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COMPUTER-BASED INSTRUCTION/SIMULATOR PROGRAM FOR FIGHTER LEAD-IN TRAINING: FEASIBILITY RESEARCH

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This technical paper documents the investigation of the training opportunities that might be afforded through advances in flight simulation and computer-based instruction (CBI) to enhance the Fighter Lead-In Training (LIT) program at Holloman Air Force Base, New Mexico. The paper provides an assessment of the LIT program, identifying those areas that could be most improved by CBI and simulation. Alternative mixes of CBI and simulation systems are evaluated for their marginal benefit to the LIT program, and the alternatives are compared using a cost-benefit analysis. Keywords:

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COMPUTER-BASED INSTRUCTION/SIMULATOR PROGRAM FOR FIGHTER LEAD-IN TRAINING: FEASIBILITY RESEARCH

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Reviewed and submitted for publication by

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Chief, Operational Training Unit Branch

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

SUMMARY

The main objective of this effort was to determine the feasibility of using computer-based instruction (CBI) and/or simulation to improve the training effectiveness of the fighter lead-in training (LIT) program. A marginal benefits analysis, cost estimates, and implementation considerations indicated that recent advances in CBI and weapon system trainers (WSTs) offer a feasible means to significantly improve the current LIT program. The analysis was rigorous, and the resultant effectiveness and costs estimates were, if anything, conservative. Based on the cost-benefit results, the inclusion of CBI and a WST simulation facility for LIT was recommended. Incorporating these training media into LIT should not significantly impact undergraduate pilot training (UPT) or replacement training units (RTUs). However, changes will be needed at the RTU level so that increased proficiency of LIT graduates can be realized.

PREFACE

This paper reports a portion of the research and development (R&D) program of the Air Force Human Resources Laboratory (AFHRL) for the Training Technology Program. The general objective of this program is to identify and demonstrate cost-effective strategies and new training systems to develop and maintain safety-of-flight and combat readiness. More specifically, the effort was part of the R&D conducted under the aegis of Aircrew Training Technology, which has as its aim the provision of a technology base for improving the effectiveness and efficiency of training aircrews. The BDM Corporation conducted the research effort. The staff of the Operations Training Division of AFHRL provided technical support under Work Unit 1123-37-13, Computer-Aided Training Concept Evaluation. The Training and Performance Data Center (TPDC), Orlando, Florida, provided funding and the Air Force Operational Test and Evaluation Center (AFOTEC), Kirtland Air Force Base, New Mexico, was the contracting agency.

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I. INTRODUCTION

Background

Teaching fighter pilots the principles of air-to-air and air-to-surface gunnery is a fundamental part of the Air Force's tactical training effort. Prior to 1973, trainees received their initial fighter training in the primary tactical aircraft following graduation from undergraduate pilot training (UPT). Due to increases in fuel prices in the early 1970s, the Air Force created the fighter Lead-In Training (LIT) program at Holloman AFB, New Mexico. To illustrate the potential savings of this program, it was estimated in 1976 that the Tactical Air Command (TAC) could reduce average total costs per flying hour from $1,200 in an F-4 to approximately $300 in the T-38 because of decreased fuel consumption and support costs (Reference 1). UPT graduates were qualified in the T-38 aircraft before coming to LIT and could therefore concentrate on learning basic gunnery skills in a familiar aircraft.

The T-38 aircraft was modified with an A-37 gunsight, sight camera, armament control panel, pylon, and bomb rack and was designated the AT-38B. Using this aircraft, the LIT program began operations in 1973. The initial program was limited to transitioning experienced flyers to fighter aircraft. In 1976, the program was expanded to include training UPT graduates in the basics of fighter aircraft maneuvering prior to Replacement Training Unit (RTU) instruction. Few changes have occurred in the program's 10-year existence. Academics are taught primarily through platform instruction, supplemented by audiovisual sound-on-slide programs. The trainees learn basic fighter skills in the AT-38B aircraft and maintain instrument proficiency in outdated T-38 simulators. The program has been a success; however, the AT-38 fleet is getting old, and the high G forces and power settings required at LIT are accelerating the aging process. Also, the aircraft the LIT graduate will fly when he arrives at his RTU base are becoming more complex from an avionics and weapons standpoint.

While the LIT program has not changed much since its inception, the computer and microchip have revolutionized training technology. Computer-based instruction (CBI)/simulator training is more realistic than before, at less cost and less risk to people and machines (Reference 2). CBI offers an efficient and effective way to present instructional materials and manage training programs. The use of high-resolution graphics, videodisc, and overlay of graphics on video are potentially applicable in teaching air-to-air, air-to-surface, and other tactical training subjects (Reference 3). Simulation capabilities are expanding rapidly. Increases in computer storage capacity and computer processing capabilities now provide the means for high-fidelity computer image generators and fast update rates at affordable costs. As a result, the varied and subtle visual cues required in teaching air-to-air and air-to-surface combat now exist through reasonably priced simulation media.

Purpose

The purpose of this investigation was (a) to identify training opportunities afforded through advances in flight simulation and CBI, and (b) to determine cost/benefit tradeoffs of incorporating these training media into the LIT program. The approach consisted of two separate but dependent tasks.

The first task was to assess the current program. The LIT charter, strengths and weaknesses of the program, and planned Air Force modifications were examined. Findings from this effort were integrated into a clear problem statement.

The second task was to analyze CBI/simulation training program alternatives that could be used to help meet LIT objectives and to solve the problems identified in the previous task. A cost-benefit tradeoff analysis was conducted and the results used to recommend the most feasible alternative that would satisfy LIT enhancement requirements.

II. ASSESSMENT OF LIT

Approach

An assessment of the past, current, and future program was undertaken in order to provide a clear problem statement. Research was conducted tracing the LIT program from its inception to the present. LIT and RTU program managers, instructor pilots, and trainees were surveyed, and LIT graduate evaluation questionnaires were reviewed to determine the strengths and weaknesses of the program. Interviews with training program managers (including general officers) at TAC Headquarters and the Air Staff were conducted to ascertain planned modifications and support for the LIT program in the future. Over 100 persons were surveyed and over 1,000 graduate evaluations reviewed during this task.

History of LIT

TAC officials began developing the concept of a more gradual transition or "lead-in" from UPT to combat crew training in the 1960s. By utilizing the T-38 in a concentrated tactical training course that taught the basic fundamentals of combat flying, many advantages could be gained, including:

1. TAC could reduce the high cost of training an F-4 or A-7 pilot. The average total cost per flying hour computed at about $319 for the T-38 versus $1,215 for the F-4 and $947 for the A-7. Estimates showed that the T-38 saved 10.1 and 9.4 training and indirect support flying hours per student compared to the F-4 and A-7, respectively. Still another significant factor, the fuel consumption of the T-38 was about 20% that of an F-4.

2. TAC also believed LIT would produce a better fighter pilot. After learning basic fighter maneuvers (BFM) and selected surface attack skills, he could theoretically advance faster than if he had started fighter training in the more difficult F-4, A-7, or F-15.

3. TAC's combat posture would be strengthened with fewer first-line fighter aircraft devoted to training missions.

Implementation of the program was accelerated by the oil crisis and T-38 availability as UPT flying hours were reduced. The first T-38 sortie was flown at Holloman AFB, New Mexico, in August 1973. USAF Thunderbird pilots who cross-trained from the F-4 to the T-38 comprised the first student class. Initially, only 40 T-38s were modified with gunsights and bomb racks, and training was limited to experienced fliers (such as O-2 and OV-10 pilots) transitioning to fighter aircraft. In October 1976, the program was expanded to 108 aircraft so that all UPT and undergraduate navigator training (UNT) inputs to tactical fighters could be trained. Over 34,000 sorties per year were programmed so that training could be accomplished.

Several training courses were established, each tailored to different categories of input/output: UPT graduates (AX course), UNT graduates, first assignment instructor pilots (FAIP), T-38 qualification, Forward Air Controller (FAC) orientation, and instructor pilot upgrade training. Every course consisted of five phases:

1. Transition
2. Formation
3. Basic fighter maneuvers
4. Surface attack
5. Low-altitude tactical navigation (LATN).

The basic mission of LIT was to teach fundamental operating procedures and techniques in high performance aircraft in the air-to-air and air-to-surface arenas. The program provided a bridge between UPT and RTUs, and taught confidence, self-discipline, situational awareness, and basic airmanship to pilots who operated in these demanding environments.

Program Changes

Many of the basic attributes of the program have remained the same over the past 10 years. The program still operates under the same charter. The aircraft flown is still the T-38, albeit 10 years older. The average age of the AT-38s is now 19.5 years. The 4-to-1 cost advantage per sortie is still valid today. The number of syllabus sorties has not changed significantly in 10 years, but the total number of training days, special tracks, and academic disciplines has increased. Additional courses in centrifuge and spatial disorientation training have been added. Table 1 compares the AX course throughput for 1976 (Reference 4) and 1986 (Reference 5). Approximately 80% of the students going through LIT training are UPT graduates using this course syllabus. A detailed comparison of flying sorties, training devices, and academic courses for the AX syllabus is available in Appendix A.

Table 1. Comparison of 1976 and 1986 LIT Programs

Major syllabus attributes	1976	1986
Total Training Days	28	45
Flying Training		
Number of Sorties	22	26
Number of Special Tracks	0	3
Training Devices		
Simulators	T-38/F-4	T-38
Special[a]	NO	YES
Academics		
Number of Courses	8	18
Total Academic Hours	44	65-82

[a] Centrifuge/Spatial Disorientation/Altitude Chamber.

Special Tracks. Special tracks were one major change incorporated between 1976 and 1986. Each student completed a basic core of sorties and then pursued a course tailored to the type of aircraft and mission he would encounter at his follow-on RTU. After completing the core course of 16 sorties, students flew 10 additional sorties providing fundamental training in air-to-air and/or air-to-surface tactics. The A track consisted of air-to-air training, and was geared to pilots flying the F-15. The B track provided air-to-surface training for future A-10 and F-111 pilots. The C track combined the A and B tracks for F-4, F-16, and A-7 pilots. A comparison between the 1976 and 1986 LIT academic programs is depicted in Table A-1 of Appendix A. The core course and track breakouts by type and number of sorties for the AX syllabus are depicted in Table A-2 of Appendix A. A typical student breakout by track per year follows: 180 A track, 210 B track, and 300 C track students. This is an important factor in evaluating simulator effectiveness, which is discussed later in this paper.

Academics and Training Devices. Training days were increased from 28 to 45 to allow for increases in academic courses and training with the centrifuge, spatial disorientation trainer, and altitude chamber. Also, a provision for an additional "exigency pad" to accomplish the flying program was included. The elimination of the F-4D simulator, used by UNT graduates and UPT pilots for basic radar and intercept training, was another significant change in the program.

Assessment of the Current Program

Air Staff, TAC staff, wing training program managers, instructor pilots, and former LIT students were interviewed to assess the LIT program. Also, all 1985 and 1986 graduation evaluations were reviewed. The evaluations provided both a good summary of the RTU flight commander's assessment of the LIT graduate and the LIT graduate's summary of the program after completing RTU.

A sample of the questions asked of the interviewees is provided below:

1. What are the major strengths of the LIT program?

2. What are the weaknesses in the program?

3. Is the LIT charter, teaching the basics of air-to-air and air-to-surface combat, still valid?

4. Is LIT preparing the trainee for the newer RTU aircraft?

5. Is the AT-38 the "right" aircraft for LIT?

6. If LIT provided a better product (that is, a pilot more proficient in the basics), how would the RTUs take advantage of this improvement?

7. Could CBI/simulation enhance the LIT program?

8. Disregarding current program constraints, what changes to the program would you recommend?

The study found no major weaknesses; the LIT program was judged to be furnishing an acceptable product. However, a number of concerns were expressed and recommendations made to improve training. The F-111, F-15, and F-16 training communities expressed a need for a higher level of proficiency in the basics of BFM and surface attack (SA). RTU instructors felt they were spending a disproportionate amount of mission time teaching basics instead of avionics/switchology and weapon use. Other concerns and recommended changes are discussed in the following paragraphs.

Flying Program

1. The F-15 community felt that LIT students were flying too many sorties with an instructor pilot. They contended that this impeded development of the student's self-confidence and ability to think for himself. (Source: F-15 RTU)

2. The RTUs believed more Low-Altitude Tactical Navigation (LATN) and Low Altitude Tactical Formation (LATF) training was needed. Both the A-10 and F-111 RTUs thought the LIT students should be better prepared in LATN and LATF. The A-10 community thought there was an overemphasis on black line low-level navigation. (Source: A-10 and F-111 RTUs)

3. The RTUs wanted night sorties reinstalled into the LIT program. LIT included a night sortie in the syllabus but deleted the requirement due to scheduling difficulties. (Source: A-10 and F-111 RTUs)

4. The F-15 and F-16 RTUs wanted BFM sorties increased. Weaknesses identified were: "Poor maneuvering in relation to the bandit" and "limited use of the vertical." In general, it was felt that the LIT graduate understood basic maneuvers, but often failed to recognize when to use them. (Source: F-15 and F-16 RTUs)

5. The A-10, F-111, and F-16 communities would like to include level bombing events in the LIT syllabus. (Source: A-10, F-111, and F-16 RTUs)

6. The A-10 RTU suggested introducing the fundamentals of surface attack tactics (SAT) at LIT. This could be accomplished by including pop-ups on a tactical range at the end of two low-level navigation sorties. (Source: A-10 RTU)

7. Everyone, including students, encouraged more instrument training. (Source: All RTU organizations and former LIT students)

8. The RTUs were concerned that basic tactical airmanship (i.e., the students' ability to make decisions on their own and prioritize tasks when task saturation occurred) should be improved. (Source: RTU and LIT Program Managers)

9. The F-4 and F-111 programs wanted more dedicated sorties for the Weapon System Officers (WSOs). They also wanted radar and Inertial Navigation System (INS) training added to the syllabus. The F-15E cadre were particularly concerned about WSO training at LIT since their assigned training aircraft would be half the normal allotment. (Source: TAC staff, F-111, F-15E, and LIT program personnel)

10. The instructor pilots wanted the AT-38 replaced with F-5s. The improved performance, radar/gunsight, and longer mission time of the F-5 would, in their opinion, provide better training and an easier transition to today's front-line fighters. If the AT-38 was to remain at LIT, the pilots wanted it modified with an INS/head-up display (HUD), videotape recorder (VTR), and Air Combat Maneuvering Instrumentation (ACMI) pods. (Source: LIT Program Managers)

Academic Program

1. The sound-on-slide program has changed little since LIT started. Instructors and students at LIT encouraged improvements and upgrades of this medium, particularly in the basic programs--BFM, SA, and LATN. (Source: LIT Program Managers)

2. Some pilots thought LIT should provide basic intercept training, especially for WSOs flying the F-4 and pilots transitioning to the F-15 and F-16. (Source: F-15 and F-16 RTUs)

Training Devices

1. When included in the LIT program, the F-4D simulator provided valuable radar and intercept training. Though it was principally included for WSO training, most pilots flew as front-seaters during WSO sorties. Former LIT graduates, regardless of their RTU aircraft, said this initial training was invaluable. They felt that using generic part-task trainers (PTTs) at LIT to teach hands-on intercept geometry, radar navigation, and radar warning and receiving principles would enhance the LIT program. (Source: RTU and LIT Program Managers)

2. Instructor pilots who had flown in the Simulator for Air-to-Air Combat (SAAC) at Luke AFB, Arizona, and in the Advanced Simulator for Pilot Training (ASPT) at the Air Force Human Resources Laboratory, Operations Training Division (AFHRL/OT), at Williams AFB, Arizona, suggested that placing a high-fidelity weapon system trainer (WST) at Holloman AFB, New Mexico, would enhance training significantly. (Source: RTU and LIT Program Managers)

The Future of LIT

The LIT Aircraft. It is highly unlikely that the AT-38 will be replaced in the near future. The intent is to keep the LIT aircraft the same as the basic UPT aircraft. This position is supported at TAC and the Air Staff. The T-38 aircraft is currently being modified under a program called PACER CLASSIC, which will extend the life of these aircraft to the year 2010. It is not likely that an INS or HUD will be added to the aircraft due to the high cost. Even if the cost were affordable, higher echelons strongly believe that such modifications are not really needed, as the LIT charter is to teach basics. The 479th Tactical Training Wing (TTW) recommended that a VTR camera be added to the aircraft. The status of this suggestion and of the recommendation to modify the aircraft with ACMI pods is at this time unknown.

Airspace Constraints. Range and airspace problems will not be alleviated in the near future. Strategic Defense Initiative (SDI) projects are increasing, and White Sands Missile Range will require more priority time for SDI in the future. This will force pilots to use airspace distant to Holloman AFB, New Mexico, thus losing quality mission time.

Increased Sorties. Most RTUs recommended adding sorties; no one recommended cutting them. Airframe availability and sortie production are already constrained. Also, range availability limits the usefulness of additional sorties. Some recommendations can be accommodated by altering the mix of syllabus sorties; however, tradeoffs are necessary. In conclusion, it is highly unlikely that additional sorties will be flown at LIT.

Academics. Civilian instructors are scheduled to join the school staff in FY88 and platform instruction will continue to be the main training mode. The sound-on-slide program will probably not be upgraded since it has limited capabilities for teaching three-dimensional concepts and integrated fighter maneuvers--basic ingredients of the LIT program.

Training Devices. Although the T-38 simulators serve LIT well for emergency procedures and instrument training, they have little or no utility for training BFM. There are no plans to upgrade the simulators to teach tactical aircraft employment skills or to add PTTs to teach basic radar and intercept principles.

Problem Statement

The LIT mission, to teach basic tactical flying fundamentals in a familiar aircraft, is still valid. In fact, learning the basics at LIT is becoming even more important as first-line aircraft become more complex. While the RTU program managers indicate that the current LIT product is acceptable, they would like to see an improvement in the LIT graduate's basic skill levels. Improving the training at LIT would allow the RTUs to devote more time to avionics and weapons employment training. Most of the recommendations for improving LIT require adding sorties, which is unlikely due to aircraft and airspace constraints. The overall objective of the current study, therefore was to determine if and how much CBI and simulation can better prepare the student on the ground, and thus make each flying sortie more productive.

This objective was met by assessing the potential contribution of CBI and simulator training to meeting criterion-referenced objectives (CROs) of tasks and procedures trained at LIT. Section III provides a cost-effectiveness analysis of CBI's potential contribution to the current LIT academic program. In Section IV, alternative simulator combinations are compared based on their cost and their potential to improve the tactical flying phases at LIT.

III. CBI COST-EFFECTIVENESS ANALYSIS

Methodology

Given a clear understanding of the LIT program's limitations, the next step was to address the requirement for improving the academic program. To this end, estimates of the effect and cost of incorporating CBI at LIT were determined.

Scope. The AX course syllabus was used as the basis for the cost-benefit analysis model. Recall that approximately 80% of the students going through LIT training are UPT graduates using this course syllabus. The analysis was further limited to include only the five tactical phases of the AX academic syllabus around which the curriculum is centered: tactical formation (TF), basic fighter maneuvers (BFM), air combat maneuvers (ACM), surface attack (SA) and low-altitude tactical navigation (LATN). The scope of the analysis was limited to these conditions so that this study could be completed within the program's designated level of effort. The reconnaissance track, a special track in the AX syllabus, was not included in this study because few students (42) are trained per year. CBI would probably benefit other courses and academic phases, but these contributions were not quantified.

The CBI system included in this effort is defined later. An unlimited number of CBI alternatives could have been evaluated, but did not fall within this study's level of effort. The CBI system selected was based on a review of CBI programs currently in operation and an assessment of the LIT program requirements.

Methodology Overview. The major steps in the CBI analysis are listed below:

1. Define the CBI system and its characteristics.

2. Select the criteria to be used in evaluating the potential contribution of CBI to the current academic program.

3. Subjectively determine the marginal contribution of CBI to each of the academic objectives.

4. Determine implementation requirements and feasibility.

5. Estimate CBI life-cycle costs over 10 years.

CBI Characteristics. In problem-solving training, the more realistic the problem is, the greater is the learning benefit (Reference 6). Based on previous research, CBI would make a significant contribution toward understanding concepts involving problem solving; three-dimensional visualization; and a dynamic, sequential, step-by-step learning approach. The subjective evaluation of CBI's marginal contribution to the academic program was based on the following CBI attributes (Reference 7):

1. Interactive video and audio

2. Graphic overlays

3. Stations integrated by LAN

4. Authoring capability

5. Feedback to students as procedures are performed

6. Student evaluations and tests.

Evaluation Criteria and Methodology. A review of the literature revealed no previous efforts specifically applicable to quantifying the contribution of CBI to a program similar to LIT. A bottom-up, subjective evaluation of the LIT academic program was conducted using data derived from subject-matter experts (see Appendix B). The overriding criterion was whether the CBI attributes listed above could improve the trainee's understanding beyond that provided by the current academic media.

Phases of academic instruction are broken up into blocks, which are further divided into elements. Associated with each element are CROs which specify performance standards. The contribution of CBI to each CRO was independently rated by the subject-matter experts using a scale from 0 (no contribution) to 5 (a significant contribution). Ratings were based on applicability, problem-solving contributions, three-dimensional visualization, dynamic step-by-step learning, interest of lesson material, interaction/feedback, and self-paced learning. Any disagreements between subject-matter expert CRO rating assignments (ratings with a variance of one or greater) were resolved through review of the element and compromise as to a final consensus rating.

Results of CBI Marginal Benefit Analysis

The potential benefit of CBI for enhancing understanding of basic concepts was evaluated for five tactical phases: Tactical formation, BFM, ACM, SA, and LATN. Phase manuals (References 8, 9, 10, & 11) provided descriptive criteria, and CROs provided learning objectives (Reference 12). The estimated contribution of CBI to each phase of instruction was computed by taking the median score of all CRO ratings within that phase. Median values of CRO ratings were used in both the CBI and the WST benefits estimation procedures because it was felt that they represented the most statistically accurate measure of central tendency.

Table 2 shows the median CRO ratings for the five phases of academic instruction. The percentage of CROs that CBI would benefit ranged from 33% for LATN to 100% for ACM. A major contribution would be in the BFM academics, where 88% of the CROs would show improvement and the median benefit rating was a 3. Overall, 140 CROs were evaluated. It was determined that 71% of the CROs would benefit from CBI. The overall median for the five tactical courses was 2. Appendix C contains a breakout of all CRO ratings, organized by phases.

Table 2. CBI Benefit to LIT Academic Program

By phase:	Number of CROs	Percent of CROs improved	Median benefit rating
Tactical Formation	13	39	0
BFM	65	88	3
ACM	6	100	2
Surface Attack	44	64	1
LATN	12	33	0
Collapsed across phases:	140	71	2

Implementing CBI

Whether a LIT student would benefit from CBI was not the only factor considered. The impact of changing the number of academic program hours required to implement a CBI program was also investigated.

The AX course syllabus requirements for academic training range from 65 to 82 academic hours. The curriculum is centered around the five tactical phases described earlier. A total of 39.5 hours are distributed among these five subject areas as depicted in Table 3.

Table 3. Current Core Academic Hours

Five phases of academics	Hours
Tactical Formation	5.5
BFM	14.5
ACM	2.0
Surface Attack	13.5
Low-Altitude Tactical Navigation	4.0
Total	39.5

Task element CROs associated with each hour of academic instruction for the different phases were identified. Marginal benefit ratings for these CROs were reviewed in an attempt to determine what and how much of the material would be appropriate for CBI. The results of this procedure are given in Table 4. This table indicates the hours of current core academic instruction containing CROs that would benefit from CBI for each phase of instruction.

Table 4. Academic Hours Best Suited to CBI

Five phases of academics	Hours
Tactical Formation	2.5
BFM	9.0
ACM	1.0
Surface Attack	7.5
Low-Altitude Tactical Navigation	1.0
Total	21.0

As indicated by the total hours, not all classes are best taught using CBI; some are better taught through normal classroom instruction. The recommended CBI program would contain 53% of the total hours offered. However, within the total LIT academic program other subjects might also be taught using CBI. Only that portion of the curriculum that concentrated on basic fighter topics was analyzed.

Feasibility of Implementing CBI

After the appropriate number of hours for conversion to CBI was determined, program feasibility was analyzed. Student flow (Reference 13) revealed that, at any given time during the year, four different AX classes are taught in the five basic courses at the same time. The average size of the four different AX classes would be 24 students in each of the first two classes, 22 students in the third, and 12 students in the fourth. The number of CBI work stations must be sufficient to accommodate scheduling of students from each of the various classes. Analysis of a typical student day indicated that AX students would spend approximately 2 to 3 hours per day using the CBI facility. Based on these requirements, it was assumed that a class schedule could be derived so that the CBI facility would be used by only one AX class at any given time. Therefore, the CBI facility can be sized for the largest AX class.

In addition to the stations required to conduct CBI training for the largest class (24 students), stations will also be required as spares and for the instructors to use in interacting with students and in developing programs. A total of 30 stations could provide training for 24 students, and include three spares and three instructor stations. Therefore, the cost of implementing CBI was based on 30 work stations.

It was assumed that the total number of academic training hours would remain constant with the addition of CBI. Although a reduction in the number of platform instruction hours could reduce the number of instructor hours required to support academic training, its impact was not considered in any detail in this effort. It could not be considered a one-for-one reduction since instructors would be needed to monitor CBI and to develop and revise CBI materials in order to maintain currency of the CBI training program. The scheduling flexibility that CBI will offer was not evaluated, but it is considered likely that it would enhance the overall academic program.

CBI Cost Estimates

Rough order-of-magnitude costs for the kind of CBI program that would fulfill LIT training requirements were estimated based on costs provided by various contractors offering such services. McDonnell Douglas and General Electric, for example, provided hardware, software, and courseware costs. Where large variances existed, the higher cost was used. Once costs were estimated, contractors were provided the estimates and asked to evaluate them. The contractors' consensus was that CBI 10-year life-cycle costs were "reasonable rough order of magnitude estimates."

CBI costs were divided into three categories: hardware, software, and courseware. The initial cost per training station was approximately $8,300. Recurring hardware costs were based on a unit/component replacement of 7% per year. One-time software costs were derived using an initial license fee of $80K for a PC-networked system; yearly costs were based on a software update service that charged 25% of the one-time license fee. Courseware costs of $12.5K per course were based on 250 hours of labor per course at $50 per hour. Courseware recurring costs assumed that modifications were incorporated that would require 15 minutes per course per year. The total breakout for capital and recurring costs per year for the LIT CBI system is shown in Table 5.

Table 5. CBI Rough Cost Estimates

	$ Per unit	Number of units	Total
Capital Cost			
Hardware	8.3K	30 stations	250K
Software		(one-time cost)	80K
Courseware	12.5K	21 hours	262.5K
Total			592.5K
Recurring Costs Per Year			
Maintenance/Modifications			
Hardware	.58K	30 stations	17.5K
Software	----	----	20K
Courseware	3.125K	21 hours	65.6K
Total			103.1K
10-Year Life-Cycle Cost	1,623.5K		

Conclusions

CBI can potentially make a significant contribution to the LIT academic program at a reasonable cost. In over 70% of the CROs, the trainee's understanding can be improved with CBI. When one considers the number of trainee-hours the system would support over the 10-year period (690 trainees X 10 years X 21 hours), the cost per trainee-hour is only $11. Clearly, CBI is a cost-effective alternative for improving academics at LIT and merits further consideration.

IV. SIMULATION COST-EFFECTIVENESS ANALYSIS

Methodology

The simulation cost-benefit analysis used a methodology similar to that used to analyze CBI benefits. The main difference was that, whereas the CBI analysis addressed the potential for improvements in the academic program, the simulation analysis focused on identifying the potential for improving the flying program.

Scope. The number of alternatives, training media combinations, flying courses, and mission areas was limited so the allotted level of effort could be maintained.

As was the case for the CBI analysis, the AX course was used as a model for the simulation cost-benefit analysis. The reconnaissance track was again excluded in the analysis because of the small number of students (42) trained in it per year. The simulation analysis also concentrated on the five tactical mission areas identified by RTUs as needing improvement and congruent with the LIT charter: tactical formation, BFM, ACM, surface attack, and low-altitude tactical navigation. Simulation would probably benefit the other courses and flying phases, but no attempt was made to quantify these potential contributions.

Three Weapon System Trainer (WST) variants and combinations were studied. An unlimited number of WST alternatives could have been evaluated, but this approach did not fall within the study's level of effort.

Generic PTTs were recommended for inclusion in the LIT program. Though it is believed PTTs could be used in that program to provide a basic understanding of radar, intercepts, and Radar Warning Receivers (RWRs), especially for WSOs, PTTs were omitted as an alternative here. Therefore, the study was limited to those Aviation Training Devices (ATDs) that could contribute directly to the AX flying program.

Methodology Overview. The major cost-benefit analysis steps are listed below:

1. Define alternative simulator system characteristics.

2. Define the criteria for evaluating each alternative system's contribution to the current flying program.

3. Determine the marginal contribution of each alternative system to the flying syllabus, assuming a specific level of training.

4. Select combinations of simulator systems to meet syllabus and student-load requirements.

5. Determine the feasibility of implementing each simulator alternative.

6. Estimate 10-year life-cycle costs for each alternative.

7. Compare relative cost/benefit ratios for each simulator alternative.

WST Characteristics. So that the marginal contribution of alternative WST configurations to the LIT flying program could be determined, three different WSTs were considered. The three alternatives were selected based on the requirement that they be capable of supporting all or a major subset of the surface attack, BFM, ACM, tactical formation, and low-altitude navigation flying training requirements. To conduct the benefits analysis, it was not necessary to specify the technical characteristics of the WST alternatives. Rather, only functional requirements needed to be specified. All three alternatives shared the following characteristics:

1. An AT-38 cockpit that included only those cockpit components necessary to fly air-to-air and air-to-ground tactical missions.

2. An Instructor Operator Station (IOS).

3. A visual refresh rate with a high enough frequency to accommodate gun-tracking maneuvers or close formation flight.

4. A Computer-Generated Image (CGI) target aircraft of sufficient definition to determine closure and aspect at 9,000 feet.

5. A single-target aircraft that includes Adaptive Maneuvering Logic (AML) and at least three levels of maneuvering, plus manual maneuvering capability at the IOS.

6. Functioning G suit but no motion.

The main difference among the WST alternatives (A, B, and C) was the visual system associated with each system. WSTA was optimized for air-to-air training. It utilized a visual system with the following type of functional characteristics:

1. Full Field of View (FOV).

2. CGI low-resolution background environment with sufficient cues to visually determine relative attitude and altitude (similar to the Simulator for Air-to-Air Combat at Luke AFB, AZ).

It was assumed that WSTB was optimized for surface attack and low-level navigation training. Its visual system was comprised of the following components:

1. Partial FOV sufficient to provide cues for target acquisition, aiming, and low-altitude navigation.

2. High-fidelity CGI background with sufficient fidelity to identify targets, navigate visually, and determine height above the ground.

WSTC combines the best features of WSTA and WSTB with a full FOV and high-fidelity CGI background.

WST Marginal Benefit Methodology. Each pilot task was evaluated and subjectively rated on a scale from 0 to 5 in terms of the simulation's ability to enhance the understanding and accomplishment of flying performance objectives. The AX syllabus provided the pilot task delineation. A description of each task was obtained from the phase manuals, and conditions and performance standards were determined from syllabus CROs. As with the CBI methodology, each WST alternative was evaluated against specific criteria. For each task, the WSTs were evaluated in terms of their ability to:

1. Perform the task - applicability.

2. Provide necessary visual cues.

3. Do multiple task repetitions.

4. Demonstrate and repeat maneuvers from same vantage point.

5. Provide real-time analysis/feedback to the student and instructor.

6. Provide debriefing to assess student performances.

Equal weighting was given to each of the criteria. The program subject-matter experts independently evaluated the flying tasks, and differences in ratings were resolved in order to obtain a final rating.

WST Marginal Benefit Results. Table 6 is an example of the estimations of WSTA's contribution to a single pilot task. Table 7 demonstrates how the pilot tasks were combined to determine their contribution to a phase block of flying. Table 8 provides an example of WSTA contributions to all phases evaluated for the total flying syllabus. It is interesting to note that the largest ratings were assigned to the air-to-air phases; however, this is not surprising since WSTA was optimized for training in air-to-air tactics.

Table 6. WSTA's Contribution to a Single Pilot Task

PILOT TASK	Low Yo-Yo
DESCRIPTION	Phase Manual
CRO	Conditions Given: 0- to 5-G maneuvering target, low aspect and angle-off, less-than-desired closure/energy state, target in any plane of motion. Standards: Recognizes the need for the maneuver. Establishes/increases closure inside the defender's flight path with nose in lead pursuit. Uses power and G as required.

WSTA MARGINAL BENEFIT RATING: 4.5 on a scale of 0 to 5.

Table 7. Phase Block Ratings for WSTA

OFFENSIVE BFM

PILOT TASKS	RATING
Gun Tracking	4.5
Range Estimation	2.5
Visual Search	3.0
Descriptive Commentary	3.0
Switchology	2.0
Acceleration Maneuver	2.5
High Yo-Yo	4.5
Low Yo-Yo	4.5
Lag Roll	4.5
High-Angle Gun Shot	4.5
Quarter Plane	4.5
Separation	4.5
Weapons Parameters	3.5
Simulated Heat Missile	4.5
Simulated Gun Shot	4.5
Lead Turn Exercise	3.6
Situational Awareness	4.5
Judgment	4.5
Flight Discipline	4.5
Median	4.5
Average	3.9

Table 8. Flying Syllabus Ratings for WSTA

Phase	Median
Tactical Formation	3.00
Offensive BFM	4.50
Defensive BFM	4.00
1-V-1 Maneuvering	4.30
ACM	.35
Surface Attack	1.50
LATN	.50

WST Effectiveness Summary. A matrix of unweighted marginal benefits for each of the alternative WST options was constructed using the assumptions discussed above and the methodology outlined in Tables 6 through 8. Table 9 shows the median raw score values assigned to each alternative to the total LIT program by flying phase evaluated. In general, WSTA, which was optimized for air-to-air, performed well in those phases. Conversely, WSTB, optimized for air-to-surface, performed poorly in the air-to-air phases but received high scores in surface attack and LATN. None of the WSTs scored high in ACM because none was equipped with the capability to simulate the additional enemy and/or friendly aircraft necessary to train ACM. WSTB received a score of 0 in Defensive BFM because of its visual system's limited-FOV display. Appendix D contains a breakout of all CRO ratings for each WST alternative, organized by phases.

Table 9. Unweighted Simulator Marginal Benefit Median Ratings

	Alternative		
Phase	WSTA only	WSTB only	WSTC only
Tactical Formation	3.0	2.0	3.0
Offensive BFM	4.5	4.2	4.5
Defensive BFM	4.0	0	4.0
1-V-1 Maneuvering	4.3	2.35	4.3
ACM	.35	.10	.35
Surface Attack	1.5	4.25	4.25
LATN	.5	4.5	4.5

The marginal benefit values in Table 9 are unweighted median scores. Because students in different tracks flew different mixes of sorties and the number of sorties differed by phase, the scores in Table 9 were weighted in the cost-benefit analysis by number of yearly student sorties flown in each phase. Since no WST alternative was particularly suited to the ACM, this phase was not included in the final cost-benefit analysis. Prior to computing the weighted benefit values the total number and configuration of trainers required to satisfy program needs, as well as life cycle cost estimates for each configuration alternative, needed to be determined. Weighted benefit values could then be determined for alternative combinations of the WSTs under consideration.

Implementing WSTs into LIT

To investigate the feasibility of implementing WSTs into the LIT program, a simulator syllabus was developed. The syllabus was based on results of the WST benefits analysis. Thus, the simulator missions were designed to focus on tasks for which the WST was estimated to provide a major training benefit. Based on expert opinion, time was estimated and allotted for an adequate number of task repetitions and instructor/student interactions. Based on this analysis, it was determined that a single 1-hour simulator mission would be required for every two flying sorties. The number of sorties per student, as designed for the different student tracks, are shown in Table 10.

Table 10. Base Case Simulator Syllabus Sorties/Students

	Track		
Block	F-15	A-10/F-111	F-4/F-16
Tactical Formation	1	1	1
Offensive BFM	2	1	2
Defensive BFM	2	2	2
1-V-1 Maneuvering	4	2	3
ACM	0	0	0
Surface Attack	0	4	3
Navigation	0	2	0
	9	12	11

The total number of simulator sorties to be accomplished per year was calculated based on data derived from the simulator syllabus. A total of 7,460 sorties were computed (see Table 11). These values were determined by multiplying the total number of students in each track by the number of simulator sorties to be accomplished for the track.

Table 11. Yearly Simulator Sorties Required

	Track		
Block	F-15	A-10/F-111	F-4/F-16
Tactical Formation	180	210	300
Offensive BFM	380	210	600
Defensive BFM	360	420	600
1-V-1 Maneuvering	720	420	900
Surface Attack	0	840	900
LATN	0	420	0
Totals	1,640	2,520	3,300
Combined Total		7,460	

Students/Year: F-15 (180), A-10/F-111 (210), F-4/F-16 (300)

A cursory analysis determined the impact on the number of training days needed if WST simulator training was added to the LIT syllabus. The analysis assumed that with academics, flying, and simulator events, only two events could be scheduled per student per day. Using the course flow in the AX syllabus and the derived WST syllabus shown in Table 10, each additional simulator mission was added to the course schedule after the corresponding academic instruction and prior to the associated flying block. An additional training day was added to the program when including the simulator mission would result in three student events for that day. The A track required 4 additional training days; the B track, 5 days; and the C track, 4 days. This cursory analysis did not investigate the intricacies of coordinating and integrating the scheduling requirements to ensure implementation; thus, it is a conservative estimate of additional days required. Additional information is contained in Appendix E.

Once the total number of simulator sorties per year was determined, assumptions about simulator operation provided an estimate of the number of simulators required to conduct training. The overriding requirement was incorporation of WSTs into the LIT program with minimum disruption to the current program. The AT-38A Programmed Flying Training assumes that 240 days of training will be conducted each year. This same planning factor determined the number of simulators required. Even though the simulator could have been available longer, operating hours were limited to 12 hours per day. Given that simulator periods would last 1 hour, 12 sorties could be flown each training day. Additionally, simulator time was padded by 8% to account for student nonprogress sorties and simulator problems. (This factor is currently being used by General Electric in their simulation facility in Tempe, Arizona.) Based on these assumptions, it was found that 2,880 simulator sorties would be generated per simulator each year. Only 2,650 sorties were available when the 8% pad was included.

Because the combined total number of yearly simulator sorties required is 7,460 and only 2,650 can be generated per simulator, three simulators will be required. Alternative mixes of WST devices were investigated in an attempt to determine the most cost-effective combination of trainers. The initial approach was to determine whether a worthwhile program could be developed if only two simulators were purchased. Two air-to-air (WSTA) or two surface attack (WSTB) simulators were considered as alternatives. The marginal benefit of each alternative was determined, reducing the total number of simulator missions in the syllabus. Thus, each alternative required a change in the type and number of missions that would be taught in the simulator; however, the number of sorties for each area in which the simulator was judged to be beneficial remained the same. Table 12 shows the breakout for each alternative in the special syllabus, the total number of missions required per year, and the total number of missions that would be available for training with two simulators.

Table 12. A/A and A/S Simulator Syllabus

	A/A syllabus track			A/S syllabus track		
	A	B	C	A	B	C
Tactical Formation	1	1	1	0	0	0
Offensive BFM	2	1	2	2	1	2
Defensive BFM	2	2	2	0	0	0
1-V-1 Maneuvering	4	2	3	0	0	0
Surface Attack	0	0	0	0	4	3
LATN	0	0	0	0	2	0
	9	6	8	2	7	5
Sorties Required Per Year	1,620	1,260	2,400	360	1,470	1,500
Totals		5,280			3,330	
Sorties Available From Two Simulators		5,300			5,300	

An additional WST alternative that mixed WSTA and WSTB simulators was also evaluated. A review of the flying syllabus revealed that approximately two air-to-air flying sorties are flown for every air-to-surface sortie. This mix suggested that two WSTA and one WSTB simulator be obtained. This mix would also permit use of the original syllabus and allow all missions to be conducted as programmed.

Rough Order-of-Magnitude Costs for WSTs

The benefit/cost analysis could not be completed without knowing the Rough Order-of-Magnitude (ROM) cost of each system.

WST Cost Estimates. Cost figures for the different WSTs were developed from estimates of systems either available on the market today or being developed for future training/weapon systems. The ROM cost estimates were provided by a variety of vendors currently involved in the production and/or research of tactical simulation systems. Vendors were provided lists of functional training specifications for each WST alternative, as defined earlier. Given these specifications, vendors computed estimates of technical requirements and associated ROM costs. The intent was not to limit the vendors to a current or specific system, but to allow them latitude to base their estimates on the most cost-effective system. As shown in Table 13, the costs are categorized into capital and annual recurring costs.

Table 13. WST Cost Estimates

	Alternative		
	WSTA	WSTB	WSTC
Capital Costs[a]			
Computer, Cockpit, IOS, Etc.	6	6	6
Visual Systems	3	5	7
Facilities	.5	.5	.5
Totals	9.5	11.5	13.5
Annual Recurring Costs[a]			
Maintenance	.7	1.8	2.0
Spares	.2	.6	.9
Operations	.2	.2	.2
Utilities	.1	.1	.1
Totals	1.2	2.7	3.2

[a] Dollars per unit (x 1 million)

For all three WSTs, the flight simulation computer, cockpit, and IOS were combined as one cost figure. The $6 million estimate is primarily based on the T-45 WST currently being provided to the Navy by the Sperry Corporation. The visual system included the display system, target generation, CGI background, and associated supporting hardware and software. As mentioned above, the type of visual system was not technically specified. Cost estimates included conventional image systems, as well as laser disc and variable visual acuity systems. The estimate for WSTC's visual system is the "softest" since it is based on variable visual acuity systems such as Eye-Slaved Projected Raster Inset (ESPRI) and Fiber-Optic Helmet-Mounted Display (FOHMD), which are still under development. The $.5 million for facilities was based on the Air Force's estimate of $1 million for a two-bay facility. To confirm their accuracy, the figures shown in Table 13 were recoordinated with the vendors from which ROM costs were originally estimated. In their opinion, the capital costs represent good "ballpark" estimates.

The baseline for recurring cost was the SAAC simulator facility at Luke AFB, Arizona. The estimate for a two-dome, two-cockpit facility is approximately $1 million per year. The sharp increase in recurring costs for WSTB and WSTC is due to the cost for maintaining the hardware and software needed to store and project the CGI data base. Operations costs include the cost of four contractor-provided instructors per WST per year. As with capital costs, these estimates were coordinated with a number of contractors and personnel at AFHRL and confirmed to be reasonable ROM estimates.

To determine the 10-year life-cycle costs for each of the alternatives, the cost per unit was multiplied by the number of units in each alternative and added to the 10-year recurring costs. The cost estimates are shown in Table 14.

Table 14. Alternative 10-Year Life-Cycle Costs

	3-WSTA	3-WSTB	3-WSTC	2-WSTA	2-WSTB	2-WSTA/1-WSTB
Capital Costs[a]						
Computer, cockpit, IOS, for example	18	18	18	12	12	18
Visual System	9	15	21	6	10	11
Facilities	1.5	1.5	1.5	1.0	1.0	1.5
Totals	28.5	34.5	40.5	19.0	23.0	30.5
Recurring Costs[a]						
Maintenance	2.1	5.4	6.0	1.4	3.6	3.2
Spares	.6	1.8	2.7	.4	1.2	1.0
Operations	.6	.6	.6	.4	.4	.6
Utilities	.3	.3	.3	.2	.2	.3
Totals	3.6	8.1	9.6	2.4	5.4	5.1
10-Year Life-Cycle Costs	67.5	115.5	136.5	43.0	74.0	81.5

[a] Dollars per unit (x 1 million).

WST Cost-Benefit Analysis

Thus far, LIT flying program marginal benefits have been derived for each alternative by type of mission. Also, 10-year life-cycle costs have been estimated for each alternative. The next step, before computing cost-benefit ratios, is to weight the marginal benefits proportionally to the number of sorties flown in each type of mission.

Weighted Marginal Benefits. As shown in Table 15, each of the three tracks flies the same number of tactical sorties (21), but a different mix of missions depending on the track. By projecting the number of students enrolled each year, the total tactical sorties can be computed by multiplying the number of students by the number of mission sorties in each track. The yearly sortie breakout by tactical mission type and track is shown in Table 16. The right-hand column depicts sortie percentage by mission type. Yearly student loads by track, shown at the bottom of the table, are based on the LIT Programmed Flying Training document for FY88 (Reference 13).

Table 15. AX Syllabus - Tactical Sorties

	Track		
Sortie type	F-15	A-10/F-11	F-4/F-16
Tactical Formation	3	3	3
Offensive BFM	3	3	3
Defensive BFM	3	3	3
1-V-1 Maneuvering	8	2	5
ACM	4	0	0
Surface Attack	0	6	7
LATN	0	4	0
Totals	21	21	21

Weighted marginal benefits were computed by taking the unweighted benefits (Table 9) and multiplying them by the total number of sorties flown in a year by mission type (Table 16). The summed total then gives the weighted, total marginal contribution of the WST that would result if applied to the current LIT program. Table 17 provides weighted marginal benefit values for each of the WST alternatives considered. The marginal benefit values in this table provide an index as to the relative potential benefit of each alternative to the LIT program. The ACM phase was deleted from this analysis for reasons presented earlier.

Cost-Benefit Analysis Results. Using the weighted total marginal benefit (MB) value (Table 17) and the 10-year life-cycle costs (Table 14), MB/cost and cost/MB ratios were computed for each alternative (Table 18). Also, cost per student, based on 6,900 AX students projected over the next 10 years, was calculated. Cost per simulator sortie is also included in Table 18. This measure of effectiveness (MOE) was based on projections that stated simulators would be utilized 100% and 2,650 sorties would be flown per simulator per year. The MB/cost ratios are graphically depicted in Figure 1.

Table 16. Tactical Sorties Per Year

	Track				
Sortie type	F-15	A-10/F-11	F-4/F-16	Total	Percent of total
Tactical Formation	540	630	900	2,070	14.3
Offensive BFM	540	630	900	2,070	14.3
Defensive BFM	540	630	900	2,070	14.3
1-V-1 Maneuvering	1,440	420	1,500	3,360	23.2
ACM	720	0	0	720	5.0
Surface Attack	0	1,260	2,100	3,360	23.2
LATN	0	840	0	840	5.8
Totals	3,780	4,410	6,300	14,490	

Information based on following AX student loads:

F-15 - 180 students/year
A-10/F-111 - 210 students/year
F-4/F-16 - 300 students/year

Table 17. Weighted WST Total Marginal Benefit

	Alternatives						
Phase	Sorties	3WSTA	3WSTB	3WSTC	2WSTA	2WSTB	2WSTA/ 1WSTB
Tactical Formation	2,070	6,210	4,140	6,210	6,210	-	6,210
Offensive BFM	2,070	9,315	8,694	9,315	9,315	8,694	9,315
Defensive BFM	2,070	8,280	-	8,280	8,280	-	8,280
1-V-1 Maneuvering	3,360	14,448	7,896	14,448	14,448	-	14,448
Surface Attack	3,360	5,040	14,280	14,280	-	14,280	14,280
LATN	840	420	3,780	3,780	-	3,780	3,780
Totals	13,770	43,713	38,790	56,313	38,253	26,754	56,313

Table 18. Cost-Benefit Summary

	Alternatives					
Measures of merit	3WSTA	3WSTB	3WSTC	2WSTA	2WSTB	2WSTA/ 1WSTB
Total Marginal Benefit	43,713	38,790	56,313	38,253	26,754	56,313
10-Year Life-Cycle Cost[a]	$64.5	$115.5	$136.5	$43.0	$74.0	$81.5
Cost/Marginal Benefit	$1,475	$2,978	$2,424	$1,124	$2,766	$1,447
Marginal Benefit/$1 Million Cost	678	336	413	890	362	691
Cost/Student[b] (6,900 students)	$9,348	$16,739	$19,783	$6,232	$10,725	$11,812
Cost/Simulator Sortie (100% Utilization, 2,650 Sorties/Simulator/ Year)	$811	$1,453	$1,717	$811	$1,453	$1,025

[a] (x 1 million).

[b] Total cost per student is $141,000 for the current program.

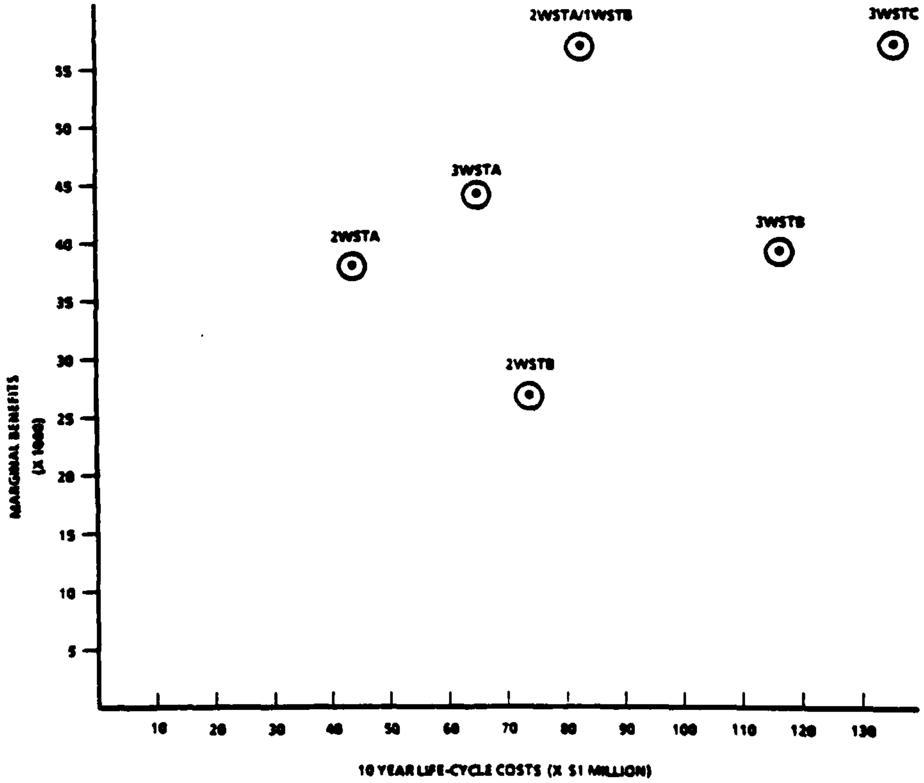

Figure 1. Cost-Benefit Ratios.

Conclusions

Among the WST alternatives, the two WSTA options had the lowest cost per MB. This occurred for two reasons. First, WSTA was the least expensive WST. Secondly, the simulator syllabus was altered (i.e., air-to-surface sorties were eliminated) to take advantage of the heavily weighted air-to-air syllabus. Conversely, the two WSTB options, though they took advantage of air-to-surface capabilities, did not compare favorably with two WSTA options for cost reasons and because relatively few air-to-surface sorties were flown in the LIT syllabus. The next best WST alternative was to combine two WSTAs and one WSTB. Using the air-to-air and air-to-surface training sorties, more students could be taught with this mix than with the two WSTA options. This finding is not surprising since the air-to-air and air-to-surface mix at LIT is two-to-one.

WSTs are expensive but have the potential to contribute significantly to the LIT program. For example, using two WSTAs and one WSTB would increase cost per student by 8%, but the increase in estimated benefit would be substantially greater.

V. IMPACT ON PROGRAMS AND RECOMMENDATIONS

Impact on UPT and RTU

If the LIT program implements CBI/simulation, the estimated impact on UPT was viewed as insignificant. Student input flow should remain the same. The additional training days projected means that more students will train at LIT at any given time, resulting in more overlap between classes; however, the UPT program would remain essentially unchanged. Review of the Reconnaissance, Attack, Fighter Training Study (RAFTS 1) and the dual-track UPT program did not reveal any expected reduction in the benefits of CBI/simulation instruction at LIT in the future. Further, the added flexibility that CBI/simulation would provide LIT program managers should increase their ability to take full advantage of anticipated improvements in the UPT product.

Initially, added training days will cause starting dates at the RTUs to slip; however, once flow is stabilized, the impact will be minimal. Perhaps the greatest impact on the RTUs will be a positive one--an increase in their training capabilities based on the projected increase in proficiency level of the LIT students. Assuming that CBI/simulation increases the basic tactical skills of the LIT graduate, the RTUs should take advantage of this increase by altering their syllabus, concentrating less on basic tactical maneuvers and more on avionics and weapons employment. Ideally, the resulting improvements at the RTU should be carried to combat squadrons and, in turn, reduce requirements for initial qualification training (IQT) and mission qualification training (MQT).

Recommendations

The LIT program should include CBI. Relative to the other alternatives, CBI teaches the basics at a significantly lower cost. Even if the program does not reduce the number of academic instructors, there will be more flexibility in scheduling, student progress monitoring, and lesson interest, making CBI an attractive addition to the LIT program.

The LIT program should include a WST simulation facility. Although combining two WSTAs and one WSTB did not give the lowest cost-to-benefit ratio, it appears to be the more robust alternative. It aligns simulation training with the flying syllabus such that all students are trained using the same proportion of air-to-air and air-to-surface sorties at the least cost. The additional training cost per student, $11,812, may seem high; but relative to the present cost of training a student at LIT, which is $141,000, it is only an 8% increase and could have a significant return of increased performance. Consider this: An F-15 training sortie costs the Air Force approximately $4,800, and an F-16 training sortie $2,600. If LIT enhancement can save three to five sorties per student before the student becomes mission ready (MR), the simulation facility will have paid for itself (Reference 14).

Allocating additional money to validate the effectiveness of CBI is probably not warranted. Validation costs would be high relative to the cost of implementing the system. Validation of the benefits of the WST facility is also not recommended. Reasons for this are as follows:

1. Previous studies have quantified the benefits when prior training is conducted in a suitable simulator. The Navy conducted a test in 1985 that verifies and scopes simulator requirements for their T-45 aircraft (Reference 15). A similar study was conducted by AFHRL and the 355th Tactical Training Wing using the A-10 ASPT at AFHRL. More recently, the Air Force conducted a study of F-5 training at Williams AFB, Arizona. Both USAF and foreign students were pretrained at General Electric's Center for Advanced Airmanship in Tempe, Arizona. Preliminary results indicate that pretraining improves student performance when students have had little previous training.

2. The validation studies cited above concentrated on the surface attack mission because the performance measure (bomb scores) is quantifiable. Air-to-air performance measures are still elusive to quantify. It is projected that the greatest benefit a WST facility will provide to LIT is in the air-to-air arena. It is questionable what validation studies at this time, or in the near future, could provide other than subjective inferences.

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APPENDIX A: CHANGES IN THE LIT PROGRAM

Table A-1. Comparison of 1976 and 1986 LIT Academic Programs by Number of Instructional Hours per Academic Block

		1986		
Block	1976	(A)[a]	(B)[a]	(C)[a]
Aerospace Physiology	---	9.5	9.5	9.5
Life Support	5	6	6	6
Specialized Training	2	5	5	5
Aircraft Systems	5	5.5	5.5	5.5
Formation	4	5.5	5.5	5.5
Physical Conditioning	---	2.0	2.0	2.0
Grading Criteria	---	2.0	2.0	2.0
Crew Coordination	---	1	1	1
Local Area Test	---	1	1	1
Basic Instruments	---	1.5	1.5	1.5
Basic Fighter Maneuvers	17	14.5	12.5	14.5
Air Combat Maneuvers (Air Attack)	4	2	---	---
Weapons Seminar	---	2	4	4
Surface Attack and Mission Planning	7	---	13.5	13.5
Low-Level Navigation	---	---	4	---
Intelligence	---	4	4	4
Audiovisual	---	3.0	3.5	3.5
Maintenance	---	1	1	1
Totals	44[b]	65.5	81.5	79.5

[a] Syllabus special track for students who have a follow-on training program in (A) F-15, (B) A-10/F-111, or (C) F-4/F-16 aircraft.

[b] Additional 21 hours allocated for academic preparation.

Table A-2. Comparison of 1976 and 1986 LIT AX Course Programs by Number of Flying Sorties and Training Device Hours per Phase of Instruction

		1986		
Phase (sorties)	1976	(A)[a]	(B)[a]	(C)[a]
Basic Core Flying Sorties				
Transition	1	1	1	1
Formation	7	5	5	5
BFM	8	8	8	8
Instrument	---	2	2	2
Special Track Flying Sorties				
BFM	---	6	---	3
ACM	---	4	---	---
Surface Attack	5	---	6	7
LATN	1	---	4	---
Total Sorties	22	26	26	26
Training Device (Hours)				
T-38 Simulator	3	4	4	4
F-4D Simulator (WSOs)	4	---	---	---
Centrifuge	0	2	2	2
Altitude Chamber	0	.6	.6	.6
Spatial Disorientation	0	.3	.3	.3
Total Hours	3 (4)	6.9	6.9	6.9

[a] Syllabus special track for students who have a follow-on training program in (A) F-15, (B) A-10/F-111, or (C) F-4/F-16 aircraft.

APPENDIX B: SUBJECT-MATTER EXPERTS

Subjective evaluations on the potential benefits of CBI and simulators were based on estimates provided by Mr. S. L. Amdor and Mr. F. W. Isley.

S. L. Amdor is Manager of Weapon System Modeling and Simulation for the BDM Corporation, Albuquerque, New Mexico. Mr. Amdor is a recently retired USAF fighter pilot and former squadron commander of an F-16 RTU squadron. He has more than 5 years of RTU training experience and more than 1,000 hours as an instructor pilot in operational and training units. He also has acquired extensive analysis and simulation experience. He was an analyst with the Air Force Studies and Analysis Fighter Division for 4 years. During the past year with BDM, he has provided technical support to the Identification Friend, Foe, or Neutral Joint Test Force (IFFN/JTF). Mr. Amdor holds masters degrees in both Operations Research and Business Administration.

F. W. Isley is Manager of Command, Control, and Communications (C^3) and Electronic Warfare Analysis for the BDM Corporation, Albuquerque, New Mexico. He is also a recently retired Air Force fighter pilot and former vice wing commander of an F-111 wing. He has more than 7 years of training experience and more than 1,400 hours as an instructor pilot in operational and training units. He is a former commander of an AT-38 squadron at fighter Lead-In Training (LIT) and a former F-4 RTU instructor pilot. Mr. Isley acquired experience in analysis and simulation during a tour with the Air Force Studies and Analysis group, and at BDM has been involved in threat simulation. He has earned a B.S. in Aeronautical Engineering and an M.S. in Aerospace Engineering.

APPENDIX C: CBI ANALYSIS RATINGS

The tables in this appendix list the subjective CBI analysis ratings for CBI's contribution to academic instruction. The ratings range between 0 and 5, and were given based on CBI's potential contribution to a specific criterion-referenced objective. Each table represents a specific block of academic instruction. At the end of each table, the median and the average for the block of instruction are noted.

Table C-1. CBI Contribution to Tactical Formation Academics

Criterion-Referenced Objective	Rating
1. Factors that impact the determination of the type of tactical formation to be flown in a given environment	0
2. Parameters that correctly describe the proper tactical formation (line abreast) position	0
3. Consequences of being out of position in tactical formation line abreast, slant range, stack high/low	3.5
4. Factors used to determine the best vertical placement of the wingman with respect to lead	0
5. Visual lookout areas of responsibility for the various members of a tactical two-ship formation	2
6. Elements and sequence for reporting a visual contact	0
7. Define brevity codes	0
8. State environments that lend themselves to the use of fluid turns and tactical turns	0
9. Identify parameters used by the flight lead and wingman in the proper execution of a fluid turn and a tactical turn	3.5
10. State the visual/timing cues that can be used by the delaying aircraft to determine when to start a delayed turn	3.5
11. Describe the procedures for a Shackle, Weave, and Check-turn	0
12. Describe the procedures of an In-place turn and a Cross-turn	0
13. Describe the maneuvering required for various tactical rejoins	2
Median	0.0
Average	1.12

Table C-2. CBI Contribution to BFM Academics

Criterion-referenced objective	Rating
Energy maneuverability:	
1. Aspect angle and angle-off	2
2. Nose tail advantage criteria	2
3. Overshoots	2
4. Energy management (EM) terms	0
5. Lead, lag, and pure pursuit	0
6. Describe effects of pursuit curve on angle-off, aspect angle, and closure	3
7. Define line-of-sight rate and influencing factors	3
8. Using EM diagram, identify altitude, airspeed, and energy state	4
9. Describe Specific power (Ps) in terms of ability to turn, accelerate, and climb	4
10. Relationship among true airspeed, O, turn rate, and turn radius	3
11. Explain use of corner velocity and identify it on maneuver diagram	4
12. Compare two aircraft using turn rate/radius and Ps advantage/disadvantage	4
Offensive maneuvering:	
13. LIFT ROE	0
14. Fox II parameters and error analysis	3
15. Fox III parameters and error analysis	3
16. Mil sizes for AT-38 at given ranges	2
17. Situation requiring acceleration maneuver	0
18. Describe acceleration maneuver	0
19. Common errors in acceleration maneuver and consequences	0
20. Situations requiring a low yo-yo	2
21. Describe a low yo-yo	4
22. Low yo-yo execution and common errors	3
23. Situations requiring a high yo-yo	2
24. Describe a high yo-yo	2
25. High yo-yo common errors and consequences	3
26. Situations requiring a lag roll	2
27. Describe a lag roll	4
28. Lag roll common errors and consequences	3
29. Differences between situations requiring high yo-yo and quarter plane	2
30. Execution differences between high yo-yo and quarter plane	4
31. Quarter-plane common errors and consequences	3
32. When to use a high-angle gun shot	2
33. Describe a high-angle gun shot	4
34. High-angle gun shot errors and consequences	3
35. Reasons for initiating a separation	2

Table C-2. (Concluded)

Criterion-referenced objective	Rating
Offensive maneuvering (Continued):	
36. How to execute a separation following a high-angle gun shot	4
37. Describe other situations where a separation can be performed	3
38. Separation common errors and consequences	3
Defensive maneuvering:	
39. Define range of equalization (Re), range of missiles (Rm), and range of guns (Rg) and how closure and aspect affect each	3
40. Given an attacker's position, choose an initial move based on the zone defense concept	4
41. Situations requiring a defensive turn	3
42. Proper execution of the defensive turn and expected results	4
43. Common errors in executing a defensive turn	3
44. Reasons for extending in a defensive situation	0
45. Relationships between attacker's nose position and angle-off and the timing and execution of an extension	3
46. Extension common errors and consequences	3
47. Objectives and description of a reversal	3
48. Conditions leading to a loaded versus unloaded reversal	2
49. Reversal common errors and consequences	2
50. Situations where high-angle-of-attack (AOA) roll may be effective	3
51. Execution of a high-AOA roll	3
52. High-AOA roll common errors and consequences	2
53. Objectives if in a scissors	0
54. Execution of a scissors	4
55. Scissors common errors and consequences	2
56. Difference between a guns jink and missile break	3
57. Situations requiring a guns jink	2
58. Execution of a guns jink	3
59. Guns jink common errors and consequences	2
One-versus-one maneuvering	
60. Principles of classic nose counter defense	3
61. Nose counter defense common errors and consequences	3
62. No-tally game plans and errors of execution	4
63. Lead turn execution	4
64. One-circle fight	4
65. Two-circle fight	4
Median	3
Average	2.62

Table C-3. CBI Contribution to ACM Academics

	Criterion-referenced objective	Rating
1.	ACM directive/descriptive commentary	1
2.	Aspects of mutual support	2
3.	Define engaged fighter and his responsibilities	2
4.	Define supporting fighter and his responsibilities	2
5.	Explain initial moves	3.5
6.	Explain different types of entries and when to use them	3.5
	Median	2
	Average	2.33

Table C-4. CBI Contribution to Surface Attack Academics

	Criterion-referenced objective	Rating
1.	Identify and describe practice ordnance	0
2.	Identify publications used for preflight	0
3.	State proper procedures for preflighting a weapons-loaded AT-38B	0
4.	Describe how to do the sight depression checks	1.5
5.	Describe how to run the camera from the front and rear cockpits	0
6.	State the position of the master arm and mode switches necessary to release bombs and fire the gun	1
7.	Describe the AT-38B jettison system	0
8.	State weight, airspeed/mach and G limits of the SUU-20 and describe weight and drag effects on approach speed	1
9.	Identify all parts of a dive bomb delivery diagram	2
10.	Identify the two values that combine to form the total depression/sight setting for free-fall ordnance	0
11.	State the purpose of initial pipper placement	0
12.	Calculate sight settings for various events using aircrew aid cards	.5
13.	Describe arming and dearming actions	0
14.	Describe how to perform a bomb check	0
15.	State cockpit tasks during trim checks	0
16.	Identify appropriate range/pattern radio calls	0
17.	Identify prominent features of Oscura and Red Rio ranges	1
18.	State how to achieve pattern spacing for a four-ship	2
19.	State pattern and release parameters for low-angle strafe, 10, 20, 30 degree deliveries	4
20.	Describe procedures for a standard dive recovery bombing pass	2
21.	Describe how and where potential mid-air collisions may occur on the range	1
22.	State NORADIO actions with and without an emergency	.5
23.	State actions for hung ordnance, runaway gun, unintentional release, and inadvertent release and recovery options	.5
24.	State foul criteria and consequences	0
25.	Describe results of bombing errors of position	1.5
26.	Describe high- and low-wire errors	4
27.	Describe results of steep, shallow, fast, slow, snatch, and bunt errors	4.2

Table C-4. (Concluded)

Criterion-referenced objective	Rating
28. Describe results of skid and bank errors	4
29. Describe results of improper base leg parameters	4
30. Explain why pressing is not an acceptable solution to errors	4.5
31. State delivery errors that occur with forward firing ordnance	2
32. State where to obtain range winds	0
33. Calculate adjustment to bombing parameters necessary to compensate for wind effects	4
34. Describe pros and cons of combat offset and mil cranking	0
35. Describe the corrections made throughout the pattern for winds	2
36. Describe differences between fully drifting and crabbed wind compensation techniques	0
37. Define minimum attack parameters (MAP)	3
38. Define angle-off	1
39. Define pull-down altitude	1
40. Define apex altitude	1
37. Define minimum attack parameters (MAP)	3
38. Define angle-off	1
39. Define pull-down altitude	1
40. Define apex altitude	1
41. Define track point	3
42. Identify points in a standard pop-up diagram	0
43. State minimum altitu when performing cockpit tasks; when not performing cockpit tasks	1
44. State 20-degree pop-up climb angle, pull-down/apex altitudes, and release parameters	1
Median	1
Average	1.32

Table C-5. CBI Contribution to Low-Altitude Navigation Academics

Criterion-referenced objective	Rating
1. State three reasons for construction of low-level navigation charts IAW regulations	0
2. Recall rules and procedures that apply while flying low-level (L/L) routes at LIT	1
3. State the minimum altitude at which LIT aircrews are allowed to fly L/L routes	0
4. State how, when, and why minimum enroute altitudes are used by TAC aircrews	1
5. State three minimum airspeeds for flight on L/L routes	0
6. State the weather minimums (visual flight rules and instument flight rules) required to fly L/L routes	0
7. Describe the two low-altitude formations available to LIT aircrews	3
8. Describe the procedures listed in TACR 55-138 (Reference 16) that pertain to L/L route aborts	0
9. List five desirable characteristics to be considered when selecting L/L navigation checkpoints	1
10. Describe the local departure routing used during L/L sorties	0
11. List recovery options available to aircrew who are recovering from local L/L routes	0
12. Describe the three L/L routes flown by LIT aircrews at Holloman AFB	0
Median	0
Average	.5

APPENDIX D: SIMULATOR ANALYSIS RATINGS

The tables in this appendix list subjective simulator analysis ratings. Each simulator's potential contribution to the flying phases of instruction was rated. The ratings range between 0 and 5, and are given to a WST contributing to a specific pilot task. Each table represents a specific phase of flying training. At the end of each table the median and average for the phase of flying are noted.

Table D-1. Tactical Formation Evaluation

Pilot tasks	Ratings		
	WSTA[a]	WSTB[a]	WSTC[a]
1. Fluid turns	3.5	0	3.5
2. Tactical formation position	3.0	2.0	3.0
3. Delayed turns	3.5	0	3.5
4. Implace turns	2.5	1.0	2.5
5. Cross-turns	3.0	0	3.0
6. Weaves	2.0	2.0	2.0
7. Vertical re-position	3.2	2.5	3.2
8. Rolling maneuver	3.2	3.1	3.2
9. Situational awareness	3.0	2.8	3.0
10. Judgment	4.0	3.8	4.0
11. Flight discipline	1.0	1.0	1.0
Median	3.0	2.0	3.0
Average	2.9	1.65	2.9

[a] The three WSTs were (A) primary air-to-air, (B) primary air-to-surface, and (C) combination of air-to-air and air-to-surface.

Table D-2. Basic Fighter Maneuvers (BFM) Evaluation

	Alternatives		
Pilot tasks	WSTA	WSTB	WSTC
Offensive BFM:			
1. Gun tracking exercise	4.5	4.5	4.5
2. Range estimation	2.5	2.5	2.5
3. Visual search	3.0	2.5	3.0
4. Descriptive commentary	3.0	2.5	3.0
5. Armament switchology	2.0	2.0	2.0
6. Acceleration maneuver	2.5	2.5	2.5
7. High yo-yo	4.5	4.0	4.5
8. Low yo-yo	4.5	4.5	4.5
9. Lag roll	4.5	4.2	4.5
10. High-angle gun shot	4.5	4.4	4.5
11. Quarter-plane maneuver	4.5	4.2	4.5
12. Separation	4.5	1.0	4.5
13. Recognition of wpns parameters	3.5	3.5	3.5
14. Simulated heat missile	4.5	4.5	4.5
15. Simulated gun shot	4.5	4.5	4.5
16. Lead turn exercise	3.6	3.2	3.6
17. Situation awareness	4.5	4.2	4.5
18. Judgment	4.5	4.2	4.5
19. Discipline	4.5	4.2	4.5
Median	4.5	4.2	4.5
Average	3.9	3.53	3.9
Defensive BFM:			
20. Defensive turn	4.0	0.0	4.0
21. Extension	3.5	0.0	3.5
22. Jinkout	3.8	0.0	3.8
23. Reversal	4.0	0.0	4.0
24. Scissors	4.2	0.0	4.2
25. High angle-of-attack roll	3.5	0.0	3.5
26. Range estimation	2.5	0.0	2.5
27. Visual search	3.0	0.0	3.0
28. Situation awareness	4.5	0.0	4.5
29. Judgment	4.5	0.0	4.5
30. Discipline	4.5	0.0	4.5
Median	4.0	0	4.0
Average	3.82	0.0	3.82
One-versus-one maneuvering:			
31. 1-v-1 low aspect, attack	4.4	4.2	4.4
32. 1-v-1 medium aspect, attack	4.2	4.0	4.2
33. 1-v-1 neutral	4.1	0.0	4.1
34. 1-v-1 low aspect, defense	4.0	0.0	4.0

Table D-2. (Concluded)

Pilot tasks	Alternatives		
	WSTA	WSTB	WSTC
One-versus-one maneuvering (Continued):			
35. 1-v-1 medium aspect, defense	3.8	0.0	3.8
36. Situation awareness	4.5	2.5	4.5
37. Judgment	4.5	2.2	4.5
38. Discipline	4.5	2.5	4.5
Median	4.3	2.35	4.3
Average	4.25	1.93	4.25

Table D-3. Air Combat Maneuvering Evaluation

Pilot tasks	Alternatives		
	WSTA	WSTB	WSTC
1. Offensive directive/ descriptive commentary	.5	.5	.5
2. Shooter cover	.8	.1	.8
3. Sequential attack	.4	.1	.4
4. Separation	.3	0	.3
5. Mutual support	0	0	0
6. Maintain visual and tally	0	0	0
7. Initial moves	1.5	0	1.5
8. Defensive directive/ descriptive commentary	.5	0	.5
9. Visual search	.4	0	.4
10. Situation awareness	.2	0	.2
11. Judgment	.3	.1	.3
12. Flight discipline	.1	.1	.1
Median	.35	0	.35
Average	.42	.10	.42

Table D-4. Surface Attack Evaluation

Pilot tasks	Alternatives		
	WSTA	WSTB	WSTC
1. Armament switchology	3.0	3.0	3.0
2. Range procedures and patterns	2.0	4.5	4.5
3. Error analysis	2.0	5.0	5.0
4. Delivery parameters and recoveries	1.0	4.0	4.0
5. 10-degree LAB	1.0	4.0	4.0
6. 20-degree LALB	2.0	4.0	4.0
7. 30-degree DB	2.0	4.0	4.0
8. LAS	1.0	4.5	4.5
9. 20-degree pop-up	0.0	9.5	4.5
10. Situation awareness	1.5	4.5	4.5
11. Judgment	1.5	4.5	4.5
12. Discipline	1.0	4.0	4.0
Median	1.5	4.25	4.25
Average	1.58	4.58	4.58

Table D-5. Low-Level Tactical Navigation Evaluation

Pilot tasks	Alternatives		
	WSTA	WSTB	WSTC
1. Altitude control	0.0	4.0	4.0
2. Heading control	1.0	4.5	4.5
3. Airspeed control	0.0	5.0	5.0
4. Map reading	0.0	4.5	4.5
5. Timing procedures	1.0	4.5	4.5
6. Low-altitude formation	1.0	4.0	4.0
7. Simulated ordnance delivery	1.0	4.0	4.0
8. Situational awareness	.5	4.5	4.5
9. Judgment	.5	4.5	4.5
10. Discipline	.5	4.5	4.5
Median	.5	4.5	4.5
Average	.75	4.35	4.35

APPENDIX E: AVAILABLE STUDENT TIME

Evaluation of the total time a student in the LIT program is scheduled to complete the program

The typical student flew about 26 sorties at LIT. Approximately 5.75 hours were spent briefing, flying, and debriefing the sortie. The total flying time dedicated to the 26 sorties would equal 165 hours if a 10% refly rate were applied.

A course requirement was that at least four T-38 simulator missions be flown. Approximately 1.75 hours were required per simulator mission. Again, assuming a 10% repeat factor, the average time spent in the simulator would equal 7.7 hours.

The B-track student is required to take the largest number of academic hours in the program. Therefore, the worst case for time spent in the academic classroom was 80.5 hours.

Adding the times together we find that 253 hours of program events have been scheduled.

Time Assumptions

The total program length was 45 training days. Assuming that, at most, only 8 hours a day should be scheduled, it is easy to calculate that a student has 360 hours of available time for program activities. A 10- or 12-hour day could be scheduled, but for planning purposes, an 8-hour day is more desirable. By scheduling 8-hour days over the length of the course, then ample time would be available for studying and student preparation. An 8-hour day was used for planning purposes only. During a typical course some training days could be longer and others shorter.

Time Availability

The difference between 360 hours of available time and 253 hours of scheduled time is 107 hours. Currently, approximately 70% of the training time available is scheduled. Therefore, ample time might be available for additional WST training, for example. However, time constraints exist at the beginning of the program when requirements must be met and various phases or sections of the program started. Slack time increases near the end of the program when flying is the major activity.

Additional Training Day Requirements

The time required to complete 12 WST missions could equal 33 hours. This would allow 30 minutes to brief a 1-hour sortie, and 1 hour to debrief. Additionally, as with the flying phase, a 10% repeat rate would be planned. A total of 33 hours could be added to the current 253 program hours and still not exceed the 360 hours computed for the 8-hour day concept. However, available time does not exist in that phase of the program where WST training would be required. Therefore, the syllabus course map was used to calculate the number of additional training days required if WSTs were added to the training program. Only two of the three major events, flying sortie, simulator sortie, or academics, were scheduled per day. This approach resulted in increased training days as follows: A-track, 4 days; B-track, 5 days; and C-track, 4 days.

Summary

In summary, WSTs could be added to the students' training program because time is available. However, the program would likely require adding training days to the course so WST missions could be added in appropriate sections of the class.