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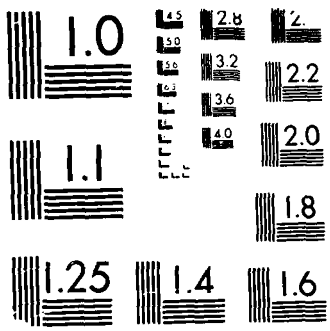

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HUMAN RESOURCES

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THE WARNET PAPERS

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OPERATIONS TRAINING DIVISION
Williams Air Force Base, Arizona 85240-6457

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This paper has been reviewed and is approved for publication.

MICHAEL C. LANE, Colonel, USAF
Chief, Operations Training Division

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Consideration is given to the use of relatively low-cost networked simulators for training of pilots, development of new aircraft, and selection of pilot training candidates. Alternatives for the deployment and use of networked simulators are considered at the conceptual level.

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THE WARNET PAPERS

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This publication is primarily a working paper. It is published solely to document work performed.

SUMMARY

Advances in microcomputer and communication technologies make a network of relatively low-cost, interconnected combat simulators possible. Such a network would allow tens or even hundreds of aircraft to fight each other in simulated but realistic battles. It would also allow aircraft to interact with ground vehicles and surface-to-air missiles (SAMs). Such a network is already being constructed for Army tanks.

This conceptual research effort examined a range of questions and options that might be considered with a network of tactical aircraft combat simulators. Although the main emphasis of the research was on training, some consideration was given to the use of such a network in aircraft development and in pilot selection. While such a network of aircraft simulators remains to be built, the results of this study suggest that such a network should be given serious consideration.

PREFACE

This document consists of several papers written, but not published, during the course of an analysis of future requirements for aircraft combat training simulators. This study was primarily an in-house effort at the Operations Training Division of the Air Force Human Resources Laboratory, Air Force Systems Command. It was requested by Colonel Dennis W. Jarvi, AFHRL Commander at the time. Russell M. Genet, an Electronics Engineer, was the principal investigator, although he had considerable assistance from a number of people, including Harold Geltmacher, Rebecca Brooks, Philip Handley, Roger Basl, and others.

The term "WARNET," suggested by Col Jarvi, captures the very essence of what networked combat training simulators are all about. Colonel Jarvi not only suggested the study and gave it its name, but gave his enthusiastic support and provided many ideas of how the concept could be expanded at the theater, inter-Service, and even free-world levels.

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THE WARNET PAPERS

I. INTRODUCTION

In May 1986, Colonel Dennis W. Jarvi, then Commander of the Air Force Human Resources Laboratory (AFHRL), asked that Russell M. Genet, Operations Training Division (AFHRL/OT), examine some cost-effectiveness aspect of aircrew training research. Genet suggested tactical combat training as the focus of such an examination, with emphasis on the potential use of training simulators. Laboratory management concurred with this suggestion, and Genet was given 6 weeks to accomplish this task with the help of 2Lt Roger W. Basl, who was working with AFHRL/OT while awaiting reassignment.

It became immediately obvious that fighter pilot input would be needed--specifically, from a fighter pilot with successful combat experience and with an interest in and an understanding of aircrew combat training. Such a pilot, Col Philip W. Handley (USAF, Retired), was located, and on 12 May 1986, was interviewed by Genet. Col Handley explained in detail what was important in combat, as well as where the shortfalls occurred in current training.

It was realized early that simulators could fill a gap--if there were enough of them connected to simulate the large numbers of human players involved in real battles, and to provide sufficiently frequent practice for achieving and maintaining a high degree of combat pilot skills. It was quite clear that: (a) the combat training simulators would have to be low in cost; (b) they would have to be interconnected to allow large battles; and (c) simulator research and development (R&D) in the Air Force was not currently heading in this direction.

Genet set out to find if anyone was or had been working on low-cost, networked simulators. He was quickly informed, from a number of sources, that the Defense Advanced Research Projects Agency (DARPA) and the US Army were working on a program called SIMNET, an R&D program to network a large number of tanks (M-1) and armored personnel carriers (M-3). They were also considering adding combat helicopters to their network. What DARPA and the Army had accomplished was examined, and had a pronounced influence on consideration of this problem. Lt Col Jack Thorpe at DARPA provided information and briefings on what had been accomplished, afforded an opportunity to "fight" in the tank simulators at Ft Knox, and joined in researching this problem.

To discover what experienced fighter pilots might think of the idea of low-cost, networked simulators, several pilots were interviewed. Their responses were most encouraging. Also, various ideas for low-cost, networked, combat simulators were discussed in detail with Harold E. Geltmacher, AFHRL/OT. He expanded on the ideas with suggestions for using such combat simulators, not only for training but for R&D and pilot selection.

Many of the ideas expressed in Sections I through IV were based on four short papers written by Genet. Col Handley and 2Lt Basl provided inputs to the first two of these papers; Mr. Geltmacher, to the remaining two. These four papers, collectively known as the "WARNET Papers," have been combined here, along with a short introduction and some conclusions.

II. WARNET: LOW-COST, NETWORKED TACTICAL COMBAT TRAINING SYSTEM

Tactical air warfare will continue to be a crucial element in future conventional wars. Without air superiority, our ground forces will be subject to air attack, and enemy ground forces cannot be interdicted and disrupted. Although we expect enemy aircraft to outnumber allied aircraft, we believe our superior technology, training, and combat teamwork will give our forces an edge.

We (Genet and Basl) were asked to examine how front-line pilots might best train for and practice tactical combat missions in the year 2000. We did this by interviewing a number of highly experienced combat pilots. We asked them to describe tactical air combat, with emphasis on those aspects that were crucial to combat, yet difficult to train. Our consultants pointed out that a large number of human players would be involved--inter-Service American and allied forces. Strike packages, which include escorts, strikers, airborne warning and control (AWACS), defense suppression, reconnaissance, electronic countermeasures, and tankers, can number more than 100 aircraft for a single mission. An even larger number of aircraft piloted by a smart and determined enemy would be encountered, and the surface-to-air missile (SAM) and anti-aircraft artillery (AAA) activity would be intense at strategic points. In this environment, communications become overloaded; plans laid out in detail go awry; and the amount of information to be assimilated quickly passes beyond the capability of all but the most experienced combat pilots.

Our combat-experienced consultants stressed that the ability to handle the many-player, fast-paced, information-intensive and unexpected situations with creativeness and teamwork separates those pilots who will survive from those who will not. Air combat experience in World War II, Korea, and Vietnam all showed that surviving exposure to the actual combat environment improves a pilot's future survivability. Loss rates are highest on a pilot's first few missions as he (quickly) overcomes gaps in training realism.

The philosophy behind RED FLAG and theater area exercises is to reduce these training gaps by providing as highly realistic combat training as possible. In the RED FLAG combat training exercises, "9-day wars" are fought with as many as 100 aircraft of various types flying both air-to-air and air-to-ground missions in the southern Nevada desert. Front-line fighter squadrons deploy to the home of RED FLAG, Nellis Air Force Base (AFB), where pilots have a chance to engage the experienced Nellis Aggressor Force and use live munitions against ground targets. RED FLAG is the most realistic peacetime training currently available. The training experience is not only highly sought after, but something our front-line tactical combat pilots cannot get enough of.

As good as RED FLAG and similar exercises are, and they are very good indeed, it is still expected that losses of pilots and planes on the first few missions of future wars will still be much higher than on later missions. This will be due, not only to too-infrequent combat-rich training, such as RED FLAG, but also to differences between such training and the actual combat environment. These differences result from unavoidable safety restrictions such as designated practice floors and ceilings, fair weather flying, and limited use of live missiles and ammunition. Differences are also due to practical considerations that result in the expected rather than the unexpected (e.g., familiarity with the terrain, and the established direction, timing, and number of the enemy).

The importance of avoiding high loss rates on pilots' first few missions cannot be overemphasized, as it could easily change the entire course of an air battle and hence, a war. Perhaps RED FLAG and similar experiences could be complemented by an innovative approach to combat training that would allow, by the year 2000, much more frequent multiparticipant practice under high workload conditions. If this approach could avoid some of the constraints of current exercises, even while adding different limitations of its own, it would be complementary to the existing exercises; and together they could fully prepare pilots for their combat missions and minimize "training" during actual combat.

One possibility we considered was tactical aircraft simulators. Without safety restrictions, engagements could be head-on with all weapons. Pilots could fly right down to the deck in dense concentrations of aircraft. Kill removal could be instantaneous and dramatic. The unexpected could be enhanced by the injection of unplanned weather and by large uncertainties in the number, direction, and timing of enemy aircraft. Not only could the terrain be new and unfamiliar each time; it could also be "actual" terrain, where a battle has or will be fought.

In the past, flight simulators have been adequate only for training basic skills and procedures, and not up to the demands of tactical combat training. Even worse, they were so expensive to build and operate (not to mention problems of operational reliability and basic pilot dislike for them) that the hundreds of simulators needed to provide realistic combat training would cost a significant portion of the Tactical Air Forces' training budget. But does this have to be the case, and would we expect it to be so in the future? We found that while aircraft simulators on the "leading edge" were rapidly approaching the performance capabilities needed to simulate tactical combat, they were still an order of magnitude too expensive and unreliable to be given serious consideration.

However, one interesting exception to the generally gloomy outlook was brought to our attention: the Defense Advanced Research Projects Agency (DARPA) and US Army project called "SIMNET." Although SIMNET involves US Army tanks, the approach already allows for high fidelity at low costs per simulator ($200K). In addition, a large number of simulators (over 200) will be engaged together at the same time in a single battle. Lt Col Jack Thorpe, the DARPA SIMNET Director, explained how this was possible. First, they studied the actual combat tasks in detail. They carefully sorted out the critical combat tasks requiring training with high-fidelity simulation from those tasks requiring only low-fidelity simulation or no simulation at all. Second, they used very-low-cost, state-of-the-art, 32-bit microcomputers instead of the larger, more expensive, less reliable minicomputers. Finally, they used distributed computing, using both local area and satellite communication networks which allowed them to interconnect hundreds of individual simulators.

We considered how the DARPA/Army SIMNET concept might be applied to Air Force tactical air combat--an application given the name "WARNET." The "nodes" in WARNET would consist of bases housing squadrons or wings of tactical aircraft and ground control intercept (GCI) operators. At each node would be a 4-ship simulator, and some nodes would also contain a GCI capability. At times, the network would not be activated, and squadron pilots could get individual practice, fly air-to-ground, 1 versus 1, or 2 versus 2. A nearby node might be challenged for a 4 versus 4; or an area of the network might be activated for large-scale practice. Major exercises involving many nodes and 100 or so simulators/pilots would be scheduled regularly. In times of potential national emergency, special missions might be flown several times in full dress rehearsal, with all the expected players, over the expected terrain.

As attractive as WARNET sounded, it was not immediately obvious that the technology which supports a network of 50-mph tanks would also support a network of 500-knot jet aircraft. However, our initial examination of the technical feasibility, costs, and benefits was encouraging.

If a demonstration were successful, the doors would be open for final development, production, and deployment of combat simulators to every tactical fighter base worldwide. The benefits of a network of flight simulators would be a thorough supplement to those aspects of training not possible in the current flying exercises, with much more frequent practice of those skills needed to handle peak combat workloads without saturation. The result would be a higher chance of survival in real combat. The lower initial loss rates and increased early mission effectiveness would accelerate enemy aircraft losses while conserving our own, leading to our domination of the air war, the disruption of their ground forces, and victory.

Details for the Technically Inclined

Even the latest low-cost, high-performance microcomputer distributed processing techniques, and networking and satellite communications technologies, would have been insufficient for a large-scale simulation network if a clever approach had not been devised to overcome two crucial problems. One was keeping the data rate over the network low enough to make the phone bill affordable. The other was overcoming the adverse effects of communications transport delays--especially if links through synchronous satellites were used. These crucial problems can be overcome by storing the entire terrain data base in each individual simulator; by storing the position, velocity, and acceleration (i.e., the state vector) of all vehicles in each simulator; and by communicating only significant state vector changes over the network.

When an aircraft is at a constant velocity, all the simulators can compute its location from its latest state vector (velocity, zero acceleration). As long as it continues at constant velocity, no updates are needed over the network. When any individual simulator "looks" in the direction of this aircraft, sure enough it is still flying along at constant velocity. When, however, the aircraft banks, climbs, fires a cannon, or launches a missile, etc., the exact current state vector of the aircraft--when compared with the state vector last communicated to, and stored by, the hundred or so other simulators--will be different. If the current actual vector is appreciably different from the last communicated vector, then an update is sent out. The tricks here are: (a) setting the "appreciable difference" such that the network is not overloaded with updates; and (b) smoothing over any "jump" in the position, velocity, etc. of other aircraft when an update is received. The smoothing algorithm works by placing constraints on how rapidly aircraft can turn, accelerate, etc., and when an updated state vector is received, allows the new state vector to be reached in a non-jumpy manner that is perceived as realistic. Cleverly designed smoothing algorithms not only allow larger appreciable differences before updating state vectors, hence reducing communication bandwidth requirements, but they smooth over and mainly eliminate all the potentially adverse effects of communications delays. Without this latter effect, networking high-speed aircraft together from around the world through satellite communications would not be possible. (See Malone, Horowitz, Brunderman, & Eulenbach, 1987.)

III. FIGHTER PILOT INTERVIEWS

A number of F-15 and F-16 fighter pilots were interviewed. To clear the air, they were asked about their impressions of simulators in general. The response was swift and decisive, and went something like this: "Sims are a waste of time and money as far as operational units are concerned! They are much too expensive, therefore being too few in number to do much good. These small numbers also cause people to be scheduled for them at ungodly hours, or worse yet, people have to travel somewhere to use them. Sims are complicated and unreliable devices that usually fail when you try to use them. They are often out of date with respect to the mods made on the aircraft they are supposed to represent, thus providing negative training. Worst of all, they are used only for the dreaded safety and procedures training."

It was then explained, very briefly, that future technology might allow low-cost yet capable simulators to be networked together across the Air Force. If this were possible, how did they think this capability might best be used, and what advice would they have? They very quickly warmed to the idea and went into a most impressive brainstorming session. Though many of their ideas duplicated ideas already developed over the previous several months, they had many genuinely new and good ideas. What follows is a summary of their ideas and recommendations.

There need to be lots of the low-cost simulators so that pilots can get plenty of time in them (without coming in at night). At each wing, or preferably at each squadron, there should be a 4-ship capability (actually, a 5-ship, as there should be a complete spare. It is imperative that the capability not be centralized at just a few locations, as the time to travel, TDY costs, and time away from families (already more than enough) would be too much. These low-cost combat simulators should provide training at three levels: (a) basic flight maneuvers--1 v 1, 2 v 2, (b) intermediate--4 v 4; and (c) cosmic level, where sizable numbers could get realistic combat practice on aircraft of different types, and where package and mission commanders could also get practice.

At the cosmic level, which is most important, there would be no reason to practice takeoffs and landings, refuelings, etc.; only the premerge, the merge itself, and the postmerge (for air-to-air combat) would be necessary. The premerge would be the most important to practice, followed by the postmerge. The merge itself, while necessary to do in order to get to the postmerge, cannot be fully duplicated on ANY simulator and takes plenty of practice using actual aircraft pulling g's on the aircraft's edge of performance.

All the pilots interviewed stressed the importance of having simulator out-the-window visual display in the premerge (and, of course, the merge and postmerge). Visual cues are used to keep wingmen in sight and to maintain situational awareness. Often the enemy is also in sight in the later part of the premerge. The visually spotted smoke trails of SAMs are absolutely vital inputs needed, along with the radar warning receiver (RWR), to evade them. The pilots pointed out that simulators were the only place where this vital SAM evasion could be practiced. The pilots also stressed [illegible] the opposing (red) force aircraft should look different (different shape) no matter [illegible] flying them or what performance characteristics they actually had (everyone [illegible] blue forces to themselves, and like red forces to the opposition--through [illegible]. Aircraft, when seen visually, should have the right size and [illegible] (with expended missiles not showing up). The sun and its position are important, and clouds and weather should be programmed-in. One pilot remarked that despite all the fancy F-15 radar and electronics, visual cues were still the most important, even in the premerge.

All the pilots [illegible] the need in cosmic level combat practice of having the command and control element--particularly GCI. They believed that computer simulation of GCI would not work very well; [illegible] GCI operators, were needed; and that opposing pilots (red forces) [illegible], not computers. They thought, however, that computers could fire the SAM[illegible], and [illegible] substitute for opposing pilots when none was available.

[illegible] add to the realism enough to overcome their nuisance factor and [illegible] terrain masking. The simulators and their network should be [illegible] with [illegible] setup time required. There should not be a big bureaucracy and a [illegible] with their use. One squadron ought to be able to call up another [illegible] would be the "world's greatest video game."

[illegible] for the importance of a replay capability--something similar [illegible] replay capability for the radar screens also. The pilots [illegible] NOT want any sort of performance evaluation capability. This is [illegible] pilots, and no computer is going to do it right. They did, however, [illegible] displayed to aid them in making appropriate evaluations of performance.

The pilots were [illegible] against even the possibility of the networked simulators being used for safety or procedures training. They recommended that all safety/procedures-type switches, dials, etc. [illegible] "wallpapered" over so that upper management could not redirect their [illegible] training to safety training.

[illegible] the F-15 undergoes significant changes about every 6 months, and these [illegible] in the simulators also, or negative learning will occur. [illegible] degree, for the RWR.

At the end of the session, we asked for any summary/parting advice they would like to give us. They suggested: (a) Call it anything BUT a simulator--a combat [illegible] device, perhaps; (b) Don't cut flying or try to substitute simulator time for flying; (c) Don't operate it at 2 a.m.; (d) Don't allow any Stan Eval procedures/safety stuff; (e) Get and keep working-level combat pilots involved in every phase and aspect of the project. (They were tired of seeing "egghead types" come [illegible] them after a project was finished, and it was very refreshing to see us before we [illegible] our project. They pointed out, as an instance, that they would quickly be able to tell if the [illegible] could be "gamed"; i.e., if there were unrealistic clues that were artifacts of the simulation [illegible] could be picked up and used unfairly by student pilots.)

Although these pilots were not forewarned of the interview and given little prompting, they [illegible] of the best and most knowledgeable in the Air Force, and their responses are [illegible] of what one would get from a much more extensive set of interviews. It is [illegible] that they [illegible] quickly [illegible] created most all of the basic WARNET concepts and then added [illegible]. This is not surprising, however, as the WARNET concept was [illegible] direct inputs from experienced combat pilots in the first place.

IV. WARNET AS A RESEARCH TOOL

[illegible] combat training, the operational squadrons would each have low-cost, [illegible]. While these can be used for individual practice or [illegible] crucial characteristic is the ability to be networked [illegible] aircraft to meet in large-scale red-versus-blue exercises [illegible] of aircraft on both sides, as well as appropriate command and control [illegible]. In [illegible] environment, key R&D organizations would be given "nodes" in the WARNET, [illegible] that represent entirely new aircraft, portions of new aircraft, or command and control [illegible] development. This would allow the new developments to be tried out either [illegible] with blue force aircraft against red force aircraft in realistic battle conditions.

[illegible] invaluable in assessing the performance of man/machine systems in [illegible] obvious in recent years, complex new sensors and weapons are [illegible], in the actual heat of combat, the pilot can properly assess the situation and [illegible] tools. With research nodes in WARNET, the abilities of pilots and [illegible] of proposed new technologies could be assessed at an early [illegible] hardware choices were made.

[illegible] research concept can perhaps be best illustrated by example. Consider, for instance, [illegible] information is displayed to pilots. The traditional manner of displaying [illegible] out-the-window visuals, head-up displays, Multi-Function Displays [illegible] be replaced with a synthetic display integrated from the various [illegible] a manner that would more closely match human sensory input and [illegible] would such a system perform in combat? Which of the many alternative cockpit [illegible] configurations would be most effective?

[illegible] would be to [illegible] test cockpits with the basic WARNET capability at [illegible] Wright-Patterson AFB. Combat pilots would be called in to train in these [illegible] against four ships at various squadrons with operational WARNET [illegible] engagements with additional blue forces against red forces. [illegible] would quickly become apparent, the best configurations would [illegible] against aircraft with conventional cockpits could be assessed [illegible].

As another example, consider the many new "Battle Management" aids to pilots, controllers, and command elements being considered for implementation. How can the true utility of these new concepts be assessed? What would a "Super Joint Tactical Information Distribution System (JTIDS)" really do for the situational awareness of the individual pilots and mission commanders during the course of [illegible] combat? Although there are command and control simulations that purport to address some of these questions (at least at the higher levels), the actions of the individual pilots, both blue and red forces, are represented by random number look-up tables. We feel that these cannot properly represent the complex human pilot element, the true abilities of a smart and capable [illegible], or the actual complexity and surprise of real combat. Furthermore, we believe the "random number" approach serves to further broaden the already too large gap between the command and control elements and the pilots they intend to serve. Pilots are not random, mindless pawns in some [illegible] chess game!

With WARNET nodes at command and control research facilities, new technologies could be tried out, not only with [illegible] commanders and controllers, but with live pilots on both sides of the conflict. This would enable us to see how well the new devices or procedures work under these conditions, and what feedback pilots at operational squadrons have regarding the researchers' approaches for improving battle management. This feedback would bring the command and control research community closer to the pilots, to the benefit of both sides.

It is interesting to note that the Army, with help from DARPA, is already planning a "Skunkworks" facility at Ft Knox that will allow future tank concepts to be tried out on simulators during early R&D stages. Of course, the Army's large network of hundreds of tank simulators (which will be on-line in only 2 years) will be used, with the new tanks and weapons fighting the already fielded varieties with their regular Army operators. The Army and DARPA are already thinking about how their facility can flexibly change cockpits, controls, etc. in a matter of hours or days, to allow new configurations and ideas to be tested.

A similar Air Force capability would, we believe, benefit the development of future aircraft systems and command and control elements. Its center might be at Wright-Patterson AFB, with outlying nodes at other Government, industry, and academic facilities as appropriate, and, of course, with full tie-ins to the regular WARNET training system. We believe that the Human Systems Division (the Armstrong Aerospace Medical Research Laboratory and AFHRL) could play a leading role in this new approach to R&D--a "fight with real pilots in 'combat' before you complete design" approach. At last, instead of the human element's being considered only tangentially and late in the acquisition process, it would play a leading role--in recognition of the true critical importance of the human element in man/machine systems in combat.

V. THE LAST STARFIGHTER OR COMBAT PILOT SELECTION WITH WARNET

In case you don't have young sons and thus don't already know about "The Last Starfighter," here is a summary for you. In a distant corner of the Galaxy, the Forces of Freedom were being overwhelmed by the Sinister Hordes of Evil, who had produced lots of cheap little space fighters. The Forces of Freedom had almost exhausted their supply of space fighters and pilots. The only thing that could save them was a super pilot with a lightning-swift brain that would take in all the data from the space fighter's many sensory and battle management systems, and translate it into swift action on the multiple weapons that would zap the enemy hordes into the oblivion they so richly deserved.

But where could such a super combat pilot be found? How could he be selected? Of course, the Forces of Freedom realized that the clever descendants of the tree swingers that used to jump from tree-to-tree while dodging branches, catching fruit on the fly, discussing the weather, and planning the nightly romantic activities would have an innately high "situational awareness."

Thus, a representative of the Forces of Freedom was teletransported to planet Earth to find the best of the best. Their approach to combat pilot selection was to develop an advanced video game that was, for all intents and purposes, exactly like real space combat, with a full array of sensors, battle management aids, and weapon controls, and of course, the Sinister Hordes of Evil intent on destruction. These advanced video games were placed at video game parlors where kids hung out. For only 25 cents, the kids could play it. True, most kids didn't get very far--it was an unusually tough game. However, some of them found the challenge irresistible and the tough opposition exhilarating, and they became very good and won lots of free games.

Our young hero Alex was, of course, the best of the best. Soon he could take on the enemy Hordes in the Super-Advanced level of the video game. A visit from afar, a fast sales pitch on saving the entire free universe, and Alex was whisked off and placed in a real space fighter, where (was there ever any doubt?) he handily defeated the Sinister Hordes of Evil without any further training.

Is there a gem of truth in this tale? Could advanced video games be used to select combat fighter pilots? In the past, pilot selection was geared toward basic flying skills, such as rudimentary hand-eye coordination. These were the kinds of skills required to fly early-type aircraft where "stick and rudder" dominated. In these aircraft, the main sensor devices were the pilot's two eyeballs, and electronic aids were limited to a few instruments and a simple radio. A typical pilot selection procedure was intended only to distinguish between those who would be able to handle basic flying skills well enough to complete undergraduate flying school from those that were too uncoordinated to do so. This does not fit today's situation, let alone tomorrow's.

Current front-line, fly-by-wire fighters such as the F-16 are well-behaved from the flight control viewpoint, without adverse yaw, etc. Many of the former problems with basic flight, such as killer stalls, have been eliminated electronically. However, the proliferation of electronics has also resulted in a larger number of electronic sensors--different types of radars and infrared systems to warn against enemy aircraft and missiles. The offensive weapons have become more complex also, with missiles of various sorts to be launched. Even navigation and communications have become complex systems, with a myriad of controls and procedures to master and operate as second nature in tight combat situations.

In discussing this situation, experienced combat pilots suggested to us that the key requirement is the ability to assimilate from the large number of information sources a mental picture of the current situation. This is given the name "situational awareness," and we believe that it is now this ability, moreso than eye-hand coordination, that is the key to success. How could one assess the ability of potential pilots to mentally process the vast amounts of sensory input in real time, selectively concentrate on the key inputs, and from this develop a mental picture of the rapidly changing battle situation? One could, of course, devise all sorts of special tasks not directly related to flying combat aircraft in any way, and then through many studies and statistical analyses find which were the best predictors. This approach has the distinct advantage of being able to select those tasks that are easy and cheap to apply, and leads to, in the extreme, simply paper-and-pencil tests. One suspects that in spite of assurances of the high correlation coefficients, something might be lost along the way, although it would keep psychologists and statisticians fully employed!

Alternatively, one might concentrate on the actual tasks themselves: Put the candidates who would like to be fighter pilots in fighter aircraft in a combat situation and see how they do. Real aircraft would not do (for cost and safety reasons, if nothing else), but the use of low-cost and realistic combat fighter simulators in WARNET could be considered. While we would expect use of WARNET by combat pilots (to maintain their skills and practice mass engagements) to take precedence over the pilot selection use of WARNET, pilots really prefer to sleep at night;

in the wee hours of the morning or on weekends, the college student pilot candidates could use WARNET.

These candidate fighter pilots would not be expected to be instant aces. We envision that there would be a progression through which potential candidates would go. First they would learn basic procedures on a home-type video game system, using a self-teaching course. Then they would be allowed to use a WARNET cockpit off-line for completion of procedures familiarization. Then they would graduate to take on fellow candidates in one versus one. Gradually, their horizons would be expanded up to and including the final "National Exercise," where hundreds of top candidates would compete with each other in mass battles. (Television networks could negotiate for coverage of the "Top Gun" Bowl.)

Of course, the performance of each candidate would be recorded and analyzed to assess learning speed, situational awareness, leadership, and other qualities deemed appropriate to combat. The selection process might even be enhanced using the performance on WARNET of our best front-line combat pilots and our most experienced veterans, with the number of kills under their belt as the validity criterion.

The author asked his 9-year-old son, Rusty, about this concept. Rusty, who was, of course, completely familiar with "The Last Starfighter," pointed out that the young pilot's name was "Alex." "How else w [illegible] select them?" he asked, not realizing that there was any other way. An explanation of paper-and-pencil tests was quickly interrupted with a "Got em!" as Rusty brought the [illegible] to bear and shot down another MIG on the F-15 Strike Eagle game on his Commodore computer. Having shot down the remaining 17 MIGs in only 23 minutes and totally vanquishing the enemy, Rusty was now ready to discuss the topic again. "Dad," he announced, "I'm ready to take on real combat aces in WARNET. Do you have a node at Williams AFB?"

VI. CONCLUSIONS, IMPACT, AND CLOSING THOUGHTS

A. Conclusions

Tactical aerial combat is a vital Air Force function. In future wars, the ability to obtain and maintain air superiority over the ground combat zone will have an important influence over the outcomes of battles. Interdiction strikes well behind the battle lines will disrupt and diminish the enemy's capabilities. Keeping enemy aircraft away from our rear areas will allow us to remain organized and effective. For the Air Force to achieve these goals in future wars, our pilots must be trained and maintained at peak combat readiness--especially as it is expected that the enemy will have more aircraft and pilots than we will. By being in peak combat condition, our pilots will be able to avoid the higher loss rate of the first few missions that was characteristic of earlier wars, as well as being more effective in destroying the enemy.

The WARNET study concluded that low-cost, networked combat training simulators could help reduce early mission losses and increase effectiveness by providing aspects of combat practice that are difficult or impossible to provide in peacetime aircraft training, and thus would provide an important supplement to aircraft combat training. Combat training simulators can "fly" over enemy terrain, need no rules of engagement (ROEs) for safety's sake, and can routinely use "live" ammunition, make head-on passes, etc. There are, however, no G-forces, and pilots do not have to worry about being killed, etc.; so, simulators are, at best, only a supplement to training in real aircraft. They could, however, be a vitally important supplement with respect to early mission losses and effectiveness in combat. Low-cost, networked combat training simulators could provide that extra edge of combat readiness that could affect the outcome of future air battles.

The WARNET study concluded that networked combat simulators are technically feasible. Such feasibility was demonstrated for Army tanks while the study was in progress, and the study concluded that the extension to jet aircraft, while not inconsequential, was entirely do-able. It was not concluded, however, that such simulators could be very low cost, at least today.

The primary difficulty was that an appropriate visual display (at low cost) was not available. Rapid progress in low-cost visual displays appears likely over the next few years, and while immediate deployment of networked combat simulators might not be appropriate, laboratory development certainly is.

The WARNET study concluded that networked combat aircraft simulators would add an important new dimension to research and development. As discussed below, AFHRL/OT changed its plans for future simulators so that they will be networked together to increase research capabilities and effectiveness. No conclusions were drawn in the WARNET study with respect to the use of networked combat simulators in pilot selection. This idea is a total departure from current approaches to pilot selection.

B. WARNET Study Impact

The WARNET in-house study and a joint study with DARPA had an immediate and sizable impact on AFHRL--especially AFHRL/OT. The $48 million Aircrew Combat Mission Enhancement (ACME) program was totally restructured as a result of the WARNET study. The near-term portion of the ACME program involving mission rehearsal was made the far-term one, due to severe problems associated with the need to generate data bases rapidly (difficult enough to generate when there is no rush). The far-term portion of low-cost networked combat trainers was made the near-term portion of the ACME program because it was found to be much more achievable and potentially more beneficial.

A tri-Service study has been initiated to establish a protocol for communications between combat aircraft simulators. This protocol will build on the SIMNET protocol established by DARPA for Army tanks.

AFHRL research on low-cost displays and low-cost simulators has received increased emphasis, as this was found to be the weakest link in the low-cost chain. A new research program on very-low-cost flight simulators and player stations has been initiated. The A-10 and F-15 aircraft were studied in detail as part of the WARNET study with DARPA. DARPA used the knowledge gained in this study to construct a low-cost A-10 simulator, and has added it to the tank simulator network at Ft Knox, where it can shoot tanks and be shot at in turn. It is clear that a new era in ground and air combat simulation has arrived, and that the WARNET study played a key role in its birth.

C. Closing Thoughts

The fighter pilots interviewed during the study really provided the key, central thoughts that, in closing, are worth emphasizing.

Aircraft simulators generally do not have a good name among fighter pilots. In the Tactical Air Forces, simulators are used mainly for safety and procedures training. While these types of training are important and simulators are useful in such training, they do not provide the sort of competitive [illegible] that appeal to fighter pilots. Generally, the simulators with which fighter pilots have [illegible] experience are old-technology devices that were expensive, unreliable, and had limited [illegible] visual displays. Pilots do not like the idea of such devices invading the sacred combat arena. Also, with some justification perhaps, they have the concern that the money and effort spent on any massive simulator effort would be at the expense of aircraft and flying.

However, the fighter pilot's love of competition is so high, that if there were devices that allowed many aspects of multiplayer combat to be practiced, and if these devices were very low in cost so they would not impact budgets significantly, and if the devices had no provisions for safety and procedures training, and if the devices were called something other than simulators, all the fighter pilots we talked to would welcome them. Thus, the challenge is: (a) to come up with an effective, low-cost display; (b) to demonstrate to combat pilots that low-cost, networked combat aircraft trainers are effective (and fun); and (c) then to move out of the way as the pilots rush out to obtain and use the trainers. It will take the enemy a long time to catch up, because, as is the case with Xerox machines, they cannot trust their people with microcomputers.

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