R-2070-PR
January 1977

The Peacetime Evaluation of the Pilot Skill Factor in Air-to-Air Combat

Peter deLeon

A Report prepared for

UNITED STATES AIR FORCE PROJECT RAND

Rand
SANTA MONICA, CA. 90406

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Published by The Rand Corporation

PREFACE

Recently, Rand has been engaged in research on the feasibility of quantitatively examining the quality-quantity tradeoff issues among aircraft whose primary mission is air-to-air combat.[1] One aspect of this investigation has been to identify the critical elements in air-to-air combat. Although the traditional foci of attention have been comparisons of the physical attributes and performance parameters of the aircraft, an equally important but much less studied element has been pilot skill and its interaction with the performance of the aircraft; i.e., can the individual pilot's capabilities significantly affect the outcome of a large number of aerial engagements? Put another way, can pilot skills be traded off for performance or numbers of aircraft?

Underlying a study of pilot skills is a host of related issues, such as how the pilot is chosen, the quality of his air combat training, how he is used, and, centrally, how "good" a pilot he is. The overarching policy question is how these different peacetime training and allocation issues might influence a pilot's performance in wartime air-to-air encounters. The issues cited concern peacetime actions or decisions that will influence the outcome of wartime air-to-air encounters. What is needed, therefore, is a better understanding of the quantitative relationship between peacetime decisions and wartime results. One goal of this research at its onset was to derive and test such a relationship for aerial combat training by linking the results of the air war over North Vietnam with peacetime training scores for individual USAF pilots who were engaged in that campaign. However, the destruction of certain Air Force files that connected Southeast Asia air combat data with individual pilot identification numbers, and the general nonretention of critical peacetime training scores, made realization of that goal impossible.

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[1] See C. T. Kelley, Jr., G. K. Smith, and W. W. Matyskiela, *Quantity-Quality Tradeoffs: An Historical Analysis of Air Combat* (U), The Rand Corporation, R-1976-AF, forthcoming, Confidential.

Nonetheless, there is value in presenting the initial research hypotheses and some tentative evidence addressing those hypotheses, in defining some specific areas for possible further research, and in suggesting specific areas in which the Air Force might wish to review its air-to-air combat training and assignment policies.

This report should be useful to Air Staff offices concerned with pilot training and use, to Hq Tactical Air Command (especially DOOT), and to TAC installations specializing in advanced fighter aircraft pilot training, such as the Fighter Weapons School at Nellis AFB. Companion research being prepared by Benjamin S. Lambeth on air-to-air combat training in the Soviet Union should offer a useful comparison.

This work was done under the Project RAND research project entitled *Quality-Quantity Tradeoffs*.

SUMMARY

One little researched area in the quantity-quality tradeoff issue for air-to-air combat aircraft is the importance of the pilot. Specifically, how critical is the role of the pilot in determining the exchange ratio between two opposing air forces? The purpose of this report is to analyze explicitly the relationship between pilot skills and the outcome of an aerial engagement and to ask if the quantity-quality arguments as well as the usual performance and physical parameters apply to this topic. To the extent that pilot quality is a factor, the report considers how pilot training and use may influence the outcomes.

Analytical examination of pilot combat skills and their influence on air-to-air engagements is notoriously difficult because of the dynamic, amorphous nature of aerial combat and the concomitant lack of reliable, relevant data. Much of the literature, anecdotal in nature, does little more than relate the exploits of the World Wars I and II and Korean Aces. The limited analysis that has been performed generally confounds the issue of preparing good fighter pilots by equating pilot skill with general flying experience--a convenient but uncertain assumption. Lacking any meaningful standard, the Air Force currently cannot objectively evaluate the proficiency of its air-to-air pilots during peacetime.

Although it would be difficult to prove that the pilot is the critical component in aerial engagements, indirect evidence gathered from the Second World War, the Vietnam conflict, and the Middle East Wars all strongly argue that the pilot is indeed very important. If this is true, what facets of his flying career or training seem to be the most important in preparing him for aerial combat? Three possible explanations for pilot superiority in air-to-air combat are discussed--flying experience, aerial tactics, and training regimen. The feasibility of peacetime training in various modes is also addressed. Flying practice combat intercept missions against the MiG-21 piloted by top Soviet pilots would obviously be an ideal technique, but it has limited practicality.

Flying experience has generally been equated with combat proficiency. But data from Vietnam suggest that the relationship is, at best, obscure. The difficulty is resolved if *combat* flying experience is examined. Statistically significant findings indicate U.S. pilots with combat flying experience demonstrated more ability to shoot down North Vietnamese fighters than contemporaries who lacked that background. Even there, however, the evidence was not clear because of the inability to control for flight positions in evaluations of "combat missions." Also in peacetime, it is impossible to acquire combat flying experience.

Air-to-Air combat tactics would seem to have some effect on determining the outcome of an aerial engagement, but the question is how much. Doubtless, good air-to-air tactics are essential for successful air-to-air combat, but it is difficult to develop tactics that, by themselves, might provide a decisive advantage. The fact that tactics are neither copyrighted nor static renders this evaluation even more problematic. The ability to *select and execute* superior tactics is, of course, quite another matter.

Air combat training (ACT) appears to be a critical element in predicting a pilot's performance in aerial dogfights, although the evidence is mixed. Still, given the body of supportive data and the consensus of experts, it is a reasonable assertion that ACT is the most effective means of preparing a pilot for air combat during peacetime. In line with the importance of ACT, TAC has established extensive advanced ACT capabilities such as the Aggressor squadrons (which use Soviet types of aircraft and tactics against U.S. planes and pilots) and dissimilar air combat training (DACT) programs. Consequently, this report concentrates primarily on the ACT aspects of a pilot's career.

One early objective of the research on the influence of pilot training on combat skills was to link previous training scores with air-to-air combat performance of U.S. pilots who flew in Vietnam to discover what aspects of a pilot's training were the best indicators of his performance in combat. However, Combat Crew Training Squadron (CCTS) documentation was not preserved, which made it impossible to derive and test a relationship. Research did disclose a number of potential ways for increasing the effectiveness of the air superiority pilot's

training and use in peacetime. These potential courses of action fall into four categories: selection from Undergraduate Pilot Training (UPT); CCTS training; pilot use; and DACT use. Further research into their relevance seems warranted.

Current methods of selection from UPT do not necessarily insure that the most promising candidates go into fighter pilot specialization. There is some evidence that psychological profile characteristic tests might be useful in identifying those candidates who have the potential to become extraordinary fighter pilots. Also, research might disclose whether any particular component or facet of the UPT curriculum has any predictive attributes or critically influences a pilot's future air combat potential.

CCTS training could presumably benefit from a series of objective flying tests that could evaluate a pilot's capabilities for aerial combat. A series of basic fighter maneuvers (perhaps graded by a stopwatch) and the ability to hit a towed target with a cannon shot within a specified number of sorties are two possibilities. Such standards would permit both the student and the instructor to assess competency levels objectively. A second research task would be to examine and compare the air combat training procedures and philosophies of other nations, such as France, Britain, and Israel. This would require more than just the usual exchange of officers. A third research task would be the greater use of the Graduate Evaluation forms. These could help to identify possible unconscious emphases of different CCTS locations. They could also supply later information concerning a pilot's air-to-air competency, thus providing more data as to what the key indicators and preparations for air-to-air proficiency in the UPT and CCTS program might be.

Pilot management seems to have the effect of rotating air combat pilots when they are probably at the peak of their skills. This policy not only seems to undermine the effectiveness of the force (since these pilots must be replaced by pilots who are less proficient) but also seems to undercut cost effectiveness. The cost of training and maintaining a pilot's combat skills is very expensive (at least $200,000 per pilot); a pilot should be retained in the cockpit as long

as possible, thereby reducing the costs of training replacement pilots. The feasibility of such a policy must, of course, also be evaluated in terms of career development patterns, USAF needs for skilled and experienced pilots in many staff jobs, and similar requirements.

Finally, *DACT use* addresses how much DACT is necessary to raise a pilot's combat skills to some predetermined level. After how many hours or sorties does DACT cease to benefit an individual pilot in terms of the cost of the program and the program's opportunity costs (i.e., working with one pilot deprives another pilot of the opportunity to engage in DACT)?

Underlying much of the above discussion is the desirability of developing a pilot skill index for air-to-air combat. Current conceptual and data problems make the imminent derivation of such an index infeasible. However, it is possible to hypothesize a number of "skill indexes" that might eventually lead to such an index. These skill indexes can be divided into offensive and defensive categories. In both, the critical problem is to identify aspects of air-to-air combat that are more or less under the control of the pilot (rather than due to chance) and are amenable to inclusion in the training program. For example, sighting an enemy aircraft is part of the pilot's skills, but the presence of the bogey is often much more a matter of luck than any inherent proficiency on the pilot's part. Among the several offensive skill ratios examined here, two--the ability to convert an engagement into a firing pass and to turn a firing pass into a kill--are presented as the basis for the offensive aspect of the pilot skill index. Korean War data indicate that these indexes appear to have some validity.

The defensive pilot skill component explicitly recognizes that not all engagements begin from a favorable position and that a great deal of flying skill might be required to extricate oneself from a position of initial tactical disadvantage. Two skill ratios seem particularly applicable, the ability to escape without being downed and the ability to reverse the initial disadvantage and shoot down the attacking aircraft.

If representative values for these pilot skill indexes could be obtained, they might then be linked with and translated into peacetime

training exercises. There are two ways in which this transition might be made, either by flying against a series of "canned" or standardized exercises or by "flying" against programmed missions in a flight simulator. Both of these alternatives have serious liabilities. However, if these obstacles can be overcome and specific training exercises formulated that evaluate the pilot's skill as he progresses through his flying tours, the Air Force would be a great deal closer to developing a consistent grading scale for measuring the skills of its air-to-air pilots, to assessing the skill level of the force, and to correcting any deficiencies that might be observed. The result would be a force with greater capabilities to conduct the air-to-air mission at its most effective level. In addition, the Air Force could begin to include the effect of pilot quality in calculating quantity-quality tradeoffs for fighter aircraft, thereby gaining a better understanding of how to allocate its resources among aircraft and weapons development, aircraft procurement, development of tactics, and pilot training programs.

ACKNOWLEDGMENTS

No study of the Air Force's preparation and management of its air-to-air combat pilot resources could have been accomplished without the generous assistance of Air Force personnel, especially those in the Tactical Air Command, whose charter specifically includes air combat training. Lt. Col. Clifford H. Rees (Hq TAC, DOOT) was particularly generous with his time and efforts. Personnel at Luke AFB, especially Colonel Rex Hammond, DOF4, who coordinated the author's visits, were kind enough to discuss the F-4 CCTS and ISD Graduate Evaluation programs. Similarly, numerous personnel at Nellis AFB, were always cooperative. These include Col. Richard G. Matthews and Lt. Col. U. B. Alford, Hq 57th TFW, Lt. Col. Larry Keith (Commander of the 414th TFTS, the USAF's Fighter Weapons School), Lt. Col. Jerry Nabors (former Commander of the 64th TFTS, the USAF's first "Aggressor" squadron), Major Rod Gunn (64th TFTS), Lt. Col. Glenn Frick (FWC/TEM), and the many FWS and Aggressor pilots who went to great lengths to explain the intricacies of aerial combat. At Hq USAF, Lt. Col. Richard M. Suter (AF/XOOSLC) shared his great knowledge of air combat training. Finally, Col. J. P. Dickey, formerly with the Air Command and Staff College, Maxwell AFB, offered the author an opportunity to make a preliminary presentation of research to his Air University seminar on fighter pilots.

The author wishes to thank the many colleagues at The Rand Corporation who have been influential in shaping his thinking; these include Arthur J. Alexander, Clyde B. East, Robert L. Perry, Edward H. Sharkey, and Giles K. Smith. William H. Albright and Felix Kozaczka offered incisive technical reviews of the manuscript. The most important contributions were made by Charles T. Kelley, Jr., who originally proposed the area of inquiry and provided continued support, encouragement, and focus for the activity.

The author takes full responsibility for any errors in fact or interpretation.

CONTENTS

PREFACE iii

SUMMARY v

ACKNOWLEDGMENTS xi

Section
I. INTRODUCTION 1

II. THE IMPORTANCE OF PILOT SKILLS IN AIR-TO-AIR COMBAT 4

III. POSSIBLE EXPLANATION FOR PILOT SUPERIORITY IN AIR-TO-AIR COMBAT 13
Pilot Experience 14
Air-to-Air Combat Tactics 18
Air Combat Training 20
Summary 23

IV. INCREASING THE EFFECTIVENESS OF THE AIR SUPERIORITY PILOT TRAINING 25
Selection from UPT 29
CCTS Training 32
Pilot Management 34
DACT Use 36
Conclusions 38

V. A PROPOSED PILOT SKILL INDEX FOR AIR-TO-AIR COMBAT 39
An Offensive Pilot Skill Index 39
A Defensive Pilot Skill Index 43
Conclusions 46

VI. SUMMARY 48

APPENDIX 51

I. INTRODUCTION

Rand's inquiry into the quantity-quality tradeoff question in the context of air-to-air combat aircraft has been made particularly relevant by the imminent delivery of two new aircraft into the USAF inventory that represent a new generation of USAF fighter aircraft. The first of these, the F-15 Eagle (which was especially designed as an air superiority aircraft), is quickly becoming operational at Langley AFB. The second aircraft, the F-16, is a product of the Air Force's lightweight fighter development program and will enter the force inventory in the early 1980s. The F-15 and F-16 represent the current high and low elements, respectively, of the Air Force's fighter modernization program.[1]

Traditionally, quantity-quality tradeoff studies have been characterized by computer simulation models comparing the physical dimensions and performance parameters of the aircraft involved (such as speed and turning radius), munitions and fire-control systems, and combat range. Although such comparisons may be sufficient for evaluating the performances of the aircraft, actual engagement results in air-to-air combat may be significantly different from those predicted by the performance comparisons. This difference may be largely attributable to the pilot, whose flying skills have been excluded from the simulation. Pilot skills are thought to have an important--perhaps dominant--effect on the outcome of real engagements. Unfortunately, this pilot skill variable has proved resistant to inclusion in combat simulations and, in general, to most analytic research.

The research originally contemplated was to address three objectives. The first and most immediate was to review descriptions of the effect of pilot flying skill on air-to-air engagement results, most of which were anecdotal. The anecdotal and substantive evidence argues strongly that flying skills are probably the critical factor in

[1]The U.S. Navy is embarked on a similar modernization program with the F-14 Tomcat and the F-18 aircraft. The former is already in active duty. The latter is a derivation of the YF-17 lightweight fighter prototype.

determining the outcome of aerial combat, but these data do not lend themselves to proposing methods of evaluating or improving these flying skills. Previous research findings were not comparable, they relied on highly subjective evaluations, they confused or misspecified causal relationships, or they were methodologically suspect. Still, one would be rash to ignore the consensus that the individual pilot's skill is often *the* determining factor in an aerial engagement, even if the analytic "proof" is lacking.

The second objective of this research was to examine the training, background, and, where possible, the combat record of fighter pilots to identify a pilot skill variable or combination of variables that could be melded into an air-to-air computer simulation model so that the results would be consonant with actual combat experience. If the sensitivity testing of such an index were seen as critical in determining the simulated outcome, it could provide evidence for recommendations to the Air Force regarding potential tradeoffs among future aircraft development, procurement, and pilot training programs.

The third objective was to examine and elaborate upon a number of factors that constitute a fighter pilot's flying experience and investigate how these influence his abilities in aerial combat. From these a set of peacetime training exercises might be derived that would be specifically designed to evaluate and improve the appropriate skills.

These objectives were directed toward the development of a standard that could be used to rate a pilot's air-to-air combat skills. Although the metric could be validated only in combat situations, ideally it could be measured in peacetime training activities. The end product of the research would have been to offer a scale for predicting how well fighter pilots might perform in the air-to-air combat arena. This type of information would be a prerequisite if the Air Force were to perform explicit tradeoffs among aircraft procurements, training budgets, and manpower allocations.

The development of such an operational index proved to be infeasible at this time for a number of reasons that will be discussed at length later in the report. Briefly, the two most important obstacles were the lack of data relating the pilot's air combat training

with his performance in combat and the inherent difficulties of grappling with the protean characteristics of aerial combat. Rather than abandon the research efforts, I prepared this report to document the analysis of air-to-air combat research, to suggest areas where important research could be done regarding improvements in the peacetime training of a pilot's combat performance, and to offer a conceptual underpinning for a pilot skill index. The research areas include the selection of the prospective fighter pilot from the Undergraduate Pilot Training (UPT) program, procedures used during the Combat Crew Training Squadron (CCTS) and advanced fighter training portions of his education, and the management of the pilot's career pattern. A great deal of work has been done on the first and third periods. Therefore, this report emphasizes CCTS and advanced pilot training. I do not mean to imply that the other periods are unimportant, just that the middle period has received less attention. Furthermore, this period is the jurisdiction of a single command--TAC--and would not require inter-command coordination to address some of the issues raised.

Section II critically reviews the research that has attempted to analyze the effect of the pilot on air-to-air combat results. Section III offers possible explanations of why some pilots might be more successful than others. Pilot experience, fighter tactics, and pilot training are examined to isolate important variables that appear to result in what one might call "pilot skill." Section IV proposes four areas for research efforts that focus on pilot skills and how they might positively affect wartime aerial combat: pilot selection, pilot combat training, career progression, and standards that can evaluate specific training procedures in terms of consistent and predictable effectiveness in combat. Section V suggests a pilot skills index and a methodology for obtaining representative values. This is distinct from the other research proposals mainly in that it is more conceptual and would require greater prior planning before the research could be initiated. Section VI summarizes the report and its recommendations.

II. THE IMPORTANCE OF PILOT SKILLS IN AIR-TO-AIR COMBAT

From World War I to the Yom Kippur War, the importance of aircraft pilot skill in determining air-to-air engagements has been an accepted axiom, but mostly anecdotally. Even with inferior aircraft, such as those U.S. pilots flew against the superior Japanese Zero in the early days of World War II, pilot skills almost always were thought to be decisive in the outcome of aerial engagements. This "knowledge" has rarely left the realm of conventional wisdom or the indirect evidence that generally equated flying experience with combat skill. The lack of analytic evidence was not due to a lack of interest. The research that was carried out generally revolved around *identifying*--both in retrospect and in projection--characteristics of pilots who recorded a large number of enemy aircraft shot down.[1] These studies focused exclusively on the exceptional pilot (one with a large number of "kills") and how he might be identified early in his career, instead of assuming that there are certain intangible skills characterizing the exceptionally skilled pilot. The latter assumption recognizes that there are some skills or factors found in the exceptional Ace that cannot be copied or taught. It would be naive to deny but even more foolish to attempt to instill through training the dictum of World War II Luftwaffe Fighter Command General Adolf Galland: "Only the spirit of attack born in a brave heart will bring success to any fighter aircraft no matter how highly developed it may be." It would be more practical to attempt to make incremental increases in the skill threshold of the modal or median pilot than to try to produce only Aces like the spectacular World War II German pilots Major Erich Hartmann or Major Gerhard Barkhorn.[2]

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[1]For example, see Raymond F. Toliver and Trevor Constable, *Fighter Aces*, The Macmillan Co., New York, 1965; or Edward H. Simms, *American Aces*, Harper and Brothers, New York, 1958.

[2]Barkhorn's record of 301 is particulary remarkable because he was shot down only once. Hartmann was shot down 18 times and shot down 352 planes. Most of their kills were recorded on the Eastern (Russian)

There have been attempts at evaluating the contributions of the skilled pilot and his attributes. These are reviewed with an eye toward answering the question: Does pilot skill have a significant effect on the outcome of aerial combat?

Only recently have analysts accumulated a large amount of quantitative data attesting to the possible effects of pilot skills in air-to-air combat. As an exercise in systems analysis, Weiss posited that

> in all past wars involving extensive air-to-air combat, a small number of pilots--the Aces--were responsible for most of the kills. It was therefore hypothesized that fighter force capability depended on the performance of a few top pilots rather than numbers of pilots and attention was shifted to measures of pilot performance.[1]

As evidence, Weiss notes that the top ten German Aces in World War II shot down 2568 Allied aircraft.[2] Drawing upon a limited number of World Wars I and II engagements, Weiss attempted to define just how critical pilot skill was. He derived the following approximation:

$P_j = K_{j-1} / (S_j + K_{j-1})$, in which

K_j = the number of pilots killed in action by enemy aircraft with some number of kills, j;

S_j = the total number of pilots living or dead with at least the score j; and

P_j = the probability that a pilot will be killed in his jth decisive combat (one in which a plane is downed).

With a limited amount of data from the two World Wars, Weiss compared

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front. The top German Ace against the British was Hans-Joachim Marseilles, who shot down 158 British aircraft without ever being hit. In one day in North Africa, he killed 17 British fighter aircraft.

[1]Herbert K. Weiss, "Systems Analysis Problems of Limited War," *Annals of Reliability and Maintainability*, Vol. 5, July 1966, p. 305.

[2]The exact number is uncertain, but the magnitude is generally agreed upon. Of course, the Luftwaffe did not rotate its pilots, and individual pilots flew hundreds of missions. See "The Luftwaffe's 'Kills'," *Flying Review International*, Vol. 21, No. 4, December 1965, pp. 243-245.

P_j with the number of decisive combats and observed that a pilot's probability of living through a decisive engagement improved 20 fold from his first to his fifth mission; see Fig. 1. Plotting P_j as a probability density function, he noted that "at best fewer than 15 percent of the pilots had a better than even chance of surviving their first [decisive] combat"[1]; see Fig. 2.

Weiss then dichotomized all pilots into "Hawks" (those that downed enemy aircraft) and "Doves" (those that were shot down) and made the following assumptions: Hawks composed 10 percent of the pilot population on both sides and could not be identified before combat (during training); all aerial engagements were one-on-one; the probability that each combat involved Hawks, Doves, or one of each was proportional to their representation in the individual forces; and finally, Hawks always shot down Doves, Hawks exchanged on a one-to-one ratio with their avian counterparts, and combat between Doves resulted in no losses. Using these probabilities and specified attrition rates, Weiss estimated that "if the precombat training and screening process delivers only 'Hawks' to one side, that side may have a 10:1 sustained exchange ratio, at all times."[2]

Weiss's conclusions are in agreement with the present research hypothesis:

> Prolonged major wars in the past have tended to witness the development of aircraft of compatible performance on both sides. In all wars these differences have been far overshadowed by the performance of Aces, as individuals.
>
> Before Korea it was believed that air-to-air combat between fighter aircraft was obsolescent, or would be combat between machines, gun sights, and computers. Events turned out otherwise. The writer suggests that the increasing complexity of equipment, and the incredibly demanding environment of air combat will only reduce to even smaller numbers, those individuals who can master their equipment and the combat environment, and whose presence as dozens, within a force of hundreds, or thousands, will be decisive.[3]

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[1] Weiss, "Systems Analysis Problems," p. 307.

[2] Ibid., p. 308.

[3] Ibid.

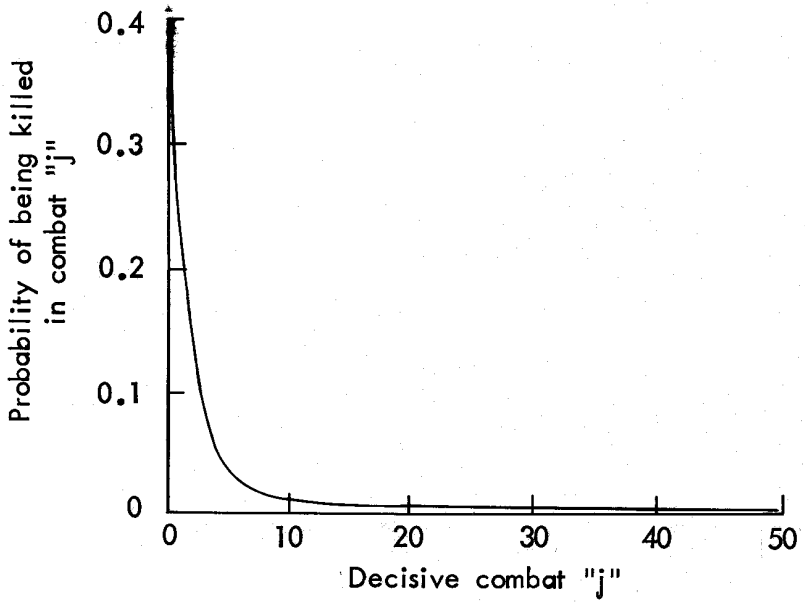

Fig. 1 — Pilot loss rate relationship to decisive combat

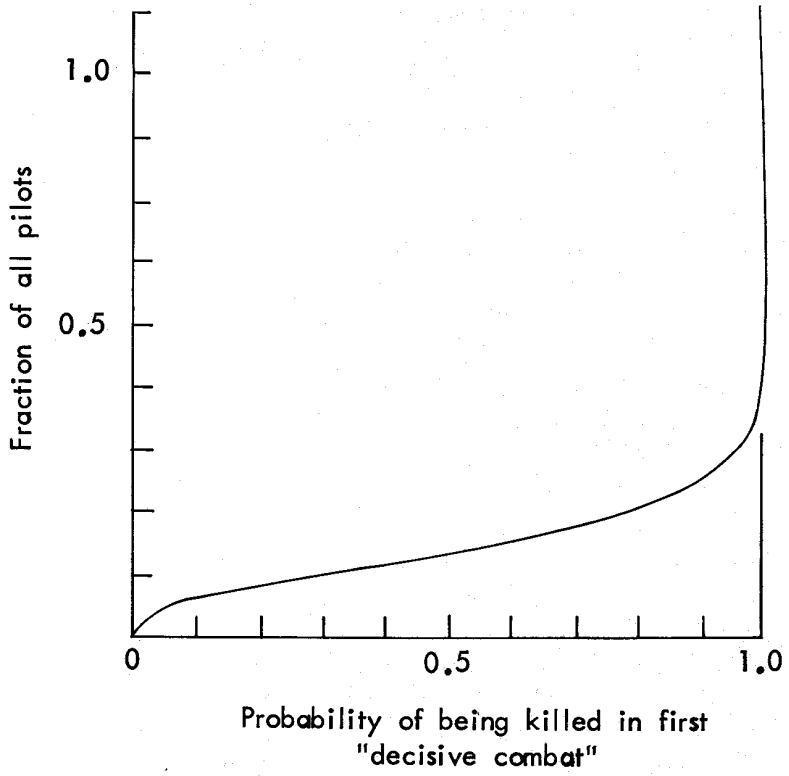

Fig. 2 — Cumulative distribution function of pilot performance

Weiss's analysis has many shortcomings that cast doubt on its applicability to contemporary conditions. First, his data set is largely derived from World War I encounters whose relevance to the current air-to-air environment is, at best, uncertain. Second, Weiss's conclusion confuses and interchanges general flying experience with pilot skill. He equates the number of sorties flown with a pilot's combat skills, an assumption and problem not unique to his particular analysis. Although the correlation between the two is assumed to be positive and significant, the assumption is open to serious question. To assume that the two are the same is analytically convenient, but to treat them as such is an example of an input measure (experience or number of sorties flown) being incorrectly used as an output or performance measure (aerial combat skill). Also, Weiss unrealistically assumes that the combat skill of the fighter pilot or his performance is constant throughout successive conflicts (there are no improvements in a pilot's aerial combat performance, a condition characterized by a horizontal learning curve), and that there is no rotation of pilots; the latter assumption is predicated upon the very high number of kills claimed by the German World War II Aces. Finally, Weiss's Hawk vs. Dove calculation appears to be seriously underestimated. The better German pilots had exchange ratios of greater than 20:1; Barkhorn downed over 300 enemy aircraft but was shot down only once. Even with a strict policy of pilot rotation, during the Korean war U.S. F-86 pilots enjoyed a 10:1 exchange ratio over Communist MiG-15s. One can only guess what that ratio might have been had the "Hawks" been permitted to remain in Korea for the duration of the conflict. Thus, even though his analysis supports the working hypothesis that pilot skills have a significant effect on the outcome of air-to-air combat, Weiss's failure to distinguish between experience and pilot skills and his questionable data and assumptions suggest that further definition and analysis are necessary to isolate pilot skill factors as they relate to aerial combat.

Other work underpins Weiss's finding that a pilot's probability of being killed decreases drastically after the first few missions flown. Morse and Kimball cite a study conducted by the Operations

Research Group of the USAAF indicating "that the chance of shooting down the enemy when once in a combat increases by 50 percent or more with increasing experience."[1] This only increases the confusion between experience and aerial combat skill while raising additional questions. For example, is the number of combat kills an adequate measure of a pilot's combat skills? and where does the slope of the experience vs. skill learning curve flatten out? More important, such statistics are self-selecting. Weaker or less skilled pilots may indeed be shot down within their first five missions, but the remaining pilots are not necessarily all skilled. The low number of Aces (let alone double or triple Aces) suggests that some pilots are better than others even after the less skilled pilots are removed from the pilot population. In other words, holding constant the number of combat engagements or experiences, exceptional pilot performances can still be identified. The questionable equating of skill with flying experience still leaves one short of a workable index or standard of pilot skills as they apply to air-to-air engagements, and certainly no closer to the goal of improving air-to-air capabilities throughout the force during peacetime.

Merritt and Sprey noted that "4 percent of the pilots have contributed 40 percent of the total kills in every war since World War I."[2] From this and the Weiss data, they concluded that

> very few pilots are good at air-to-air combat, and they tend to run up high scores, almost exclusively at the expense of the large number of pilots on the opposing side who have low skills. The implications are clear: with intensive pilot training and selection, an air force could develop a pilot group capable of sustaining 5:1 or 10:1 exchange ratios against any air force that simply produces pilots on a standardized production line curriculum.[3]

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[1] Philip M. Morse and George E. Kimball, *Methods of Operations Research*, The MIT Press, Cambridge, 1951, p. 46.

[2] Jack N. Merritt and Pierre M. Sprey, "Negative Marginal Returns in Weapons Acquisition," in Richard G. Head and Ervin J. Rokke (Eds.), *American Defense Policy*, The Johns Hopkins University Press, Baltimore, 3rd Ed., 1973, p. 493. This article is reprinted under the title "Quality, Quantity, and Training," *USAF Fighter Weapons Review*, Summer 1974, pp. 7-14.

[3] Ibid.

Although Merrit and Sprey share the same conclusions as Weiss, and Morse and Kimball, once again their analysis and evidence are suspect. They make no attempt to identify the skill factor to which they ascribe so much importance. They base their conclusion on the Weiss evidence with no additional analysis of their own. However, their article does explicitly relate the pilot skill factor to the quantity-quality trade-off issue. Furthermore, they implicitly raise the other side of the quantity-quality issue. That is, improved pilot skills might not only result in greater numbers of enemy aircraft being shot down but they could also reduce the number of one's own aircraft being lost in combat. The latter could provide tangible manpower and fiscal savings, completely aside from the less tangible battlefield advantages of destroying the opponent's air capabilities.

Two--perhaps three--sets of combat experience data strongly support the proposition that pilot skill is perhaps the critical element in air-to-air combat. In the 1950 Korean conflict, American F-86 Sabre jets were often matched against Soviet MiG-15 aircraft flown by Chinese Communist pilots. Both jets were considered to have similar performance packages[1] and both sides rotated pilots through combat tours. The outcomes were grossly dissimilar: 484 MiG-15s were shot down while only 48 Sabres were lost, an exchange ratio of 10:1.[2] A difference of this magnitude, especially given the tactical advantages of the MiGs, can best be attributed to the superior skills of the Sabre pilots.[3]

The second example occurred during the Vietnam conflict. During the first half of the air war over North Vietnam (1965-68), the USAF and the USN both achieved roughly the same exchange ratio, about 2.3:1,

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[1]There were, of course, some differences; the F-86 had a superior gunsight and superior performance at lower altitudes, while the MiG had a better turning radius.

[2]See Robert Futrell, *The United States Air Force in Korea, 1950-1953*, Duell, Sloan, and Pearce, New York, 1961.

[3]A thorough discussion of fighter pilot skills in Korea is in Dennis Strawbridge and Nannette Kahn, *Fighter Pilot Performance in Korea*, Institute for Air Weapons Research, University of Chicago, 15 November 1955.

with the North Vietnamese Air Force (NVAF). It should be recognized that the Navy and Air Force flew against different targets, had different degrees of radar support, used their aircraft differently, and encountered varying degrees of sophisticated defenses. Still, their exchange ratios were approximately the same, 2.25 for the USAF and 2.42:1 for the Navy.[1] In 1968, the Navy authorized a high priority research project led by Capt. Frank Ault to explain what the Navy hierarchy considered to be an inadequate performance by its combat fighter pilots. Among the findings of the Ault report was that Navy pilots were poorly trained to perform the air-to-air mission. The Navy immediately initiated an advanced air-to-air training program (Top Gun, at Mirimar Naval Air Station) that featured dissimilar air combat training (DACT).[2] In 1971, U.S. decisionmakers renewed the air war over North Vietnam. From 1971 to the peace settlement in 1973, Navy pilots, flying the same kinds of missions as before, produced an exchange ratio of 12.5:1. Average kills per engagement rose from .20 in the earlier period to 1.04 during the 1971-1973 period. The USAF exchange ratio was unchanged. Every person--Air Force or Navy--interviewed in the course of this research has attributed the remarkable improvement in pilot kills to the Navy's DACT program.

The Top Gun training was given only to the Navy's best, most experienced pilots. One might therefore contend that this evidence represents just another mixing of the skill vs. experience conundrum, especially since most of the Navy's pilots had flown more missions than their Air Force counterparts. However, the Navy was flying essentially the same missions as before the training, it was flying against a more experienced and better equipped NVAF, and its missions took it over a

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[1]These statistics are from "'You Fight Like You Train' and TOP GUN Crews Train Hard," *Armed Forces Journal International*, May 1974, p. 26.

[2]Before the Top Gun Program, most air combat training matched individual pilots against each other, each flying the same type of aircraft. With DACT, pilots fly different types of aircraft against each other. See Philippe Grasset, "Dissimilar Air Combat Training--A Revolution in Realism," *International Defense Review*, Vol. 8, No. 6, December 1975, pp. 823-27.

sophisticated air defense network. Improved air combat skills, largely honed by the new training emphasis, thus seem to be the only new variable that could have resulted in the Navy's singular success.

A final example of the effect of pilot superiority is the record of Israeli pilots over the Soviet-trained and equipped Egyptian and Syrian pilots. In the October 1973 war, the exchange ratio of the Israeli Air Force against all Arab air forces was conservatively rated at 50:1.[1] The early destruction by the Israelis of the Egyptian Air Force on its own airfields in 1967 makes exchange ratios in the earlier conflict less pertinent. Although the exchange ratio is startling, the issue is obscured by different models of aircraft and motivation factors. Still, it is probably safe to assume that the superior selection and training of the Israeli jet pilot contributed significantly to the air superiority enjoyed by Israel.[2] Israeli pilots and commanders seem to agree that in the October war air superiority battles they held "a significant edge in actual dogfighting" because of "their own razor sharp pilot training that never stops."[3]

One can safely assume that pilot skill is an important determinant of the outcome of aerial combat, even when there is a limited number of engagements. The analytic problems are to identify what sorts of factors define or make up those skills, suggest (possibly quantitatively) how important those skills are in aerial combat relative to other variables (e.g., airplane maneuverability or air-to-air missile reliability), and to propose how these factors might be translated into peacetime training recommendations. Are a pilot's air skills best explained (or predicted) by his flying experience, his tactics, or his training? The following section examines each of these in some detail.

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[1]Robert Hotz, "Israeli Air Force Faces New Arab Arms," *Aviation Week & Space Technology*, 10 March 1975, p. 16, cites a "60-to-1 kill ratio in air combat against four Arab air forces in October, 1973." Also see Edward Luttwak and Dan Horowitz, *The Israeli Army*, Allen Lane for Penguin, London, 1975, p. 347.

[2]Certainly this was the sentiment of Israeli commanders before the Yom Kippur war; see William Stevenson, *Zanek*! Viking Press, New York, 1971, pp. 69-72.

[3]See Hotz, "Israeli Air Force Faces New Arab Arms," p. 16.

III. POSSIBLE EXPLANATIONS FOR PILOT SUPERIORITY IN AIR-TO-AIR COMBAT

There are many answers to the question of what makes a good pilot but they can conveniently be divided into factors a person possesses before his undergraduate pilot training (UPT) curriculum and those acquired after he has been awarded his wings. In the first category are a number of physical prerequisites, such as certain height, vision, and physical coordination standards. These are all reflected in the physical requirements of the Air Force. A second component of this category deals with motivational and psychological factors such as desire, determination, and intensity. These are much more difficult to define and specify in advance for two reasons. First, there is little concrete evidence as to the preferred psychological makeup of a fighter pilot, let alone the exceptional fighter pilot.[1] Second, the instruments of psychological measurement currently available are thought to lack the necessary precision and reliability.

This report focuses on an examination of variables that are part of the fighter pilot's preparation after his graduation from the UPT program. These include an evaluation of pilot experience, the development and use of aerial combat tactics, and air combat skills. A related question is how manipulatable are these variables in a pilot's preparation. That is, simulated combat flown against frontline Soviet MiGs and pilots might be ideal preparation for air-to-air combat but the situation is hardly feasible. Unlimited sorties in the F-15, given the current level of the American defense budget, are highly unlikely.

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[1] One of the better attempts to profile successful fighter pilots psychologically is E. Paul Torrance, Carl H. Rush, Jr., Hugh K. Kohn, and Joseph M. Doughty, *Factors in Fighter-Interceptor Pilot Combat Effectiveness*, Air Force Personnel and Training Research Center, Lackland AFB, AFPTRE-TR-57-11, November 1957; however, there are many methodological problems that vitiate their analysis, some of which are acknowledged. The McDonnell-Douglas Corporation in St. Louis is currently engaged in a study for the Defense Advanced Research Projects Agency, proposing to identify key psychological characteristics of the successful fighter pilot.

PILOT EXPERIENCE

Many observers argue that experience and flying skill are indistinguishable and, in effect, the more flying experience or hours or sorties a pilot has, the better that pilot is. Indeed, the number of flying sorties is a major Air Force criterion for a pilot's training. This assumption is surely valid to a certain degree and for certain types of missions. For example, routinized skill in performing standard operating procedures can probably be obtained and honed through repetition. However, even here, one would expect a dramatic leveling off of the learning curve;[1] is a pilot who has flown two hundred SAC missions twice as good as one who has flown only one hundred? In the chaotic air combat mission, there is even less evidence in favor of equating general flying experience with air-to-air combat skills.

"Flying experience" is generally defined in terms of the number of sorties flown or perhaps hours recorded in a cockpit; often this is delineated by the specific types or models of aircraft. A further distinction should be made between combat missions and aerial combat missions. The first includes all war zone flights in which aerial encounters are not recorded. Because the Air Force defines an air-to-air encounter as a mission in which one side's aircraft takes hostile action or affects the outcome of the mission, this suggests that many sorties over hostile territory would not be enumerated as air combat missions because no bogeys were encountered, which was common on Air Force missions over Route Package I during the Vietnam conflict. The second distinction is the acquisition--not necessarily the engagement--of an enemy aircraft.

Most of the research reviewed above implicitly assumed that the more hours in the cockpit--regardless of the context--the more skilled the pilot was in shooting down his enemy counterpart. The important distinction between missions with and without air-to-air combat and their relation to a pilot's combat skills were not analyzed separately. The earlier analyses, Weiss's for example, implied that noncombat

[1]Substitute "Number of Missions" for "CCTS Scores" on the horizontal axis of Fig. 3, p. 27, for a graphical representation.

experience and combat experience were indistinguishable in preparing a pilot's combat skills.

Some of TAC's analyses of the air war in Vietnam, conducted under the Red Baron project, provide data with which to address the relationship of flying experience to combat results.[1] Red Baron II and III compared USAF pilot experience with a pilot's record of success or failure in decisive combats (again defined as one in which a kill was recorded by either side). Experience in Red Baron II was measured as the number of previous hours flown in (a) all aircraft, (b) all fighters (Red Baron III substituted jet aircraft for this category), (c) all tactical fighters, and (d) the aircraft flown during the decisive encounter. Red Baron II analysts used the non-parametric statistical median test to test data from encounters between 1965 and 1969.[2] There was no statistically significant difference between all pilots and those who had shot down MiGs when they were judged by the number of sorties in all aircraft (total flying hours) or in tactical fighters or fighter aircraft; Red Baron II did report a significant difference in the number of hours flown in a pilot's combat aircraft (usually the F-4) between the total pilot population and the MiG killers. No differences were observed in these four experience categories between the pilot population in general and those U.S. pilots shot down by MiGs. In short, Red Baron II data argue that only flying experience in the combat aircraft seemed to be a significant factor in predicting a

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[1] Red Baron data cited in this report are abstracted from "Analysis, Part 1: Tactics, Training, Command & Control," *Project Red Baron II* (U), Vol. II, USAF Tactical Fighter Weapons Center, Nellis Air Force Base, January 1973 (Secret); and "Analysis, Part 1: Tactics, Command & Control, and Training," *Project Red Baron III* (U), Vol. III, USAF Tactical Fighter Weapons Center, Nellis Air Force Base, June 1974 (Secret). These volumes are hereafter referenced as *Red Baron II* and *Red Baron III*.

[2] The statistical median test compares the number of observations from one sample with the number of observations in a second sample that are above the combined median value of the total population. The significance probabilities are based on a hypergeometric distribution. For a more complete explanation, see James V. Bradley, *Distribution-Free Statistic Tests*, Prentice-Hall, Englewood Cliffs, N.J., 1968, Chap. 8.

successful air-to-air combat pilot. Red Baron II did not separately test for combat flying experiences.

Red Baron III data argue the contrary. Analysts used Chi-square tests for independence between the four categories of aircraft experience and decisive engagement results for the period 1971 to 1973. These data show that flying time in the pilot's combat aircraft and in all jet aircraft were not statistically significant at the 10 percent level for differentiating between those pilots who shot down MiGs and those who were shot down.[1] Red Baron III argues that flying hours spent in tactical fighters and the total time spent in all aircraft were statistically significant (at the 10 percent level) for distinguishing between the two pilot groups. At best, experience appears to be only a vague measure of a pilot's air-to-air combat skills. Yet, flying experience is a major criterion in determining a pilot's advancement in both CCTS and operational training.

A subset within the experience variable is aerial combat experience or combat missions flown. Red Baron III examined three types of combat missions: (a) previous air-to-air encounters; (b) combat missions over North Vietnam; and (c) total combat missions. Again with a Chi-square test, the 1971-1973 data suggest that the relationship between previous aerial combat encounters and success or failure in a decisive combat was significant at the 5 percent level and that missions over North Vietnam and total combat missions were significant at the 2.5 percent level. That is, there was a significant difference between pilots who were successful in shooting down MiGs and those who were lost to MiGs in terms of previous combat missions flown; previous combat missions and air-to-air combat results were not statistically independent of each other. Thus, one can begin to argue that combat

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[1]The null hypothesis in this case is that there is no difference between the two observed groups (those who have shot down MiGs and those who are shot down themselves); i.e., the probability of shooting down a MiG or being shot down was independent of the pilot's experience. The Chi-square test result does not allow one to reject the null hypothesis at the 10 percent level, which is to say that nine times out of ten, there is no difference between the distributions of the two groups in terms of experience.

missions flown (survived) can predict success or failure or be used as a pilot skill index for air-to-air combat.

This assertion, however intuitively satisfying, raises a number of troublesome questions. First, one needs to inquire about the flight position in which the pilot logged his combat missions. Although flying the wingman (second and fourth) positions in the Air Force's "fluid four" formation demands great concentration and skill, these requirements and the opportunities to make a firing pass are markedly different from those placed on the first and, to a lesser extent, on the third position. The Red Baron III data clearly show that the first and third positions recorded the greatest number of enemy aircraft kills, while the fourth position displayed a disproportionate number of losses during aerial combat. However, the analyses did not discriminate between flight positions when testing on experience so one cannot ascertain if all combat missions are equal as predictors of success or failure or in serving as a surrogate for pilot skill using the existing data base. Second, one must ask where or when the improvements in pilot skills as measured in combat missions begin to flatten out or tend toward zero and if that number of missions is more or less than the hundred missions USAF pilots flew in Southeast Asia before they were rotated out of the war zone. Third, all combat missions are not the same. A sortie against Hanoi was much different from one over the DMZ, and a bombing or CAP mission was different from an air-to-air engagement, in terms of both the dangers encountered and the lessons learned. A fourth and final issue is particularly relevant in the peacetime environment. How can the USAF train and evaluate its pilots for air-to-air combat if previous combat experience is the most important preparation and indicator by which the Air Force can gauge a pilot's combat performance, especially given the safety considerations that justly dominate peacetime TAC training procedures?

By 1981 the Air Force may have to cut back on flying hours by as much as 25 percent because of rising fuel costs.[1] If one does assume that experience is an adequate indicator of a pilot's air combat skills

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[1]See Edgar Ulsamer, "Dogfights at Zero Mach," *Air Force Magazine*, Vol. 58, No. 10, October 1974, pp. 65-67. The magnitude is open to debate, but the fact is generally acknowledged.

(and this assumption is difficult, although convenient), then the impending reduction of flying hours will leave the Air Force with a pilot population that will have logged insufficient flying experience to enable a forecast of high competencies in its air-to-air combat role. The use or ability of flight simulators to compensate for fewer flying hours is one possible corrective measure, but its value is still uncertain. Brig. Gen. Norman C. Gaddis, Special Assistant for Flight Simulation Matters to the USAF Chief of Staff, has stated that there is particular uncertainty in the case of "fighter aircraft, where simulator benefits are largely unknown."[1] In summary, if flying experience or the number of sorties is the measure of pilot skill, and flying hours are to be reduced, the Air Force will be unable to train air combat pilots to the current skill levels (as a function of the number of sorties or missions), unless simulators can adequately compensate for the lost flying time. The alternative is to substitute or emphasize another facet of air combat training or pilot management to compensate for the reduced number of missions. This, in turn, requires the definition of another measure of pilot skill so that the revised curriculum can still produce a highly skilled fighter pilot as well as a standard to evaluate those skills.

AIR-TO-AIR COMBAT TACTICS

Tactics undoubtedly have some effect in determining success in air-to-air combat. This was particularly true in World War I as the British, French, and German fliers continually experimented with and evolved unit and individual flying tactics and formations that have strongly influenced aerial combat maneuvering to the present day. The

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[1] Ibid., p. 66. TAC is currently testing a Singer F-4 air-to-air combat simulator at Luke AFB. The results of these tests should provide some information on the ability of a ground simulator to substitute for air-to-air combat flying hours. TAC has recently conducted a preliminary evaluation of the Vought Air Combat Simulator (VACS) as a means to supplement the current air combat flying training programs; see USAF Tactical Fighter Weapons Center, *TAC ACES I: Special Project to Develop and Evaluate a Simulator Air Combat Training Program*, DCS/Tactics Analysis and Development, USAF Tactical Fighter Weapons Center, Nellis AFB, Interim Report, April 1976.

tactics developed by Chennault for his Flying Tigers permitted his technically inferior P-40s to enjoy some measure of success against the Japanese Zero. Fighter tactics are a critical part of a pilot's education today.[1] Even a brief reading of the Red Baron series will illustrate how the Air Force altered its air-to-air tactics to meet the changing requirements presented by the evolving and increasingly well-coordinated and sophisticated North Vietnamese air defense system. Because of the Southeast Asia experience and the perceived requirements of future air combat in the European arena, the Air Force tactical fighter community now has largely adopted a major change in its standard tactical flying formations and gone from the "fluid four" with its defensive (or "welded") wingman concept to the two-aircraft formation, which the TAC has named the "fluid two."[2] One of the main advantages of the second formation is that it more actively engages the wingman in an offensive mode, for example in sequential firing passes.[3]

The fundamental question is not which formations or tactics are used or how they change but how instrumental they are in determining the outcome of an engagement. The issue can be argued from either side, but the answer remains unclear. Navy fighter pilots flew their version of the two-aircraft formation, the "loose deuce," over Vietnam during the 1965-68 period yet did not enjoy significantly greater success than did the Air Force with its four-aircraft, two-element fighting wing. Indeed, some argue that because the Navy pilots flew over less heavily defended areas and encountered MiG-17s while the Air Force was battling MiG-19s and MiG-21s, the Navy aviators did not do as well as their Air Force counterparts, especially if the Navy pilots were

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[1]Tactical Air Command Manual 3-1, *Tactical Fighter Weapons Employment* (U), August 1974, Volumes 1-6 (SECRET). These studies are co-issued by TAC with PACAF and USAFE. They detail all phases of air-to-air tactics.

[2]See Major Donald Gish, "F-4 Air-to-Air Training," *USAF Fighter Weapons Review*, Fall 1975, pp. 1-5. The *Fighter Weapons Review*, published by the USAF Fighter Weapons School at Nellis AFB, is an excellent reference for observing the evolution of Air Force fighter tactics.

[3]Part of the purpose of the joint Air Force and Navy ACEVAL/AIMVAL tests to be conducted at Nellis AFB this year is to evaluate the effectiveness of different tactics and formations.

flying a "superior" tactical formation. It was only after the dissimilar air combat training program the Navy instituted in 1968 that its combat exchanges ratios showed marked improvement. Also, it is particularly difficult to gauge just how much effect various tactics have against an enemy who is perfectly willing and able to change his tactics as he sees U.S. tactics evolving. Tactics are neither static nor copyrighted. Certainly both sides in World Wars I and II borrowed fighter tactics or formations as they appeared to be successful.

Air combat tactics and formations almost surely have an effect on determining the outcome of an aerial engagement and therefore are candidates for inclusion in a pilot skill rating. The major obstacle, however, is that there seems to be no way of compensating or controlling for other intervening variables (e.g., aircraft types) or ascertaining just what is the effect of tactics, given the state of flux in tactics compounded by other complexities in air-to-air combat. What is surely important is the ability of the air combat pilot to recognize which tactics are appropriate for a given situation and his ability to execute them. This suggests, then, that the critical element here is the pilot and how he uses his "bag of tactics," rather than the tactics themselves.

AIR COMBAT TRAINING

Air combat training (ACT) is defined here as those training exercises, following the pilot's UPT graduation, designed to instruct the pilot in air-to-air combat skills and later to maintain and improve those skills. ACT would therefore include a pilot's fighter lead-in and combat crew training squadron (CCTS) experiences, his training with his assigned unit so that he meets its operational readiness requirements, exercises designed to sharpen or at least maintain those skills (e.g., exercises against the Air Force's Aggressor squadron), and any advanced training that the Air Force offers to which he might be assigned, such as the Fighter Weapons Instructor Course (FWIC) at Nellis's Fighter Weapons School (FWS).

There seems to be little argument that advanced air combat training can have a salutary effect on the outcome of air-to-air combat.

Red Baron II reported that FWIC graduates constituted 7.7 percent of the pilot sample yet accounted for slightly greater than 15 percent of the MiGs downed. Testing for differences in flying experience as a possible explanation, the median test indicated that there was no significant difference in combat aircraft hours between the FWIC graduates and the remaining pilots who shot down MiGs. The Red Baron II analysts therefore concluded:

> It is suspected that the combined results show an increase in the ability to fly under the more rigorous air-to-air engagement environment. As a result of their training at the Fighter Weapons Instructor School, the FWIC pilots undoubtedly experienced more pertinent, concentrated experience per hour in the aircraft than did the non-FWIC Grad MiG killers.[1]

Red Baron III data generally confirm this conclusion. Chi-square statistics reveal a 5 percent level of statistical significance for the relationship between intensive ACT (which was defined as a tour at Nellis FWS) and success or failure in a decisive engagement during 1971-73. The earlier noted improvement in the Navy's exchange ratio between 1965-68 and 1971-73 has also been attributed to intensive ACT, specifically the Top Gun dissimilar air combat training program.

The data are not conclusive in support of the effectiveness of increased or improved ACT. Half of the Air Force pilots who recorded multiple MiG kills did not attend the FWIC. Red Baron III computer records do not consistently identify the Navy's Top Gun pilots so one cannot isolate or test the relationship between Top Gun graduates and the rest of the Navy's pilot population, let alone the other Navy MiG killers. The relationship between FWS graduates and combat performance as a function of kills was obscured because, as Red Baron III points out, FWS graduates flew a disportionate number of flights in the lead position from which the greatest number of enemy kills were recorded. Again, as was noted in the discussion of the Top Gun graduates, only the Air Force's best pilots were selected for FWS training, so it is unclear whether the FWS experience or their previous skills (even

[1] *Red Baron II*, p. V-16.

holding experience constant) were the more instrumental in creating this disproportionate number of enemy kills. Most damaging is that Red Baron III analysts tested the relationship between advanced ACT and success or failure for the 1965-68 period and found that it did not even demonstrate dependency at the 10 percent level of significance, thus directly contradicting Red Baron II findings.

Even with these reservations, a strong consensus does exist in the Red Baron data and in the numerous personal interviews I conducted to the effect that air combat training is closely linked to success or failure in the air combat role. Indeed, many of the criticisms voiced by veterans of the Vietnam air war were directed to what they described as shortcomings in their ACT at the CCTS levels.[1]

The Red Baron III staff conducted an extensive Delphi exercise among air crews who had engaged in air-to-air encounters in Vietnam to determine what were the most important factors in *achieving* and *maintaining* an "offensive posture in an air-to-air encounter in SEA." The survey also asked what areas the U.S. Air Force should emphasize "in preparation for future air-to-air conflicts."[2] Responding to the "achieving an offensive posture" section, the pilots rated "training and experience" second only to "warning and detection" in importance. "Training and experience" were considered most important in "maintaining an offensive posture" and tied for most important with "aircraft performance" in future air superiority. "Air-to-air combat experience" and "dissimilar-aircraft ACM training" were the crews' choice as the most crucial means for achieving air superiority. The same ranking holds in maintaining superiority, except that "combat experience over NVN" is ranked second. In the future category, DACT is the clear first choice, with similar ACT second.

Again, the overlap and interplay among flying experience, combat experience, and training should be noted. However, given the forecast reduction in available flying hours that the Air Force is facing,

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[1] A representative sample of comments is appended to *Red Baron II* and *III*.

[2] These data are reported and elaborated upon in "Delphi Aircrew Survey (Air-to-Air Factors)," *Red Baron III*, Chap. IV.

experience in terms of flying time or sorties in the aircraft will almost certainly be less available. Clearly, in peacetime operations, Air Force pilots cannot expect to obtain combat experience. The remaining alternative, if one wants to obtain and maintain a high degree of air-to-air combat skills, is to place heavy emphasis on air combat training exercises, especially between dissimilar aircraft. TAC has already adopted these measures. Two DACT "Aggressor" squadrons (the 64th and 65th TFTS) are already stationed at Nellis AFB and equipped with F-5Es that can closely replicate the flight characteristics of the MiG-21. USAFE and PACAF have recently received their own Aggressor squadrons, the 527th TFTS (with a full squadron of F-5Es) and the 26th TFTS (12 T-38s), respectively.[1] If the Air Force chooses to pursue the ACT options, as seems apparent, the questions then become, What are the most important elements or components of air combat skills that might be translated into peacetime training exercises? How does one define an index of pilot skills for measuring what a pilot has learned and for predicting later success in air-to-air combat?

SUMMARY

Levels of combat experience and air combat training appear to have the greatest effect on a pilot's ability to succeed in air-to-air combat. However, only training is available for peacetime exercises. The issue now becomes how to design research to use ACT most advantageously for the air-to-air role. For example, how can DACT be improved so that a high-skill level can be maintained in the face of funding restrictions? Or how might the Air Force train and then allocate its FWIC graduates to maximize their effectiveness? Most critical, and certainly most difficult, how can the Air Force select, produce, evaluate, and deploy the highly skilled air-to-air pilot who will best perform the air superiority mission of the F-15 and F-16? The benefits

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[1] For details on the "Aggressor" squadrons and their underlying concept, see the testimony of Lt. Col. Jerry Nabors, then the Commander of the Nellis Aggressor Squadrons, in U.S. Senate, *Hearings Before the Committee on Armed Services: Tactical Airpower*, 94 Cong. 2d Sess., Part 9, 1976, Washington, D.C., pp. 4907-4919. The USAFE squadron is reported on in "F-5E Training Unit Assumes MiG Role," *Aviation Week and Space Technology*, Vol. 105, No. 2, 12 July 1976, p. 35.

of such research could be significant in two ways. First, a dramatic improvement in the exchange ratio would severely restrict the enemy's resources and his ability to carry out his missions, thus improving the capability of friendly forces. Second, fewer USAF losses would result in both a continued capability to fly crucial battlefield sorties and in savings approaching 50 percent in terms of replacement costs for USAF pilots and aircraft.[1] In arenas where the United States, with limited resources, faces a numerically superior enemy (such as in central Europe), this latter advantage could be critical. At the present time, the Air Force has no consistent and objective set of guidelines with which to evaluate the proficiency of its combat pilots. Should an evaluative measure be devised, the increment in pilot training costs could be assessed in terms of expected wartime effectiveness. Both of these reasons argue strongly that the proposed research agenda merits careful consideration.

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[1]This estimate is strictly suggestive of the potential savings. It is derived from a set of assumptions and cost approximations shown in the appendix.

IV. INCREASING THE EFFECTIVENESS OF THE AIR SUPERIORITY PILOT TRAINING

So far I have argued that the role of the individual pilot in air-to-air combat is perhaps the single most important factor in determining the outcome of the engagement and that extensive air combat training and combat experience appear to be the best two alternatives for preparing that pilot and predicting his ultimate success or failure in decisive combat. These assertions are generally shared by members of the tactical fighter community. In conversations with Air Force personnel at Hq. USAF and TAC facilities, I have noted another consensus: The Air Force has not been as judicious in the selection, training, evaluation, and management of its fighter pilot resources as it might have been. If this is true, pilots are often not as well prepared for aerial combat as they could be, and the best air-to-air combat pilots are not always available for that mission.[1] The problem, then, is to identify more precisely how important the pilot is to the effective operation of the weapons system and, specifically, if the above observations are verified, how the necessary pilots can best be marshalled.

If one accepts these opinions, the issues to be resolved concern how the air-to-air combat pilot is selected, trained, and assigned to duty. Further, is it possible to make objective and consistent evaluations of how he will perform in combat? The major impediment to the resolution of such questions is the paucity of pertinent data. Many important research avenues would be unproductive because of the inadequate or nonexistent data. For example, some critics have observed that current training standards for air combat pilots are inconsistent, that different CCTS bases unintentionally produce different emphases of pilot skills rather than the world-wide assignable pilot, that there is a wide variation in levels of pilot skills among CCTS locations, and,

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[1] Again, pilots quoted in the appendixes of *Red Baron II* and *III* suggest that they were not adequately prepared for the air-to-air mission requirements in the Vietnam conflict.

most disconcerting, that the overall quality of pilots has diminished in the past five years.[1] These are all important statements, but they are mostly based on observations and anecdotal evidence drawn from a restricted sample. There does not seem to be any method for analytically refuting or supporting those statements. Quantitative data, such as CCTS scores and flying evaluations, are not consistent. Even if they were, they are currently not retained by TAC over a sufficient period of time to weigh such statements longitudinally. TAC might be willing to adopt a set of objective or consistent measures to evaluate their pilots, but validating such metrics without extensive and expensive TAC cooperation would be impossible. Just as important, it would be most difficult to demonstrate before (and perhaps even after) such tests how these new measures would be related to actual air-to-air combat; i.e., would a standard deviation above the mean pilot score predict a 20 percent, 30 percent, or x percent better performance in combat? The lack of relevant data would make the estimation of the worth of the proposed measures problematic, and TAC would have little *a priori* reason to test such a program, let alone carry it out.

Ideally, one would like to posit and derive a relationship that would reliably correlate a pilot's CCTS performances with both his combat air-to-air skills and the skills of the general pilot population, as exemplified in Figs. 3 and 4. If the CCTS pilot skill curve resembled pilot A in Fig. 3, it would argue that high CCTS scores could result in an increased payoff in terms of combat effectiveness; this finding might well recommend to TAC that it initiate a program to improve its pilot training to achieve higher CCTS scores. A relationship resembling pilot B would argue agains the additional training.[2]

The original objective of this research was, in fact, to establish the relation between CCTS performance and combat effectiveness using

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[1]See Col. James A. Cook, USAF, *Quantity or Quality? An Analysis of Current UPT Philosophy*, Air University, Maxwell AFB, Ala., Professional Study No. 4544, January 1972.

[2]For the sake of illustration, assume that the current average pilot skill level is at $\bar{X}_0$, but since pilots A and B cannot be distinguished, it is impossible to determine which curve would result from increased ACT.

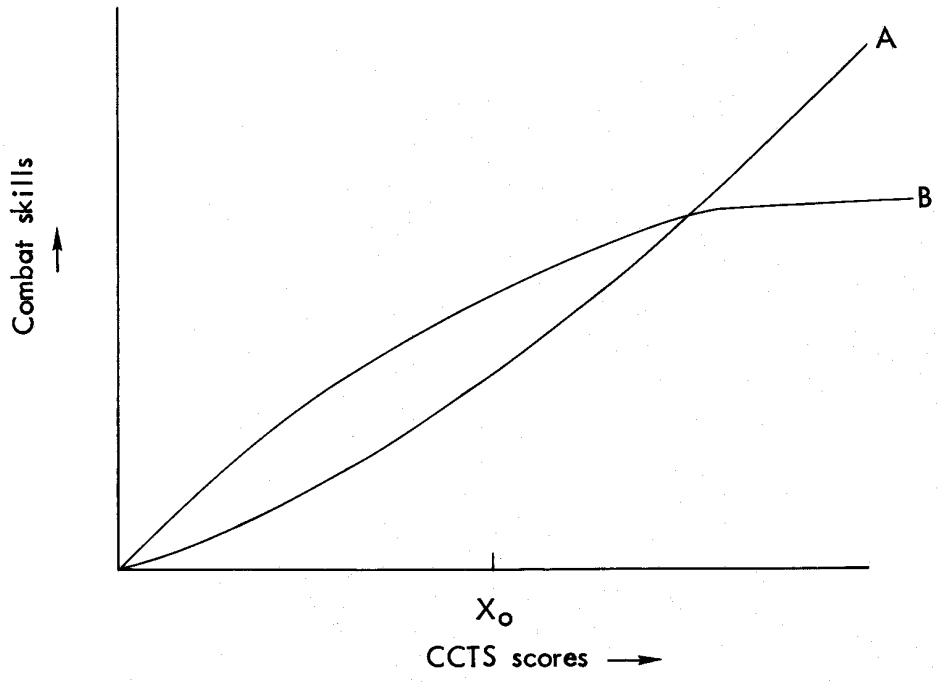

Fig. 3 — Theoretical effects of training on combat capabilities

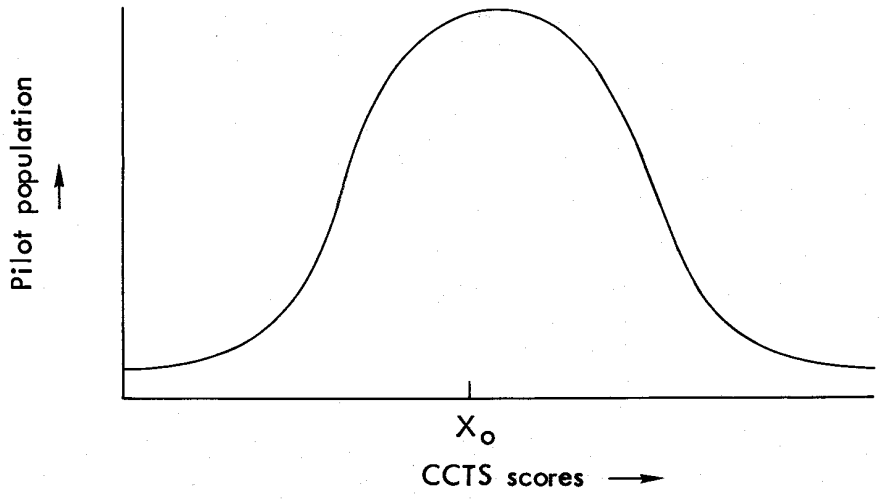

Fig. 4— Distribution of pilots by CCTS ACM scores

the Red Baron data, but the Red Baron data files containing pilot identification numbers were destroyed to preserve the anonymity of the correspondents. Furthermore, TAC does not retain CCTS scores in a central repository over an extended period of time. Therefore, this objective had to be abandoned. Given the current condition and availability of the data, the relationships posited by Figs. 3 and 4 are simply not testable. Still, the potential payoffs from deriving such a relationship could be well worth the effort. The research problem is to frame important, relevant questions given the restrictions of the data set. Perhaps the central issue to the air-to-air pilot quality question is the development of a scale that would allow the Air Force to judge a pilot's ACT skill during peacetime and translate it somehow into an expected value for wartime performance. This could then be used to grade an individual pilot's skills and predict a certain proficiency in combat across the entire force. Again, Figs. 3 and 4 illustrate how such a hypothetical relationship might appear. This issue presents extremely difficult problems as to both concept and practice. The Red Baron data permitted some measures of the pilot combat skills demonstrated during the Vietnam conflict, but, as already noted, it was not possible to compare or correlate a pilot's CCTS and flying evaluation scores with his Vietnam performance.

Because of these data limitations and the dynamic, complex nature of aerial combat, the development of an ACT proficiency scale linking peacetime training exercises with combat performance is not imminent. However, there are four research areas whose demands are less forbidding and whose applications are more readily usable. The first concerns the combat pilot's selection to CCTS, particularly to the air-to-air role, from his UPT class. The second involves the training procedures during CCTS. The third discusses possible problems in the Air Force's management of its pilot resources. The fourth facet of the research examines the effectiveness of the Air Force's DACT program. The combined results, especially if the tasks in the second and fourth areas can be successfully completed, might well offer important insights that could lead to a direct encounter with the central issue of measuring pilot skill.

This analysis is inherently asymmetrical in that it addresses only one side of an air-to-air engagement--that represented by U.S. pilots and aircraft. It implicitly assumes a standard or constant enemy pilot skill level. In actual combat, of course, the opponents may vary widely, and skill levels adequate to defeat one enemy may be found wanting against another. The report's objective is not to model aerial combat with complete fidelity; it is to present a research agenda for improving the performance of U.S. combat pilots. The assumption of holding the opponent's skill level constant is therefore not particularly debilitating. However, to compensate for this bias, one might ascribe a greater proficiency to enemy pilots than intelligence information might suggest is the case.

A second possible shortcoming must be acknowledged. Most of the combat data cited above, especially the Red Baron figures, are recorded for two-man aircraft flown by the pilot and the radar intercept officer, or the Guy-in-Back (GIB). By most accounts, the GIB with his "second pair of eyes" was a definite asset to the pilot's air combat proficiency. The GIB's contribution was explicitly recognized by the Air Force and Navy in that both he and the pilot were credited with a kill for each enemy aircraft their airplane shot down. The research proposals offered below do not address the GIB's preparation because the pilot was the central focus of the study, and the coming generation of the Air Force's air combat aircraft, the F-15 and F-16, are both single-seat aircraft.

SELECTION FROM UPT

The graduation from UPT into the Fighter Lead-In program at Holloman AFB[1] and later to a CCTS assignment is TAC's first opportunity to observe, then to train, the prospective fighter pilot. There is some evidence that the quality of the UPT training has declined in the past decade[2] and that existing selection procedures do not necessarily insure

[1]For a brief description, see Lawrence R. Benson, "The New USAF Fighter Lead-In Program," *Air University Review*, Vol. 26, No. 3, March/April 1975, pp. 55-66.

[2]See Cooke, *Quantity or Quality?* for a critical assessment of UPT's role in training future fighter pilots. TAC's Fighter Lead-In program was initiated partially to alleviate this problem.

that the UPT graduates holding the most promise as air-to-air pilots are admitted to that specialization. The result, if the assertions are valid, is that Air Force fighter instructor pilots (IPs) must work harder to overcome early training deficiencies.[1] As noted above, the data do not permit evaluation of this statement. What can be addressed is the actual selection process that assigns pilots to TAC for advanced training.

There is some evidence that certain psychological and behavioral patterns are more characteristic of fighter and attack pilots than of bomber and tanker pilots[2] but much uncertainty as to precisely what these traits might be, or if any testing would be conclusive. Extensive research using Korean War data has concluded that "the [psychological] qualities necessary for success in combat are not well understood."[3] Later research and advances in psychological and psychomotor testing have not proved definitive in either direction.[4] Still, the reported successes of the Swedish[5] and Israeli[6] air forces in using

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[1] This sentiment was repeatedly expressed by F-4 instructors whom I interviewed.

[2] See Robert E. Miller, *Optimal Assignment of Air Force Pilots,* Human Resources Laboratory, Lackland AFB, Texas, AFHRL-TR-73-59, February 1974. Earlier work to this point was done by Paul M. Fine and Bryce O. Hartman, *Psychiatric Strengths and Weaknesses of Typical Air Force Pilots,* USAF School of Aerospace Medicine, Lackland AFB, Texas, November 1968.

[3] Strawbridge and Kahn, *Fighter Pilot Performance in Korea,* p. 72.

[4] A pessimistic evaluation is provided by Major DeWan D. Madden, USAF, *Tactical Fighter Pilot Selection Considerations,* Air University, Maxwell AFB, ALA, Air Command and Staff College Research Study, No. 1810-73, May 1973, especially Chap. 3. A more optimistic assessment is given by Major Marcus F. Cooper, Jr., USAF, Major Stanley M. Imaye, USAF, Major Robert H. Karre, USAF, Capt. James F. Robertson, USAF (ANG), Capt. Michael E. Ryan, USAF, and Major William T. Sakahara, USAF, *Application of Operational Pilot Selection Criteria,* Air Command and Staff College, Air University, Maxwell AFB, Ala., Research Study No. 0615-76, May 1976.

[5] See Lt. Col. Louis A. Wootton, USAF, "Swedish Trip Report," ATC/DOXD, Randolph AFB, Texas, 25 February 1972; cited in Cooper et al., ibid.

[6] This was described to me in personal interviews with Israeli pilots; also see David A. Brown, "Israel Spurs Pilot Training to Fill Ranks," *Aviation Week & Space Technology,* Vol. 104, No. 7, 16 February 1976, pp. 18-19.

psychological tests to identify certain types of aircraft pilots suggest that there are ample grounds for exploring the area and possibly conducting a statistical experiment.[1]

A second possibility for improving the CCTS selection process is to understand what UPT areas correlate most closely with the pilot's later performance in combat. Examination of the Korean and the Red Baron Vietnam data might permit differentiation among pilots who performed well, those who were "average," and those who did less than average, perhaps were even shot down. However, the number of "kills" is not an adequate measure of pilot skills. The sample size is too small, and the sole reliance on enemy aircraft downed as an index of pilot skills may hide more than it reveals for the vast majority of pilots. As an initial alternative measure, one might use the pilot skill indexes discussed in the next section with allowances taken for flight position, combat experience, and the initial configuration of the combatants. If such a set of indexes could be applied to Vietnam data and the UPT scores for the representative number of pilots in this population could be obtained, one might be able to identify UPT areas that indicate later successful performance in decisive combat. This would provide the USAF Military Personnel Center with guidelines when they review the assignments and qualifications of UPT graduates who might be recommended for assignment to TAC by ATC's Advanced Training Recommendation Board. This would also provide some guidelines to TAC in deciding which UPT graduate might be better suited for flying the different types of aircraft in that Command.

Two research caveats are necessary. First, the Red Baron data, the most complete compilation of Vietnam air engagements, cannot be used for this calculation because Social Security numbers, the only link between the pilots and their training records, were not retained. A sample population is needed that would identify pilots who flew combat missions in Vietnam and roughly estimate their performance. Then their UPT scores could be compared. Second, the availability of UPT data for

[1]Cooper et al., *Application of Operational Pilot Selection Criteria*, offer a number of psychological and physiological tests that might be considered.

Vietnam pilots who graduated from UPT before 1965 is uncertain. (The Air Force's Human Resources Laboratory has computerized the UPT records of post-1965 graduates.) The inclusion of CCTS or Graduate Evaluation flying scores is an obvious use of Vietnam combat indexes; but, again, these scores have not been preserved by the TAC, except possibly (in the latter case) in aggregated form.

In general, the concern here is less with the prospective fighter pilot's rank or standing in his UPT class than with identifying predispositions toward the specialized requirements of aerial combat and the portions of the UPT curriculum that correlate most closely with success in air-to-air combat. If these can be identified, they would greatly improve the CCTS selection of future air-to-air pilots.

CCTS TRAINING

The fighter lead-in and CCTS programs introduce the prospective fighter pilot to the flight requirements, tactics, and aircraft that distinguish his profession. CCTS is only the beginning of a pilot's training; the SABER WINGS study emphasized "that fighter pilots are not born in a short TAC fighter CCTS course, but that the unique skills in flying fighter aircraft are developed over a long period of time."[1] Still, the CCTS experience provides the student pilot with fundamental air combat skills, such as Basic Fighter Maneuvering (BFM), upon which he will later build his combat proficiency. Further, the CCTS period provides TAC with an opportunity to observe the prospective fighter pilot and determine if he will be a first-rate, average, or a substandard fighter pilot.

A major obstacle in making this judgment is that the present criteria are so subjective. There are few consistent, objective evaluation standards for air-to-air proficiency against which flying performance can be measured except for the number of training sorties completed, and these rarely indicate a pilot's true level of competence. CCTS instructors are reluctant to fail a young pilot because of the extensive

[1] Assistant Chief of Staff/Studies and Analysis, Hq. USAF, *A Study of Pilot Proficiency Flying: SABER WINGS*, Washington, D.C., 1 March 1969 (Confidential), p. 58.

documentation required on their part and because of the severe consequences for the pilot's career in the Air Force. In a future characterized by more expensive aircraft, a skilled and dedicated enemy, and immensely increased training costs, is it worth training marginally skilled pilots for the advanced generation of high performance aircraft and for the air-to-air mission in a future conflict?

The key to a possible policy change in this regard would be either a heavier reliance upon the subjective judgment of the instructor pilots--a lot few of them would welcome--or the development of a series of objective BFM standards that could be used to establish a proficiency threshold.[1] Although there are shortcomings to the proposal, one attractive option is a series of specified standard BFMs graded by a stopwatch to ascertain how quickly the student could reach a firing position.[2] A second example of a proficiency requirement might be to fire upon and hit a DART within a certain number of missions, rather than the existing requirement of completing a specified number of sorties against the DART. A third would be to achieve an air-to-air missile "kill" according to the Air Combat Maneuvering Instrumentation (ACMI) Range within a certain number of training sorties. Such a set of standards would permit both the student and the instructor to observe the skill level obtained with some degree of objectivity. The exceptional student pilot could then accelerate through the program or concentrate his time on identified shortcomings in other areas. By the same token, the IPs could identify the student who needed remedial instruction and allocate the appropriate amount of time. Finally, the IPs and students would have objective standards for recognizing that a particular student would not be a suitable fighter pilot.

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[1]This is not meant to imply that subjective evaluations should be completely eliminated. There is little question that certain aspects of what characterizes an air combat pilot are subjective and should be so evaluated. The contention here is that other aspects can be objectively evaluated and should be. Objective criteria should supplement the subjective evaluations, not replace them.

[2]Squadron Leader F. S. O'Flynn, RAF, *A Better Way to Teach Basic Fighter Manoeuvres* (unpublished paper, 1975), presents a number of test conditions for this option. Sqn. Leader O'Flynn was on an exchange assignment to the CCTS F-4 Instructor's Squadron at Luke AFB when he wrote this paper.

the rotation of its pilots. Earlier research has indicated that current policies do not represent the best use of highly skilled pilots and the significant resources they represent. For example, in 1971, Stewart estimated that the cost of training a new TAC pilot (from UPT to operational readiness status) was over $200,000.[1] General inflation, the rapid rise in the cost of petroleum products, and expensive equipment have almost certainly driven the estimated cost of pilot training much higher. The Air Force might realize important fiscal savings if fighter pilots were assigned additional flying tours because the increased duration of duty in the cockpit would reduce both the number of new pilots and the cost of their training.[2] Such a policy would also raise the skill level of the pilot force because the individual pilot would have had a longer exposure to intensive ACT, which would perfect and maintain his skills. Under present conditions, a pilot might be transferred to a non-flying position just when he has reached the peak of his flying ability and may not easily reclaim it later. His replacement would almost certainly be a less-skilled pilot whose training costs would at best be as great as those of the pilot he replaced, and the effectiveness of the force would suffer.

The feasibility of such a policy change must also be evaluated in the context of such other important considerations as officer career development patterns, the supplement force, and the need for skilled and experienced pilots in many non-flying positions. This is the most contentious research area proposed here. It directly confronts two central USAF management concepts. The first is the policy of maintaining a large corps of good fighter pilots in case of war rather than a smaller force of highly skilled pilots.[3] Second, such a change would

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[1] See William A. Stewart, *Pilot Management Policy and Pilot Training Rates*, The Rand Corporation, R-690-PR, March 1971, pp. 81-86.

[2] Stewart presents some possible options and the resulting savings in "Effects of Lengthening Initial Cockpit Tours: Rotational Career Models," ibid., Sec. V.

[3] See Lt. Col. George Kyer, USAF, *Selection and Training of Air Superiority Pilots*, Air University, Maxwell AFB, Ala., Air War College Thesis No. 4976, April 1973; and Cook, *Quantity or Quality?* for the opinions of two Air Force officers whose findings strongly support the latter position.

run contrary to the management philosophy of personnel rotation and possibly be perceived to have deleterious effects on individual career patterns.[1] In sum, it would profoundly affect how the Air Force allocates and distributes its manpower resources.[2] Even in the face of these basic organizational precepts, if it can be demonstrated that highly skilled pilots significantly improve the exchange rates, thereby raising the effectiveness of the force, the Air Force might reconsider the possibility of lengthening the cockpit tour for at least those personnel who fly its high-performance fighter aircraft. Precedent for this action is not difficult to find. Most of the NATO pilots, as well as the Israelis, have longer tours of flying duty than their USAF counterparts. The rationale is even more persuasive. Underlying the Rated Distribution and Training Management System is the philosophy that "Limited assets, high cost of training, and budget constraints make it *absolutely necessary* that the Air Force manage advanced weapons systems and the associated personnel resources in the *most efficient manner possible*."[3]

DACT USE

One of the most valuable "lessons" from the Vietnam conflict was the rediscovery of dissimilar air combat training.[4] The Navy's "Top Gun"[5]

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[1]For an appreciation of this problem, see Hq. USAF, Deputy Chief of Staff/Personnel, *The USAF Personnel Plan: Officer Structure (TOPLINE)*, Department of the Air Force, January 1970, Vol. II. The best article on TOPLINE is by Col. George H. Roop, Jr., "TOPLINE: USAF Officer Personnel Plan," *Air University Review*, Vol. 21, No. 6, September-October 1970, pp. 15-23.

[2]The difficulties in manipulating this system are made apparent in Hq. USAF, Deputy Chief of Staff/Personnel, *The USAF Personnel Plan: Officer Structure*, Department of the Air Force, June 1975, Vol. II.

[3]Ibid., p. B-37; emphasis added.

[4]For a general DACT description, see Grasset, "Dissimilar Air Combat Training."

[5]The Navy's program is described in "'You Fight Like You Train' ...;" more recent activities of the Top Gun program are detailed by its commanding officer, Commander James Ruliffson, in his testimony before the United States Senate, *Hearings Before the Committee on Armed Services: Tactical Air Power*, 94th Cong., 2d Sess., Washington, D.C., 1976, Part 10, pp. 5338-5348.

and TAC's program at Nellis[1] are direct results of the Vietnam experience. Both services use aircraft that are similar in dimensions and performance to Warsaw Pact fighters, and both instruct their pilots in enemy combat tactics.[2] These programs are considered extremely successful in preparing U.S. pilots for future engagements. However, several research questions could valuably be posed regarding DACT. For example, does some number of DACT hours make a better air-to-air pilot? If so, by what measure and how many hours and how much better? Other questions would include an estimation of where the positive benefits curve for DACT begins to level off (see pilot B, Fig. 3), or perhaps become negative, and how to translate DACT and skill levels into predicted combat effectiveness. DACT costs should include recognition of opportunity costs; that is, working with one pilot deprives another pilot of the opportunity to fly against the aggressor IP. Finally, should some number of DACT missions lead the Air Force to expect some significantly greater number of combat kills or fewer combat losses, and can these returns be estimated?

Red Baron III data indicate that close to one-third of the losses of U.S. aircraft over Vietnam could be attributed to inadequate pilot training. If this value is even approximately accurate, then DACT benefits and payoffs could indeed be substantial. But this is not the same as saying they are infinite, even if training budgets were limitless, which they certainly are not. Therefore, evaluating the costs and benefits of TAC's DACT would be a valuable research effort and product. One possible way of arriving at a rough estimate of DACT's relationship to the wartime environment might be to conduct a carefully monitored Delphi exercise with a number of Air Force pilots who have flown both DACT or Aggressor squadron missions and combat missions.

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[1] See Benjamin F. Schemmer, "USAF's Fighter Crews Train and Win in TAC's Air Combat Program," *Armed Forces Journal International*, May 1974, pp. 29, 30, 37, 40. Also see the testimony of the former commander of the Aggressor Squadron, Lt. Col. Nabors, in U.S. Senate, *Hearings*, 94th Cong., 2d Sess., Part 9, 1976.

[2] Capt. Don Carson, USAF, "Teaching Tactics in TAC's MiGs," *Air Force Magazine*, March 1974, pp. 44-47; and Capt. Mike Press, USAF, "Meet the Aggressors," *USAF Fighter Weapons Review*, Fall 1973, pp. 30-33.

Another possibility would be to use the Red Baron files to compare the performance of the Navy's Top Gun graduates with pilots who had no DACT training.

CONCLUSIONS

The development of a proficiency scale would permit the Air Force to measure and evaluate its pilots' air-to-air flying skills with greater objectivity and consistency than currently possible. If such a scale or metric can be developed, the Air Force could decide what skill level would be required to meet the defined threat environment, to judge the effect of a given level of pilot effectiveness on the outcomes of air-to-air engagements, and to estimate the costs and benefits of raising or lowering skill level standards. These larger questions, however, can only be posed--not resolved--by the suggested research efforts.

$\psi_o = \psi_o$ (S/M, E/S, F/E, K/F) in which

ψ_o = the composite offensive pilot skill index represented by some combination (either individually or collectively) of the following variables:

S/M = sightings per mission;

E/S = engagements per sighting;

F/E = firing pass per engagement; and

K/F = kills per firing.

The advantage of these skill ratios is that each represents some distinct component of pilot skills, most of which are considered "teachable." For example, FWS instructors say they can teach a student how to expand his visual scope and make faster, more accurate visual identifications. How much do each of these represent skill factors and how many are largely chance?

Many students of aerial combat argue that the top fighter pilots consistently see the enemy aircraft long before their comrades and often before the enemy identifies the friendly pilot.[1] Red Baron III reports that close to two-thirds of the MiGs shot down over North Vietnam were initially acquired by visual sightings; the remainder were acquired by radar, other pilots' sightings, or a remote facility. The ability to see an enemy aircraft before being spotted himself permits a pilot to gain a significant tactical advantage that is perhaps the decisive feature in air-to-air engagements. As mentioned above, this facility can be improved in a pilot's training program. However, its inclusion in a pilot skill index is questionable because of the large amount of randomness that enters into the phenomenon of finding enemy aircraft. A highly skilled, potential Ace pilot could fly multiple tours and simply never be exposed to a sighting opportunity. There is no guarantee, of course, that a visually acute pilot will avail himself of this talent; in an extreme case, he might use it to avoid combat. If one were to calculate a pilot skill index from existing engagement records, the inclusion of S/M would heavily bias the result toward

[1] For example, see Edward H. Sims, *The Aces Talk*, Ballantine, New York, 1972.

events over which the pilot had little control--i.e., events in which his air-to-air combat skills could not be manifested. The increasing reliance on advanced avionic systems makes this variable even more difficult to treat and include. This is not to suggest that the S/M skills are not important, or that they should be excluded from the training curriculum, only that there is too much chance in visual acquisition to justify including them in a pilot skill index.

The ability to convert a sighting into an engagement with the enemy can certainly be viewed as one measure of pilot skill. His ability to engage the enemy from a favorable position will have a major effect on determining the final outcome.[1] The ability to do so necessarily requires a certain amount of pilot skill. There is also a great deal of chance in this variable. For example, a pilot might see a bogey leaving the combat zone at such advantage that chase would be futile. Similarly, a USAF element might sight such a large number of enemy aircraft or such advanced models that good pilot instinct or tactics would require an exit from the battle zone. A pilot who is low on jet fuel or ordnance would be hesitant to convert a sighting into an engagement. In such cases, closure or engagement was impossible for reasons beyond the pilot's control, and the E/S measure would unfairly reflect against him. To include E/S in the pilot skill equation might not only inject a large degree of randomness into the index but it might also misrepresent those incidents where the good pilot would deliberately not want to enter into an engagement. Both contingencies would weigh against the skilled pilot and cast serious doubt upon the validity of the E/S ratio as part of a pilot skill index.

The ability to convert an engagement into a firing pass is a third possible indicator of pilot skill. In this index, the firing ordnance (guns or missiles) is not as important as the ability to maneuver the aircraft into a position in which the pilot thinks he has an opportunity to kill the enemy aircraft. This measures the pilot's flying ability and also reflects his conceptual grasp of the situation and his

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[1] *Red Baron III* documents the importance of initial position in determining the outcome of the encounter. This is anecdotally confirmed, ibid.

knowledge of the weapon system. For example, the skilled pilot would not release a missile at 100 yards nor would he fire a cannon burst at two miles. This index also has the ability to discriminate between those pilots who somehow (perhaps inadvertently) become engaged yet do not fire and those who, once engaged, at least work for a kill opportunity. "There can be little doubt that the pilot who has a high F/E ratio has fired on more enemy aircraft per encounter and consequently has demonstrated greater ability to maneuver into firing position than the pilot who has a low ratio."[1] This measure might be weakened by a pilot's tendency to fire blindly or outside the performance envelope of his ordnance, or to scare the enemy without a realistic chance for a hit. However, a large number of F/E events plus the last ratio, K/F, should serve to negate or at least dampen this effect.

The K/F ratio represents the ability of the fighter pilot to fire his ordnance--be it guns or missiles--accurately. This would manifest the pilot's knowledge of the weapon system, its performance parameters, and how the weapon systems interact with the aircraft to record a kill. Obviously, the K/F ratio would only apply to those firings in which the weapon system performed according to expectations. Misses accounted for by weapons malfunctions would not register against the pilot. However, those misses due to pilot miscalculation, such as firings outside the missile's performance envelope, would count against him. Red Baron II and III both document the problems pilots had in learning and recognizing the performance envelopes of their missiles. Many AIMs were fired that apparently had no chance of hitting the target.[2] Lucky shots might bias the calculations, but their occasional occurrence should easily be dampened out over a large number of observations. This measure would be adversely affected by the occasional missile that is fired for psychological purposes at the enemy without a realistic chance for a hit, but only if there are a large number of such firings. The main advantage to the measure is it penalizes the pilot who indiscriminately fires his ordnance and rewards those pilots who fire only when they have a good probability of a kill.

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[1] Strawbridge and Kahn, *Fighter Pilot Performance in Korea*, p. 49.

[2] See *Red Baron II*, "Comments on Training," Appendix.

Clearly, there is variance among pilots in these last two measures. In a Korean War sample of pilots, all of whom had a minimum of 15 air-to-air combat missions (experience was given a baseline so that no inexperienced pilot data were included), the E/F ratio ranged from .88 to .12; that is, one pilot was able to obtain a firing pass in close to 90 percent of his engagements. The average value was 42 percent, with a standard deviation of almost 15 percent. The K/F range was from .70 to zero (one pilot killed no MiGs in ten firings); the average value was close to 35 percent with a standard deviation of 17.5 percent.[1] As might be expected, both samples were distributed normally. The 69 F/E and K/F Korean data points were tested for independence and found to have little correlation (R = .128). The Korean data do show that the Aces generally had the higher F/E and K/F values. Similar values have not been calculated for the Vietnam war.

A DEFENSIVE PILOT SKILL INDEX

The defensive pilot skill index is more subtle and perhaps less appreciated, partially because of the prevailing "No Guts, No Glory" aura of air-to-air combat.[2] That is, the predominant, almost exclusive emphasis in air-to-air combat is on the attack. Good pilots are defined as those who have recorded the greatest number of enemy kills. However, as has been argued previously, kills *per se* are not an adequate and certainly not a complete measure of a pilot's combat skills. Similarly, a pilot's defensive skills should also be recognized, because the ability to avoid being shot down might be more demanding than the ability to record a kill, especially given the extensive use of GCI in Soviet fighter tactics. During the 1971-73 period, Red Baron III data note

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[1] The raw data are found in Strawbridge and Kahn, *Fighter Pilot Performance in Korea*, Table 4, pp. 54-55; partial kills are indicated in these data.

[2] "No Guts-No Glory" was introduced to the ACM literature by then-Major Frederick Blesse, "No Guts-No Glory," *Fighter Weapons Newsletter*, March 1955. It has been amended and reprinted in the *USAF Fighter Weapons Review*, Fall 1973, pp. 2-28. It should be noted that General Blesse recognized the importance of defensive maneuvering; half his essay is devoted to defensive actions, but these are almost completely oriented to gaining an attacking position.

that over 20 percent of U.S. MiG kills were achieved when the MiG held the initial advantage. In other words, the American pilot was forced into a defensive position and demonstrated enough flying skill to reverse the advantage and kill his attacker. He not only avoided getting himself shot down but actually recorded a kill. The true extent of the pilot's skill in these engagements would be inadequately represented if a downed enemy aircraft were the only measure. By the same token, another pilot might have been forced to use exemplary flying facility merely to avoid being shot down when the enemy had a decisive initial advantage. Again, these particular skills would not be noted because he did not record a kill. Perhaps even more important, however, is that he avoided becoming a kill himself. In a period characterized by fewer aircraft and skilled pilots, and combat in areas where the enemy enjoys a large numerical superiority, the ability to escape being shot down could loom large.

The fundamental assumption here is that the air-to-air pilot will occasionally find himself in a position where he cannot dictate the initial terms of the engagement, where he must maneuver defensively to avoid becoming a casualty or POW statistic. To assume that he will always enjoy an offensive position or initiate attacks at his discretion or advantage is not only misleading, it is potentially dangerous. Therefore, a balanced pilot skill index must include a reflection of his defensive skills as well as his offensive ones.

A "defensive" position can be defined as one in which the pilot does not have the initial tactical advantage. Encounters in which there was no apparent tactical advantage at the beginning of the engagement would also be treated as "defensive." In Vietnam, close to 10 percent of the USAF's kills during 1971-73 were made when there was no apparent initial advantage according to Red Baron III. At the same time, one must be careful not to be overly inclusive with the defensive label. Soviet-trained Arab and North Vietnam pilots are thought to have threatened aircraft with the sole intent of making them jettison their ordnance, of forcing them to break off their bombing runs, or of generally aborting their missions. In these cases, there was little serious attempt to shoot down the attacking aircraft. Once the mission was

aborted, the MiGs chose to retire on their own volition, and defensive tactics on the part of the threatened aircraft were no longer an issue. In other words, there was no possibility of an air-to-air engagement. Therefore, I further define "defensive" as involving an attack on an aircraft in which the friendly aircraft does not hold the initial tactical advantage and the enemy is considered to have made a firing pass or attempted to gain position for a firing pass.

In symbolic notation:

$$\psi_d = \psi_d(E_s/EA,\ K/E_s),$$

in which ψ_d = the composite defensive pilot skill index;
E_s = escape by friendly aircraft;[1]
EA = enemy attack; and
K = an enemy aircraft shot down.

In this representation, E_s/EA represents those engagements in which the friendly pilot was able to avoid being shot down. For K/E_s, the friendly pilot not only avoided being shot down but managed to record a kill of his own. Without detailed information on particular engagements, it is impossible to say *a priori* which task is more difficult, but certainly E_s/EA is the more important of the two because a pilot can scarcely record a kill if he is shot down first.

As noted earlier, the Red Baron III analysis reports that over 20 percent of the USAF's kills were recorded after the enemy had an initial advantage; another 10 percent of the kills resulted from situations of no initial advantage. The Korean War and Red Baron analyses did not identify or aggregate the E_s/EA indicator. However, one would expect as much variance in these two indicators as was noted in the offensive aspects of the pilot skill indexes. The relevant information is included in the Red Baron data bank. The number of incidents of defensive maneuvering in the Red Baron II and III data are limited, however,

[1] A further refinement of E_s might distinguish between an escape and an escape that did not permit the bogey to obtain a firing opportunity.

so the values that could be calculated might be drawn from an insufficient sample population.

CONCLUSIONS

Two components of a proposed pilot skill index represent the offensive (ψ_o) and defensive (ψ_d) nature of the air-to-air combat mission. Major obstacles to the use of these indexes in the training regimen are the calculation of representative ψ values from U.S. combat engagements and the ability to translate and correlate these measures into peacetime training exercises. Analysis of the Korean War and Vietnam conflict aerial encounters should provide a benchmark for ψ_o and ψ_d values, with appropriate controls taken for flight position and the number of previous air-to-air missions. Different values for both ψ would be expected for pilots at different stages of their ACT; most new CCTS graduates could hardly be expected to fly as well as the FWS instructor. The more difficult problem lies in linking these indexes to the peacetime training environment. That is, how can similar ratings be obtained for pilots who have not had combat experience? The nature of aerial combat makes this an extremely complex and demanding problem. One alternative is to prepare a series of "canned" exercises against which the new fighter pilots could test their air-to-air skills.[1] (There is no compelling reason why these tests should be applied only to new pilots. More strenuous tests could be devised and "canned" for the experienced pilot to insure that his skill levels are commensurate with his continued training.) The new pilot could then fly against a subset of these exercises and be evaluated, perhaps using gun cameras and the Air Force's Air Combat Maneuvering Instrumentation (ACMI) range facility. A second alternative would be to design and program a set of combat situations on an air combat simulator that could be used to evaluate fighter pilot proficiency levels.[2]

Clearly there are severe problems with both of these alternatives. Regarding the first, no two aerial combat conditions are identical,

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[1] A possible series of "canned" attacks for evaluating CCTS students has been proposed by Squadron Leader F. S. O'Flynn, RAF, "A Better Way to Teach Basic Fighter Manoeuvres."

[2] This objective is partially addressed in the TAC ACES program.

so to "can" standardized combat situations that could be used to rate a large number of pilots would be extremely difficult. The combat simulator could present identical situations to pilots, but there is a great deal of uncertainty about the comparability of flying a fighter aircraft and "flying" a simulator. At the extreme, some argue that the only thing a pilot learns from flying a simulator is how to fly a simulator; indeed, flying a simulator could conceivably give the pilot bad flying habits. Even if technological advances in combat simulators can overcome these objections, the problem of calibrating simulator tests to these combat indexes remains to be addressed. Still, the potential benefits of these training/evaluation measures suggest that research efforts along these lines be initiated.

The tasks of calculating representative values for ψ_o and ψ_d from combat data, determining what values approximate an acceptable skill level, and translating these data into peacetime training exercises and evaluations are not easy. However, if these obstacles can be overcome and specific training exercises can be formulated to measure the pilot's skill as he progresses through his flying tours, the Air Force would be a great deal closer to developing a consistent grading scale for assessing the skill of its air-to-air pilots, to determining the skill level of the force, and to correcting any deficiencies that might be observed.

VI. SUMMARY

This report cannot offer any definitive research conclusions for two reasons. First, it has not been possible to prove that a fighter pilot's air-to-air combat skill is the most critical variable in determining the outcome of an aerial engagement. However, indirect evidence seems tentatively to confirm that hypothesis. Second, because of the lack of essential data, the research initially envisioned could not be completed. Therefore this report has had the limited goal of summarizing general findings about the value of the fighter pilot and suggesting avenues for further research into the processes by which the Air Force selects, trains, and manages its fighter pilot resources.

The skill of the individual pilot is perhaps the critical variable in determining the outcome of a decisive air-to-air encounter. These skills should be carefully honed and hoarded. Air combat training and combat experience seem to be the two best indicators of a pilot's prospective success (or ability to avoid failure) in air-to-air combat. In a peacetime environment, ACT is the Air Force's only reasonable mode of preparing pilots for aerial combat. Measuring air combat maneuvering (ACM) and pilot skills is difficult. The Air Force has few objective, verifiable methods of assessing in advance how well or how poorly a pilot will perform in combat. Further, the Air Force faces tight budget constraints, which will bring on a future reduction in the numbers of aircraft, flying hours, and personnel. But there is no counterpart indication that the Air Force mission requirements will be proportionally reduced; indeed, given the nature of the threat and the growing substitution of technology for manpower in the American armed forces, those requirements could become more difficult to satisfy.[1] The Air Force will presumably be required to perform its past assignments, perhaps more, and with fewer resources.

This report is concerned with a more efficient preparation for and use of the Air Force's pilot resources in the air superiority role.

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[1]See William D. White, *U.S. Tactical Air Power: Missions, Forces, and Costs*, The Brookings Institution, Washington, D.C., 1974.

The additional research suggested here reflects the judgment that a more effective air superiority force can be maintained at lower costs.

The fundamental research goal should be to develop an objective, reliable, and replicable ACT standard that could be used in peacetime to indicate or predict a pilot's performance in a wartime environment. The Aggressor concept and the ACMI perhaps provide baselines for such measurement, but much conceptual work remains to be done. A practical, short term research strategy might be to focus on the selection, training, and use of the Air Force's air combat pilots to improve the process of selecting future pilots. Changes in selection from the UPT programs, providing a set of objective measures or scores for CCTS instruction and evaluation, and mandating longer flying tours are candidate approaches. Although these measures do not directly address the problem of developing a pilot skill factor, their trial could suggest means of improving the caliber of the fighter pilot force until a definitive standard can be established--if that proves to be both feasible and desirable.

A prospective impediment to many of the research programs proposed here is lack of relevant data. For example, TAC does not keep its pilots' CCTS scores. Unless UPT and CCTS data are available, later comparisons of the training program outcomes with demonstrated pilot flying skills becomes impossible. This is not to say that a proven pilot should be evaluated in terms of CCTS scores any more than should an architect or lawyer be judged by his high school transcripts. But it is not the individual pilot who is being evaluated; it is the training regimen and the ability of the Air Force to predict later flying proficiency on the basis of early training. Appropriate data are essential.

Such research, in conjunction with other elements of quantity-quality tradeoffs, generates recommendations for making more efficient use of Air Force air-to-air pilot resources. They could provide criteria that TAC could use in estimating the importance of the pilot to future wartime mission requirements and could suggest how TAC might satisfy those requirements in operating against an increasingly more capable enemy within the constraints of an increasingly limited budget. This, in turn, would permit TAC to distribute its pilot resources more exactly to fulfill its mandated roles.

None of the research proposed above is easy, but savings that might result from successful research would make them well worth while. The results would assist the Air Force in making quantity-quality tradeoffs for fighter aircraft. They would provide additional information on how to allocate its resources for the air-to-air mission among aircraft and weapons development, aircraft procurement, tactics improvements, and pilot training programs.

Appendix

The cost estimate of a 50 percent savings is predicated upon a change in the exchange ratio from approximately 2:1 to 10:1. This does not seem an impossible goal in light of the Korean exchange ratio. More pertinent, perhaps, is the observation that Navy pilots improved their exchange ratio relative to North Vietnam from approximately 2:1 to 12:1 after their Top Gun DACT training.

The training calculations, set in the Vietnam context, are only meant to be suggestive of possible savings. They are based upon the following approximations:

1. U.S. air-to-air combat losses (1965-1973) of 75 and North Vietnam losses of 184 aircraft.[1]
2. An average replacement cost of $5 million per U.S. aircraft.[2]
3. A training cost of $200,000 per TAC pilot.[3]

The Vietnam exchange ratio can be represented as:

$E_v = O_v/A_v = 184/75 = 2.45$, where

E_v = Vietnam exchange ratio;

O_v = Opposition (NVN) Vietnam air-to-air combat losses; and

A_v = American Vietnam air-to-air combat losses.

Assume that if the U.S. exchange ratio were improved from 2.45:1 to 10:1, the U.S. losses in Vietnam would have been decreased by some constant (K) while NVN losses would have been increased by the same constant. This implies that increased U.S. pilot skills would not only

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[1]These figures are from Benjamin F. Schemmer, "USAF's Fighter Crews Train to Win in TAC's Air Combat Program," *Armed Forces Journal International*, May 1974, p. 38.

[2]This figure is only meant to be representative.

[3]This estimate is derived by Stewart, *Pilot Management Policy and Pilot Training Rates*, pp. 81-86. It does not include the training costs for the radar intercept officer, the Guy-in-Back of the F-4.

result in more enemy aircraft shot down but would also produce a lower attrition rate for U.S. aircraft.

Algebraically:

$E_x = 0_x/0_v = 10$ (Projected exchange ratio)

$0_x = K \times 0_v$ (Projected opposition losses)

$A_x = A_v/K$ (Projected American losses)

$E_x = 10 = 0_v K \div A_v/K$

$= 0_v K^2/A_v.$

If $0_v = 184$ and $A_v = 75$, solve for K:

$10 = 184\ K^2/75 = 2.45K^2$

$K^2 = 10/2.45 = 4.07$

$K = 2.02.$

Therefore: $0_x = K \times 0_v$

$= 2.02 \times 184 = 371.5$ enemy aircraft shot down, and

$A_x = A_v/K$

$= 75/2.02 = 37.1$ American aircraft lost.

Using the cost assumptions noted above:

	Actual U.S. Losses (2.45:1 ratio)	Projected U.S. Losses (10:1 ratio)
A/C lost	75	37
Pilots lost[a]	75	37
Cost of A/C lost	$375M	$185M
Training costs to replace pilots lost[b]	$ 15M	$7.5M
Total Replacement Costs	$390M	$192.5M

[a]This assumes that the pilots of aircraft shot down are not rescued. It does not include the losses of the GIB.

[b]Again, GIB replacement costs are not taken into account.

Thus, the improvement of the exchange ratio reduces U.S. replacement costs by close to $200M, or slightly over 50 percent. With higher unit cost aircraft, the cost ratio would remain the same, but the magnitude of the savings would increase.

Although this represents sizable yet plausible savings, one should be cautioned against taking these estimates literally. They do not represent current funds released for research programs or advanced pilot ACT. They are only meant to suggest the savings in terms of replacement costs that might be possible if intensified ACT would, in fact, result in a marked improvement in the exchange ratio.