedback and refinement.<sup>16</sup> Ericcson and Lehmann observe the following:

In many domains, knowledge of effective training procedures has accumulated over a long time, and qualified - often professional - teachers draw on this knowledge to design deliberate practice regimens for individual students.<sup>17</sup>

Fighter crew combat skill development is clearly one of these domains. During the course of the Cold War USAF fighter crews developed increasingly refined routines for the systematic planning, execution and meticulous critique of all training sorties. By the late 1980s these

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baseball to computer operation. See C.A. Ashworth, "Skill as the Fit Between Performer Resources and Task Demands" in Proceedings of the 14<sup>th</sup> Annual Cognitive Science Meeting, pp 444-449 Erlbaum, Hillsdale, NJ, 1992 for a review of this literature.

<sup>15</sup> See K. Anders. Ericsson, Ralf. Th. Krampe, Clemens. Tesch-Romer, "The Role of Deliberate Practice in the Acquisition of Expert Performance, *Psychological Review*, 100(3): pp 363-406 for a review.

<sup>16</sup> See K. Anders. Ericsson and A. C. Lehmann, "Expert and Exceptional Performance: Evidence of Maximal Adaptation to Task Constraints", in Annual Review of Psychology, ed. J. T. Spence et al, 47: pp. 278-279, Annual Reviews Inc., Palo Alto CA, 1996.

<sup>17</sup> Ibid.

activities routinely involved the examination of film, audio and video tape as well as detailed reconstruction - on whiteboards or with model aircraft - of particularly eventful or instructive phases of flight such as ground target attacks or simulated air to air combat engagements. The post-mission critiques (debriefs) were so detailed they routinely equaled or exceeded the duration of the training mission. In contrast, most peace operations sorties flown since 1991 have afforded USAF fighter crews little or no opportunity to deliberately practice their most important combat skills. One way to interpret the comments made by USAF commanders and Fighter Weapons School instructors presented in the preceding section is that they are describing a situation where USAF fighter pilots have moved from spending almost all of their time on deliberate practice activities to one where they spend considerable amounts of their flight time engaged in general exposure activities that psychological studies have shown contribute very little to skill proficiency.

A final important point on the relationship between practice and performance is that consistency is important. Research has shown that intense deliberate practice causes physiological and neurological changes in the human body and brain. Physical changes such as increased heart size and increased muscle volume in response to exercise are familiar, but recent studies have shown that near-sightedness is increasingly common in developed countries because activities such as reading, working with computers and watching television require sustained focus on nearby objects that causes adaptive changes in the shape of the human eye.<sup>18</sup> Much of human learning consists of the development and maintenance of extensive knowledge structures. Deliberate, focused practice activities forge the connections between facts and experience that forms the foundation for knowledge structures. Additional deliberate practice fleshes out the structure as more knowledge is added and more connections are formed. These webs of connection that constitute knowledge are accompanied by neurological changes in the brain that are analogous to the physiological changes

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<sup>18</sup> J. Wallman, "Nature and Nurture of Myopia", Nature, 371:201-202.

that result from repeated exercise.<sup>19</sup> Other studies have shown that once intense deliberate practice stops skill levels begin to decline.<sup>20</sup> This research has obvious implications for hypotheses about the impact of peace operations on the combat skill performance of USAF fighter crews. However, before presenting these hypotheses in Chapter 4, the following section examines previous studies of the aircrew practice-performance relationship.

#### **PREVIOUS STUDIES OF THE AIRCREW PRACTICE-PERFORMANCE RELATIONSHIP**

During the Cold War there were relatively few studies of the relationship between flying experience, recent practice and aircrew combat skills. Those studies were designed to address questions like: "How many hours should tactical pilots fly per month or per year?" While the questions and policy issues involved were somewhat different, the results of prior studies in this area can shed some light on how we can expect peace operations to impact MTW combat skills.

A 1989 study by Hammon and Horowitz at the Institute for Defense Analysis investigated the relationship between flying hours (both career total and "recent practice") and performance of some air combat skills. It found a statistically significant relationship between monthly flight hours and both bombing accuracy and simulated air-to-air combat victories. Statistical analysis of over 1200 Navy and Marine Corps fighter sorties indicates that a 10 percent reduction in total flight time leads to a 2 percent increase in bomb miss distance for ground attack crews and a 5 percent reduction in air-to-air combat victories for fighter crews.<sup>21</sup>

This study clearly shows that we can expect some degradation in the combat skill proficiency of fighter crews engaged in peace operations, with air-to-air skills more sensitive to declines in recent practice

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<sup>19</sup> See James J. Gallagher, "Teaching and Learning: New Models", in Annual Review of Psychology, ed. J. T. Spence et al, 45: pp. 171-195, Annual Reviews Inc., Palo Alto CA, 1994 for a review.

<sup>20</sup> See K. Anders. Ericsson, Ralf. Th. Krampe, Clemens. Tesch-Romer, "The Role of Deliberate Practice in the Acquisition of Expert Performance, *Psychological Review*, 100(3): pp 363-406

than air-to-ground skills. However, there are serious aspects of the current peace operations situation it was not designed to address. Hammon's and Horowitz's data only allowed them to assess the impact of relatively small changes (on the order of 5 to 10 percent) in monthly flight training hours on aircrew performance - not the impact of reducing training in certain skill areas to zero as our current peace operations Concepts of Operation (CONOPS) require. During the late 1980s when the study was conducted, flight hours were a good proxy measure for actual training accomplished because, for virtually all US military aircrews, the vast majority of time spent in the air was high quality training time. So the variation in training time from month to month for individuals and units was relatively small. With the rise of peace operations during the post-Cold War era this is no longer the case, so more specific input measures of combat related tasks performed on a mission, rather than simply its duration, are now required.

Another study of the relationship between training and tactical aircrew combat proficiency conducted in the late 1980s used somewhat different methods. In his Continuation Training Flying Hours Requirements Study Osborn related data on the number and frequency of training events accomplished by F-15 and F-16 fighter pilots to the same pilots' subjective judgements about their own performance.<sup>22</sup> He estimated "learning" and "forgetting" parameters for a variety of tasks ranging from formation take-offs to various bomb deliveries to air-to-air combat for both experienced and inexperienced pilots.<sup>23</sup>

Osborn's approach is interesting, and for many relatively routine tasks like takeoffs and landings he is able to accurately estimate how many times per month a pilot must practice a task to maintain a given level of proficiency. Task proficiency was rated on a five point scale as follows:

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<sup>21</sup>See Colin P. Hammon and Stanley A Horowitz, Flying Hours and Aircrew Performance, Working Paper, Institute for Defense Analyses, Washington D.C. June 1989.

<sup>22</sup> James H. Osborn, Continuation Training Flying Hours Requirements Study, Project No. 92-01-03a, HQ TAC/DO, Langley AFB, VA, 1 May, 1992.

<sup>23</sup> Osborn used the standard Air Combat Command (TAC at the time) definition of experience. Pilots with less than 500 fighter hours were considered inexperienced, those with more than 500 hours were considered experienced.

- ONE - NOT PROGRESSING indicates a need for additional instruction in basic concepts.
- TWO - PROGRESSING - indicates additional supervised practice is needed.
- THREE - NEARLY PROFICIENT - indicates additional practice is needed, with no special supervision required.
- FOUR - PROFICIENT - indicates additional practice needed only to maintain proficiency.
- FIVE - HIGHLY PROFICIENT - indicates task performance exceeds standards in all respects.

The 11 tasks rated by F-15 pilots included tasks such as formation takeoff, 4-ship fighter sweep, tactical formation intercept tactics and simulated threat reactions. F-16 pilots also rated themselves on 11 tasks, but because the F-16 is a multi-role fighter capable of both air-to-air and air-to-ground missions while the F-15 is a dedicated air-to-air fighter the tasks differed considerably with F-16 crews evaluating themselves on tasks like low angle low and high drag bomb deliveries, and ground strafing. Interestingly, F-16 pilots rated themselves on landing while F-15 pilots did not. Osborn was able to successfully estimate skill learning and decline rates for many of these skills based on data collected from two fighter squadrons in early 1989.

However, for many of the tasks his sample sizes were extremely small, especially for inexperienced pilots. For many of the categories of tasks under study he had 20 or fewer observations. This lack of data may help explain the relatively large standard errors associated with most of his coefficients for inexperienced F-16 pilots. Osborn's estimates of inexperienced F-16 pilot performance were statistically significant for only 3 of 11 events - tactical formation, chaff and landing. He was unable to estimate the effect of practice, or lack of it, on what many would consider more important combat tasks such as day intercepts, low-altitude low- and high-drag bomb deliveries, strafe, and mutual support.

In addition, the study's reliance on pilot self-reports of performance as a measure for the dependent variable - proficiency - has

some practical disadvantages. Such subjective self evaluations are clearly subject to bias, inconsistency, and because they are ordinal rather than cardinal measures of task performance, they are difficult to interpret in concrete terms. For example, judging the practical value of increasing a F-16 pilot's low altitude bomb delivery skills from "proficient" to "highly proficient" is difficult. As with any dependent variable we are better off with a continuous measure of performance such as bomb miss distance which is both objectively measurable and far easier to interpret in terms of practical effect. Knowing a pilot can, on average, put a bomb within 100 meters of a target verses 20 meters allows us to determine whether, again on average, an accuracy improvement of this magnitude would change the likelihood of successfully neutralizing a particular target with a particular weapon. This is far more than we can tell from the subjective criteria defined by Osborn.

In order to assess the true impact of peace operations on aircrew combat skills we need better measures of both inputs and outcomes than those used in either the Hammon and Horowitz or Osborn studies. What we would like to measure is the number and type of training events accomplished over a given time period by USAF aircrew, and then objectively measure proficiency at the important combat tasks mentioned above, or clearly related proxy measures, to determine the true relationships between training, experience and task proficiency. This is exactly the approach adopted in the next several chapters.

#### **4. MODEL SPECIFICATION, SKILLS OF INTEREST AND HYPOTHESES**

##### **PRELIMINARY IDEAS ON MODEL SPECIFICATION**

In order to improve on the studies described above, and to address the relevant policy questions it will be necessary and desirable to estimate parameters for at least two separate components contributing to fighter crew skill proficiency. One component will be related to lifetime experience in the task (or similar tasks) of interest, and the other to recent practice.

A preliminary review of much of the literature on the relationship between practice, experience and skill proficiency reveals several competing schools of thought on what is the best functional form for capturing the effect of experience on task proficiency. In general, the literature on skill acquisition curves agrees that skill acquisition follows a pattern in which there is decreasing improvement per trial as the number of trials, or practice, increase(s). Or, in other words there are decreasing marginal returns to training. Learning curves with this characteristic are referred to as "negatively accelerating" curves. As mentioned above, this characteristic - more learning from early versus late trials - naturally leads to larger variance in performance of arbitrarily defined inexperienced versus experienced groups and helps explain some of the difficulty Osborn had in achieving significant results for inexperienced crews.

##### **Functional Forms**

There are a wide variety of mathematical forms that would yield negatively accelerating learning curves. However, four forms have received discussion in learning literature. They are the power law, the exponential, the hyperbolic, and the Log(N) form. In 1981 Newell and Rosenbloom conducted a study to compare the relative explanatory power of the power law, exponential, and hyperbolic functions. All of these functional forms exhibit negative acceleration, and do a creditable job explaining increasing task proficiency as a function of increased trials or experience with typical R-squared values between 0.80 and 0.98.

In their analysis of data from dozens of previous studies, Newell and Rosenbloom found the power law clearly superior to either the exponential or hyperbolic (a special case of the power law) in explaining learning over both short and long time periods for a variety of cognitive, motor, and industrial tasks. They concluded the generalized power law fit most learning data so well there is little additional variation remaining for alternative shapes to explain, and that the power law is equally applicable to cognitive and perceptual-motor skill learning.

However, in 1986 Lane compared the performance of the power law, exponential, hyperbolic, and a function he refers to as the "Log(N)" function. He found that for a wide variety of tasks ranging from fencing lunges to keystroke speed to reading time to simulator bomb deliveries and carrier landings the Log(N) functional form provided a better fit than any of the three competing forms - *including the power law* - in 8 of 15 data sets, making it by far the most robust functional form. This functional form relates performance in original units to a percentage increase in practice.<sup>1</sup>

A concrete example may help illustrate how this functional form works. Suppose a study of dart throwing accuracy found that for every 10 percent increase in the total number of dart tosses a person has made darts stick 1 inch closer to the bullseye. An "inexperienced" person who has made 100 throws can improve accuracy by 1 inch by making an additional 10 practice throws. An "experienced" person who has made 1000 throws will on average place darts much closer to the bullseye, and therefore must work harder to achieve the same absolute improvement - making an additional 100 practice throws to increase accuracy by 1 inch.

Lane notes that most of the psychological community believes the underlying assumptions of the power law are easily explained by existing theories of learning. However, he goes on to say: "From a pragmatic viewpoint, the processes involved in generation of a learning curve may matter less than the fidelity with which changes in performance can be

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<sup>1</sup> Norman E Lane, Skill Acquisition Curves and Military Training, IDA Paper P-1945, Institute for Defense Analysis, Alexandria, VA, January 1986, p. 45-52

represented."<sup>2</sup> With this point in mind, a wide variety of functional forms were evaluated against the available data and used to draw conclusions about the impact of extended deployments with limited training opportunities on fighter crew combat skills. Both the functional forms evaluated and the data used to evaluate them are described in Chapters Five and Six.

#### **SKILLS OF INTEREST**

As briefly mentioned earlier, fighter crews engaged in peace operations do have the opportunity to practice some valuable combat skills. Of particular interest are skills related to the most salient images of Operation Desert Storm - medium altitude precision guided munition (PGM) delivery skills. F-15Es and many F-16s are equipped with imaging infrared targeting systems that allow these aircraft to acquire and precisely attack targets from low or medium altitude at night. Peace operations missions provide ample opportunity for crews to practice medium altitude PGM deliveries like the ones coalition crews used to attack Iraqi targets for most of operation Desert Storm, but provide little or no opportunity to practice low-level PGM deliveries.

During the first three days of the 1991 conflict Coalition forces conducted a campaign to disrupt and destroy the Iraqi air defense system with particular emphasis on destroying Iraqi radar guided medium and high altitude surface to air missile (SAM) systems. Once these systems were largely eliminated Coalition aircraft could operate with relative impunity from a medium altitude "sanctuary" above the effective ceiling of Iraqi anti-aircraft guns. For the remaining 40 days of the 43 day conflict most Coalition aircraft operated within this sanctuary. Accurate bomb delivery from medium altitude, usually above 20,000 feet, required PGM systems and training that many USAF strike aircraft (E.G., F-16s and A-10s) and crews did not possess. As a result, aircraft such as the F-111F, F-15E and F-117 that could accurately guide weapons from medium altitude were responsible for destroying a disproportionate share of Iraqi targets. The USAF has responded to the unexpected demand for medium altitude PGM delivery by adding this capability to a large number of F-16s and increasing crew training in this area.

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<sup>2</sup> IBID, p. 54.

However, it is important to note that while this capability and the skills associated with it may be important in later phases of a MTW, and that peace operations provide ample opportunity to practice them, during the opening phases of an MTW a significant portion of USAF crews will almost certainly rely on low altitude PGM and even unguided bomb delivery skills since they will be obliged to adopt low-level ingress and egress tactics until enemy medium and high altitude air defenses are eliminated. This low-level attack phase could last considerably longer than three days should the USAF face a more capable or competent foe than the Iraqis proved to be in 1991.

#### **A Note on the Importance of Low Altitude Combat Skills**

Many people, both inside and outside the Air Force, would argue that the lesson of the 1991 Gulf War is that USAF aircrew will fight the next war using precision guided munitions delivered from a medium altitude sanctuary secure from enemy anti-aircraft artillery (AAA), surface to air missiles (SAMs) and fighters. As a result, the low altitude bomb delivery skills discussed in this chapter, and the navigation and terrain avoidance skills associated with them, are relics of outdated Cold War era tactics that are no longer necessary.

Evidence of this attitude includes a 1997 ACC directive that there is no longer any need for fighter crews to fly below 500 feet. It eliminated the 100 foot qualification program and allows only a few aircrew previously qualified to fly at 300 feet to maintain this qualification. The fact that the typical F-16 squadron equipped with LANTIRN pods qualifies all its mission ready pilots to drop and designate targets for laser guided bombs (LGBs) from medium altitude, but less than 20 percent (4 or 5 out of ~25 assigned crews) of the assigned combat mission ready crews are qualified to fly night low-level missions, and less than a third of these crews (only one or two per squadron) are qualified to drop and guide LGBs from low altitude also reflects this trend. Because of the demanding nature of these missions, maintaining these qualifications takes consistent practice that units perceive as detracting from their primary medium altitude mission. As a result, for example, the 388<sup>th</sup> Fighter Wing at Hill AFB is seeking permission from ACC to eliminate its remaining low-level combat qualifications.

However, contrary to the popular impression left by CNN coverage and aircrew experience during the last 40 days of the 43 day war, coalition aircrew (excluding F-117 crews) did not operate from medium altitude with impunity from the outset of Desert Storm. For the first several days of the war the vast majority of coalition strike aircraft - B-52s, F-15Es, F-111s, Tornados, A-6Es, F-16s, F/A-18s etc. - operated at low altitude to avoid exposure to the most lethal threat systems available to the Iraqi defenders early in the war: radar guided SAMs.<sup>3</sup>

Figure 4.1 below shows the cumulative total of coalition aircraft lost during Desert Storm and breaks the losses down by type of threat system responsible for the kill. It shows that during the first three days of the war Iraqi defenses downed 16 coalition aircraft, and that radar SAMs were responsible for seven of these 16 kills - more than any other type of enemy threat system (AAA, the next most lethal system accounted for five coalition aircraft in the first three days). This is especially remarkable when one considers that low altitude operations were specifically designed to decrease the warning time and target tracking capability of radar SAMs, but put coalition aircraft in the heart of the aimed AAA and IR SAM envelopes. Thus, crews were operating in an altitude regime where AAA and IR SAMs are at their peak effectiveness and radar SAMs at their trough. Had coalition aircrew in non-stealth platforms attempted to operate at medium altitude before the Iraqi radar SAM threat was attritted by coalition electronic combat (EC) assets losses would probably have been much greater.

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<sup>3</sup> See Cohen, Elliot A. Gulf War Air Power Survey (hereafter GWAPS) Vol. II, Government Printing Office, Washington DC, 1993, PP. 119-155 for a description of low-level operations by these, and other, platforms early in Desert Storm.

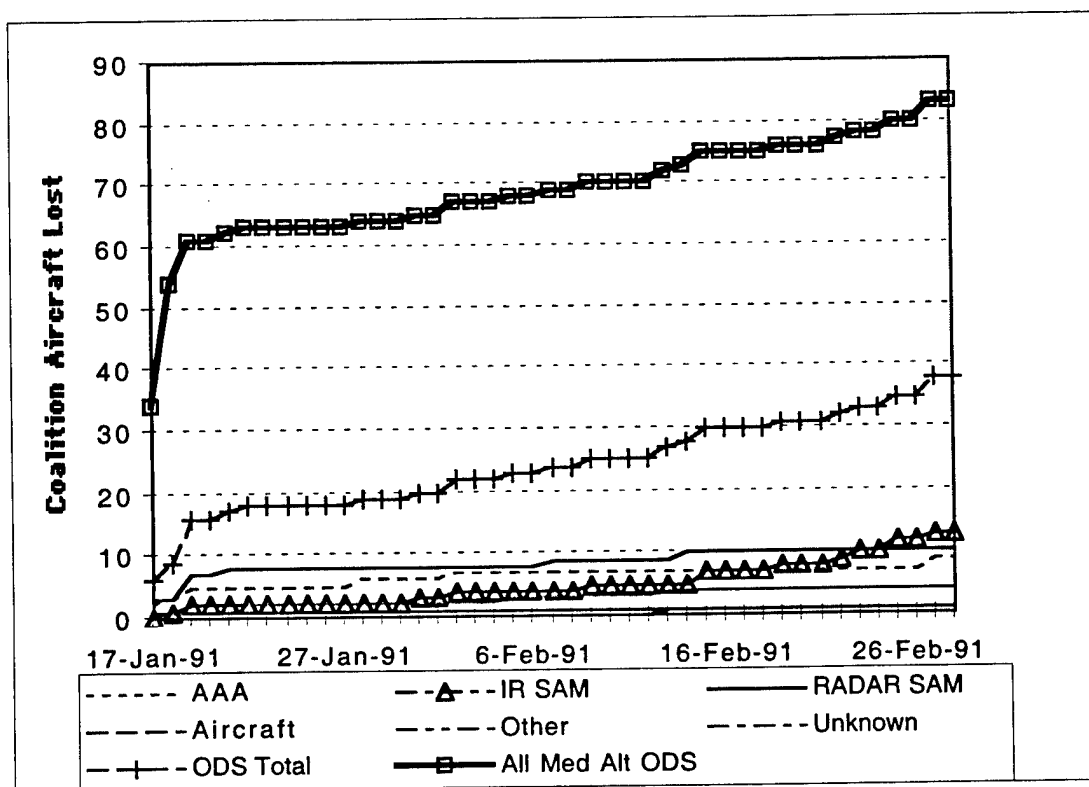


**Figure 4.1: Coalition aircraft lost to enemy action by day and threat type.**

However, two of the seven radar SAM kills were actually achieved against F-16 aircraft operating against Baghdad at medium altitude on day three of the war. One could therefore argue that against low altitude targets radar SAMs were not more lethal than AAA since both AAA and radar SAMs brought down 5 coalition aircraft operating at low altitude during the first three days of the war.

The two F-16s in question were part of "Package Q". This was the largest attack package of the war. It consisted of 72 F-16s supported by F-4G Wild Weasel defense suppression aircraft tasked to attack three important government headquarters in downtown Baghdad. Coalition planners hoped to use such large formations for continuing attacks against large, "symbols of the regime" since "(m)ost of these structures were so big that F-16s, even though less accurate (than PGM capable aircraft from medium altitude), could hit such targets with a fair

probability of success."<sup>4</sup> It was hoped that "the destruction of such headquarters would have major political and military effects."<sup>5</sup>

Bad weather over Saudi Arabia caused problems for some of the F-16s linking up with their tankers. As a result, four aircraft were forced to abort the mission. However, once reaching Iraqi airspace the weather cleared and the package proceeded more or less as planned despite intermittent and ineffective Iraqi anti-aircraft fire. The Iraqi defenders launched some unguided SAMs at the F-16s as they approached Baghdad, but were afraid to turn on their missile guidance radars as long as the F-4Gs, with their HARM anti-radar missiles were still on the prowl.

As the last eight-aircraft flights of F-16s approached their targets the F-4Gs were forced to leave the area because they were running low on fuel. Soon after the Weasels' radio announcement that they were leaving the Iraqi SAM operators turned on their radars and began launching guided SAMs into the F-16 formations. Many pilots were forced to jettison their bombs and external fuel tanks over populated areas to make "last ditch maneuvers" to avoid being hit by guided SAMs. At one point pilots counted 20 SAMs in the air, and one pilot was forced to dodge six. Two pilots were not so lucky. Their aircraft were hit by SAMs. Both ejected and survived the war.<sup>6</sup>

This is the only real example of an attempt by non-stealthy coalition aircraft to engage Iraqi targets from medium altitude in the face of more or less intact radar SAM defenses. It resulted in the loss of two of the 68 attacking aircraft, or about three percent of the attacking force. One could argue that this engagement is not typical of what could have been expected if the coalition had operated from medium altitude from the beginning of the war since the F-4Gs ran short of fuel and left early - allowing the Iraqi SAM operators to effectively engage the F-16s.

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<sup>4</sup> GWAPS Vol. II p. 176.

<sup>5</sup> IBID.

<sup>6</sup> See GWAPS Vol. II pp. 171-177 for an in depth description of Package Q.

However, the F-4Gs had to arrive in the target area some minutes before the F-16s in order to suppress the defenses.<sup>7</sup> This requirement for early arrival, combined with the relatively high fuel consumption of the F-4G made the early departure of the Weasels far from unusual. If the performance and composition of Package Q is typical of the sort of medium altitude packages coalition planners would have assembled to go against other Iraqi targets from the first night of the war if they had a "medium altitude only" mentality similar to the one prevailing in some analytic and USAF circles (and there is ample evidence that it is), then it is likely that Iraqi radar SAMs would have caused similar attrition throughout the entire attacking force on the first night of the war.

While it is true that Baghdad was the most heavily defended area of Iraq and that defenses in other areas at the outset of the war were not as dense as those in and around the capital, by day 3 the Baghdad defenses had suffered attrition from "...two large SEAD packages (that) had struck Baghdad's defenses in the first two days, while a number of conventional strike packages probed right up to the capital's suburbs."<sup>8</sup> So, it is not unreasonable to assume that Iraqi defenses outside of Baghdad on the first day of the war would have performed about as well as the partially attritted Baghdad defenses performed against medium altitude strike packages on Day Three.

What if coalition air planners had opted to attempt a "medium altitude only" Desert Storm air campaign? On the first day of the war the coalition flew 1053 offensive counter air (OCA) and interdiction sorties against heavily defended Iraqi targets with non-stealth aircraft. Had these sorties been flown at medium altitude, instead of at low level, the Package Q experience suggests that approximately 31 of

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<sup>7</sup> The F-4Gs used during Desert Storm have been retired and replaced by F-16s with a pod-mounted HARM Targeting System (HTS). This system is in some ways less capable than the APR-47 system carried by the F-4Gs. However, it does allow HTS equipped F-16s to determine the range and bearing to threat radars and target HARMs effectively. While no doubt cheaper to operate than the aging F-4Gs they replaced, the F-16 HTS aircraft obviously have no more range or endurance than the F-16s they will be supporting, so the requirement to arrive early to suppress defenses before the arrival of the strike package will continue to result in early departure of the defense suppression aircraft in many cases.

<sup>8</sup> GWAPS, Vol. II, p. 164.

these sorties would have fallen victim to Iraqi radar SAMs. This is over ten times the number of radar SAM losses suffered by the low-altitude attackers on day one of the actual Desert Storm. If we further assume that the Iraqi radar SAM effectiveness degrades rapidly from its full effectiveness on day one to essentially zero on day three (as it did during Desert Storm, outside of Baghdad), then we can expect about half the loss rate on day two of the notional "medium altitude Desert Storm" as we suffered on day one.

On day two of the war the coalition flew 875 non-stealth sorties. Flying the same number of sorties at medium altitude against a radar SAM defense half as effective as the one encountered over Baghdad on Day Three would have resulted in about 14 aircraft lost to radar SAMs. So, it seems that had coalition air planners conducted a medium altitude campaign from the beginning against Iraq during Desert Storm they would have lost on the order of 45 aircraft to radar SAMs during the first two days of the conflict. This compares very unfavorably with the three actually lost to radar SAMs at low level, and the total loss of 9 aircraft to enemy action through the end of Day Two. It is also nearly 20 percent more aircraft than the coalition lost to all types of enemy action throughout the entire 43 day Desert Storm campaign.

This analysis may be pushing the available information too far. However, even if the typical Iraqi radar SAM defense outside of Baghdad on the first day of the war was only half as effective as the partially attritted Baghdad defenses were on day three, the Coalition would have lost about 20 aircraft to radar SAMs in a all medium altitude war. So, it is clear that Coalition planners and aircrew were correct in conducting the vast majority of attacks during the opening days of Desert Storm from low altitude, just as they were almost certainly correct to shift to medium altitude operations after day three when the radar SAM threat had been largely eliminated.

The important point here is that the Desert Storm air campaign, like most offensive military operations, consisted of two distinct phases. In the first "engagement" phase the coalition forces used stealth aircraft, EC platforms, and low-level tactics to engage and destroy important Iraqi targets and their radar SAM defenses. Once the

defenses were attritted, the Coalition shifted to medium altitude operations for the "exploitation" phase of the operation.

Coalition aircraft and aircrews were probably over-optimized for the engagement phase of Desert Storm. Their aircraft were equipped to accurately deliver weapons from low altitude against point targets and the crews were superbly trained for low-level operations because they had been preparing to face the extraordinary Soviet/Warsaw Pact SAM defenses in central Europe during the final years of the Cold War. NATO air planners thought it was impossible for non-stealth aircraft to survive at medium altitude over Soviet controlled eastern Europe. As a result, the most numerous aircraft, F-16s and F/A-18s did not have the capability to deliver weapons accurately from medium altitude.

While the decision to move to medium altitude after Day Three of Desert Storm protected Coalition aircrew from the most lethal *remaining* defenses - AAA and IR SAMs - it had "a severe impact on the accuracy of the munitions other than precision-guided in attacking fixed positions or equipment. In effect, that decision robbed platforms such as the F-16 and the F/A-18 of much of their ability to attrit enemy ground forces..."<sup>9</sup>

The inability of many platforms to accurately hit point targets from the safety of medium altitude was frustrating for both planners and aircrew. However, Coalition leaders were determined to minimize losses even if it meant a longer and less efficient exploitation phase of the air campaign due to decreased bombing accuracy. After the war, the USAF worked promptly to add LGB capability to its F-16 force as a result of the frustration of having its most numerous combat aircraft producing "...less than stellar results against small point targets when aircrews released "dumb" bombs during dive deliveries."<sup>10</sup> This was certainly a wise thing to do in view of the USAF's medium altitude bombing experience during Desert Storm.

The need for more medium altitude precision guided munition delivery capability is not the only important lesson for the USAF to learn from the Desert Storm. Improved PGM capability undoubtedly improve the USAF's efficiency in exploiting a medium altitude sanctuary

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<sup>9</sup> GWAPS, Vol. II, p. 155.

<sup>10</sup> GWAPS, Vol. IV, p. 139.

in any future conflict. However, an equally important lesson is the value of being prepared for the more demanding and dangerous tasks of the engagement phase. If most of its non-stealthy combat aircrews (the bulk of the force until the Joint Strike Fighter (JSF) comes into operational service sometime in the second decade of the next century) are not proficient in low-level combat skills, the USAF leadership will have lost a valuable tactical option that could prevent significant aircrew and aircraft losses in the engagement phase of a future air campaign. USAF leaders may face a situation where they need to quickly deliver large quantities of munitions in order to halt a ground invasion, and must choose between taking losses to radar SAMs at medium altitude, or withholding the bulk of their forces from the conflict for days or weeks while a medium altitude sanctuary is created. Alternatively they could start a low-level training program to rapidly qualify crews for the demanding low-level flight and weapons delivery profiles they will need to fly to increase their survivability early in the conflict.

This would lead to many crews being rapidly trained, during wartime, for missions more demanding than those they were typically expected to perform during peacetime. This is just the reverse of the situation during Desert Storm where many USAF and Navy crews commented that the missions they flew were often less demanding and less dangerous than their peacetime training exercises. It was the extraordinarily high level of aircrew proficiency and training, combined with superior technology and strategy that lead to such impressive performance by US airpower in the 1991 Gulf War. The Gulf War Air Power Survey echoes this view in the conclusion of its evaluation of aircrew training. "The force that defeated Iraq was decades in the making and emphasized realistic, combat-oriented training from the beginning. ... The training or the personnel had indeed matched the quality of the weapons systems and tactics, and the combination of the three overwhelmed the enemy."<sup>11</sup>

Low-level operations are not the only way to address the radar SAM threat. Improved standoff weapons combined better Command, Control, Communications, Computers, and Intelligence (C4I) could help non-stealth

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<sup>11</sup> GWAPS, Vol. II, p. 358.

platforms attack important targets from medium altitude without exposing themselves to lethal radar SAMs. However, by placing less and less emphasis on the perishable skills needed to operate in the demanding low-level environment, the USAF may be depriving itself of an important hedge against standoff weapons or C4I systems that do not perform as advertised under combat conditions, improvements in adversary radar SAM technology and tactics, the development of radars or other sensors that can effectively detect and track stealth aircraft, or other unforeseeable developments that could dramatically increase the cost - in lives and aircraft lost - of future medium altitude air campaigns.

The argument here is that the USAF needs to maintain a robust capability to operate against a broad spectrum of possible threat scenarios during the engagement phase of an air campaign in order to ensure that it will be able to quickly and reliably create the conditions to efficiently exploit air supremacy. Maintaining the aircrew skills needed to take advantage of the low-level navigation and targeting capability built into the USAF's non-stealth weapons systems is an important part of ensuring the USAF maintains such a robust combat capability.

#### **Other Combat Skills of Interest**

In addition to examining the impact of prolonged lack of practice on low altitude combat skills, any consideration of the impact of peace operations deployments on the MTW combat skills of USAF fighter crews should also analyze what happens to other important fighter crew skills when USAF squadrons participate in peace operations. One important set of skills has already been mentioned in passing, the ability to accurately deliver PGMS from medium altitude, is a clear candidate for analysis. Another important set of MTW skills is air-to-air combat skills. Both of these skill sets are widely regarded as extremely important to the USAFs ability to carry out its mission in future MTW so I will not go into a lengthy justification of their continuing relevance except to say that most of the USAFs procurement over the next 10 years will be directed toward improving its air-to-air combat platforms through the purchase of F-22 dedicated air superiority fighters and increasing the number and variety of PGMS and aircraft capable of

delivering them. Therefore, the impact of peace operations deployments on fighter crew PGM delivery and air-to-air combat skills will also be examined.

## **HYPOTHESES**

In this section I will advance some hypotheses about how peace operations impact USAF fighter crews' ability to perform low level ground attack missions. In addition, I will advance some hypotheses about the impact of peace operations deployments on PGM delivery skills and air-to-air combat skills.

### **Low Level Bombing Skills**

Data from an F-15E squadron from the 4th Fighter Wing at Seymour-Johnson AFB North Carolina, and an F-16C squadron from the 388th Fighter Wing at Hill AFB Utah will be used to test these hypotheses. This analysis is presented in Chapter Five.

Based on the arguments, anecdotes and results of previous studies presented in Chapter Three I hypothesize that proxy measures of low altitude combat skill error (e.g. bomb miss distance) will be negatively associated with measures of experience (e.g. instructor status). Or, in other words, I expect more seasoned pilots to have smaller bomb miss distances, holding recent practice constant, than less experienced pilots.

Common sense and psychological research also suggests the more time that passes since a given event was last accomplished the greater the bomb miss distance, etc. will be on average. So, I further hypothesize a negative relationship will exist between the number of times a given type of low altitude bomb delivery is performed in a month and average bomb miss distance.

Another hypothesis that I will test is that "old pros" skills might degrade more slowly and/or return more quickly than less experienced "rookies". This particular hypothesis will be tested by comparing nested statistical models to determine whether the impact of practice is greater, less or the same for pros vs rookies.

### **Medium Altitude PGM Delivery Skills**

Data from an F-16C squadron from the 388th Fighter Wing at Hill AFB Utah will be used to test these hypotheses. This analysis is presented in Chapter Five.

As discussed above, medium altitude PGM delivery skills are viewed as increasingly important, and in some quarters as the primary, ground attack skills USAF fighter crews will use in a future conflict. My initial hypotheses for medium altitude PGM delivery skills are essentially the same as those for low altitude skills: That seasoned crews will perform better, on average, than less experienced crews, and that more frequent practice will result in a larger proportion of hits with guided weapons..

### **Air-to-air Combat Skills**

Data from an F-16C squadron from the 388th Fighter Wing at Hill AFB Utah will be used to test this hypothesis. This analysis is presented in Chapter Six.

Anecdotes, the Osborn, and Hammon and Horowitz studies all indicate that air-to-air combat skills are among the most perishable of fighter crew skills. Therefore, I hypothesize that the impact of recent practice (or lack of practice) on proxy measures of air-to-air combat performance will be larger relative to measures of experience than it is for air-to-ground combat skills. In other words, due to the extremely demanding nature of air-to-air combat, recent practice will be a more important predictor of air-to-air combat skill performance than experience.

## **5: F-15E AND F-16C BOMBING SKILLS**

### **LOW-ALTITUDE BOMBING SKILLS**

Because fighter crews participating in them often go for months at a time without practicing some of their important combat skills, peace operations deployments offer an opportunity to conduct a quantitative analysis of the impact of prolonged lack of practice on the low-altitude air-to-ground combat skills of USAF aircrew. While the data available on F-15E and F-16C crews does not allow an analysis of all important aspects of low-altitude combat skills such as mission planning, low-level navigation, threat reactions, tactical formation, mutual support, etc., it does allow for an analysis of the relationship between bombing accuracy and practice and experience variables. Bombing accuracy is not the only important aspect of low altitude air-to-ground combat, but it is the best documented and most accurately measured.<sup>1</sup> In addition, to the extent that it is positively correlated with the other aspects of the low-altitude combat art, the relationships revealed from an analysis of bombing accuracy and practice should shed some light on the relationship of these other skills and practice as well. Or, in other words, bombing accuracy will be used as an easily quantifiable proxy measure for the less easily measured tactical skills listed above.

#### **Types of Low Altitude Bomb Deliveries**

The two broad categories of low altitude bomb deliveries analyzed in the following sections are Low Angle Low Drag and High Drag (LALD/HD) and Loft deliveries. LALD/HD deliveries are performed by pilots of both F-15E and F-16C aircraft.<sup>2</sup> When performing a LALD/HD delivery pilots acquire and track a target visually. They align the target with the

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<sup>1</sup> See Appendix A for a discussion of air-to-ground and air-to-air combat skill measures and ways they could be improved.

<sup>2</sup> These aircraft types were analyzed because the F-15E force provides the bulk of the USAFs deep strike/interdiction capability while F-16Cs are the most numerous aircraft in the active fighter force.

illuminated "pipper" in their Heads-Up Display (HUD). They then attempt to stabilize the aircraft in wings level one-G flight and release the bomb(s). All of this takes place while the aircraft is diving toward the target at an angle of not more than 30 degrees. The aircraft then over-flies the target and leaves the area. After leaving the aircraft high drag bombs deploy large hinged fins that rapidly slow the bomb. This creates greater separation between the aircraft and the bomb, and when compared to low drag bombs (which do not have the hinged fins) allows the aircraft to attack from lower altitudes and still escape the fragmentation pattern of the bomb. The delivery techniques for low drag and high drag bombs are so similar they form a single category in USAF fighter squadron bombing competitions. They will be treated as a single category in this analysis. Figure 5.1 illustrates a typical LALD/HD delivery profile.

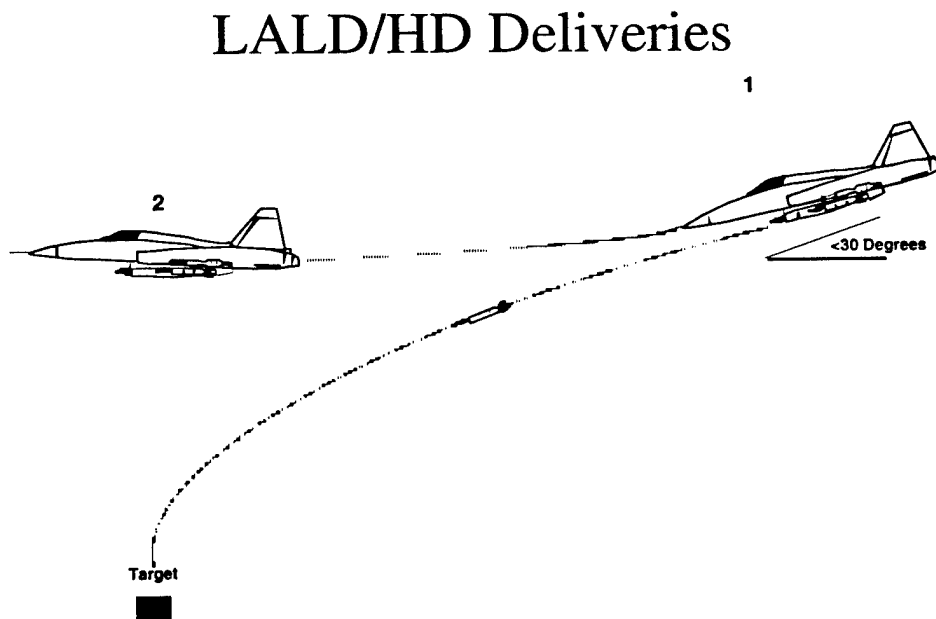


**Figure 5.1 -- LALD/HD Delivery Profile**

The second type of low altitude bomb delivery analyzed in the following sections is the loft delivery. All loft deliveries analyzed in this chapter were performed by F-15E Weapons System Officers (WSOs). A WSO is the second crew member in two seat fighters such as the F-15E

responsible for operating navigation, electronic countermeasures, and other sophisticated systems. During a loft delivery WSOs use the aircraft's radar and computer systems to aim bombs.

The loft is a low altitude climbing delivery that maximizes weapon range, and minimizes aircraft exposure to target area defenses. Loft deliveries are generally less accurate than LALD/HD deliveries. To perform a loft delivery the WSO identifies and tracks a target using the aircraft's ground mapping radar. At a pre-determined range from the target the pilot pulls the aircraft into a climb, usually less than 45 degrees nose high, and the aircraft computer targeting system release the bomb(s). Following bomb release, the pilot begins a tight descending turn designed to minimize aircraft exposure to target defenses. Unlike LALD/HD deliveries the aircraft does not over fly the target.

## Loft Deliveries

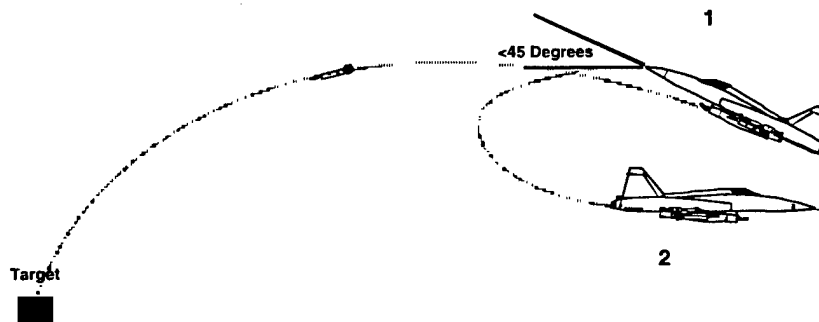


Figure 5.2 -- LOFT Delivery Profile

## F-15E LOW LEVEL BOMBING SKILLS

### The Variables

In order to conduct a quantitative analysis of the importance of practice, experience, and other relevant variables on aircrew combat skills I collected data on 55 F-15E aircrew - 30 pilots and 25 WSOs - assigned to the 4<sup>th</sup> Fighter Wing, 335<sup>th</sup> Fighter Squadron at Seymour-Johnson Air Force Base, North Carolina. I collected the following seven "demographic" variables on each crewmember:

- Aeronautical Rating - Dummy variable for aeronautical rating.  
The sample contains 30 pilots and 25 WSOs
- Experienced - Dummy variable for whether or not a crewmember is considered experienced by USAF standards. 73% of pilots and 76% of WSOs in the sample were experienced.
- Total USAF Flight Hours - Total flight hours in USAF aircraft.
  - Minimum: 125.4
  - Maximum: 3333.2
  - Mean: 1385.2
- Total Fighter Hours - Total flight hours in fighter aircraft.
  - Minimum: 125.4
  - Maximum: 2932.7
  - Mean: 1210.3
- F-15E Flight Hours - Total hours in F-15E aircraft.
  - Minimum: 125.4
  - Maximum: 2374.4
  - Mean: 537.4
- Deploy - Dummy variable for whether or not a particular crewmember deployed to Saudi Arabia in support of Operation Southern Watch from February through June 1997. ~47 % of both pilots and WSOs deployed.
- Instructor - Dummy variable for whether or not a particular crewmember was a qualified instructor in the F-15E. 30% of pilots and 39% of WSOs were instructors.

In addition, I collected the following six variables related to low-altitude bomb delivery practice and performance:

- Visual Low Drag/High Drag Bomb Deliveries - Number of visual low drag and high drag deliveries a particular crewmember performed by month for January through November 1997
- Visual Low Drag/High Drag Bomb Hits - Number of visual low drag and high drag bombs dropped by a particular crewmember judged hits by USAF hit criteria by month for January through November 1997
- Visual Low Drag/High Drag Bomb CEA - Average visual low drag and high drag delivery miss distance by crewmember by month for January through November 1997
- RADAR Loft Bomb Deliveries - Number radar loft deliveries a particular crewmember performed by month for January through November 1997
- RADAR Loft Bomb Hits - Number of radar loft bombs dropped by a particular crewmember judged hits by USAF hit criteria by month for January through November 1997
- RADAR Loft Bomb CEA - Average visual low drag and high drag delivery miss distance by crewmember by month for January through November 1997

#### **Data Overview**

Figure 5.3 below shows the average number of radar and visual bomb deliveries performed by all 55 aircrew in the sample by month (1 corresponds to January, 2 to February, etc.). In addition, it shows the average number of radar and visual bomb hits for the sample by month. The five months that stand out are February and March with almost no bomb deliveries and hits, and August through October with unusually high numbers of deliveries and hits - especially visual deliveries and hits. As explained above, the squadron providing this data deployed to Saudi Arabia from late February through late June 1997. When one takes into account the disruption of normal training due to preparations for the deployment in early February (allowing deploying aircrew and support personnel to take leave to tend to family matters prior to a long

separation, the need to configure and otherwise prepare the aircraft for the long deployment flight, etc.) and post deployment "spin-up" in Saudi Arabia (reconfigure/repair aircraft, familiarize aircrew with local procedures, etc.) the decrease in air-to-ground training in February, and to some extent March, is understandable. Overall the squadron seems to have accomplished somewhat reduced bombing practice during its deployment.

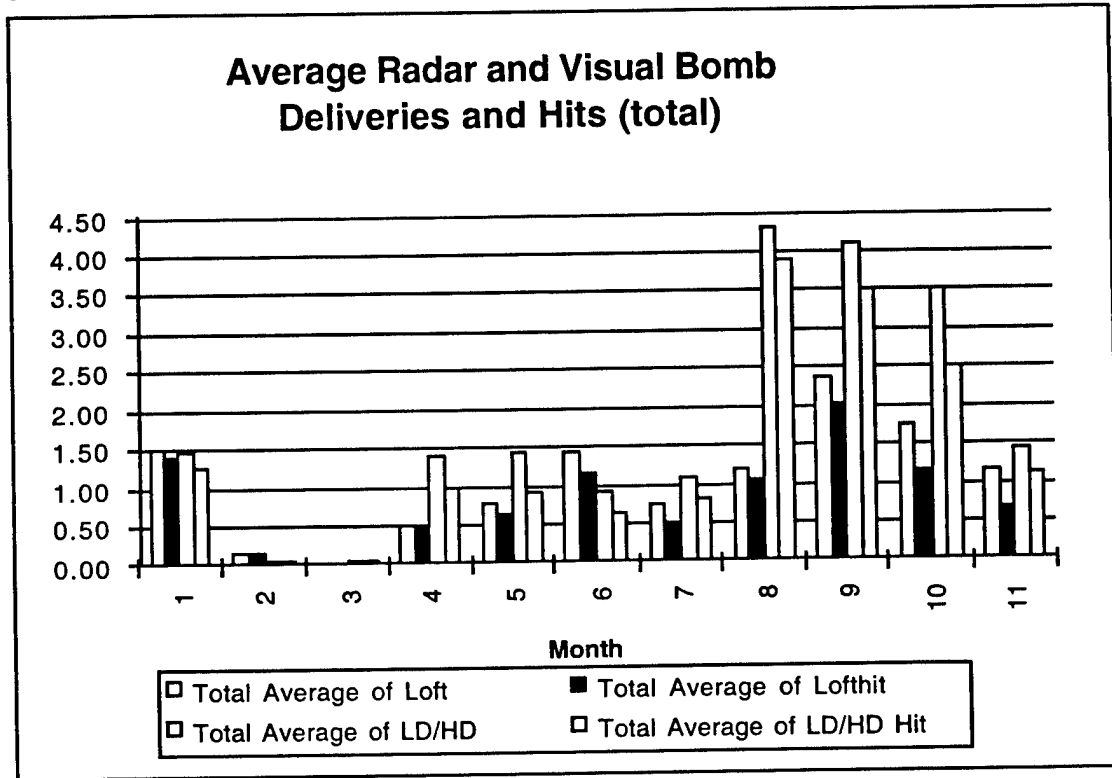


**Figure 5.3 -- F-15E bomb deliveries and hits: entire squadron**

However, this overall picture is deceiving. Again, recall from Table 5.1 that approximately half the aircrew assigned to the squadron did not deploy between February and June 1997. Figures 5.4 and 5.5 below make it clear that it was these non-deployed aircrew who recorded ALL of the practice low-level bomb deliveries for the squadron for the four months between March and July. In other words, none of the deployed aircrew accomplished a low altitude practice bomb delivery during the deployment.

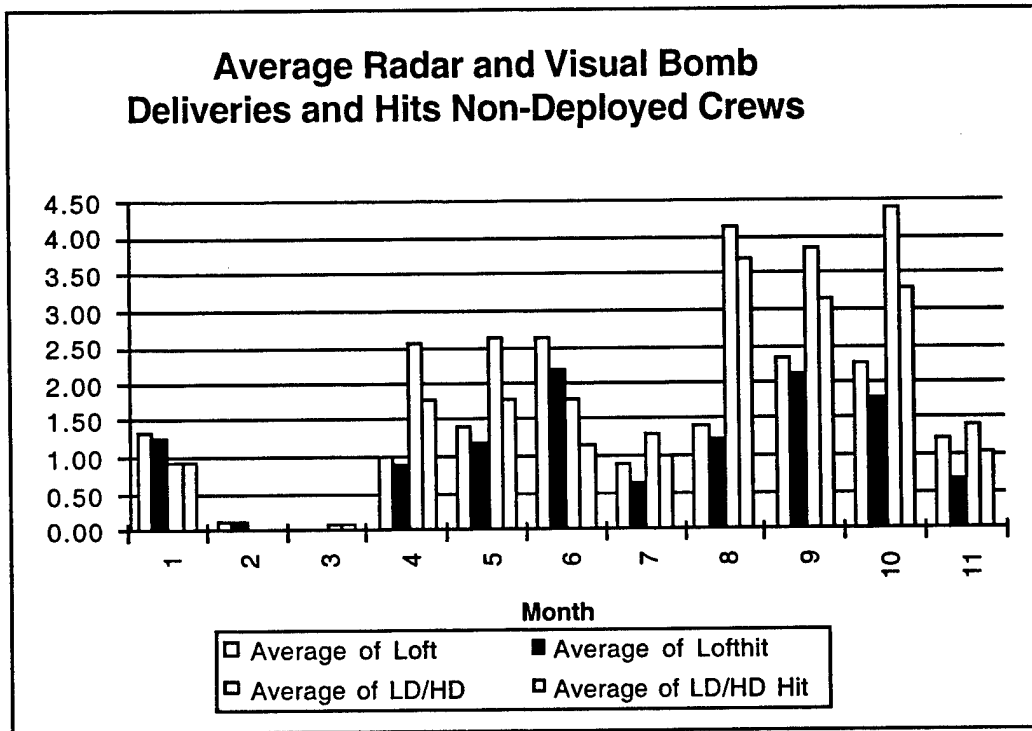


Figure 5.4 -- Average Radar and Visual Bomb Deliveries and Hits: Non-Deployed Crews

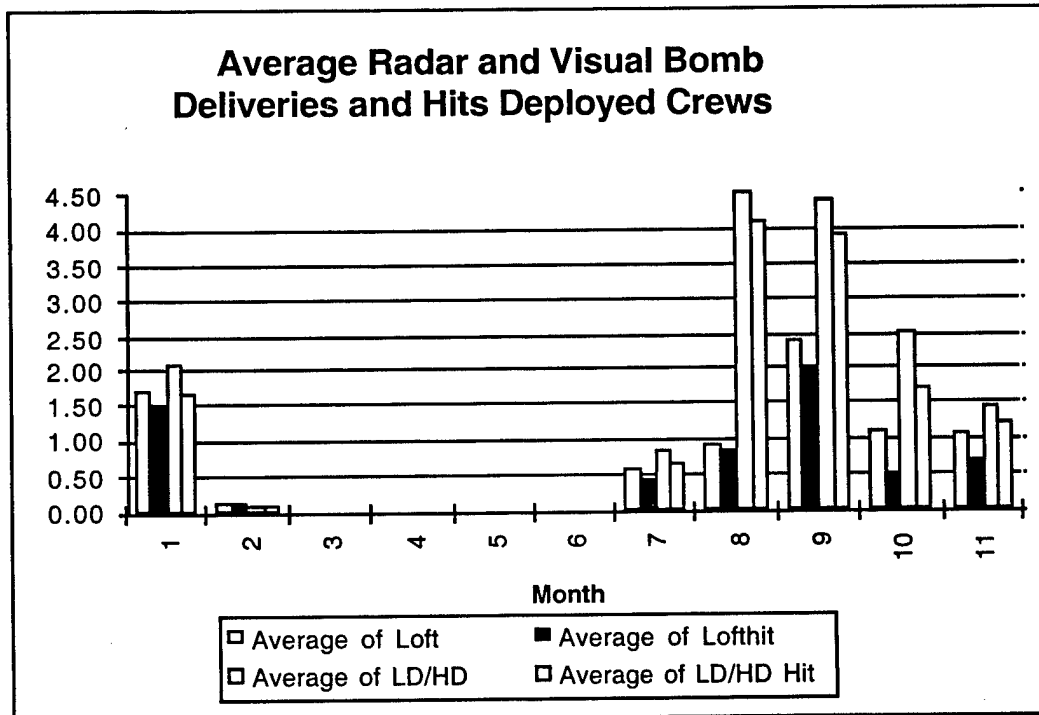


Figure 5.5: Average Radar and Visual Bomb Deliveries and Hits: Deployed Crews

## Statistical Analysis

In order to determine the best predictors for F-15E aircrew low-level bomb delivery performance extensive regression analysis was performed. A large number of possible model specifications and functional forms were investigated and compared to determine which of the available independent variables, or combinations and/or transformations of them, were the best predictors of visual and radar bomb miss distance.

The first regression model specifications tried were those suggested by the literature on learning theory discussed in Chapter Two. These specifications involved predicting bomb miss distance as a function of the log or a power transformation of an experience component, such as total or fighter hours, and the log or power transformation of a recent experience component such as the number of bombs dropped in the past 30 days.

These theory based model specifications produced coefficients with the expected signs. They predicted that as experience (measured by fighter hours) increased bomb miss distance (in terms of Circular Error Achieved or CEA) decreased for a given number of practice bombs dropped in a month. They also indicated that holding experience (fighter hours) constant, increasing the number of bombs dropped also decreased bomb miss distance. However, these specifications were not particularly good at predicting CEA even though they often had statistically significant coefficients. The best of these models achieved R-square values less than 0.10 for visual deliveries and less than 0.01 for radar deliveries.

For this particular data set a linear model controlling for instructor status and the number of practice deliveries in the past 30 days is a much better fit with an R-square value of 0.18. for visual deliveries performed by pilots about 0.03 for radar, or loft, bomb deliveries performed by WSOs.<sup>3</sup> These R-square values indicate the

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<sup>3</sup> The impact of number of bombs dropped 31 to 60 and 61 to 90 days prior on CEA was also investigated. Coefficients for these variables, either singly or in combination, were not significant in either the linear or non-linear model specifications.

linear specification fits the available data about twice as well as the theory based models for visual bomb deliveries and about seven times better for radar deliveries. This may result from the level of experience of the individuals involved. Recall from Chapter Two that learning theory postulates s-shaped learning curves as shown in figure 5.6 below. The figure illustrates how performance increases from some arbitrary minimum level to a maximum as a function of the number of times a person has accomplished the task in question, or trials.

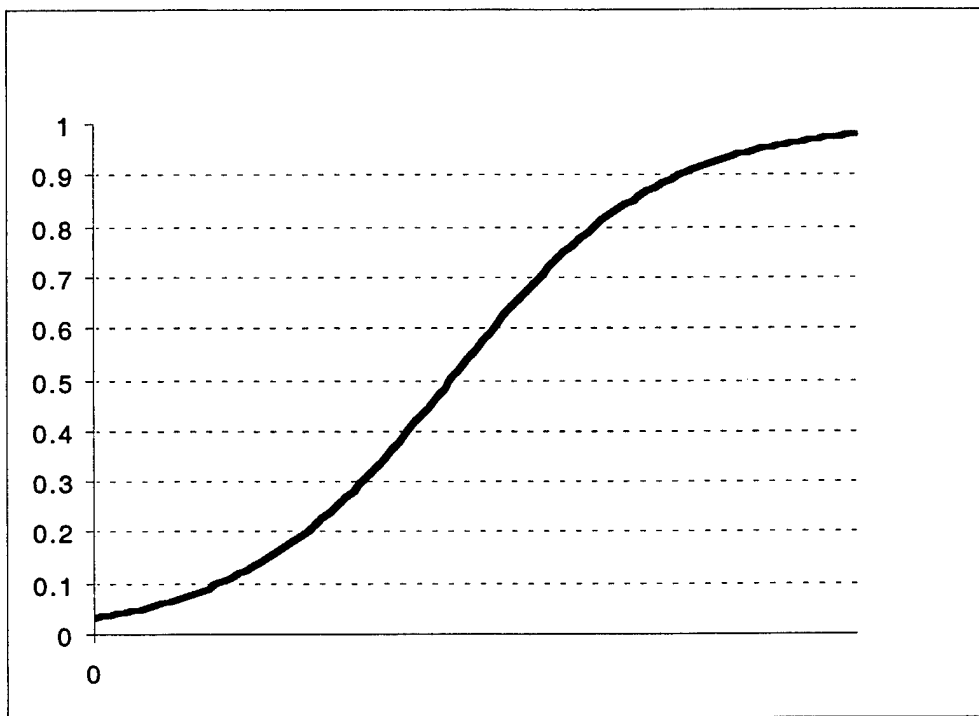


Figure 5.6 - Typical S-Shaped Learning Curve

Theory states that novices learn slowly with each trial. However, as their experience builds, they fairly quickly acquire enough experience so that the proficiency they gain from each successive trial increases, and then remains constant over a broad range of experience. Eventually, experience builds up to the point that there is little room for improvement due to physical or mental limitations on human performance, and the performance gain from additional trials again declines. The broad middle range of experience in the center part of

the s-curve is essentially linear. So, if all, or even the vast majority of the crews under study here are in this broad middle range of experience, then a linear model will fit the data better than an s-curve.

This is quite plausible since combat ready USAF squadrons do not have any true novice crews. Even the least experienced second lieutenants have considerable by the time they arrive at an operational squadron. Much of the experience they have was gained in the Replacement Training Unit (RTU) where they had their initial exposure to all types of tactical flying in the same type of aircraft they eventually fly when they report to an operational squadron - in this case the F-15E. So, there are probably no true novices among the crews under study here. For these crews it appears that the impact of practice within the past 30 days on the performance of all crews - from the least to the most experienced - is essentially the same.

This does not mean that experience does not matter, or that crews perform the same regardless of their experience level - far from it. Recall that the model under discussion here uses two components to predict average bomb miss distance or CEA - recent practice (represented by the number of practice bomb deliveries of a given type accomplished in the past 30 days) and instructor status.

#### Visual Bomb Deliveries

Instructor status is a proxy measure for three important factors that contribute to aircrew bombing performance. First, since instructors tend to be among the more experienced members of a squadron, instructor status is something of a proxy measure for cumulative experience.<sup>4</sup> Second, in order to become an instructor a fighter crew member must compete against his or her peers for a limited number of instructor upgrade course spots. As a result, the best performing - or most talented - have a better chance of upgrading to instructor status. Third, as the second point implies, instructors complete rigorous formal upgrade training courses where they learn instructional techniques while further honing their already considerable skills in the tasks they will

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<sup>4</sup> For the F-15E crews under study here instructors had, on average, almost 70 percent more fighter hours than non-instructors.

be teaching to their squadron mates. So, in short, instructor status is a powerful predictor of air-to-ground combat skill performance because instructors tend to be more experienced, more talented, and more highly trained than non-instructors. Table 5.3 below presents the regression coefficients for a model estimating LDHD CEA as a function of instructor status and LDHD deliveries in the current month.<sup>5</sup>

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<sup>5</sup> Note: The t-statistics and p-values presented in table 5.3 reflect the use of Huber standard errors. One of the underlying assumptions of ordinary least squares regression is that the error terms (the difference between predicted and actual bomb miss distance (CEA) in this case) are normally distributed and do not vary systematically as the magnitude of the independent variables increase. A Goldfeld-Quandt test was performed to test if this important assumption held. The results of the test indicated that error terms were much larger for low values of LDHD than for high values ( $p=0.025$ ). In other words, the model predicts bomb miss distance (CEA) better for pilots who have dropped a relatively large number of bombs in a month than for those who have dropped relatively few bombs. This is logical because pilots who have dropped a relatively large number of bombs recently will probably be more consistent than those who have dropped relatively few. Huber's formula produces robust standard errors and covariance matrices regardless of error distribution. Therefore, it compensates for the non-constant error terms and produces more accurate standard errors, t-statistics and p-values for data with non-constant variance (heteroscedasticity).

A final technical point on the data analyzed here. It consists of cross sectional data on 55 individual pilots and WSOs collected over a period of eleven months. This combination of cross sectional and time series data is called pooled data. In pooled data it is possible that cross sectional parameters may shift over time, or that larger processes, related to the passage of time, may explain some of the variation in performance. One way to correct for these possibilities is to control for individual variation and differences across time periods by including a series of dummy variables for the individuals and time periods. This allows average performance to vary over both time and between individuals.

To determine if it was necessary to include dummy variables in my models I conducted a nested models test. The error sum of squares for models containing the dummy variables were compared to the error sum of squares of models without the dummy variables. Since the models without the dummy variables have more restrictions (coefficients for all individuals and time periods are assumed to be the same), if the dummy variables have significant explanatory power, we would expect the models with the dummy variables to have significantly lower error sums of squares than the restricted models. (See Robert S. Pyndyck and Daniel L. Rubinfeld, Econometric Models & Economic Forecasts, Third Edition, McGraw-Hill, New York, 1991, pp. 223-226.) For the F-15E LALD/HD model the F-test statistic with 101 and 66 degrees of freedom is 0.595

| Variable                               | Coefficient | Standard Error | t-Statistic | P-Value |
|----------------------------------------|-------------|----------------|-------------|---------|
| N=104                                  |             |                |             |         |
| Constant                               | 25.34121    | 1.792022       | 14.181      | 0.000   |
| Instructor                             | -7.564915   | 1.873251       | -4.038      | 0.000   |
| Practice<br>(LDHD<br>Current<br>Month) | -0.4662477  | 0.2119053      | -2.200      | 0.030   |

**Table 5.3 - F-15E Visual Bomb Delivery Regression Coefficients**

All of the coefficients meet the standard test of statistical significance (p-values less than 0.05 for their individual t-statistics), but what does this regression analysis say about the practical impact of instructor status and recent practice on average visual bomb miss distance? First, the constant can be interpreted as the average bomb miss distance - in meters - for a non-instructor who has not dropped any practice bombs in the past 30 days. In this case it is approximately 25 meters. The instructor coefficient is an estimate of how much better an instructor does, on average, than a non-instructor. In this case, instructors' bombs landed about 7.5 meters closer to the target than a non-instructors' if both have dropped the

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(p=0.991) and for the Loft model the F-test statistic with 192 and 133 degrees of freedom is 0.41 (p=0.99). For the F-16 LALD/HD model described later the F-statistic with 164 and 114 degrees of freedom is 1.15 (p=0.216). So, in all cases I failed to reject the null hypothesis that the models without dummy variables were the correct specification at the p=0.05 level. Therefore, the simpler models are used throughout this analysis.

This has a big advantage. Sample size here is relatively small - only 104 observations for visual bombs and 195 for the radar bomb analysis presented below, and 166 for the F-16 visual bomb analysis presented later. In the F-15 cases adding dummy variables for each pilot/WSO and each time period adds 35 variables to the LALD/HD and 59 to the Loft regression equation (50 variables in the F-16 case), so the models is probably overspecified for the available data. So in this case the best option is probably the Huber regression since it corrects for known heteroscedacity while providing unbiased and consistent parameter estimates.

same number of practice bombs in the current month. Finally, the practice coefficient indicates that for each additional practice bomb dropped CEA decreases by about 0.46 meters, or about 18 inches, on average for both instructors and non-instructors.<sup>6</sup>

With these estimates of average bomb miss distance, the instructor effect and the impact of practice within the past 30 days on visual bomb miss distance it is possible to estimate how far any given visual bomb dropped will fall, on average, from the target if we know the pilot's instructor status and the number of practice low altitude bombs he has dropped in the past month. We can then compare these predicted average bomb miss distances to established USAF hit criteria for various bomb deliveries to determine if pilot performance under a variety of assumptions about instructor status and recent practice is likely to meet minimum USAF standards for bomb accuracy.

At first glance it would appear that we can simply compare the estimated miss distances to the USAF low angle low drag/high drag bomb hit criteria. The following calculations assume any LALD or LAHD bomb predicted to land within 27.5 meters of the intended target is a hit. This is in line with USAF hit criteria for these types of bomb deliveries from F-15E aircraft.<sup>7</sup> Comparing predicted bomb miss distances to the hit criteria indicates that, on average both instructors and non-instructors will achieve a hit even if they have not dropped any bombs in the past 30 days. Non-instructors are predicted to have an average miss distance of about 25.3 meters, instructors about 17.8 meters under these conditions. So, with everyone achieving hits on

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<sup>6</sup> An additional model incorporating an interaction term for instructor and LDHD was estimated to investigate the possibility that incremental improvement from recent practice bombs was not the same for the two groups. This term was not significant. This indicates that an additional practice bomb improves bomb miss distance by the same amount for instructors and non-instructors.

<sup>7</sup> Actual USAF hit criteria for LALD bombs for F-15E pilots is 30 meters. A hit for a LAHD bomb is 25 meters. Source: Multi-Command Instruction 11-F-15E. Since these deliveries are almost identical from a technical point of view, and the data consists of equal numbers of each, I combined them to increase sample size and increase the statistical power of the regression analysis discussed above. Averaging the 25 and 30 meter hit criteria gives an new average hit criteria for the combined data of 27.5 meters.

average, it seems that lack of practice has little impact on an individual pilots ability to accurately drop visually aimed bombs from low level.

However, before we can compute the predicted probability of hit (Ph) we must account for the expected variation around the estimated average miss distances. The predicted 25.3 and 17.8 meter miss distances are average miss distances. Some bombs will land closer to the target and some much farther away. Very few will land at exactly 25.3 or 17.8 meters from the intended target. To calculate the predicted probability that a particular pilot will drop a bomb within the 27.5 meter hit criteria, we need to know not only the average predicted miss distance, but also the magnitude of the variation around that average miss distance. An example can help illustrate this important point. Lets assume ten non-instructors who have not dropped any visual practice bombs in the past 30 days fly out to the bombing range and all drop one bomb and return to base. Based on the regression analysis presented earlier, and assuming normally distributed errors, we would expect five of the bombs to land between zero and 25.3 meters from the target and the other five bombs to land more than 25.3 meters from the target. Given the relatively small difference between the average impact distance and the limit of the hit criteria, it is likely that a sizable fraction of the bombs dropped - say four out of ten - will actually land outside the hit criteria limit. It is possible virtually all the bombs could land within the hit criteria if dispersion about the average miss distance is small enough - on the order of about 1 meter.

I calculated the standard deviations of the bomb miss distance predictions for all possible values of LDHD (from 0 to 18) for both instructors and non-instructors. For non-instructors the standard deviations of the predicted bomb miss distances ranged from 11 to about 18 meters. For instructors they ranged from about 15 to about 22 meters. Combining these standard deviations, and the regression analysis parameters from table 5.3 it is possible to calculate the probability of hit for all combinations of instructor status and number of LALD/HD deliveries in the data set. These probabilities are presented graphically in figure 5.7 below.

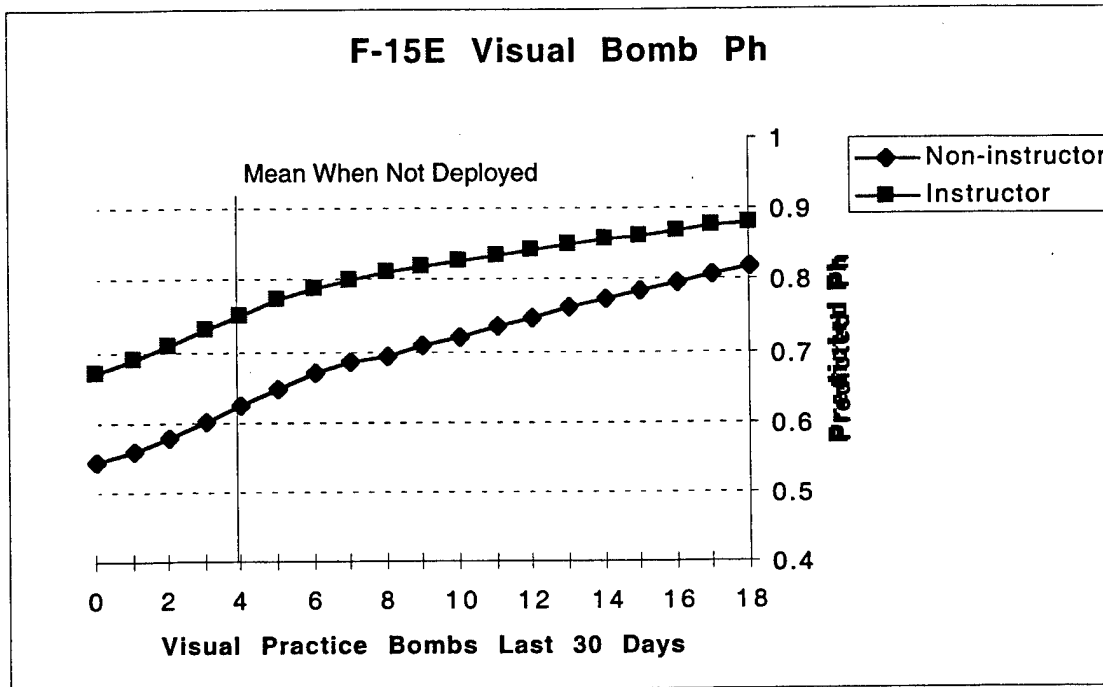


Figure 5.7 -- Visual delivery probability of hit for F-15E instructor- and non-instructor pilots as a function of bombs dropped in the past 30 days.

Figure 5.7 shows that instructors generally have a higher probability of hitting a target with a LALD/HD delivery. When the squadron is not deployed to a peace operation, both instructors and non-instructors drop, on average, about four practice LALD/HD bombs per month. At this level of practice non-instructors achieve about the same hit probability as instructors have had no practice in the past 30 days.. Non-instructor hit probability decreases from 0.62 for a normal month at home with three practice deliveries to about 0.54 when a non-instructor has not practiced visual bomb deliveries in the past 30 days. This may seem to be a relatively trivial decrease in hit probability, but if viewed from the perspective of the probability of miss things look a bit more serious. For non-instructors, the probability of missing an important target with the most common visual low-level delivery increases almost 20 percent (from 0.38 to 0.46) if the pilot in question has been deployed to support a peace operation, or other

mission, where training opportunities for important MTW low altitude combat skills are limited or non-existent. For instructors the probability of missing increases about 25 percent from 0.25 with recent practice to about 0.33 without.

#### Radar Bomb Deliveries

An analysis similar to the one conducted for visual bomb deliveries was conducted for radar bomb delivery accuracy. The focus was on loft deliveries - the primary night low level radar aimed bomb delivery technique for F-15E crews. During a loft delivery the crew cooperates to deliver a weapon. The pilot flies the aircraft through the loft maneuver while the WSO uses the aircraft's radar and computer systems to aim the bomb and compute the proper release point. The loft delivery profile allows the WSO to keep the target within the radar's field of view up to bomb release, and decreases exposure to terminal defenses. However, these advantages come at the cost of increased bomb release distances. This, of course, increases the unguided time of flight of the bomb and makes these deliveries inherently less accurate than visual deliveries. This difference is reflected in both the regression analysis results presented below, and the expanded USAF hit criteria of 110 meters for loft deliveries.

Like the F-15E visual bomb delivery model discussed above the constant and instructor coefficients are statistically significant. Just as in the visual delivery case the regression results presented in table 5.4 use Huber standard errors, and the model fits the available data better than any other functional form examined. However, the coefficient for recent practice - measured by the number of loft deliveries in the current month - does not meet the test of statistical significance.

| Variable                               | Coefficient | Standard Error | t-Statistic | P-Value |
|----------------------------------------|-------------|----------------|-------------|---------|
| N=195                                  |             |                |             |         |
| Constant                               | 85.58033    | 5.768699       | 14.835      | 0.000   |
| Instructor                             | -13.43073   | 5.597754       | -2.399      | 0.017   |
| Practice<br>(LOFT<br>Current<br>Month) | -1.599719   | 1.207627       | -1.325      | 0.187   |

**Table 5.4 - F-15E Radar Bomb Delivery Regression Coefficients**

I have elected to retain LOFT as an explanatory variable for several reasons. First, there are sound theoretical reasons, outlined in Chapter Four, to believe that recent practice is an important determinant of performance. Second, these theoretical reasons for including LOFT are reinforced by significant results for the recent practice measure in both the F-15E visual bomb delivery model discussed above and the F-16C visual bomb delivery model presented below. Third, as described above, LOFT deliveries depend - to a much greater extent than visual deliveries - on the performance and skill of both the pilot and WSO. Unfortunately, the data available did not include information on which pilots and WSOs were teamed for LOFT deliveries. So it is possible that on his first delivery in a month a WSO might be teamed with a instructor with lots of recent practice in LOFT deliveries, while on subsequent delivery attempts that month the WSO is teamed with an inexperienced pilot with less recent practice. Under these conditions the impact of pilot performance on bomb accuracy will tend to weaken the link between WSO practice and bomb accuracy. Statistically this situation will result in larger standard errors for the LOFT coefficient than we would expect if we could control for pilot practice. Larger standard errors will, in turn, result in less significant t-statistics and p-values. Obviously, this is not the best imaginable model for predicting LOFT miss distance. However, it is the best possible model given the limitations of existing data.

Interpretation of the regression coefficients is essentially the same as for the LALD/HD bomb delivery model described earlier. The constant represents the average bomb miss distance for a non-instructor WSO with zero loft deliveries in the preceding 30 days. In this case this is approximately 85.6 meters. The instructor coefficient indicates that, on average, instructor's LOFT bombs land about 13.4 meters closer to the target than non-instructors with the same amount of recent practice. And finally, the LOFT coefficient is an estimate of the incremental effect, controlling for instructor status, of each additional practice LOFT delivery in the preceding 30 days on average bomb miss distance measured in terms of CEA. In this case an additional practice delivery reduces CEA by about 1.6 meters.

Estimates for CEA and standard deviations were estimated for both instructors and non-instructors while previous practice varied from zero to 12 LOFT deliveries in the previous month. The CEAs, USAF hit criteria, and standard deviations were then used to estimate the probabilities of hit shown in figure 5.8 below.

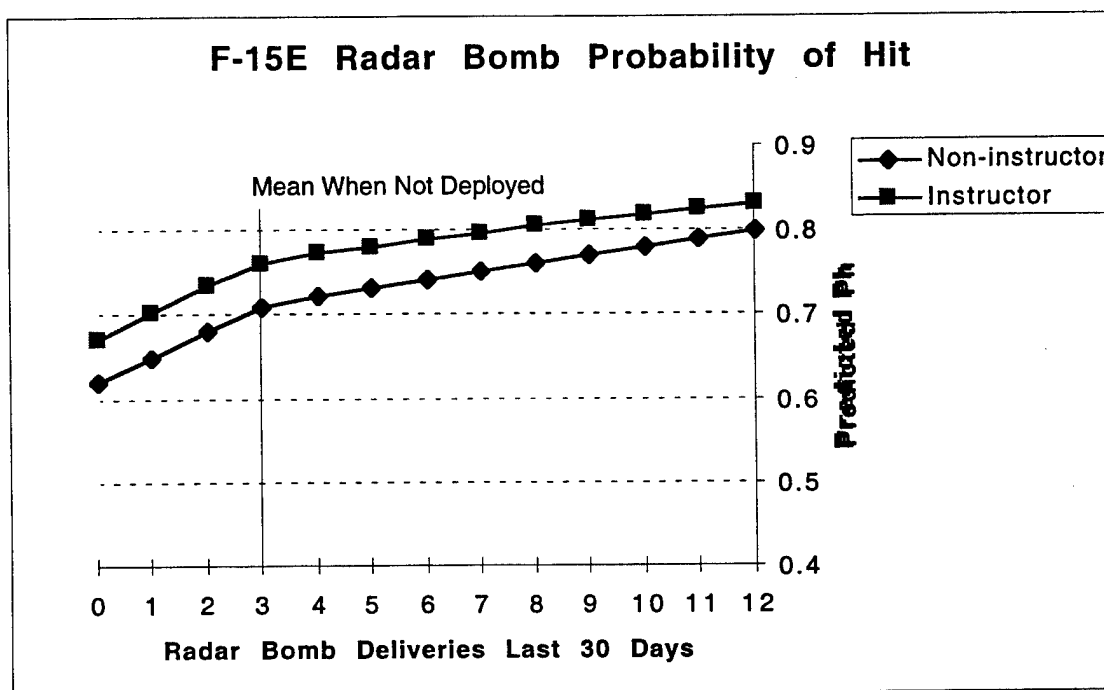


Figure 5.8 -- Radar delivery probability of hit for F-15E instructor-and non-instructor WSOs as a function of bombs dropped in the past 30 days.<sup>8</sup>

What do these predicted hit probabilities tell us? First of all, again it seems instructors have an advantage when it comes to hit probability. Here again, non-instructors with normal recent practice achieve hit probabilities approximately equal to instructors with no practice. When not deployed in support of a peace operation the average WSO - whether instructor or not - in this data set dropped 3 practice LOFT bombs per month. However, just as with visual bombs, the probability of non-instructors dropping acceptable bombs declines for deployed crews who can not practice LOFT deliveries. The probability a non-instructor WSO with no practice in the previous month hits a target with a LOFT delivery is only about 0.62 compared to approximately 0.71 for a non-instructor pilot dropping visual bombs with no recent practice. Similar probabilities for instructors are 0.67 and 0.76. Here again the probability crews with no recent practice will miss their

<sup>8</sup> Note: The radar bomb practice effect is not significant at the  $p=0.05$  level.

intended targets increases by 20 percent for non-instructors and 25 percent for instructors.

#### **Estimated Impact of Deployments on F-15E Squadron Low Level Bomb Delivery Performance**

The coefficients from the regression analyses of both visual and radar bomb deliveries can be combined with data on the average number of practice deliveries F-15E crews from the 335<sup>th</sup> Fighter Squadron accomplished between January 1 and November 30 1997 to estimate the hit probabilities for instructors and non-instructors. Figure 5.9 below shows the results for pilots dropping visual bombs.

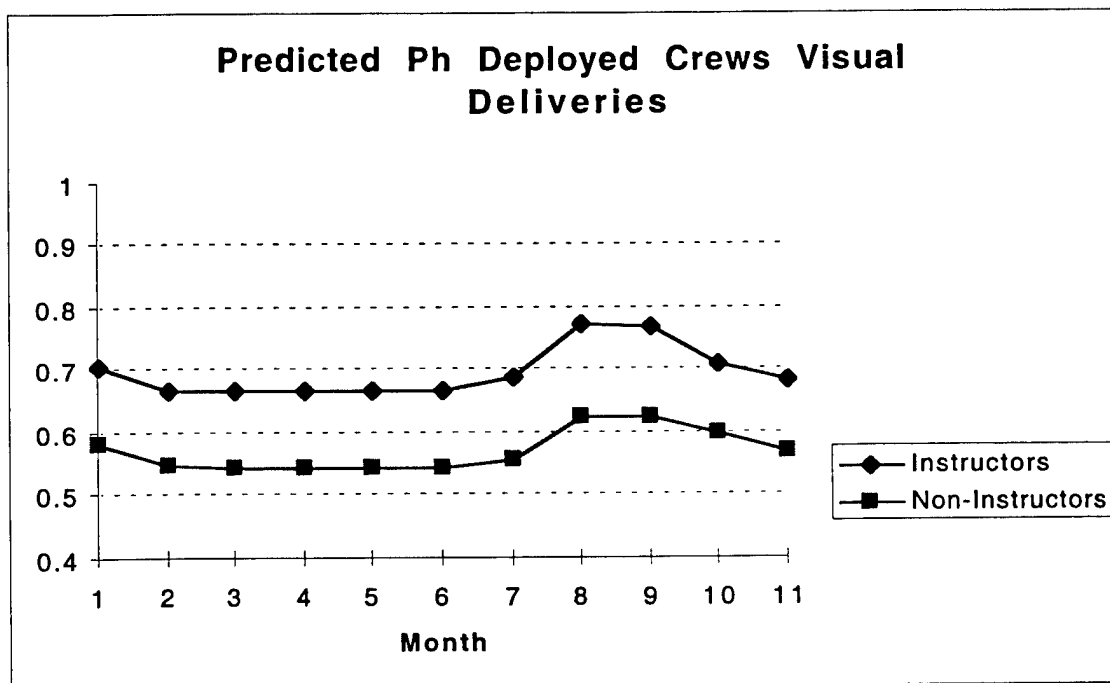


**Figure 5.9 - Predicted Probability of Hit (Ph) for Visual Bombs for F-15E Crews Who Deployed to Saudi Arabia February through June 1997**

Figure 5.9 presents estimated probabilities of hit for instructors and non-instructors assigned to the 335<sup>th</sup> Fighter Squadron based on the average number of practice LALD/HD deliveries accomplished by each group per month from January through November 1997. The squadron deployed to

Saudi Arabia from February through June.<sup>9</sup> During the deployment none of the pilots in Saudi Arabia accomplished a single practice LALD/HD bomb delivery due to the lack of training facilities and extreme demands no-fly zone sortie commitments placed on the squadron's available sorties.

As one might expect from the preceding discussion, both instructors' and non-instructors' LALD/HD accuracy declines with lack of practice lack of practice. Within 30 days - and probably less - of arriving in Saudi Arabia, crews chances of hitting a target with a LALD/HD bomb had decreased from about ten percent from their non-deployed average where they remained for the rest of the deployment. Bomb accuracy does not decline further as the months without practice go by because, as described previously, an analysis of bombs dropped in the past 03, 60 and 90 days indicated only bombing practice within the most recent 30 days had a statistically significant effect on bombing accuracy. In other words, the statistical analysis indicates that there is no significant difference in bombing skills between crews who have gone 30 days without practice and those who have gone 90 days without practice. Skills may deteriorate beyond 90 days, but it is not possible to determine if or how much they decline with the data available. Figure 5.10 below presents similar predictions for radar aimed LOFT deliveries.

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<sup>9</sup> Numbers on the horizontal axis of figures 5.9 through 5.11 correspond to months of the year (e.g. 1 = January, 2 = February, etc.).

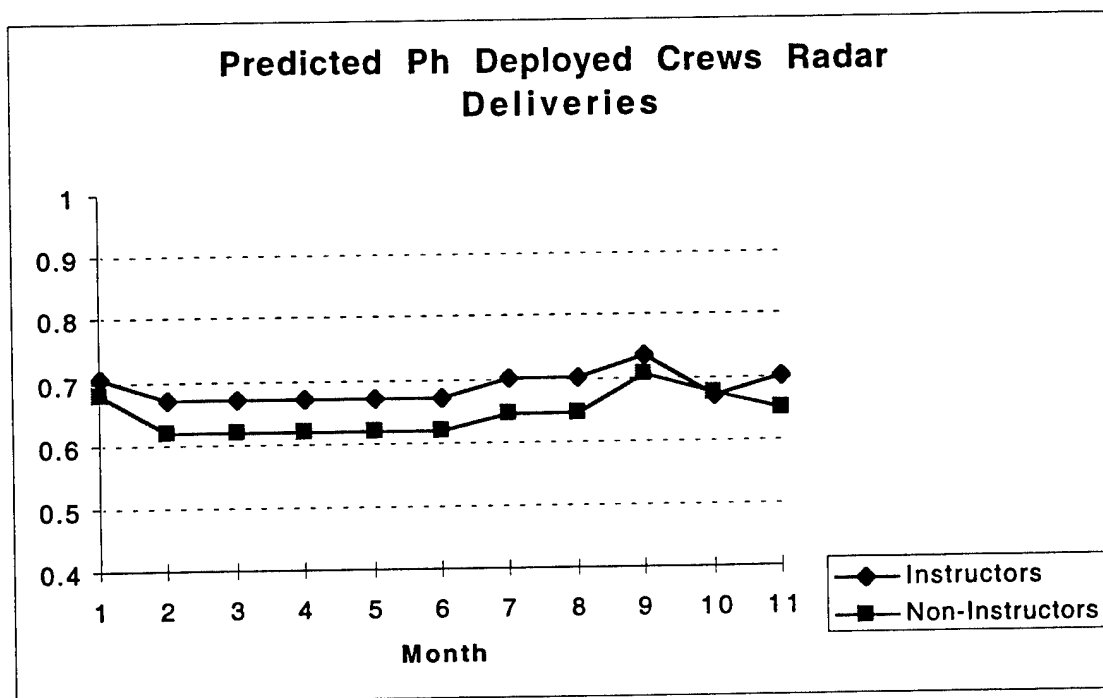


**Figure 5.10 -- Predicted Probability of Hit (Ph) for Radar Bombs for F-15E Crews Who Deployed to Saudi Arabia February through June 1997**

A final step toward an estimate of the overall impact of lack of practice on the probability the squadron as a whole will hit - or miss - targets it might be tasked to attack from low altitude is to compute a weighted average of the instructor and non-instructor hit probabilities. Approximately 35 percent of both pilots and WSOs in the 335<sup>th</sup> Fighter Squadron are instructors. So, the overall probability the squadron will hit its assigned visual and radar targets is closer to the non-instructor probability of hit than the instructor probability of hit. Figure 5.11 below presents the other side of the probability of hit analysis shown so far by presenting estimates of the overall chances pilots and WSOs of the 335<sup>th</sup> Fighter Squadron would have MISSED assigned low level targets during 1997.

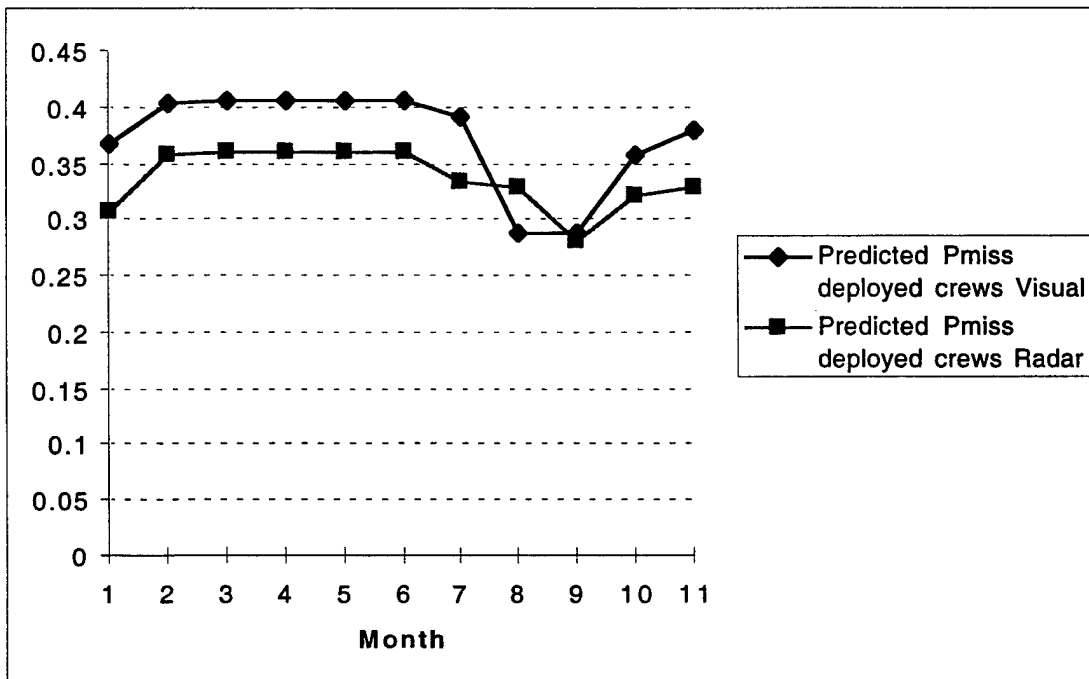


**Figure 5.11 - Predicted Probability of Miss for F-15E Crews Who Deployed to Saudi Arabia 1997**

Figure 5.11 clearly illustrates how the overall probability a squadron will miss assigned low level targets increases about 20 percent when the squadron deploys in support of peace operations for both visual and radar bomb deliveries. So, if crews deployed to a peace operation were suddenly faced with the requirement to conduct low altitude strikes against well defended targets, it is likely that many more targets would require re-attack due to inaccurate bomb deliveries than one might expect based on their performance just prior to deployment. This would be inconvenient and somewhat costly, but since crews would rapidly regain proficiency as operations progressed, the impact of decreased accuracy would probably be both temporary and relatively minor when compared to the overall air campaign objectives and timetable of a MTW.

Figures 5.12 and 5.13 below illustrate how bombing accuracy might impact the number of targets hit in the opening days of a MTW air campaign. The figures use data from Operation Desert Storm as a

starting point.<sup>10</sup> The top line in each figure shows the cumulative total of targets attacked by F-15Es and F-16s. During this phase of Desert Storm there were 48 F-15Es and 210 F-16s in theater. On average these aircraft flew about one sortie per day and attacked one target per sortie. The middle line on each chart uses the predicted squadron hit probabilities for F-15E loft (presented above) and F-16 visual deliveries (presented in the next section) assuming crews had an average number of practice loft deliveries in the previous 30 days at the start of the war, and that combat bomb deliveries improve accuracy to the same extent as practice deliveries.<sup>11</sup> The bottom line on each chart assumes crews start the notional replay of Desert Storm while in the middle of a peace operations deployment with no practice bomb deliveries in the past 30 days. F-15E WSOs hit about 12 percent fewer targets on the first night without practice than they would with practice, while F-16 pilots with no practice miss about 18 percent more targets on the first day. After ten days in action, this analysis predicts F-15E WSOs who start the war with no recent practice will have hit about 95 percent of the targets they would have if they had begun the war with normal peacetime training in the previous month. F-16 pilots without recent practice are predicted to have hit about 88 percent of the targets they would have in the first ten days with practice.

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<sup>10</sup> See GWAPS Vol. V pp. 419-429 and 556-565 for data on F-15E and F-16 aircraft in theater, and targets attacked during the first ten days of Operation Desert Storm.

<sup>11</sup> During the opening days of Desert Storm almost all F-16C ground attack sorties were flown during daylight hours and used visual bomb delivery techniques while about 90 percent of F-15E sorties were flown at night and used radar bomb delivery techniques.

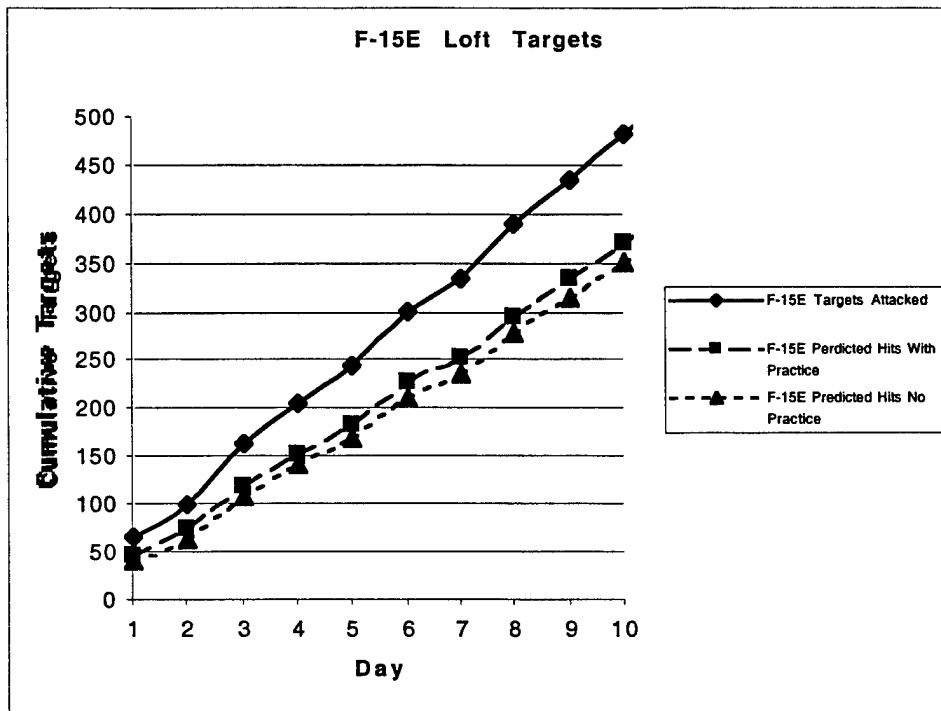


Figure 5-12 - F-15E Targets Attacked and Hit by Crews With and Without Practice in a Notional Replay of the First Ten Days of Desert Storm

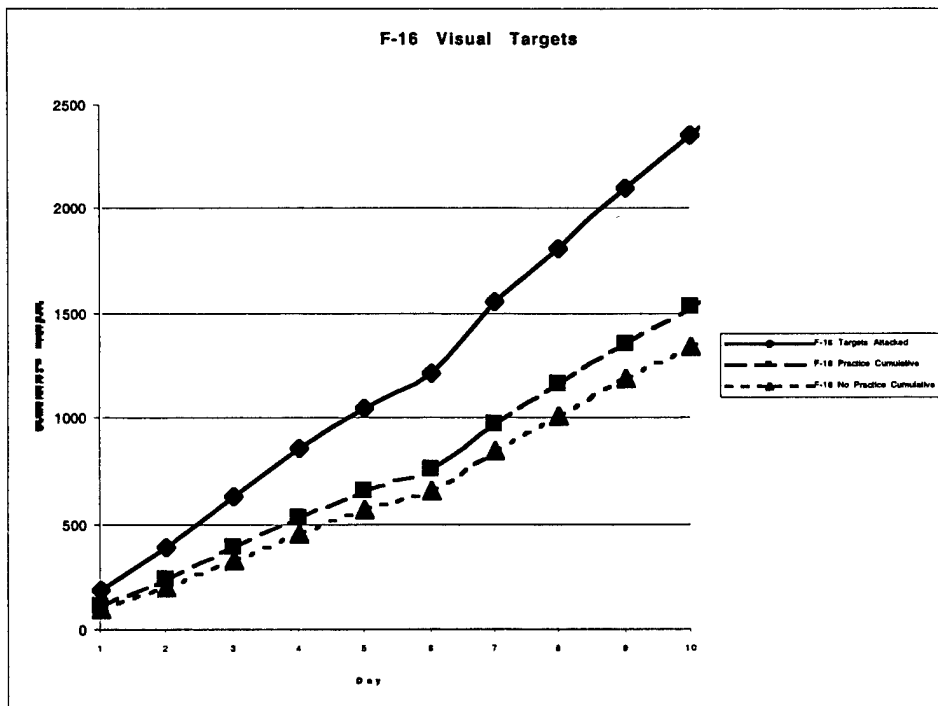


Figure 5-13 - F-16C Targets Attacked and Hit by Crews With and Without Practice in a Notional Replay of the First Ten Days of Desert Storm

However, these predictions represents an upper limit of how well crews who transition directly from peace operations to combat missions would do compared to crews fresh from normal peacetime training. To the extent that decreased low level bombing accuracy is a proxy for the loss of other important tactical skills crews need to successfully carry out demanding missions during the opening days of a MTW, we can expect crews ability to navigate at low altitude, employ electronic systems and countermeasures, evade threats, maintain tactical formation, acquire and engage a target(s) etc. to decrease as well. Decreased performance along any or all of these dimensions of tactical air operations will almost certainly lead to additional missed targets due to navigation errors, and possibly to increased losses to enemy defenses and increased "ground kills" resulting from crews with insufficient recent practice attempting to execute tactical maneuvers and threat reactions in the unforgiving low altitude environment.

In addition, since successful mission accomplishment requires crews to competently perform all of these demanding tasks, the decline in bombing accuracy discussed above almost certainly *underestimates* the overall impact of lack of tactical training on the ability of USAF fighter crews to successfully accomplish typical early MTW ground attack mission profiles. For example, suppose fighter crews must accomplish ten tasks such as those just enumerated in order to successfully complete a combat mission. If lack of practice reduces their ability to perform each individual task by ten percent (as it does with bomb hit probabilities), then the overall probability of successfully accomplishing the mission is not 90 percent. Because each task must be accomplished successfully, the probability of successfully accomplishing the mission is only 35 percent.<sup>12</sup>

In addition, the preceding analysis of bombing accuracy considers only how lack of practice impacts the chances that an individual aircraft will hit an individual target. It does not take into account how lack of practice might impact the ability of a formation of two or

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<sup>12</sup> I am indebted to RAND colleague Alan Vick for this observation.

more aircraft to successfully coordinate their attacks against a target or targets. Since most early MTW ground attack missions, especially daytime visual bombing missions, will be conducted by multiple aircraft flying and attacking in formation, simply aggregating the individual impact of lack of practice probably overstates the probability a formation of aircraft will successfully complete its mission.

Furthermore, it is important to note that the regression analysis showed that practice improved instructor bombing accuracy just as much as non-instructor accuracy. Even though instructors performance was generally better than non-instructors, practice still helped them perform better. So, even for seasoned, well trained and talented crews recent practice is critical for MTW combat skill performance.

Finally, the discussion of hit probabilities in this section and the next rest on the assumption that USAF hit criteria are adequate to ensure the destruction of all types of targets USAF fighter crews might be tasked to attack early in a MTW. While dropping 500 to 2000 pound bombs within 25 to 30 meters (the USAF hit criteria for visual bombs) is adequate to ensure destruction of some types of targets such as petroleum storage facilities or personnel in the open, other important target classes such as armored vehicles and artillery require much higher accuracy. Therefore, the decline in hit probability discussed above probably represents only the proverbial tip of the iceberg in terms of the detrimental impact of peace operations deployments on USAF fighter crews' ability to successfully complete many important air-to-ground combat missions during the opening phases of a MTW.

#### **F-16C BOMBING SKILLS**

In addition to looking at F-15 pilot and WSO low level bombing skills, I also analyzed low level visual deliveries and medium altitude laser guided bomb deliveries accomplished by pilots from the 388<sup>th</sup> Fighter Wing, 4<sup>th</sup> Fighter Squadron.

#### **F-16C Low Altitude Visual Bomb Deliveries**

The data available from the 4<sup>th</sup> Fighter Squadron was almost identical in terms of structure and variables to the data from the 335<sup>th</sup>

Fighter Squadron described in tables 5.1 and 5.2 above. The major difference is that data were available over a 14 month period from January 1997 to February 1998 for 4<sup>th</sup> Fighter Squadron crews versus the 11 month period for the 335<sup>th</sup> Fighter Squadron crews. Another difference is that the maximum number of LALD/HD deliveries used in this analysis was 15 versus 18 for the F-15E data.<sup>13</sup> An additional difference is that the F-16C is a single seat aircraft, and radar aimed Loft deliveries are not an important part of the squadrons combat tactics. Accordingly, the only F-16 low level bomb delivery skills analyzed here are for Low Angle Low Drag/High Drag visual bomb deliveries.

Initially, just as with the F-15E LALD/HD and LOFT deliveries, a variety of functional forms and variables were tested to determine which model specification best fit the available data on CEA. The best model specification turned out to be the same as that used for the F-15E data. Here again, the model predicts average LALD/HD miss distance in terms of CEA as a function of a pilot's instructor status and the number of LALD/HD deliveries he had performed in the past 30 days. Table 5.5 below summarizes the model results for 163 F-16C LALD/HD CEAs.

| Variable                               | Coefficient | Standard Error | t-Statistic | P-Value |
|----------------------------------------|-------------|----------------|-------------|---------|
| N=166                                  |             |                |             |         |
| Constant                               | 30.30446    | 3.11003        | 11.442      | 0.000   |
| Instructor                             | -10.72795   | 3.41654        | -3.140      | 0.002   |
| Practice<br>(LDHD<br>Current<br>Month) | -0.5632309  | 0.23725        | -2.374      | 0.019   |

<sup>13</sup> One very inexperienced pilot did accomplish 24 practice LALD/HD deliveries in a single month with only mediocre accuracy. This observation was dropped from the analysis because it was an extreme outlier with high leverage, and was therefore driving the results of the model.

**Table 5.5 - F-16C Visual Bomb Delivery Regression Coefficients**

As with the two previous sets of regression results, interpretation of these coefficients is relatively straightforward. The constant represents the average miss distance for non-instructor pilots who have not dropped any practice LD/HD bombs in the preceding 30 days. The USAF hit criteria for the mix of LALD and LAHD deliveries in this data again about 27.5 meters.<sup>14</sup> So, unlike non-experienced F-15E pilots who drop bombs just inside their hit criteria on average, non-experienced F-16C pilots in this data set tend drop their bombs outside the hit circle at 30.3 meters on average unless they have had some recent practice. The instructor coefficient is simply the difference in average instructor and non-instructor performance. In this case, F-16C instructors dropped their bombs almost 11 meters closer to the target on average than did non-instructors. Finally, the practice coefficient is the average decrease in CEA for each additional practice bomb dropped. For F-16C pilots this incremental increase in accuracy from each additional practice bomb is estimated to be about 0.56 meters (approximately 22 inches) on average. Just as in the F-15E analysis, these coefficients were combined with estimated standard errors for recent practice ranging from zero to 15 LALD/HD deliveries for both instructors and non-instructors to produce estimated probabilities of hit. These probabilities are presented in figure 5.12 below.

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<sup>14</sup> Multi-Command Instruction 11-F16, 1 July 1997.

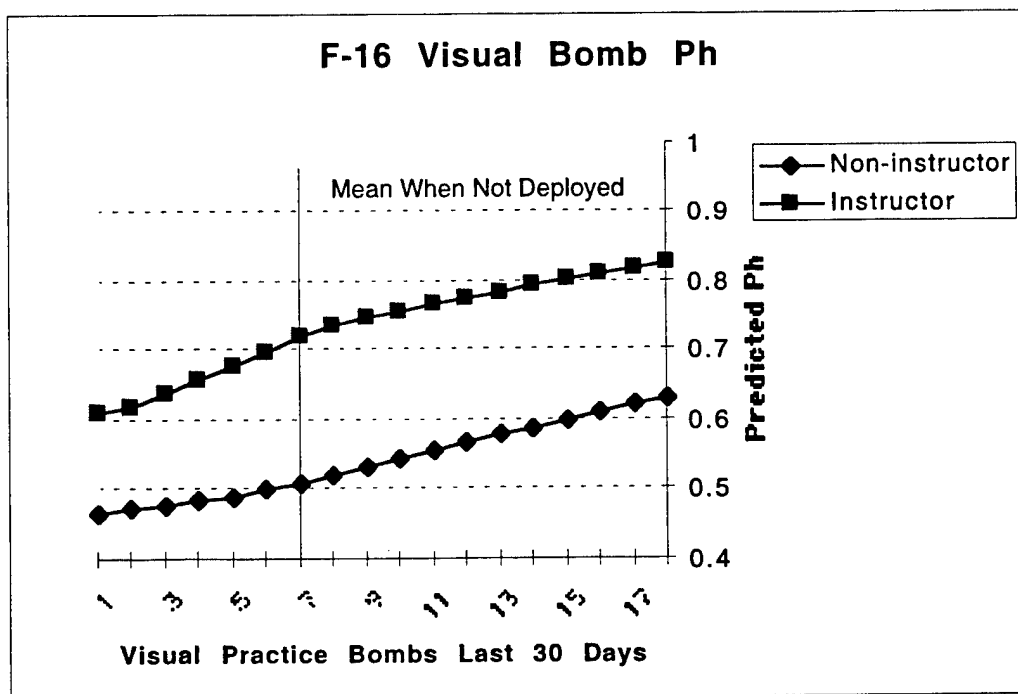


**Figure 5.12 -- Visual delivery probability of hit for F-16C instructor and non-instructor pilots as a function of bombs dropped in the past 30 days.**

The figure shows the same general pattern as that produced by the F-15E model outputs. Here again instructors have a considerable, and even larger, advantage over non-instructors in terms of average hit probability. In fact, non-instructors flying F-16Cs need to drop about seven bombs per month to achieve an estimated probability of hit just above 0.5 while F-16C instructors achieve an estimated hit probability of about 0.75 with the same amount of practice

#### **Estimated Impact of Deployments on F-16C Squadron Low Level Bomb Delivery Performance**

The estimated hit probabilities presented in table 5.12 were combined with actual data on the average number of bombs instructor and non-instructor pilots from the 4<sup>th</sup> Fighter Squadron dropped between January 1, 1997 and February 28, 1998 to produce estimates of the probability of hit for each group displayed in figure 5.13 below. The

general pattern here is similar to the estimates for F-15E visual bomb deliveries presented earlier. However, since non-instructor F-16C pilots need considerable practice just to hit on average, the overall estimated hit probabilities for the entire squadron are lower than for their F-15E counterparts. The 4<sup>th</sup> Fighter Squadron made two deployments to Saudi Arabia during the period under study here - one in March and April of 1997 and another in December 1997 and January 1998.<sup>15</sup> The figure clearly illustrates the dramatic decline in LALD/HD hit probabilities for both instructors and non-instructors during these deployments.

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<sup>15</sup> The estimated probability of hit of about 0.72 for November 1997 reflects a decreased level of training activity late in the month so that necessary preparations for the up-coming deployment could be completed. This period of decreased training tempo prior to a deployment is necessary to allow squadron personnel time to take care of personal and family business prior to a long absence, and to prepare the aircraft and other equipment for the long trip to Saudi Arabia. A similar "stand-down" period usually occurs at the end of a deployment as well to allow squadron members some time off to reacquaint themselves with their families, etc. As a result, 45-day deployments usually result in 60 to 70 days of little or no training in the MTW combat skills of interest here. 90-day deployments stretch this period to 120 days.

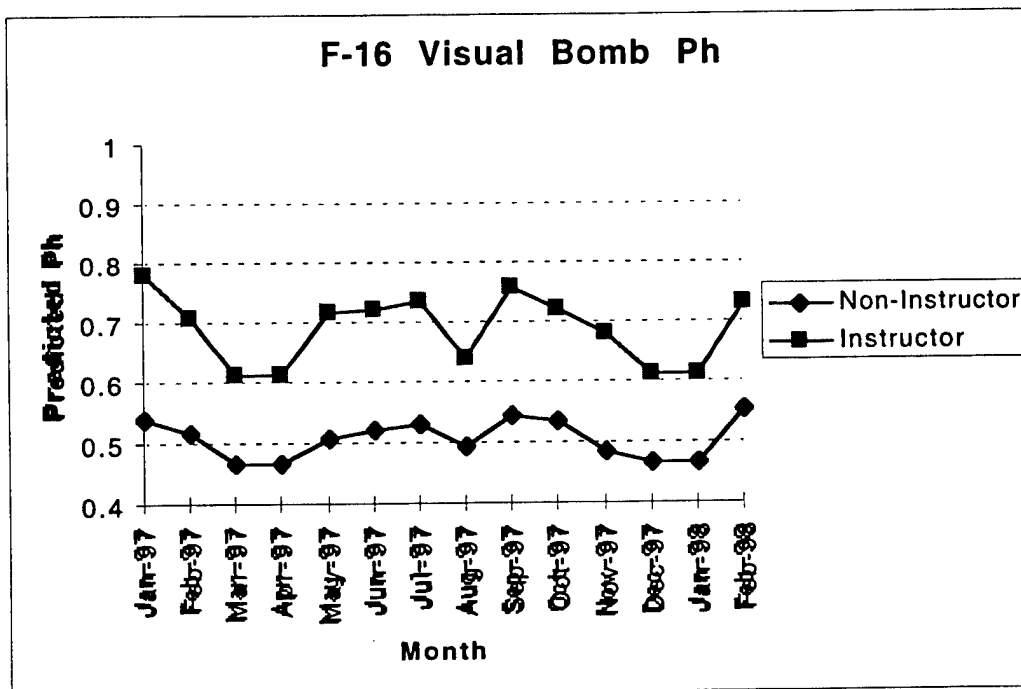


Figure 5.13 -- Predicted Probability of Hit (Ph) for F-16C Instructors and Non-Instructors January 1997 Through February 1998.

Just as in the F-15E LALD/HD analysis presented earlier the instructor and non-instructor hit probabilities were weighted to reflect the relative proportions of instructors and non-instructors in the squadron (again approximately 65 percent non-instructors and 35 percent instructors) to produce an overall estimate of the proportion of targets the squadron as a whole would have hit over the time period under study. Figure 5.14 below presents the predicted probability the squadron would miss LALD/HD targets (one minus the weighted average probability of hit) for the 4<sup>th</sup> Fighter Squadron for 1997 and early 1998. It clearly shows that for the squadron as a whole, the chances of missing a target attacked from low altitude with visually aimed bombs increase 25 percent during, and around, peace operations deployments.

Again, it is important to remember that this overall decrease in low level bombing accuracy is a proxy for the loss of other important tactical skills such as low level navigation, mutual support, threat reactions etc. that almost certainly decline as well. It is worth re-emphasizing that this decline in bombing accuracy probably represents a lower bound for the negative impact of peace operations on MTW combat

capability because the cumulative impact of relatively small decreases in proficiency in a variety of mission critical skills generally not practiced during peace operations sorties such as the ability navigate at low altitude, employ electronic systems and countermeasures, evade threats, maintain tactical formation, acquire and engage a target(s) etc. is much greater than the decline in any single skill would indicate. The cumulative impact of decreased combat skill proficiency could easily result in even more missed targets and possibly increased aircraft and pilot losses in the opening phase of a MTW for both non-instructors and instructors.

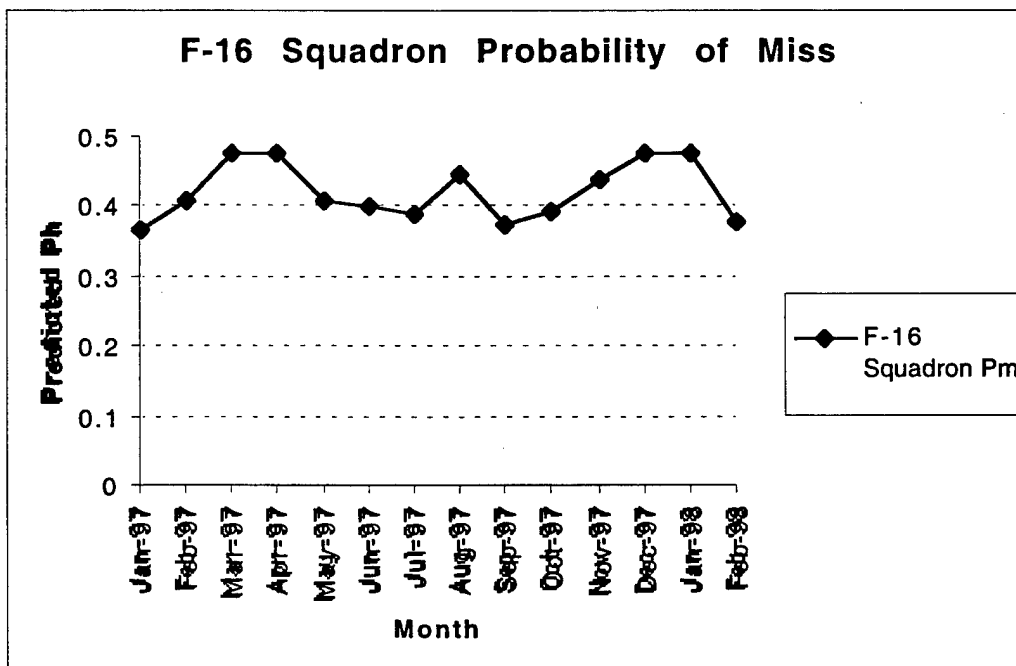


Figure 5.14 - Predicted Probability of Miss for F-16C Pilots 1997 and Early 1998

#### SUMMARY OF F-15E AND F-16C LOW LEVEL BOMBING SKILL ANALYSIS

Figures 5.15 through 5.17 below present a graphic summary of the low level bombing skill analysis for both F-15E and F-16C crews presented above. Figure 5.15 presents a series of four predicted impact

patterns for F-15E crews dropping visually aimed LALD/HD bombs. Each pattern uses the average bomb miss distances and standard deviations described above combined with random dispersion in azimuth to depict the distribution of average miss distances for non-instructors and instructors both with and without practice. The upper left pattern in each figure presents results for non-instructors with no practice deliveries in the preceding 30 days. The upper right pattern is for instructors with no practice. The lower left pattern is for non-instructors who have dropped the average number of practice deliveries crews accomplished when not deployed, and the lower right pattern is the same for instructors. In all cases the circle represents the maximum limit of USAF hit criteria. Each of the 100 dots represents a bomb dropped by a particular class of crew members (either instructors or non-instructors) who have dropped a given number of bombs. For example, suppose there are 100 non-instructors in a squadron. Further assume none of them has dropped any practice bombs in the past 30 days. If we send all of them to the bombing range, and have each drop one bomb we would see a dispersion pattern similar to the pattern in the upper left of each figure.<sup>16</sup> For visual bombs the axes extend to + or - 100 meters, for radar bombs they extend + or - 300 meters.

In all cases, for both instructors and non-instructors, practice deliveries decrease the average miss distance - drawing the impact patterns closer to the center of the circle and decreasing the fraction of bombs that fall outside the hit limit. It is worth noting the F-16C non-instructor impact pattern is mostly outside the USAF hit criteria for pilots with no practice in the past 30 days.

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<sup>16</sup> Note: These figures assume regression error terms for average bomb miss distance are normally distributed. The distribution of error terms for all three regressions were examined using QQ plots to confirm this assumption. In each case the error term distributions closely approximated the normal distribution.

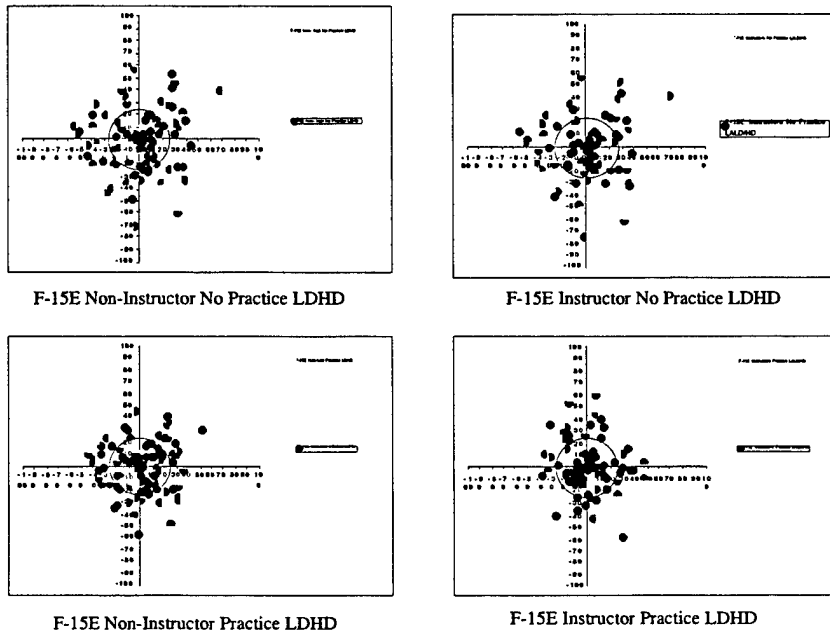


Figure 5.15 - Graphic Depiction of F-15E Low Level LALDHD Bomb Accuracy

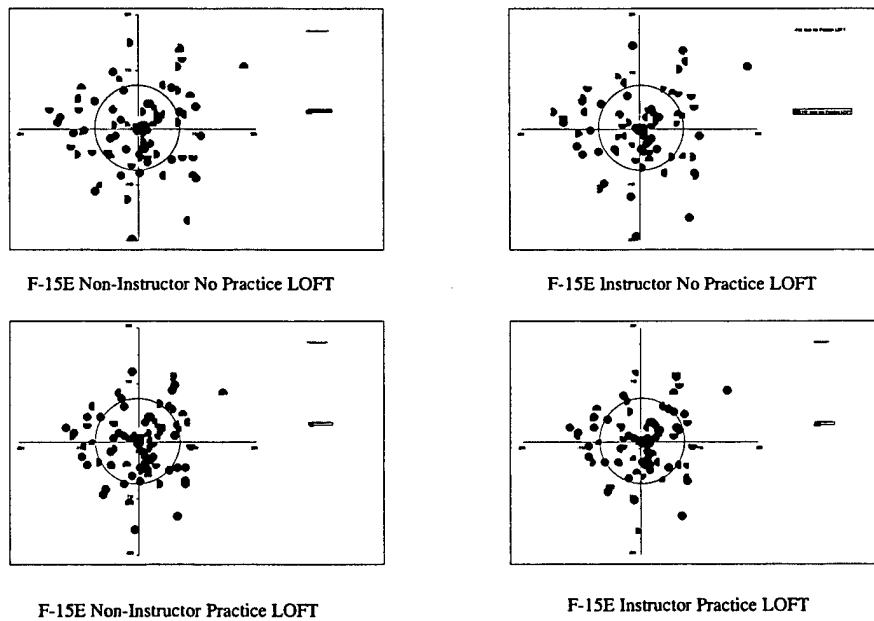


Figure 5.16 - Graphic Depiction of F-15E Low Level LOFT Bomb Accuracy

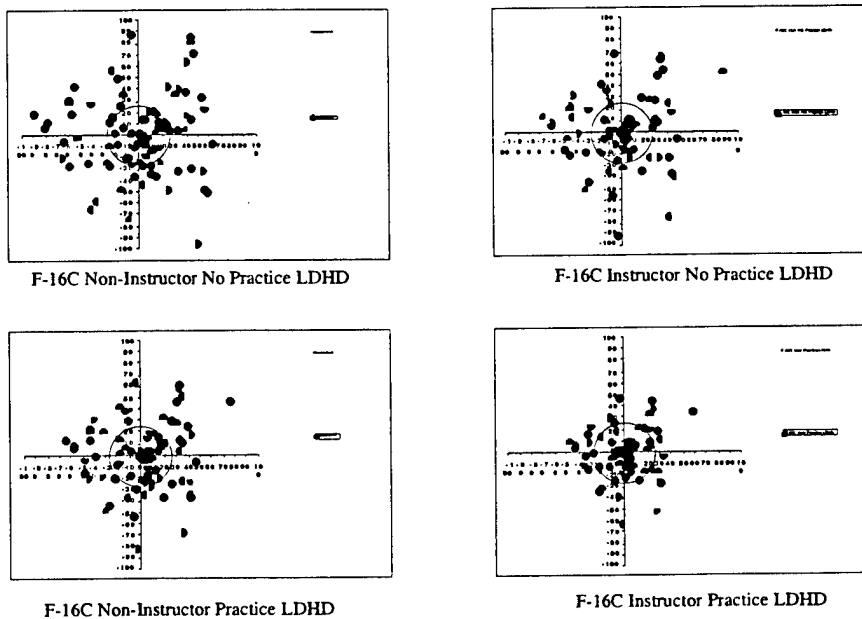


**Figure 5.17 - Graphic Depiction of F-16C Low Level LALDHD Bomb Accuracy**

#### **F-16C MEDIUM ALTITUDE LASER GUIDED BOMB DELIVERIES**

Before closing this discussion of the relationship between experience, practice and bombing accuracy it is important to examine what happens to the ability of USAF aircrew to deliver precision guided munitions from medium altitude as a result of deployments in support of peace operations. While delivering laser guided bombs (LGBs) from medium altitude is not a skill F-15E or F-16C crews are likely to be called upon to use during the opening engagement phase of a MTW, the ability to accurately deliver LGBs is important during the later exploitation phase of a MTW. In addition, these skills may also be useful in enforcing the no-drive zone portion of peace operation missions or other contingency operations.

Figure 5.16 below illustrates a typical medium altitude LGB delivery. To accomplish this type of bomb delivery the pilot (or in the case of the F-15E the WSO) of the aircraft usually uses the aircraft's radar or computerized navigation systems to roughly identify a target's

location and slew the aircraft's imaging infrared targeting pod sensor to the approximate target location. The operator then uses a joystick to center the sensor's crosshairs on the target. When the aircraft's computer systems confirm the target is close enough for the LGB to reach it the operator drops the LGB. Once clear of the aircraft the LGB is guided by invisible coded laser signals transmitted by the aircraft's targeting pod and reflected from the target. A small computer takes inputs from the sensor that detects the reflected laser signals and transmits steering commands to guidance fins mounted on the nose of the bomb. The bomb continues steering itself toward the target until impact.

## Medium Altitude LGB Deliveries

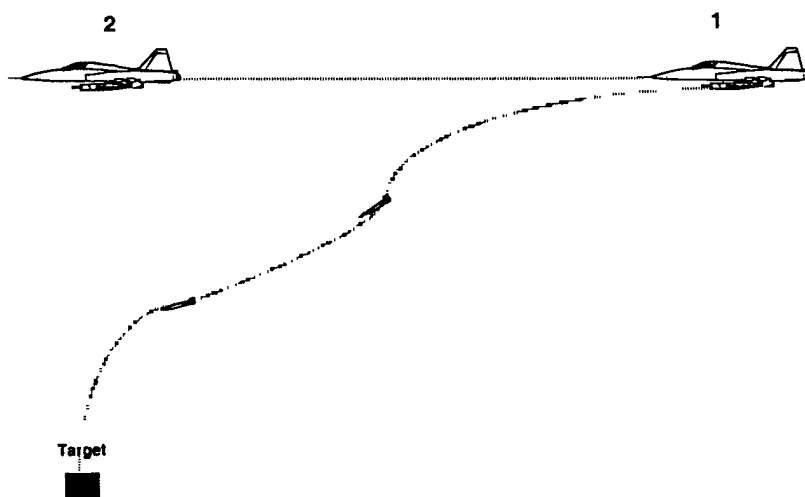


**Figure 5.16 - Typical Medium Altitude LGB Delivery**

If the crosshairs of the targeting system remain centered on the target, the bomb was within range when it was dropped, the laser is activated at the proper time and functions properly, and the bomb's guidance system works as advertised a hit is almost assured. This guidance system allows crews to train without actually dropping

practice, or live, ordinance. All elements of the system and relevant operator skills, can be assessed by viewing video tapes of the targeting pod images and accompanying displays after the mission with the exception of the functioning of the bombs guidance system. So, if post mission review indicates the crosshairs were on the target, simulated bomb release was within range, and the laser activated, then the operator has done all that could be expected in an actual delivery, and the simulated attack can be graded a hit. If, however, the operator makes some sort of error in identifying or tracking the target, or in dropping the bomb or activating the laser, the simulated attack is graded a miss.

Beginning on October 1, 1997 the 4<sup>th</sup> Fighter Squadron began keeping detailed records on all simulated LGB attacks by its pilots. Between October 1, 1997 and February 28 1998 pilots of the 4<sup>th</sup> Fighter Squadron accomplished 465 simulated medium altitude LGB attacks. In contrast to low altitude LALD/HD, they were able to continue to train for these types of attacks even while deployed to Saudi Arabia during December 1997 and January 1998 because they could accomplish this training while flying missions in support of the Operation Southern Watch no-fly zone. This was possible because pilots could lock their targeting pods onto convenient objects and structures inside the no-fly zone and practice simulated LGB deliveries while on patrol. There was no statistically significant difference in the number of simulated attacks pilots conducted per month while deployed to Saudi Arabia and the number conducted when at home station. Table 5.6 below shows how much more consistent LGB training was than LALD/HD training for the same pilots over the same time period.

Table 5.6 illustrates how much more consistent LGB practice was than LALD/HD for the 4<sup>th</sup> Fighter Squadron throughout this period. On average pilots time between practice LGB deliveries was only one quarter that of LALD/HD deliveries. In addition, the variation about the LGB mean was much less than that around the LALD/HD mean. Pilots went a week or less between practice LGB deliveries 50 percent of the time, two weeks or less 75 percent of the time and, as the table shows, dropped a practice LGB every four weeks or less 90 percent of the time. For

LALD/HD practice comparable figures are 20 days, 68 days and 110 days, respectively.

| Delivery | Mean | Standard Deviation | 90 percent < |
|----------|------|--------------------|--------------|
| LGB      | 10.9 | 11.4               | 28           |
| LALD/HD  | 41.1 | 45.1               | 110          |

**Table 5.6 - Mean, Standard Deviation, and 90<sup>th</sup> Percentile Days Between F-16C LGB and LALD/HD Practice Deliveries October 1997 Through February 1998**

The average frequency and consistency of practice with LGB deliveries make it impossible to detect a practice effect with the available data.<sup>17</sup> This is probably because very few pilots went long enough between deliveries for their proficiency to decline to the point where a detectable decrease in their hit probability occurred. It might be possible to determine this relationship with a much larger data set - one containing several thousand practice LGB deliveries - but the 465 observations available do not have sufficient statistical power to detect the very small differences in proficiency that result from the relatively small variation in practice frequency.

However, just as with the low altitude bombing skills, there was a large difference in the hit probabilities of instructor and non-instructor pilots.<sup>18</sup> On average, instructors were assessed to have hit their targets in 87.5 percent of the 136 simulated LGB attacks they accomplished. In contrast, non-instructors were judged to have hit in only 79.3 percent of their 329 simulated LGB deliveries. This difference is statistically significant<sup>19</sup>, and reinforces the advantage

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<sup>17</sup> Here, again, a wide variety of model specifications were evaluated including linear, log and other non-linear transformations of the practice variables. None produced significant coefficients for the practice terms.

<sup>18</sup> As in the low altitude analysis other measures of experience such as the number of hours a pilot had flying fighters, total flying hours, instructor hours, etc (and various transformations of them) were also evaluated. None performed as well in explaining the hit probability difference as instructor status.

<sup>19</sup> Pearson chi-squared test with 1 degree of freedom equals 4.2982 (p=0.038).

superior talent, training and experience gives instructors as a group where air-to-ground munitions delivery skills are concerned.

#### **SUMMARY**

This chapter has presented a short description of two different types of low altitude bomb deliveries. In addition, it has described the data on bomb delivery practice, accuracy and pertinent pilot characteristics collected from an F-15E squadron from the 4<sup>th</sup> Fighter Wing and an F-16C squadron from the 388<sup>th</sup> Fighter Wing. It summarizes the extensive statistical analysis carried out to investigate the relationship between various measures of experience, recent practice and bomb delivery accuracy (and by extension other combat skills important during the opening phase of a MTW). It also presents an analysis of F-16C medium altitude LGB deliveries. The most important results of this analysis can be summarized as follows:

- Instructor status is a significant and powerful predictor of bomb hit probability for a variety of precision and non-precision bomb deliveries
- Measures of recent practice, while not always as statistically significant, are good predictors of low level bombing accuracy and hit probability.
- Practice is especially important in maintaining the combat effectiveness of non-instructors as measured by low altitude bombing accuracy.
- Lack of practice during peace operations deployments has a dramatic negative impact on individual, and overall squadron, bomb accuracy and probability of hit.<sup>20</sup>
- The probability a squadron will miss assigned low level targets increases by at least 20 to 25 percent during peace operations deployments.
- Accuracy returns rapidly once normal training resumes.

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<sup>20</sup> The same sort of erosion in MTW combat skill proficiency could result from Air Expeditionary Force (AEF) deployments to various crisis spots around the world if crews are not afforded the opportunity to practice tactical skills.

- Unlike low level bombing accuracy, medium altitude LGB hit probability does not seem to be negatively effected by peace operations deployments.

The next chapter will present an analysis of data on valid and invalid simulated air-to-air missile shots from the 4<sup>th</sup> Fighter Squadron to investigate the relationships between pilot experience, practice and air-to-air combat skill proficiency.

## 6. AIR-TO-AIR COMBAT SKILLS

This chapter presents an analysis of 137 simulated air-to-air missile launches accomplished during air-to-air combat training missions by F-16C pilots from the 4<sup>th</sup> Fighter Squadron between October 1 1997 and February 28 1998. Throughout this discussion it is important to remember that air-to-air combat is one of the most cognitively and physically demanding tasks fighter pilots engage in. It demands that a pilot deftly manipulate small switches on his control stick and throttles to control radar and weapon systems while keeping track of, and responding to, opponent(s) and friendly aircraft maneuvers in a rapidly changing three dimensional environment. He or she must do this while often flying his or her aircraft at the very limits of its turning performance and straining virtually all of his or her major muscles to prevent loss of consciousness resulting from extreme g-forces. It has been likened to simultaneously playing the piccolo, driving a formula-one race car, and bench pressing 200 pounds. In addition, previous work in this area, as described in Chapter Four, supports prevailing fighter pilot intuition that air-to-air combat skills are among the most perishable fighter crew combat skills, making recent practice an important factor no matter how experienced a pilot might be.

It would be difficult to quantify all of the dimensions of such a demanding activity even if separate measures of the physical, psychological, and tactical skills involved were available. Unfortunately, the very nature of the air-to-air combat environment almost guarantees that any easily collected and quantified measure of performance in this area will be, to an even greater degree than the average bomb miss distances used previously as proxy measures for air-to-ground combat skill performance, only a rough proxy for the wide range of skills involved in air-to-air combat. In addition, fighter squadrons do not routinely collect and retain data on multiple measures of air-to-air combat performance. In fact, the best data set available consists of data on the 137 simulated air-to-air missile launches mentioned above.

## **DATA DESCRIPTION**

The data available for analysis consisted of the same information on crew qualifications and experience that were presented in table 5.1. In addition, video tapes of aircraft heads up display (HUD) symbology and images were used to assess whether a simulated air-to-air missile launch during an air-to-air combat training sortie was within established launch parameters. The range, relative velocities, aspects, altitudes and maneuvers of the launching and target aircraft at the moment a simulated missile is launched are assessed to determine if it could have guided on and reached its intended target - or, in other words, if the missile shot was valid.

As previously mentioned the data set used here contains information on 137 simulated air-to-air missile shots made by pilots of the 4<sup>th</sup> Fighter Squadron between October 1, 1997 and February 28, 1998. Nineteen of the 137 shots ( 13.8 percent) were judged to be invalid. It was extensively analyzed to investigate what, if any, relationships exist between a number of pilot experience and recent practice variables, and air-to-air missile shot validity.

## **STATISTICAL ANALYSIS AND RESULTS**

A variety of model specifications were investigated and various transformations of the available pilot qualification and practice variables were evaluated. The structure of this data set is slightly different than that of the bomb data evaluated in Chapter Five. Unlike most of the bomb data, it includes the date each simulated missile shot occurred. Therefore, it was possible to determine, for any given shot, how many days it had been since the pilot had launched his last simulated missile. A number of statistical models were evaluated using various combinations of pilot qualification and experience variables and transformations of the days since last shot variable. The median time between missile shots was just 13 days. However, pilots went 50 days between shots more than 25 percent of the time, and ten percent of the shots were taken after a lapse in practice of 115 days or more. The considerable variation in time between shots is due to the squadron's deployment to Saudi Arabia during December 1997 and January 1998 in

support of ongoing peace operations. No simulated air-to-air combat training was conducted during the deployment.

Unlike the air-to-ground combat skill analysis presented in Chapter Five, there was no evidence of a statistically significant difference between the performance of instructors and non-instructors in firing valid simulated air-to-air missile shots.<sup>1</sup> However, logistic regression analysis did reveal a significant positive relationship between the log of the numbers of days since the last practice shot and the probability of an invalid shot.<sup>2</sup>

To further clarify the relationship between practice and the probability a pilot executes an invalid simulated air-to-air missile shot, data from all pilots were combined into four groups. The groups each contain data on 27 to 43 simulated air-to-air missile shots. Shots were grouped based on the number of days since the pilot's last simulated air-to-air missile shot. The groups included shots taken between one and three days after the last shot, shots taken four to ten days after the last shot, shots taken 11 to 30 days after the last shot, and shots taken 30 to 120 days after the last shot. Grouping the shots this way reveals just how strong the relationship between the probability of launching an invalid simulated air-to-air missile shot and the number of days since the last shot is. Figure 6.1 below reveals that only one of 27 simulated missile shots (3.7 percent) taken between one and three days were invalid. Three of 28 shots (10.7 percent) taken between 4 and 10 days were invalid. Seven of 43 shots (16.28 percent) of shots taken between 11 and 30 days were invalid. Finally, eight of 37 shots (21.6 percent) taken between 31 and 120 days were invalid.

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<sup>1</sup> See implications section below for a discussion of this somewhat counter-intuitive finding.

<sup>2</sup> Logistic regression is a standard statistical analysis used when the dependent variable - in this case whether a simulated missile shot is valid or invalid - is binary. The model yielded a odds ratio of 1.42, z-statistic of 1.96 and p-value of exactly 0.050.

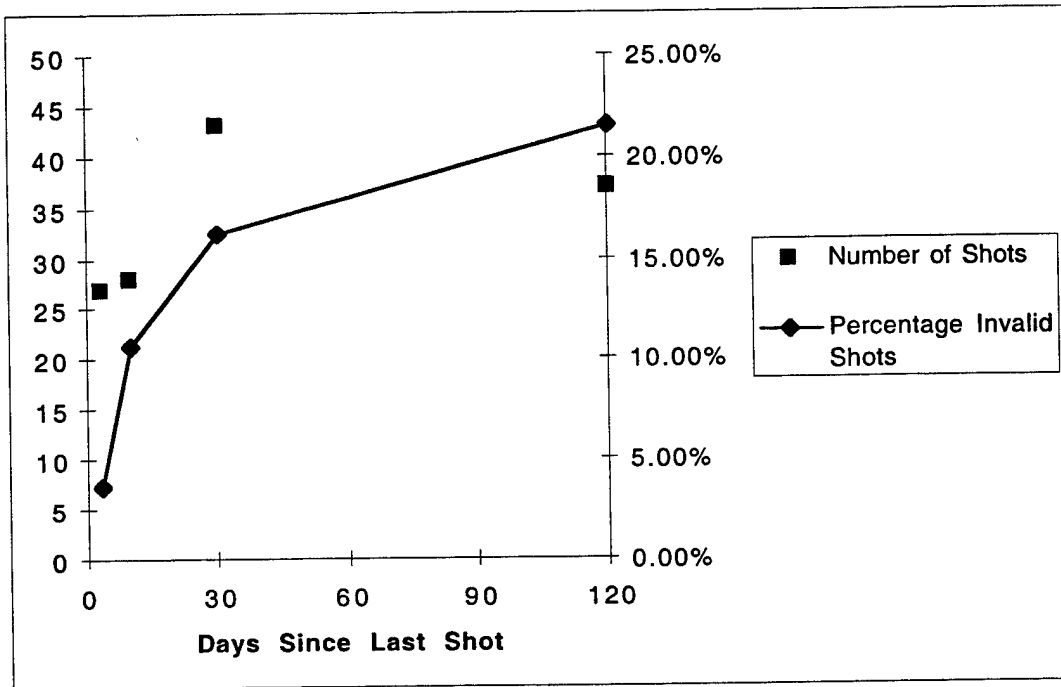


Figure 6.1 - Graph of Air-to-air Missile Shot Groups Showing Number of Shots and Percentage of Invalid Shots in Each Group

Further analysis of these grouped shots reveals a very strong logarithmic relationship between the probability a pilot launches an out of parameters simulated air-to-air missile shot and the number of days since he last exercised his air-to-air combat skills. Figure 6.2 below plots a curve based on this logarithmic relationship against the actual probabilities of invalid shots first presented in figure 6.1.

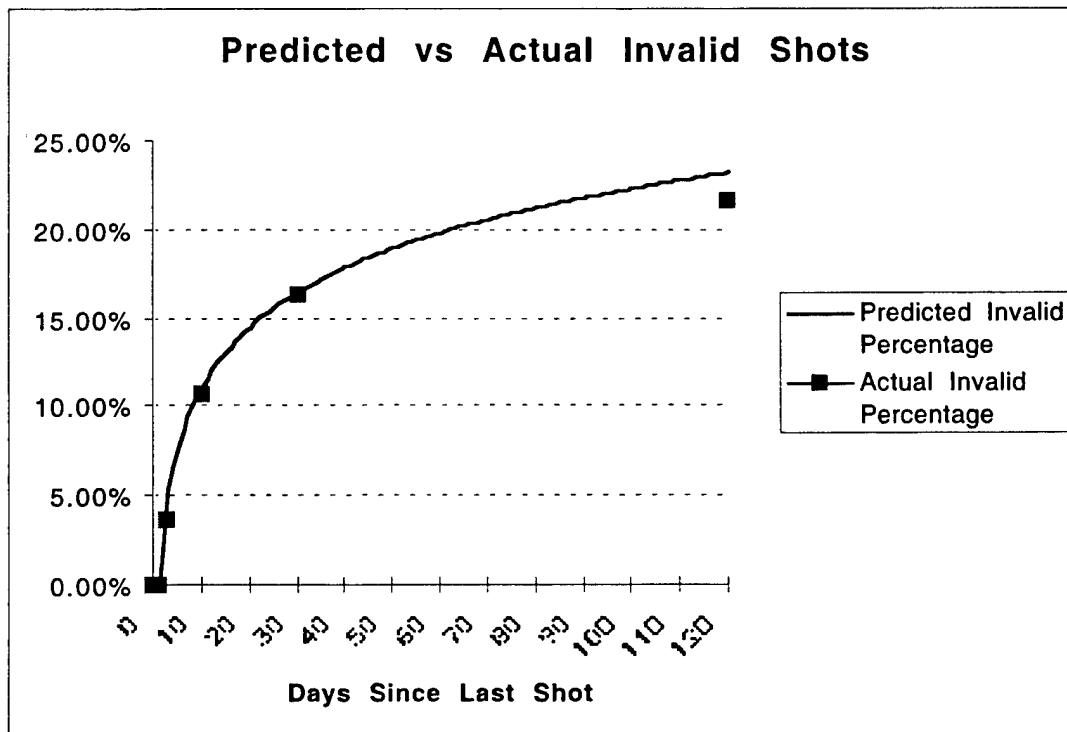


Figure 6.2 - Predicted vs Actual Invalid Air-to-air Missile Shots Based on Days Since Last Shot

#### IMPLICATIONS

What does this analysis reveal about air-to-air combat skills? First, it supports fighter pilot intuition<sup>3</sup>, and findings of the Osborn and Hammon and Horowitz studies that air-to-air combat skill performance is much more dependent on frequent, regular practice than on experience when compared with air-to-ground combat skills. Both the lack of any statistically significant evidence that experience or instructor status has an impact on the likelihood of invalid simulated missile shots and

<sup>3</sup> RAND colleague, and former USAF F-4E squadron commander, Bill Taylor and Col Thomas "Snake" Donaldson, current ACC/DOT commented that this counter-intuitive conclusion makes perfect sense to them. They explained that long after they were experienced they have been soundly trounced in air-to-air combat training after significant lapses in training by much less experienced crews with lots of recent practice. Conversely, they both pointed out that experienced crews with little recent practice could go to the bombing range with little recent practice without fear of embarrassing themselves.

the rapid increase in the probability of launching an invalid shot as time passes since the last practice support this conclusion. However, it is important to note that with a larger sample of simulated air-to-air missile shots it is possible a difference in invalid shot probability in favor of instructors might emerge, and that experience is an essential prerequisite for successfully leading and employing formations of two or more aircraft in air-to-air combat.

Second, the analysis sheds some light on the impact of peace operations on air-to-air combat skills. On average, before deploying to Saudi Arabia 4<sup>th</sup> Fighter Squadron pilots went, on average, nine days between simulated air-to-air missile shots. This analysis indicates pilots who practice air-to-air combat once every nine days have about a ten percent chance of launching an invalid missile shot. None of the 4<sup>th</sup> Fighter Squadron pilots who deployed to Saudi Arabia logged a simulated air-to-air missile shot during the deployment. On average, by the end of the deployment these pilots had gone about 70 days without air-to-air combat practice. During this time their chances of launching an out of parameters missile doubled to over 20 percent.

Third, the implications of an increased probability of launching an invalid air-to-air missile shot probably go beyond the mere wasting of an expensive piece of ordinance. The decision to launch an air-to-air missile is one of the most important decisions a pilot makes during an air-to-air engagement. Mistaken missile launches are almost certainly associated with lower performance in other important air combat skills such as radar searches, tactics, formation integrity, visual lookout, and g-tolerance to name a few. In addition, launching a missile out of parameters indicates a pilot has either fundamentally misjudged the relative position of his or her aircraft and the target, misread information on the HUD, thrown the wrong switches, or otherwise misunderstood or mishandled the situation. In short it demonstrates a lack of what fighter pilots refer to as "situation awareness". This is a most important aspect of air combat. The pilot, or group of pilots, who maintains the best understanding of where friends and foes are relative to their own position during the confusing, time compressed air combat engagement will most likely emerge the victor.

Fourth, air superiority missions, just like ground attack missions, require successful completion of a long string of important tasks. To the extent that valid air-to-air missile shot rates are positively correlated with radar searches and sorts, tactics, formation integrity, visual lookout, etc the overall probability USAF crews will successfully complete air superiority missions declines much more than an examination of the decline in valid missile shot rate during peace operations deployments indicates. Therefore, if a major war broke out, pilots who had recently engaged in peace operations deployments would be less prepared to achieve air superiority than their counterparts were during Operation Desert Storm. Obviously, this could lead to more air-to-air combat losses, an increase in the length of time required for US and allied forces to achieve air superiority, or both. It is even possible that decreased air-to-air combat effectiveness could allow a clever and bold adversary to employ fighters to disrupt USAF offensive operations for a considerable period of time as the North Vietnamese did during Operations Rolling Thunder, Linebacker I and Linebacker II.<sup>4</sup>

Finally, throughout the history of air warfare the side that consistently fielded the superior fighting force has been able to inflict unacceptable losses on its adversaries and eventually achieve air superiority. A fighting force can be described according to the number of personnel and weapons it possesses, the quality of its equipment and the skill of its personnel. This last aspect - operator skill - has been especially important in air-to-air combat.

At the beginning of 1944 the US 8<sup>th</sup> Air Force and the German Luftwaffe had approximately the same number of single engine fighters

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<sup>4</sup> North Vietnamese MiGs remained a threat to USAF operations throughout the entire air campaign against North Vietnam. In addition to damaging and shooting down literally hundreds of USAF fighters, they forced thousands of strike aircraft to jettison their bombs in order to maneuver to survive MiG attacks, and forced strike formations to adopt tactics, formations and other measures that dramatically reduced the effectiveness of USAF operations. See Marshall L. Michel III, Clashes: Air Combat over North Vietnam 1965-1972, Naval Institute Press, Annapolis MD, 1997 for a detailed analysis of the impact of MiG attacks on USAF strike packages during the Vietnam War.

engaged in the struggle for air superiority over occupied Europe.<sup>5</sup> The quality of the opposing aircraft was approximately equal in terms of combat performance.<sup>6</sup> By June of 1944 the Luftwaffe fighter forces had suffered 2262 fighter pilot losses from an average fighter pilot strength of 2283 - a staggering 99 percent attrition rate over a six month time period with monthly pilot loss rates averaging over 16 percent.<sup>7</sup> This was achieved with a loss of only about 250 US fighters in air-to-air combat for an exchange ratio of 9.1:1.<sup>8</sup> This superior performance of US fighters against German adversaries with similar equipment is generally attributed to the large, and as time went on, increasing gap in basic and operational training the American fighter pilots enjoyed. Overoptimistic German assumptions of quick victory in 1942 and early 1943 resulted in a bottleneck in pilot training capacity. The over tasked flying schools attempted to meet increasing demands for fighter pilots as the combined allied bomber offensive progressed by decreasing the length (and therefore the quantity and quality) of student training. Less skilled pilots lead to higher combat losses which further increased the pressure on the training schools to churn out ever larger numbers of progressively less skilled pilots resulting

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<sup>5</sup> Williamson Murray, Luftwaffe, The Nautical & Aviation Publishing Company of America, Baltimore, MD pp. 224-227.

<sup>6</sup> While not wishing to join the long, and ongoing, debate over which aircraft was the best fighter of World War Two, it is important to acknowledge that the three US fighter types involved - the P-38, P-47 and P-51 - achieved this essential equality in combat performance (a function of speed, ceiling, maneuverability) combined with combat radii previously attainable only by much larger bomber aircraft. The large combat radii were part and parcel of their primary bomber escort mission, but came at the expense of firepower. Their German opponents - principally late model Me-109 and FW-190 fighters - did not have the same range (and generally did not need it as they were operating over their home territory) but carried much heavier armament. The German fighters carried multiple 20mm and 30mm cannon designed to blast heavy bombers out of their tight formations. These weapons had much greater range and hitting power than the smaller 0.50 inch (12.7mm) machine guns that were the mainstay of the American fighters' armament.

<sup>7</sup> Murray, . 228.

<sup>8</sup> Statistical Summary of Eighth Air Force Operations, European Theater, 17 August 1942 - 8 May 1945, p. 29, p. 61.

in a catastrophic downward spiral in pilot quality.<sup>9</sup> By early 1944 US fighter pilots had, on average twice as much flight training as their German counterparts and over three times as much training in air-to-air combat and other operational skills.<sup>10</sup>

US Air Force pilot skill was again a key factor in the success of F-86 equipped fighter squadrons against less well trained communist MiG-15 pilots over "MiG Alley" in northwestern Korea from 1950-1953. During this conflict USAF F-86 pilots shot down 792 MiG-15s in air-to-air combat while losing only 78 F-86s for a kill ratio of 10.15:1.<sup>11</sup> Here again both sides possessed aircraft with remarkably similar performance. It was the superior training and experience - many USAF fighter pilots in Korea were veterans of World War II - that made the difference.

The importance of quality training in air-to-air combat was demonstrated by the US experience in Vietnam and Israeli experience in the Middle East. The dramatic increase in the Navy's MiG kill ratio after it adopted its "Top Gun" training program during the Vietnam war (discussed previously in Chapter 2) provides additional evidence of the importance of training in air-to-air combat. Israeli Air Force leaders attribute the resounding success of their pilots in air-to-air combat in the 1973 Yom Kippur War where they achieved a 50:1 kill ratio largely to "their own razor sharp pilot training that never stops."<sup>12</sup> Israeli pilots expressed similar sentiments again after the air battles against Syrian pilots over Lebanon in 1982 where they achieved a 85:1 kill

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<sup>9</sup> The next section on the long term impact of peace operations on describes how peace operations could be contributing to a similar downward spiral in overall USAF fighter crew quality.

<sup>10</sup> Murray p. 240, 262. See also Wesley Craven, ed., et al. The Army Air Forces in World War II: Volume III, University of Chicago Press, 1951, p. 62-63 for more details on how the Luftwaffe pilot quality problem led to defeat in the battle for air superiority over Europe in early 1944.

<sup>11</sup> Robert F. Futrell, The United States Air Force in Korea, Office of Air Force History, Washington DC, 1983, p. 695.

<sup>12</sup> Robert Holtz, "Israeli Air Force Faces New Arab Arms," Aviation Week & Space Technology, 10 March 1975, p. 16. Quoted by Peter deLeon, The Peacetime Evaluation of the Pilot Skill Factor in Air-to-air Combat, RAND, Santa Monica, 1977, p. 12.

ratio.<sup>13</sup> While it might be argued the Israelis had the advantage of superior equipment, a senior Israeli Air Force officer pointed out "They (the Syrians) could have flown the best fighter in the world, but if they flew it the way they were flying, we would have shot them down in exactly the same way. It wasn't the equipment at fault, but their tactics"<sup>14</sup> In short, the type, quantity and timeliness of air combat training pilots receive is a critical factor in air-to-air combat.

The analysis presented so far in this chapter shows the long lapse in air-to-air combat training associated with peace operations deployments increases the probability USAF pilots will launch air-to-air missiles outside parameters - decreasing their combat effectiveness and their ability to enforce the no-fly zones they patrol while deployed. In addition, they probably decrease pilot situation awareness during air combat engagements and negatively impact other important air combat skills such as radar search and sort skills, tactics, formation, etc. As with air-to-ground mission profiles, the cumulative effect of decreased proficiency across a broad range of air-to-air combat skills almost certainly has a much larger impact on the ability of crews to successfully accomplish MTW air superiority missions than the increase in proportion of invalid missile shots alone would indicate. These factors increase the probability pilots and aircraft will be lost in the event no-fly zone patrols are challenged. In addition, in combination with historical experience this analysis indicates that the ability of USAF fighter pilots to rapidly achieve and maintain air superiority during a MTW without suffering excessive losses could be substantially decreased for pilots with little or no recent air-to-air combat training.

#### **POSSIBLE LONG TERM IMPACT OF PEACE OPERATIONS DEPLOYMENTS ON USAF COMBAT CAPABILITY**

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<sup>13</sup> Benjamin S. Lambeth, Moscow's Lessons from the 1982 Lebanon Air War, RAND, Santa Monica, 1984, p. 9.

<sup>14</sup> "Beka'a Valley Combat," *Flight International*, October 16, 1982, p. 1109. Quoted by Lambeth IBID, p. 9.

Up to this point this discussion of reduced USAF fighter crew combat effectiveness has focused on quantitatively measurable variables that indicate considerable short term decreases in the average ability of USAF fighter squadrons to conduct MTW air-to-air and air-to-ground combat missions as a result of peace operations deployments. However, the long family separations and breaks in tactical training associated with peace operations deployments impact the long run combat effectiveness of USAF fighter squadrons in two related ways.

First, there are a large number of anecdotal accounts, supported by exit interviews and surveys, that the long family separations, the poorly articulated rationale for peace operations and the booming civilian job market are contributing to unsustainably low retention rates among USAF fighter crews as well as maintenance and support personnel. The following quote from a recent article by a retired USAF Lieutenant General summarizes this concern well:

Critical-skill personnel aren't leaving just for the money, although that is a factor. They are leaving because they can't justify to their families the need for being away from home half the year when US interests really aren't at stake. And, just as importantly, they can't justify to themselves not being the best.

We don't train like we used to. We used to be a cohesive fighting force, serving with unlimited liability to protect and defend the United States," a pilot said. "We were called to the profession of arms. The 'Evil Empire' was the focus of our training and we had a clear understanding of what constituted the United States' vital interests. Those times are gone, and we're tired of droning holes in the sky; protecting allied airspace where we're not welcome. They shackle us in the air, on the ground and during our time off.<sup>15</sup>

The same article points out that so far this year only ten percent of USAF pilots has accepted a six-year commitment beyond the initial obligation required for pilot training despite the increased \$110,000 bonus package. This is expected to lead to a shortfall of between 1500

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<sup>15</sup> Harley Hughes, *Bailing Out: Air Force Retention is in a Tailspin, and the Worst is Yet to Come*, Armed Forces Journal International, September 1998, p. 45.

and 1700 experienced pilots by the end of FY 98. Future prospects for addressing the shortfall are not promising.<sup>16</sup>

The pilot quoted above alludes to the second way peace operations deployments impact long term USAF combat readiness when he mentions training. Both this chapter and Chapter Five show that the training value of no-fly zone sorties is essentially zero for many important MTW combat skills. While the proficiency lost during the deployments may return in a matter of a few weeks or months once normal training resumes at home, the weeks or months of tactical training opportunities lost during the deployment can not be recovered. This results in slower "tactical seasoning" of USAF fighter crews and is already causing problems for squadron leadership, and over the long run may result in a significant decrease in USAF combat effectiveness.<sup>17</sup>

The following example provided by the operations officer of an F-15C squadron from the 1<sup>st</sup> Fighter Wing at Langley AFB, VA illustrates this problem. During an interview in late 1997 he explained that by the end of their first operational tour in the F-15C, pilots today have only flown about half as many tactical training missions as their counterparts from seven to ten years ago. There are two main reasons for this.

First, the average length of a pilot's initial operational tour has decreased from about four years during the late 1980s and early 1990s to about two years eight months today. There are a number of reasons for this including the need to bring "banked" pilots into operational units and requirements for experienced fighter pilots to serve as instructors at Undergraduate Pilot Training (UPT) bases.

Second, the training value of these shorter tours is diluted by several lengthy deployments in support of no-fly zone operations. The typical 1<sup>st</sup> Fighter Wing pilot now spends about nine months of their average thirty-two month initial operational tour flying circles over

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<sup>16</sup> IBID, p. 42.

<sup>17</sup> Note: The idea that peace operations deployments result in slower tactical seasoning of USAF fighter crews is consistent with psychological research discussed in Chapter 3 that emphasized the importance of deliberate practice, rather than general exposure, in producing expert performance in a variety of mental and physical tasks.

Iraq. As a result, they have only about one year eleven months of high quality tactical training sorties at the end of their first assignment. So, while the typical pilot seven to ten years ago went off to his second assignment as a 4-ship flight lead or even an instructor pilot, his counterpart today usually leaves the 1<sup>st</sup> Fighter Wing as a brand new 2-ship flight lead. The bottom line is that current USAF fighter pilots who participate in peace operations deployments have not experienced as much high quality tactical training at a given point in their career, as measured by total fighter hours, as their counterparts seven to ten years ago had.

This situation leaves USAF leaders a stark choice. They can upgrade current pilots to four ship flight leads or instructors at the same point in their careers as pilots a decade ago - and accept the de facto reduction in standards this implies. Alternatively, they can delay upgrading current pilots until their actual tactical experience approximates that of "Cold War" pilots upgrading to the same qualification.

The first option carries with it the prospect that future instructors and flight leads will be less expert than those of the past, with negative consequences of unknown magnitude for future students and wingmen. This option could well lead to a downward spiral as these less well trained students and wingmen become even less proficient flight leads and instructors, and so on. The F-15C community is not alone in facing this problem. This first approach is essentially the approach adopted by the F-15E community toward its RTU instructors. Interviews with senior instructors and training managers at the 4<sup>th</sup> Fighter Wing indicate that the even though standards for becoming a RTU instructor are the same as in years past the actual experience and capability of crews returning from their first operational assignments to upgrade as instructors are markedly below those of the past.

The second option - delaying upgrades until current crews have experience levels equivalent to that of Cold War crews - has the advantage of maintaining historic standards, but is also problematic. Since crews typically spend up to a quarter of each year, or more, deployed in support of peace operations opting to wait for equal

"tactical seasoning" means increasing the total time required to produce an instructor or flight lead by 25 percent or more. With so many USAF personnel opting to leave at the end of their initial commitment, an increase in the average time to upgrade means an eventual decline in the number of instructors, four ship flight leads, mission commanders and other specially qualified crews available to each squadron. This could, for example, result in a shortage of four ship flight leads - forcing USAF leaders to employ their fighters as two ship elements. No one knows if, or how much, this will impact the combat effectiveness of USAF fighter units. However, it is disturbing that a de facto change in operational doctrine could be adopted by the USAF as a response to a creeping decline in overall pilot qualifications rather than as deliberate change founded on the belief that smaller elements operating independently are as (or more) effective as larger elements acting in concert. This is essentially the response adopted by the 1<sup>st</sup> Fighter Wing leadership, and some squadron commanders and operations officers are already beginning to see a looming shortage of four ship flight leads.

The long term impact of peace operations on USAF combat effectiveness is even more difficult to measure than the short term impact. However, it is clear that the impact will be negative. Just how much of a difference the combination of decreased retention and reduced training opportunities will make in qualitative aspects of air operations at the individual and formation level is impossible to predict with any degree of precision. The important point to keep in mind is that there are long term deleterious effects of peace operations on USAF combat readiness in addition to the short term effects described earlier. Any proposed solution to the peace operations readiness impact problem must address the short term skill loss and long term retention/readiness issues if it is to be truly effective.

#### **SUMMARY**

This chapter has presented an analysis of data on 137 simulated air-to-air missile shots taken by pilots from the 4<sup>th</sup> Fighter Squadron between October 1 1997 and February 28 1998. The analysis indicates

that practice is much more important to air-to-air combat skill proficiency than experience. In fact, there is no statistically significant evidence in the data examined here that experience has any impact at all on air-to-air combat skill performance. This is probably not strictly true. Experience may help to a certain extent. However, its impact is small relative to that of practice. In fact, it is so small that its effect was undetectable using standard statistical analysis and levels of significance in this particular data set. It is possible an experience effect could be found in a larger data set or in data from a different squadron.<sup>18</sup> In addition, the analysis shows that frequent practice is necessary to maintain proficiency in air-to-air combat skills. Lack of consistent practice during peace operations deployments results in a doubling of the probability that a pilot will launch an air-to-air missile out of parameters, and probably has a similar impact on other important air-to-air combat skills and overall situation awareness, and MTW combat effectiveness.

This chapter also presents more qualitative evidence that peace operations negatively impact the long term combat capability of USAF fighter crews and squadrons. This long term effect is the result of decreased retention and long-term reductions in training opportunities associated with peace operations deployments. Chapter Seven reviews the conclusions reached here and in Chapter Five. It then lays out and evaluates a variety of possible policy responses to the various USAF combat readiness costs posed by peace operations.

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<sup>18</sup> This last possibility is unlikely to the extent that USAF fighter pilots receive highly standardized training, are the products of a rigorous selection process, and are assigned (more or less) at random to operational squadrons. These factors tend to diminish differences between USAF fighter squadrons and therefore decrease the chances that a study of other USAF squadrons would produce results significantly different from the results presented in this chapter and Chapter Five.

## 7. POLICY OPTIONS AND CONCLUSIONS

### THE READINESS IMPACT OF PEACE OPERATIONS

The preceding chapters have presented evidence showing that combat peace operations deployments degrade the combat readiness of USAF fighter crews in the following ways:

#### SHORT TERM IMPACT

- Proxy measures for important MTW air-to-ground and air-to-air combat skills show a rapid and marked decline during peace operations deployments.
- The probability of missing a target with a low level bomb delivery increases dramatically during deployments for non-instructors and for squadrons as a whole.
  - Probability of miss for F-15E visual and radar bomb deliveries increases, on average, by 20 to 25 percent.
  - Probability of miss for F-16C visual bomb deliveries increases, on average, by 25 percent.
- The probability of launching an invalid air-to-air missile shot during a peace operations deployments doubles compared to normal non-deployed training.
- Proficiency returns within a matter of weeks for both air-to-air and air-to-ground combat skills once normal training resumes.
- These skill losses are almost certainly associated with decreased proficiency in other important MTW combat skills, so the overall combat effectiveness of USAF fighter crews performing peace operations missions probably declines more, and perhaps much more, than these measures indicate.

#### LONG TERM IMPACT

- Anecdotal accounts, backed up by some exit survey evidence, suggest peace operations deployments are significant contributors to a

disturbing decline in average USAF fighter crew tactical experience levels. They contribute in two ways:

- First, the long family separations and lack of compelling rationale for personal sacrifice contribute to extremely low retention rates for experienced fighter pilots and WSOs.
- Second, the near zero tactical training value of the sorties significantly decreases the amount of tactical training crews accomplish over the long term - forcing the USAF leadership to choose between a shortage of instructors and flight leads brought on by increased upgrade times, or a de facto lowering of standards for these important positions.

Both the long term and short term impacts have two important aspects in common. First, they constitute important non-monetary costs associated with employing USAF fighter crews and squadrons to enforce no-fly zones and other peace operation missions. Second, these additional costs take considerable time, and a good deal of systematic study, to manifest themselves. In short, these costs - which may constitute the bulk of the overall burden peace operations impose on USAF fighter crews - do not show up as a budget line, and have emerged only slowly over time.

#### **POSSIBLE POLICY RESPONSES**

This section will address a number of possible policy responses to the detrimental impact of peace operations deployments on USAF fighter crew combat skills. It will briefly describe a number of possible political, programmatic and operational responses to this problem. Many of the possible solutions would require expenditure of diplomatic effort to reduce the military readiness costs of what were referred to as stability enhancing activities in Chapter 2. Others might require accepting slightly greater short term risks of regional instability in return for higher short term and long term USAF fighter crew combat readiness. Some of the proposed solutions could be implemented more or

less autonomously by the USAF, while others would require approval of senior US political leaders and cooperation of government agencies outside the Department of Defense (e.g. the State Department).

Figure 7.1 below is a decision tree illustrating possible options for mitigating the impact of peace operations deployments on USAF fighter crew combat skills. It is almost certainly not an exhaustive list of possible policy responses. Many readers may be able to think of other options. This is a good thing since this document is probably closer to the first word on this issue than the last. However, what the figure presents, and the discussion which follows amplifies, is a relatively wide range of policy responses to the readiness issues related to USAF fighter crew participation in peace operations. This section presents a brief discussion of the options presented in figure 7.1 - many largely within USAF control - that could be adopted to mitigate the effects of peace operations without changing the number of peace operations the USAF is committed to or the resources available to conduct them.

Options that would reduce the number of peace operations the USAF is committed to, or even if the USAF conducts peace operations at all, constitute the first two branches of the decision tree in figure 7.1. While the USAF may have some influence on whether one of these approached is adopted by national decision makers, the decision to abandon or severely curtail the scope of one or more of the three no-fly/no-drive zones USAF fighter forces are currently committed to is beyond the control of USAF leaders and the scope of this report.

This leaves us on the third, "Do Same" branch of the decision tree. If the USAF is going to continue to conduct the same number of no-fly zone peace operations in the future as it does today, then there are essentially two courses of action it can adopt. Senior USAF leaders can opt to continue to conduct operations as they have up to now and absorb the costs - decreased short term and long term MTW combat readiness. This is clearly an unattractive option. The alternative is to make

changes in the way the USAF fighter units conduct no-fly zone operations.<sup>1</sup>

There are essentially three broad categories of changes the USAF could make to reduce the negative combat readiness impact of peace operations on fighter crews and their units: alter the nature of the deployments, conduct more training while deployed, or alter the concepts of operation (CONOPS) used by USAF fighter forces to enforce no-fly zones.

#### Changes to Deployments

One of the most consistent findings of the analysis presented in Chapter Five is that instructors with no practice in the preceding month perform as well, or better than, non-instructors with normal practice at the bombing range. Therefore, one might believe it possible to reduce the combat readiness impact of peace operations deployments by sending all (or mostly) instructors to enforce no-fly zones. However, as explained in Chapter Five, instructors' bombing accuracy declines with lack of practice just as much as non-instructors' accuracy does, but

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<sup>1</sup> Note: The "no change" and "make changes" options exist on the "do less" branch of the decision tree discussed below as well. They are identical to the options presented in this section.

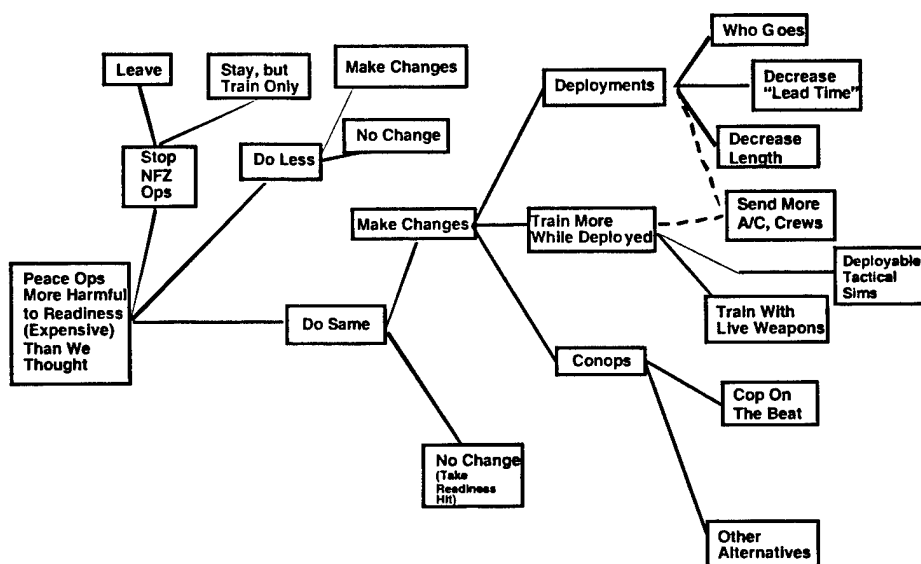


**Figure 7.1 - Decision Tree of Policy Options for Mitigating the Negative Impact of Peace Operations on USAF Fighter Crew Combat Skills**

without practice their accuracy still declines. To the extent that average bomb accuracy is an accurate reflection of other important MTW combat skills like threat reactions, low level navigation, etc. then, even for instructors, these skills - and overall combat effectiveness - will deteriorate with lack of practice

In addition, the analysis of air-to-air combat skills presented in Chapter Six found no evidence that instructors are more resistant to the deleterious effects of lack of practice on their air-to-air combat skills than are non-instructors. So, while sending only instructors on peace operations deployments would decrease the loss of some air-to-ground combat skills, it would not address the loss of air-to-air combat capability. Since instructors make up only about one third of any squadron, deploying only instructors would require USAF instructors to spend, on average, almost three times as much time deployed as they currently do if the intensity of operations is to be maintained.

Obviously, this would not help address the severe difficulties the USAF is experiencing in retaining these highly experienced and talented personnel. Finally, such a policy would leave the non-instructors back home with no one to oversee their systematic acquisition of higher levels of combat proficiency and qualifications. In short, sending only instructors to enforce no-fly zones is a poor policy choice for a variety of reasons.

Another possible way to decrease the impact of deployments on short term combat skill proficiency is to decrease the amount of time deploying squadrons stand down from training both before and after deployments. It was briefly noted earlier that squadrons typically stop flight training five to ten days prior to a deployment so that squadron personnel can take care of personal preparations and spend time with their families prior to a long absence. In addition, the stand down allows maintenance personnel to properly configure aircraft (by adding external fuel tanks, etc.) and fix outstanding maintenance discrepancies in preparation for the long deployment flight. Following a deployment to enforce a no-fly zone, squadrons usually allow personnel another period of time off to reconnect with their families, reorganize their work areas, etc. If these periods could be shortened, then the length of time crews go between meaningful tactical training events could obviously be reduced. One possible way to do this is to have deploying squadrons swap aircraft and equipment with those they are replacing to the maximum extent possible. This would eliminate the need to configure and deploy aircraft to and from the theater - shortening the down time at either end of a deployment. Two squadrons from the First Fighter Wing at adopted this option during the summer of 1998 when one replaced the other to support the no-fly zone over southern Iraq for these reasons. However, unless the squadrons involved are from the same home base, this option would require reshuffling aircraft between the deploying and returning squadron's bases.

There is probably a limit to how much these periods could be shortened and still allow necessary pre- and post-deployment activities to occur even if the USAF was willing to eliminate the opportunity for personnel to take care of legitimate personal and family preparations

and readjustments. So, the payoff in terms of decreased total time away from training is likely to be only on the order of five to ten days, and the cost of this option is, again, likely to be a further exacerbation of the family separation issue that has contributed to the current USAF retention problem.

Another possible option is to shorten peace operations deployments. The USAF has already adopted this option. Prior to 1997 typical peace operations deployments lasted about 90 days. Since then the USAF has made an effort to decrease average deployments to about 45 days. Of course, this means squadrons will have to make twice as many deployments in order to maintain a given USAF operational tempo in the no-fly zones over Iraq and Bosnia. It also means increased costs as squadrons move their people, aircraft and support equipment half way around the world twice as often as they used to. The reduced duration policy was adopted as a response to the family separation issue, not in an attempt to reduce short term combat skill loss, and it is unlikely that further realistic reductions in deployment length would make much of a difference in short term skill deterioration. This is because crews need to practice their MTW combat skills about once a week to maintain proficiency. It is unrealistic to expect the USAF to reduce average combined deployment, preparation and recovery time to less than two to three weeks. Therefore, further reductions in deployment duration are unlikely to make much of an impact on short term combat readiness. In addition, simply adopting more frequent, shorter deployments does nothing to address the long term combat readiness issues that stem from the fact that most USAF fighter crews spend between 25 and 30 percent of their flying hours "boring holes in the sky" instead of conducting intensive tactical training.

#### Train More While Deployed

Another possible course of action that could address the combat readiness costs associated with peace operations deployments is to make it possible for squadrons to conduct more intensive tactical training

during peace operations deployments. Currently deployed squadrons devote the vast majority of their sorties to no-fly zone enforcement. Crews fly very long sorties - averaging six to seven hours - three days a week while deployed to maintain a continuous presence in the no-fly zone areas.<sup>2</sup> Crews typically show up to plan and brief their missions two to three hours prior to take-off and remain for an hour or more after engine shut-down to debrief. So, simply flying a single no-fly zone sortie requires virtually an entire 12 hour crew duty day. Obviously, crews can not fly one mission to the no-fly zone and then accomplish a second training mission in the same day. Conversely, it is impossible to first plan, fly and debrief a training sortie and then fly a no-fly zone sortie in one day for the same reason. However, since the typical training sortie lasts less than two hours, crews can accomplish two, and sometimes three, high quality training sorties in a single 12 hour duty day.

The most obvious way to train more while deployed would be to decrease the number of no-fly zone enforcement sorties and increase the number of training sorties crews fly when deployed. Assuming the appropriate airspace, bombing ranges and low level training routes are available (and this is by no means certain) conducting substantial combat training during peace operations deployments would require a significant reallocation of sorties from no-fly zone enforcement to training. The analysis presented in Chapters Five and Six indicates that crews will probably need to fly practice missions on the order of once a week in order to maintain proficiency in a wide array of MTW combat skills. Since crews can not conduct both a training mission and a no-fly zone sortie on the same day, any crews conducting training will not be available to fly in support of the no-fly zones. The following example using data from the 71<sup>st</sup> Fighter Squadron's deployment to Saudi Arabia in the summer of 1997 illustrates the nature of tradeoff between

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<sup>2</sup> Data obtained from the 71<sup>st</sup> Fighter Squadron, 1<sup>st</sup> Fighter Wing (F-15Cs) indicate pilots flew about three no-fly zone sorties and about 0.70 training sorties per week, on average, during their 1997 deployment to Saudi Arabia in support of Operation Southern Watch.

no-fly zone and training sorties required to ensure a minimum on one training sortie per week per pilot.

Between July and September 1997 the 71<sup>st</sup> Fighter Squadron (an F-15C air-to-air squadron) deployed 18 aircraft, 23 pilots and supporting personnel from Langley Air Force Base, Virginia to Saudi Arabia. Over the course of the deployment the squadron flew 874 sorties - on average 16 sorties per day, five days per week.<sup>3</sup> Seven hundred and one (80 percent) of these sorties were flown in support of the Southern Watch no-fly zone in Iraq while 173 (20 percent) were training sorties. This works out to an average of about 13 no-fly zone sorties and three training sorties per day, five days per week.<sup>4</sup> However, most of the training sorties were devoted to upgrading a few pilots to higher levels of qualification, so the available training opportunities were not distributed equally among the squadron's pilots. This was necessary because USAF squadrons can not afford to stop upgrade training during deployments.

In order to function properly a fighter squadron needs a minimum number of 2-ship and 4-ship flight leads, mission commanders, and instructors. Newly minted pilots enter the squadron qualified to fly and employ their individual aircraft and enter formal upgrade training programs as they gain experience. These upgrade programs typically

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<sup>3</sup> Squadrons enforcing no-fly/no-drive zones operate in staggered rotations that approximate normal work weeks. Source: Author's conversation with Maj. Scott Perdue, Assistant Operations Officer 334<sup>th</sup> Fighter Squadron, 4<sup>th</sup> Fighter Wing January 12, 1999.

<sup>4</sup> This is probably close to the maximum number of sorties the squadron can generate on a sustained basis given the length of no-fly zone sorties and other constraints. Among the most important of these other constraints is aircrew availability. While the squadron has 23 pilots, on an average day 13 of them can only fly one sortie because they are committed to the long no-fly zone missions. Several others will be unavailable because they must perform non-flying duties essential for safe and efficient military flight operations. These duties include a senior squadron supervisor, squadron duty officer, and one or two squadron schedulers. In addition, at any given time one or more pilots is probably suffering from a cold or other medical problem that temporarily restricts him or her to Duties Not Involving Flying (DNIF) status. So, on any given day the squadron probably has 3 pilots who fly a training mission and perhaps one or two others who are well and neither fly nor perform mission essential ground duties.

consist of some ground training and a number of increasingly demanding sorties where the trainee is supervised and evaluated by an instructor. If a squadron stops its upgrade training while deployed there will be a four to eight month gap in the flow of new flight leads etc. This is an important consideration because the typical USAF fighter squadrons loses many of its most experienced members as pilots are reassigned to act as instructors at pilot training bases, serve staff tours, or separate from the service each year. Therefore, any extended break in the upgrade training cycle during a deployment would leave the squadron with a huge backlog of upgrade training, and - as the most experienced pilots move on - fewer instructors to accomplish the training.

The need to continue upgrade training while deployed results in a very uneven distribution of the currently available training sorties. Since most upgrade training rides require instructor supervision, experienced instructors and a few less experienced pilots upgrading to higher qualification levels get the bulk of the training sorties with the rest of the squadron left with few high quality training opportunities. This is illustrated by the fact that while 71<sup>st</sup> Fighter Squadron pilots upgrading or acting as instructors flew as many as eight or nine training sorties a month while deployed, for the deployment as a whole 65 percent of the pilots flew less than four training sorties per month, and at any given time almost 30 percent had not flown any training sorties in the previous month.

If we take the need to continue upgrade training at its current level and the squadron's daily sortie generation capability as given, how many more training sorties would the 71<sup>st</sup> Fighter Squadron have had to fly in order to get every pilot one high quality training sortie per week? Data on the number of training sorties flown by deployed 71<sup>st</sup> Fighter Squadron pilots indicates that the squadron would have had to fly a minimum of 130 additional training sorties while deployed to achieve a minimum of one training sortie per pilot per week. Assuming a two to one trade between no-fly zone and training sorties, the squadron would have had to shift its daily sortie allocation from about 13 no-fly zone and three training sorties to about 11.5 no fly zone and 6 training sorties. If the squadron had done this it would have flown 303 training

sorties (about 27 percent) and 636 no-fly zone sorties (about 72 percent) during the deployment. This sortie allocation would have resulted in the squadron flying about 10 percent fewer no-fly zone sorties. Figure 7.2 below depicts the alternative sortie allocations described above.

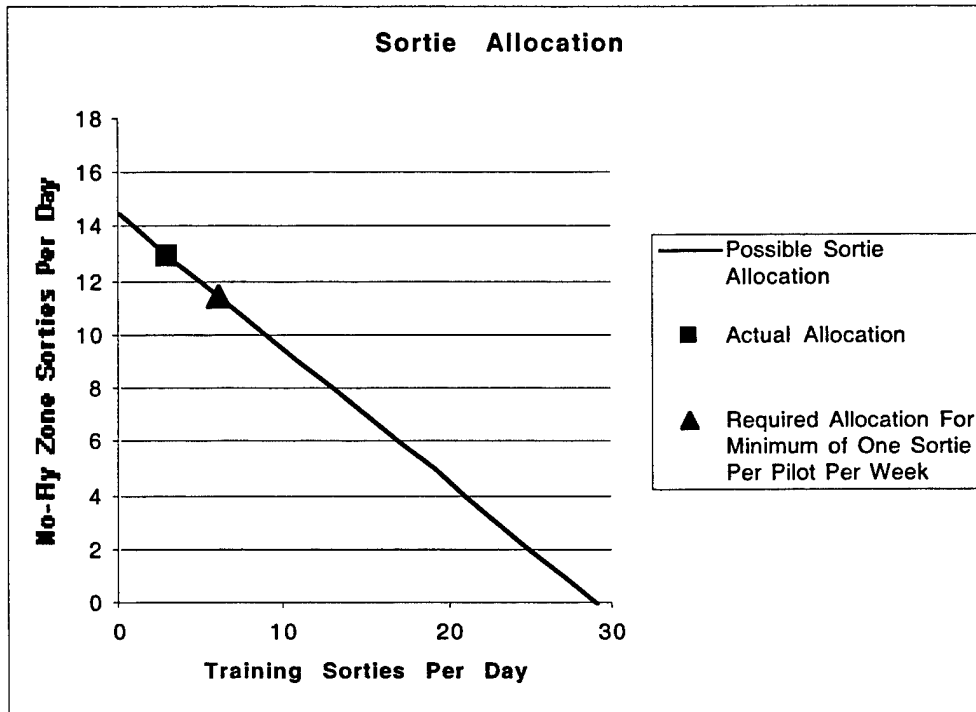


**Figure 7.2 - Actual daily sortie allocation of 71<sup>st</sup> Fighter Squadron Summer 1997 vs allocation required to achieve a minimum of one training sortie per week per pilot (two to one trade rate).**

A two to one tradeoff between no-fly zone and training sorties is not a bad assumption. With a typical 85 to 90 percent aircraft mission capable rate, the squadron can expect to have about 16 aircraft operational on average. If it devotes 12 to no-fly zone sorties it has four left to fly on the first round of training sorties and then must be able to quickly re-launch two of these to accomplish 6 training sorties in a day. On average the squadron can expect to have about six pilots not committed to no-fly zone operations or important non-flying tasks so it will have enough pilots to fly 17 or 18 missions without flying any

pilot more than once (see footnote 3 above).<sup>5</sup> The shorter duration of the training sorties should make it possible for the squadron to fly more sorties in a day if it devotes more of its resources to the shorter training missions.

However, it is possible that due to scheduling difficulties, maintenance problems, or other operational snags the two to one trade ratio between no-fly zone and training sorties is too optimistic. A worst case trade ratio is one to one. If the squadron could only trade sorties at this rate it would have flown the same 303 training sorties to ensure a once a week minimum training sortie distribution, but it would have flown only 571 no-fly zone sorties - about 20 percent fewer than it actually flew in the 1997 deployment. Its daily sortie allocation would have been six training sorties and 10 no-fly zone sorties. Figure 7.3 below illustrates this case.

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<sup>5</sup> It would be possible for the pilots to fly more than once and this would certainly improve their combat skill performance. However, the analysis presented in Chapters 5 and 6 suggests that combat skill performance decays quickly (especially for air-to-air combat skills) so flying two training missions this week and none next week is not as helpful as flying one mission each week. If the goal is to get every pilot one practice mission each week while maintaining upgrade programs and maximizing no-fly zone sorties non-upgrading pilots should fly once a week, every week and only once a week.

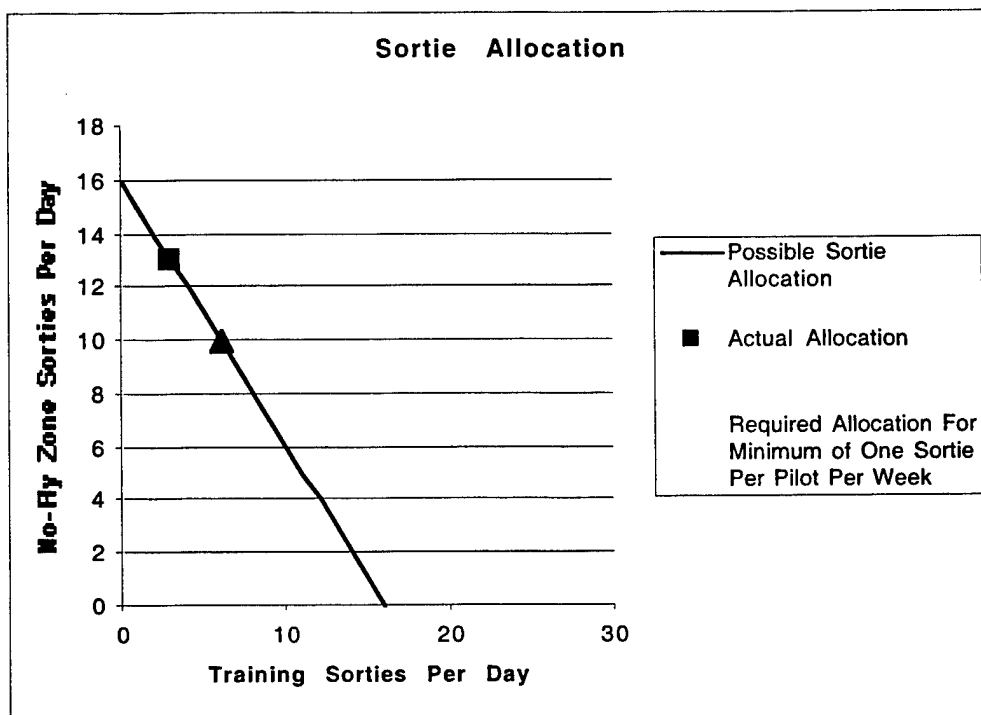


**Figure 7.3 - Actual daily sortie allocation of 71<sup>st</sup> Fighter Squadron Summer 1997 vs allocation required to achieve a minimum of one training sortie per week per pilot (one to one trade rate).**

Whether it is operationally sound to decrease the number of no fly zone sorties by ten, or at worst 20, percent in order to improve the short term combat readiness of deployed crews is a question for military commanders to answer. How military commanders answer this question depends, in part, on what political objectives they are attempting to achieve (see page 112 for further consideration of this point). If it is not, then the lost no-fly zone sorties will have to be replaced somehow. One possibility is to ask the deployed squadrons to increase the number of sorties they fly by ten to 20 percent.

Such a sustained increase in sortie generation is probably not possible without deploying additional aircraft and crews for several reasons. First, for reasons described above, squadrons are probably operating at, or very close to, their long term maximum sustained sortie generation capability simply to support existing training and no-fly

zone sortie commitments. So, generating additional sorties could be very difficult.

Second, a further complication is that any aircraft used on training sorties could not quickly or easily be substituted for an aircraft slated for a no-fly zone mission which suffers a mechanical failure. Aircraft patrolling the no-fly zones carry live air-to-air missiles and bombs. They also carry external fuel tanks to maximize their time on station. While dropping the live ordinance would provide effective air-to-ground combat skill training, it would be much more costly than dropping practice bombs. Using an aircraft weighed down with bombs and large external fuel tanks for air-to-air combat training is unrealistic since any pilot engaged in actual air combat would immediately jettison these items. In addition, asking fighter crews to fly simulated air-to-air combat engagements with live missiles on the aircraft, even with cockpit switches in "safe" positions, is like asking soldiers to practice ground combat with loaded rifles with the safety on.<sup>6</sup> No one likes having live air-to-air missiles pointed at their aircraft with good reason - even with the best intentions and efforts, there is always the chance of an accidental launch. The USAF has a long standing policy against conducting simulated air-to-air combat with live weapons on the aircraft.<sup>7</sup> So, unless the USAF opts to conduct training with live weapons on board its fighter aircraft, a potentially expensive

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<sup>6</sup> Simulated air-to-air combat is typically conducted with "captive" missile seeker heads. These consist of infra-red or radar missile guidance package bolted to an inert rocket motor. The seekers can receive and send information to the aircraft's fire control system to determine if a target is within launch parameters. However, since they have no propulsion system or warhead, they are the airborne equivalent of blanks.

<sup>7</sup> This policy was reinforced in 1987 when a US Navy (which had no such policy) F-14A downed a USAF RF-4C during a NATO exercise with a live AIM-9M Sidewinder air-to-air missile. Fortunately, the USAF crew survived because the missile was launched at such close range the warhead did not have time to arm before impact. However, the missile knocked the horizontal stabilizer off the RF-4C causing it to depart controlled flight. The crew ejected, sustained moderate injuries (including a broken wrist for the WSO), and was rescued by the Navy after parachuting into the Mediterranean Sea. The RF-4C in question was based at Zweibrücken Air Base Germany where the author was temporarily assigned at the time of this incident.

and/or dangerous proposition, squadrons deployed in support of no-fly zone operations would need to maintain one set of aircraft configured with live weapons for no-fly zone sorties and another set configured for training.

To support additional training more aircraft would need to be maintained in the training configuration. These would be in addition to the aircraft currently deployed by the USAF in support of peace operations. But how many additional aircraft would be necessary? As previously mentioned, up to 20 percent more sorties would be required to support regular proficiency training for deployed crews if no-fly zone sorties are not reduced. However, since these training sorties would last only one to two hours, each training configured aircraft could probably support two training sorties per day. Therefore, only about ten percent more aircraft would need to be deployed to meet the regular training requirement.

Recent RAND research indicates that since the start of long term no-fly zone operations in 1991 the USAF has continuously deployed about two fighter wing equivalents (FEW) to support them.<sup>8</sup> So, increasing the number of deployed aircraft by ten percent would require an additional 0.2 deployed wings on average. This research further indicates that the current total fighter force of 10.41 active and 7.63 reserve fighter wings force structure has the capacity to support 2.14 wings deployed in support of peace operations.<sup>9</sup> Therefore, the current force structure does not have the capacity to support all the required additional sorties.

The difference between total force capacity for deployment and required capacity appears small at about one-tenth of a fighter wing. However, simply adding a tenth of a fighter wing to the force structure will not close the gap. On average each active duty fighter wing needs 5.1 aircraft at home to support every one deployed, while reserve fighter wings require 15 aircraft at home for every one deployed.<sup>10</sup> So,

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<sup>8</sup> David E. Thaler and Daniel M. Norton, Air Force Operations Overseas in Peacetime: OPTEMPO and Force Structure Implications, RAND, Santa Monica, CA, 1998, p. 6.

<sup>9</sup> IBID, p. 23

<sup>10</sup> IBID, p. 22

maintaining an additional tenth of a fighter wing deployed would require adding about half a fighter wing to the active duty force structure.

There are only two ways to create this additional half wing of active duty fighters. First, the Congress and administration could be convinced to fund the additional force structure. Second, it could be transferred from the reserve to the active component. Neither of these alternatives will prove to be easy. Force structure has been contracting for more than a decade and is slated to continue to shrink - not grow - for several more years at least. The Air National Guard and Reserve have demonstrated the inclination and ability to tenaciously oppose any attempt to reduce the size of the reserve component.

Even if one or both of these difficulties could be overcome, this analysis has perhaps oversimplified a bit too much. It has assumed that all fighters are essentially fungible. This is not the case. Many of the reserve component fighters are older versions of the F-16 that have been modified for the continental air defense mission. Even if transferred to the active force the aircraft are not capable of performing many of the missions most in demand for no-fly zone enforcement such as defense suppression or ground attack missions with LGBs. To be effective, this option would probably require the USAF to buy a relatively small number of a variety of fighter models more or less reflecting the composition of forces currently deployed to support no-fly zone operations.

Another problem with this approach is that while it might arrest short term combat skill loss, flying only one training sortie per week would probably not allow most pilots to enhance their combat skills as they would if they were flying two or three sorties per week as they do when not deployed. So, upgrade times to flight lead, instructor, etc. would still be increased due to the low tactical training value of no-fly zone sorties which would still constitute the vast majority of the sorties flown by most crews during peace operations deployments.

In addition, this approach would not decrease the amount of time critical USAF personnel spend away from their families to support peace operations. This makes it especially problematic since this option would entail an approximate five percent increase in the number of

active duty fighter pilots at a time when the USAF is experiencing extreme difficulty retaining enough pilots to meet its existing needs.

One possible deployed training solution that would not require additional aircraft is deployable, high fidelity tactical simulators. If squadrons could deploy with simulators that presented a realistic 360 degree visual environment for air-to-ground and air-to-air combat task training, then pilots could practice many of the MTW combat skills they are unable to exercise on no-fly zone sorties. These simulators would have to be relatively light weight and would probably need a network capability so that pilots could practice formation tactics and compete against each other in air-to-air combat engagements. Several advanced simulators with these characteristics are under development, and experiments are under way to determine how well they compare to actual flight training. The aim of the experiments is to determine if it might be possible to trade flight time for high quality simulator time in the course of normal training. However, a more important application might be as the primary tactical proficiency training under conditions - such as peace operations deployments - where little or no flight training is possible.

One big drawback of this option is that it relies on unproven technology that is years away from operational use under the best of circumstances. A second drawback is that while this option would require no more aircraft, it would require more aircrew to deploy in support of peace operations. Pilots briefing, flying and debriefing simulator training missions obviously can not also fly no-fly zone enforcement sorties. So, if units are to take advantage of the simulators, they must deploy more crews than they currently do in support of peace operations. Therefore, even if this technology were ready today, acquiring deployable simulators would, at best, address some of the combat skill losses associated with peace operations deployments while most likely increasing the retention and other PERSTEMPO problems associated with these deployments. In the mean time the USAF needs some viable options for addressing the training shortfall. The most immediate way for commanders to adapt to changed or unexpected circumstances is by changing the way they operate their

forces. The next section briefly presents an operational concept that could help address the problems associated with peace operations deployments.

### Operational Concepts

An example of how operational concepts can lessen the burden of peace operations on USAF fighter crews is one that has been advanced in previous RAND research. It is called the "cop on the beat" approach to peace operations and is described as follows:

Generally, what the United States is trying to do in peace operations is to deter aggressive air or ground activity by one or more parties, not to prevent 100 percent of the flight activity or to shoot down 100 percent of enemy aircraft. We recognize that, to establish the credibility of the peacekeeping force, the initial stage of a peace operation might call for combat-style optempo. After an initial period of round-the-clock operations, however, the Air Component Commander could adopt a 'cop-on-the-beat' approach to peace operations.

Under the cop-on-the-beat approach, a small package of fighter aircraft would patrol at random times and places within the areas of interest. Surveillance, reconnaissance, tanker and other support aircraft would be kept to the absolute minimum necessary for effective operations; heavy use would be made of unmanned assets. Additional aircraft could be on call to support patrols if they ran into trouble, and to punish aggressors for any unauthorized ground or air activity occurring while no patrols were airborne. If unauthorized activities increased significantly, reinforcing units could be deployed to the theater within days, or in some cases, hours.<sup>11</sup>

This approach clearly requires far fewer fighter aircraft and crews to fly peace operations sorties each day than were required by the high tempo round-the-clock operations conducted through 1996. However, over the past two years the USAF has essentially adopted this approach to

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<sup>11</sup> Alan Vick, David T. Orletsky, Abram M. Shulsky and John Stillion, Preparing the U.S. Air Force for Military Operations Other Than War, MR-842-AF, RAND, Santa Monica, CA, 1997, p. 39.

enforcing no-fly zones so there seems little prospect that innovative operational concepts will have more than a marginal impact on the number or duration of USAF fighter crew deployments in support of peace operations.

## CONCLUSIONS

With many solutions unattractive, dangerous, or years away the USAF finds itself on the horns of a real dilemma. On the one hand, there seems to be no slackening of demand for USAF fighter crew participation in stability enhancing peace operations. One way US national decision makers might facilitate the reduction in the number of fighter sorties required to support peace operations is to clarify the political goals of these operations so that military commanders can better judge the level of military effort required to achieve the desired outcome. If, for example, the goal of current peace operations over Iraq is to apply pressure to the Iraqi regime and demonstrate UN and US resolve by operating combat and surveillance aircraft within Iraqi airspace, then it might be possible to achieve these political objectives with far fewer and less frequent sorties than the USAF currently flies. Different political objectives - say, preventing or punishing any Iraqi violation, no matter how small, of the no-fly zone - and the need to ensure any aircraft operating within the no-fly zone are adequately supported might result in USAF fighter sortie levels equal to, or even greater than, the current effort. To date it is not clear exactly what US objectives are over Iraq and Bosnia, or how those objectives have resulted in the current level of USAF effort.

None of this is meant to dismiss peace operations as irrelevant to US national security concerns. These operations are an important part of the environment shaping aspects of the current national security strategy and are therefore certainly a part of the "real mission" of the Air Force and other services. Therefore their objectives should be formulated with the great care attention to the desired goals and potential costs. As this report has explained, peace operations have real, non-trivial negative consequences for both the long- and short-

term MTW combat readiness of fighter crews who participate in them. These negative effects will almost certainly impact the USAF's ability to effectively defend US national interests the next time it is called on to conduct a MTW air campaign. In short, there seems to be an inherent conflict between two important USAF missions that did not exist to anything like the same extent during the Cold War, and especially from 1975 to 1990.

This research shows that current commitments exceed the USAF fighter forces capacity to simultaneously conduct peace operations and maintain the same training and readiness standards developed during the last 15 years of the Cold War. These training standards are the result of lessons learned and relearned, sometimes the hard way, in combat during World War II, Korea and Vietnam. Crews trained to these standards achieved outstanding results during Operation Desert Storm and the public, political leaders, and many in the military have accepted Desert Storm as the standard of performance they expect from American armed forces. With few attractive technological or operational solutions available it seems clear that sooner or later US national leaders must do one of the following:

- 1) Decrease the commitments USAF fighter forces currently face by bringing one or more of the current peace operations to an end through diplomatic or other means.

- 2) Increase the capacity of USAF fighter forces to simultaneously conduct peace operations deployments and high quality training.

OR . . .

- 3) Continue to accept decreased, and declining, levels of USAF fighter crew MTW combat readiness and the attendant risks of casualties and operational reversals.

These are not attractive choices. The first two options have relatively high short term political or fiscal costs. However, it is important to remember that any delay or decision not to decide is in reality a choice to continue to stick with option three - the option that clearly has the highest long run cost.

## **APPENDIX A**

### **BETTER MEASUREMENT OF FIGHTER CREW COMBAT SKILLS**

This appendix puts forward a number of suggestions for improving the type of information the USAF could collect to improve its ability to measure fighter crew combat skills. In addition, it describes how data the USAF currently collects on air-to-ground combat skills could be managed and stored in a more complete and systematic way so that more a in depth and complete analysis of these skills could be conducted.

#### **COLLECTING NEW MEASURES**

Air-to-air combat is the most complicated aspect of air warfare. It is therefore difficult to capture all of the dimensions of air-to-air combat in a single measure such as the invalid air-to-air missile shots used in Chapter Six. However, data on invalid missile shots is the only air-to-air combat measure USAF squadrons routinely collect and (sometimes) save for any period of time. The pilots themselves know a great deal about exactly what happened during the mission. In order to get the most from their training and learn the most from their, and others, mistakes air-to-air combat training missions are meticulously reconstructed as a matter of course during the post mission debrief. However, the richness of these reconstructions survives only as mental notes, lessons learned and increased experience and competence of the crews involved. This is important and even if the entire debrief could be recorded it contains too much detail to be usefully analyzed. What is needed are a few relatively simple measures crews could quickly and easily compute during the debrief and then record. This will, of course meet with considerable resistance from the crews who already feel - with considerable justification - that as the old Air Force saying goes "the mission isn't over until the weight of the paperwork equals the weight of the airplane". However, there is no way to produce more meaningful

measures of air-to-air combat without asking the only people who know what happened during a training mission - the crews - to somehow record what they know in a systematic way.

Previous RAND research has suggested some relatively simple measures that, if collected, could dramatically improve the ability of USAF commanders to gage the combat capability and readiness of their crews and units.<sup>1</sup> This research suggested constructing both an offensive and defensive air-to-air combat skill index. Each index would consist of a number of ratios. For example the offensive index would be a function of, among other things, the ratio of firing passes per engagement and kills per firing pass. The proposed defensive skill index would be a function of the ratio of escapes per enemy attack and the number of kills a pilot achieves per escape.

These measures would provide a much richer set of measures and would capture much more of the substance of typical fighter crew debriefs than the best measure currently available - proportion of invalid missile shots. An additional measure of this sort not proposed in earlier RAND research on this topic would be the proportion of neutral air-to-air combat set-ups converted to the pilot's advantage. In addition, some measure of proficiency at detecting, tracking, identifying and attacking targets in increasingly important beyond visual range (BVR) combat is also required.<sup>2</sup> Obvious candidates include

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<sup>1</sup> See Peter deLeon, The Peacetime Evaluation of the Pilot Skill Factor in Air-to-air Combat, RAND, Santa Monica, 1977, Chapter 5.

<sup>2</sup> Seventeen of the 43 coalition air-to-air kills during Operation Desert Storm were achieved with medium range AIM-7 missiles without the opposing aircraft closing to within sight of each other (BVR). Author's analysis of data contained in John M. Deur, Wall of Eagles: Aerial Engagements and Victories in Operation Desert Storm, Intercept Publications, Cleveland, OH, 1994. BVR kills were obviously not possible until the advent of air-to-air missiles increased the range of aerial weapons beyond the distance the human eye could detect an opposing aircraft. Even after missiles became the primary armament of advanced fighters during the 1960s BVR kills were relatively rare due to the difficulty of detecting, and especially identifying, hostile aircraft at long range. Advanced airborne surveillance systems such as the E-3 AWACS and advances in radar technology have made long range detection easier, but even during the 1991 Gulf war concerns for fratricide and continuing difficulties in detection and identification

the proportion of opposing aircraft detected, tracked, identified, and/or killed per engagement.

Bomb miss distance and the ratio of hits to practice bombs dropped probably do a better job of representing the offensive aspects of air-to-ground combat than invalid missile shots does for air-to-air combat. However, these measures do not capture many important defensive aspects of air-to-ground combat missions such as the ability of crews to avoid/react to simulated threats, formation integrity, visual/radar lookout, and many other skills that can be loosely grouped under the heading "survivability". There are no obvious ways to construct objective ratio measures of performance in this area, so if the USAF is interested in measuring this area it may need to develop a set of standards or guidelines that could give some structure to the subjective evaluations of the crews involved. Much of this work may already exist in the form of standards, guidelines and rules of thumb USAF crews are graded against on their tactical check rides.

#### **BETTER DATA MANAGEMENT**

With or without new measures of combat skill proficiency the USAF could significantly improve its ability to assess the combat readiness of its units if it required them to systematically save and forward data squadrons routinely collect on bomb scores and valid air-to-air missile shots to higher headquarters for analysis. In the course of this research I visited eight operational USAF fighter squadrons at three different bases. All of the leaders, training and weapons officers I met with took time from their busy schedules to meet with me and all of them expressed interest in this project and wished me well in my efforts. However, only two of the eight squadrons I visited maintained records of pilot combat skill performance for more than six months. Even for these units the data available were not as complete or useful as they could have been. For example, the bomb miss distance data used in the analysis in chapter 5 consisted of average bomb miss distances

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led to over 60 percent of coalition air combat victories resulting from visual range engagements.

achieved by pilots and WSO in a particular month. In order to compute these averages the squadrons had to collect and store miss distances for every bomb every crew member dropped. However, at the end of each month, the individual bomb scores are averaged and then the individual scores are erased. This is not meant as a swipe at the squadrons who provided data for the analysis presented in this study - it could not have been done without their help. Rather it is meant to point out that since there is no USAF requirement to maintain longitudinal data on fighter crew skill performance, few units do. Since all the individual bomb scores are entered into computers at some point, it seems that the USAF could rapidly develop a large and potentially very useful database for evaluating fighter crew combat readiness with relatively little investment.

## BIBLIOGRAPHY

### BOOKS

- Anderson, John R., The Architecture of Cognition, Harvard University Press, Cambridge MA, 1983.
- Chase, William G. ed., Visual Information Processing, Academic Press, New York, 1973.
- Chi, Michelene T. H, Robert Glaser and Marshall J. Farr, The nature of Expertise, Lawrence Erlbaum Associates, Hillsdale, NJ, 1988.
- Cohen, Elliot A., Gulf War Air Power Survey, US Government Printing Office, Washington DC, 1993.
- Craven, Wesley, ed., et al. The Army Air Forces in World War II: Volume III, University of Chicago Press, 1951
- de Groot, A. D., Thought and Choice and Chess, The Hague, Netherlands, Mouton Press, 1946/1978.
- Deur John M, , Wall of Eagles: Aerial Engagements and Victories in Operation Desert Storm, Intercept Publications, Cleveland, OH, 1994.
- Futrell, Robert F., The United States Air Force in Korea, Office of Air Force History, Washington DC, 1983
- Murray, Williamson, Luftwaffe, The Nautical & Aviation Publishing Company of America, Baltimore, MD.
- Michel, Marshall L. III, Clashes: Air Combat over North Vietnam 1965-1972, Naval Institute Press, Annapolis MD, 1997.
- Pindyck, Robert S. and Daniel L. Rubinfeld, Econometric Models & Economic Forecasts, Third Edition, McGraw-Hill, New York, 1991.

### REPORTS AND PAPERS

- DeLeon, Peter, The Peacetime Evaluation of the Pilot Skill Factor in Air-to-air Combat, RAND, Santa Monica, CA, 1977.

Hammon, Colin P. and Stanley A Horowitz, Flying Hours and Aircrew Performance, Working Paper, Institute for Defense Analyses, Washington D.C. June 1989.

Lambeth, Benjamin S., Moscow's Lessons from the 1982 Lebanon Air War, RAND, Santa Monica, CA, 1984.

Lane, Norman E, Skill Acquisition Curves and Military Training, IDA Paper P-1945, Institute for Defense Analysis, Alexandria, VA, January 1986.

Osborn, James H., Continuation Training Flying Hours Requirements Study, Project No. 92-01-03a, HQ TAC/DO, Langley AFB, VA, 1 May, 1992.

Proctor R.W. and A. Dutta Skill Acquisition and Human Performance, Sage, Thousand Oaks, CA, 1995.

Smith, James F. and William G. Matheny, Continuation Versus Recurrent Pilot Training, Air Force Human Resources Laboratory, Flying Training Division, Williams Air Force Base, AZ, 1976.

Statistical Summary of Eighth Air Force Operations, European Theater, 17 August 1942 - 8 May 1945.

Thaler, David E. and Daniel M. Norton, Air Force Operations Overseas in Peacetime: OPTEMPO and Force Structure Implications, RAND, Santa Monica, CA, 1998

Vick, Alan, David T. Orletsky Abram N. Shulsky and John Sillion, Preparing the USAF for Military Operations Other Than War, MR-842-AF, RAND, Santa Monica, CA, 1997.

#### **NEWSPAPER, MAGAZINE AND JOURNAL ARTICLES**

"Air Force battles pilot burnout, steep dive in numbers", *The San Diego Union-Tribune*, Saturday, June 7, 1997, p. A-21.

Ashworth C.A., "Skill as the Fit Between Performer Resources and Task Demands" in Proceedings of the 14<sup>th</sup> Annual Cognitive Science Meeting, pp 444-449 Erlbaum, Hillsdale, NJ, 1992.

Chase, William.G. and H.A. Simon, "The Minds Eye in Chess", in Visual Information Processing, ed. W.G. Chase, pp. 215-281, Academic Press, New York, 1973.

Chi Michelene T.H., Robert. Glaser and M, Rees E. 1982, "Expertise in Problem Solving", in Advances in the Psychology of Human Intelligence, ed. R. S. Sternberg, pp 1-75. Erlbaum, Hillsdale, NJ, 1982.

Ericsson, K. Anders. and A. C. Lehmann, "Expert and Exceptional Performance: Evidence of Maximal Adaptation to Task Constraints", in Annual Review of Psychology, ed. J. T. Spence et al, 47: pp. 273-305, Annual Reviews Inc., Palo Alto CA, 1996.

Fullhum, David A. "USAF Designs Enticements to Keep Younger Pilots", *Aviation Week & Space Technology*, May 26, 1997, p. 76.

Grier, Peter, "Stressed Systems", *Air Force Magazine*, July 1997, pp. 52-55.

"How US Defense Spending Compares", *Air Force Magazine*, March 1998, pp. 72-75.

Hughes, Harley, "Bailing Out: Air Force Retention is in a Tailspin, and the Worst is Yet to Come", *Armed Forces Journal International*, September 1998, p. 45.

Matthews, William, "A Little Down Time: Giving Troops Two Weeks Off After a Deployment is a Popular Way to Relieve Stress", *Air Force Times*, September 1, 1997, p. 10.

Newell, A. and P. S. Rosenbloom, "Mechanisms of Skill Acquisition and the Law of Practice", in J. R. Anderson (ed.) Cognitive Skills and Their Acquisition, Erlbaum, Hillsdale, NJ, 1981.

"Readiness at the Edge," *Air Force Magazine*, June 1997, p. 58.

"Stretched to the 'breaking point,'" *Air Force Times*, April 21, 1997 p. 3-4.

Voss J. F., T. R. Greene, T. A. Post, B.C. Penner, "Problem-Solving Skill in the Social Sciences", in The Psychology of Learning and Motivation: Advances in Research and Theory, ed, G. H. Bower, 17:165-213, Academic Press, New York, 1983.

Wallman J., "Nature and Nurture of Myopia", Nature, 371:201-202.