DOCUMENT RESUME

ED 109 423 CE 004 262

AUTHOR	Woodruff, Robert R.; Smith, James F.
TITLE	T-4G Simulator and T-4 Ground Training Devices in USAF Undergraduate Pilot Training.
INSTITUTION	Air Force Human Resources Lab., Brooks AFB, Texas.; Air Force Human Resources Lab., Williams AFB, Ariz. Flying Training Div.
PUB DATE	Nov 74
NOTE	25p.
EDRS PRICE	MF-$0.76 HC-$1.58 PLUS POSTAGE
DESCRIPTORS	Aircraft Pilots; Aviation Technology; *Course Evaluation; Curriculum Development; Educational Technology; *Flight Training; Military Training; Post Secondary Education; *Simulators; Technical Education; *Training; *Undergraduate Study
IDENTIFIERS	*Air Force

ABSTRACT

The objective of the project was to investigate the utility of using an A/F37A-T4G T-37 flight simulator within the context of Air Force undergraduate pilot training. Twenty-one subjects, selected from three undergraduate pilot training classes, were given contact flight training in a TP4G/EPT simulator before going to T-37 aircraft for further training. Fourteen of these subjects were also given instrument training in the T-4G/EPT before completing such training in the aircraft. The remaining seven subjects received instrument training in the UPT T-4 instrument and procedures trainer. A specially designed syllabus was used which incorporated batch training, proficiency advancement, and other revised instructional strategies. Check pilot scores for each of the instructional phases were used in comparing performances of the experimental subjects with those of the conventionally trained students. Results indicate devices having the capabilities of the T-4G could be used to achieve an average saving per student of three aircraft hours in contact flight training and ten hours in instrument training. Results also indicate a savings of eight aircraft hours could be achieved in instrument training by using the specially devised syllabus of instruction with existing T-4 instrument trainers. (Author)

AFHRL-TR-74-78

AIR FORCE

HUMAN RESOURCES

T-4G SIMULATOR AND T-4 GROUND TRAINING DEVICES IN USAF UNDERGRADUATE PILOT TRAINING

By

Robert R. Woodruff
James F. Smith

FLYING TRAINING DIVISION
Williams Air Force Base, Arizona 85224

November 1974
Final Report for Period February 1972 – June 1973

Approved for public release; distribution unlimited.

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report was submitted by the Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona 85224, under project 1123, with Hq Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235. Mr. Robert R. Woodruff was the principal investigator.

This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DoDD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

WILLIAM V. HAGIN, Technical Director
Flying Training Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
AFHRL-TR-74-78

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
T-4G SIMULATOR AND T-4 GROUND TRAINING DEVICES IN USAF UNDERGRADUATE PILOT TRAINING

5. TYPE OF REPORT & PERIOD COVERED
Final
February 1972 – June 1973

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Robert R. Woodruff
James F. Smith

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Flying Training Division
Air Force Human Resources Laboratory
Williams Air Force Base, Arizona 85224

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
62703F
11230303

11. CONTROLLING OFFICE NAME AND ADDRESS
Hq Air Force Human Resources Laboratory (AFSC)
Brooks Air Force Base, Texas 78235

12. REPORT DATE
November 1974

13. NUMBER OF PAGES
24

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Paper based on this research was presented at the Fourth Annual Symposium on Psychology in the Air Force, April 1974. AFHRL-TR-74-44 reports development of the syllabus in detail. AFHRL-TR-74-61 reports results achieved in first of three phases of this study.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

flying training
flight simulation
ground training devices
pilot training
visual system evaluations
syllabus development
personnel selection, training, evaluation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Twenty-one Ss, selected from three Undergraduate Pilot Training classes, were given contact flight training in a T-4G/EPT simulator before going to T-37 aircraft for further training. Fourteen of these Ss were also given instrument training in the T-4G/EPT before completing such training in the aircraft. The remaining seven Ss received instrument training in the UPT T-4 instrument and procedures trainer. A specially designed syllabus was used which incorporated batch training, proficiency advancement, and other revised instructional strategies. Check pilot scores for each of the instructional phases were used in comparing performances of the experimental Ss with those of the conventionally trained students. Results indicate devices having the capabilities of the T-4G could be used to achieve

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Item 20 (Continued).

an average saving per student of three aircraft hours in contact flight training and ten hours in instrument training. Results also indicate a savings of eight aircraft hours could be achieved in instrument training by using the specially-devised syllabus of instruction with existing T-4 instrument trainers.

SUMMARY

Problem

The objective of this effort was to investigate the utility of using an A/F37A-T4G T-37 flight simulator within the context of Air Force Undergraduate Pilot Training (UPT).

Approach

Groups of UPT students were given basic contact and instrument training using special instructional techniques in the T-4G (in later phases in the conventional T-4 also) and then allowed to complete training in the T-37 advancing on a proficiency basis. Syllabus length for simulator students was similar to conventional length.

Results

Evaluation was comparison of the flying hours used by T-4G/T-4 students to usual syllabus requirements. Simulator students saved an average of three aircraft hours in basic contact and an average of 9.3 hours in instruments. Analysis of total trials on each maneuver by type of training device indicates that a much greater percentage of the total practice trials was conducted in the ground trainer during instrument training than during contact training. An analysis of the percentage of practice trials failed in each device suggests that more practice in the trainer on advanced instrument maneuvers and most contact maneuvers would have resulted in more efficient transfer of training.

Conclusions

The A/F37A-T4G is an effective adjunct in T-37 UPT, particularly in instrument training. The conventional T-4, used with special training techniques, can reduce flying time required in T-37 UPT.

PREFACE

This study was conducted in support of Project 1123, Flying Training Development; Task 112303, Exploitation of Flight Simulation in Undergraduate Pilot Training (UPT). Dr. William V. Hagin was project scientist; Mr. James F. Smith was task scientist; and Mr. Robert R. Woodruff was principal investigator. This report covers research performed between February 1972 and June 1973.

This study was conducted by the Flying Training Division of the Air Force Human Resources Laboratory (AFSC), in coordination with Headquarters, Air Training Command, and supported by the 82d Flying Training Wing and 96th Flying Training Squadron of Williams Air Force Base, Arizona.

Appreciation is extended to the many people who contributed to the conduct of this project. A few without whom the work could not have been completed are: Hq ATC, LtCol Brian McMahon; WAFB FTW, LtCol R. A. Morris and Captains J. T. Mullen and James Winans; AFHRL/FT, Capt Steven K. Rust; and Mr. Loren Dawson and Mr. Fred Kubota of the Simulator Products Division, Singer Company.

TABLE OF CONTENTS

LIST OF TABLES

List of Tables (*Continued*)

T-4G SIMULATOR AND T-4 GROUND TRAINING DEVICES IN USAF UNDERGRADUATE PILOT TRAINING

I. BACKGROUND

In early 1972, Flying Training Division, Air Force Human Resources Laboratory (AFHRL) (AFSC), Williams AFB, Arizona, supported by the 82nd Flying Training Wing, Air Training Command (ATC), Williams AFB, Arizona undertook a study to determine to what extent a ground-based T-37 simulator (A/F37A-T4G, hereafter referred to as T-4G) (detailed description of the T-4G, Appendix A) with modest fidelity, two degrees of motion, and a narrow angle film source visual system could be used to reduce T-37 aircraft flying time in undergraduate pilot training (UPT). The objective of this study was later expanded to include a comparison of the relative effectiveness of this device with the existing nonvisual nonmotion UPT instrument and procedures trainer (T-4).

The primary objective of the study necessitated using the T-4G to train students within the context of UPT. A special syllabus was constructed for this purpose. Samples of students from three consecutive UPT classes were subjects (*S*s) for this study; thus, the study was conducted in three parts (referred to as Phases I, II and III) over a twelve month period. Phase I *S*s used the T-4G only; Phases II and III *S*s used the T-4G for contact flight training, but were divided between T-4G and T-4 trainers for instrument training.

This report summarizes training results obtained for all three phases. More detail on construction of the special syllabus, description of instructional strategies, and trainer capabilities is provided in two reports published earlier (Rust, Smith, & Woodruff, 1974, Woodruff, Smith, & Morris, 1974).

II. PROCEDURE

Consideration of T-4G capabilities suggested its use should be limited to the basic contact and instrument training segments of the T-37 UPT syllabus; aerobatics, formation, navigation (VFR pilotage) and cross-country were judged to be inappropriate for T-4G training.

Comparison Techniques

To provide for comparison with the regular syllabus, *S*s using the new syllabus began in the T-4G and completed training in the T-37. In the T-37, *S*s were advanced as they achieved proficiency on maneuvers, training hours were not frozen. A comparison was made between aircraft hours required using the new syllabus versus the regular schedule and between attained class scores.

Subjects

Thirty-two student pilots who had little or no flying experience were selected at random from volunteers for this study; eight from class 7306, twelve from class 7309, and twelve from class 7403. During the course of training eleven *S*s were lost, two self-initiated elimination, one manifested anxiety in the air, four were medically disqualified, three were deficient in flying ability, and one failed academically. Twenty-one *S*s completed the program six from class 7306, seven from class 7309, and eight from class 7403.

Instructor Pilots (IPs)

The first group of IPs were selected from volunteers who were regularly assigned to Williams AFB. These IPs were highly experienced and, before T-4G instruction began, assisted in the development of the training syllabus, performance recording procedures, instructional strategies, and performance assessment criteria. In addition, they received a thorough indoctrination in the theory and operation of simulators, flew several sorties in the left seat of the T-37 aircraft for familiarization with the student's visual environment and practiced instructing each other in the T-4G to develop and refine instructional techniques. Because of IP turnover and the use of more *S*s in Phases II and III, it was necessary to use additional IPs, some of whom were much less experienced than those used in Phase I. Despite this lack of experience and because no syllabus or instructional strategy development time was required, it was possible to shorten the length of the indoctrination period considerably. Under these conditions, 10 to 12 training hours per IP provided sufficient orientation.

Training Strategies

The standard UPT syllabus provides all students a scheduled number of hours in T-37 aircraft and T-4 instrument and procedures trainers. One or two trainer hours are scheduled prior to each aircraft ride during instrument training. Airmen instructors are used in the ground trainers except for procedures training. The standard student/IP ratio is on the order of 3:1 and IPs perform numerous additional duties essential for the conduct of flight training operations.

To conduct this study, these conventional procedures were altered. The more significant changes were:

1. *S*s progressed on a proficiency basis in the aircraft.

2. T-4G/T-4 instruction was given in blocks. The relative effectiveness of integrated training (i.e., the normal practice of two periods in a ground device followed by an aircraft period) versus block training (i.e., all training in a ground device followed by all aircraft) was not a research issue in this study; block training was used because it facilitated scheduling control and data comparison, and ensured that no *S* practiced a maneuver in the T-37 before he learned it in a ground trainer.

3. IPs were used in all ground device training since only a pilot could insure that a *S* possessed the skills necessary to perform maneuvers successfully on his first trial in the aircraft. In addition, this procedure permitted the IP to become knowledgeable about his *S*'s strengths and to redistribute practice time to areas of weakness, it also promoted IP confidence necessary to permit a *S* to fly complete maneuvers the first time he was airborne.

4. A *S*/IP ratio of 1:1 was used to reduce instructor load thereby providing him additional time to cope with the use of novel equipment capabilities, the application of training practices different from the existing program and to function as a training manager. In addition, instructors were relieved from most of their additional duties.

5. A special syllabus of training was written for the T-4G. The syllabus incorporated modern concepts of the systems approach to training and programmed learning in order to facilitate student learning.

Treatment

*S*s from all three classes received essentially the same treatment. The batched sequence of instruction was: (a) basic contact in the T-4G, (b) basic contact in the T-37, (c) instruments in the simulator, and (d) instruments in the T-37. Contact and instruments were blocked separately to enable *S*s to learn contact maneuvers, teachable only in the T-37, before beginning instrument training as well as to maximize learning in the simulator. To insure completion of T-37 training by the scheduled graduation date, a maximum number of training days was designated for each simulator block; 15 days (22 training periods) for contact training, and 12 days (17 periods) for instruments. Figure 1 is a flow chart which facilitates comparison between the conventional ATC syllabus (ATC, 1971) and the experimental training schedule used in this project. These comparison are by training day, media used, and category of learning objectives.

Upon entering the T-37 program, *S*s received a block of T-4G contact sorties followed by T-37 contact sorties leading to solo and the midphase contact flight check. When judged ready, *S*s received their midphase check regardless of the number of flying hours completed. Following successful completion of this check, *S*s returned to the simulator for instrument training in which similar procedures were used.

III. CONTACT FLIGHT TRAINING

Training Procedure

All *S*s began their training with a block of contact instruction in the T-4G using the simulator syllabus. This training included some composite instrument/contact training since the literature indicates that learning instrument flight skills first improves efficiency in learning contact flight skills (Ritchie & Hanes, 1964). Procedures training and academics were unchanged from the regular syllabus.

Following T-4G contact instruction, *S*s flew the T-37 where they were assessed for proficiency on skills learned in the T-4G, received additional training on tasks which required more practice, and learned other tasks not taught in the T-4G; e.g., the traffic pattern. During this training, IPs were encouraged to bring their *S*s back to the T-4G if they believed this would be of benefit.

Table 1 provides a list of simulator contact maneuvers/learning objectives included in the original experimental syllabus. All maneuvers shown were taught to *S*s in Phase I. *S*s in subsequent phases used a slightly altered syllabus wherein changes were made to conserve T-4G time and reduce student load. First, all training in emergency procedures was eliminated. Second, practice repetitions on composite tasks and

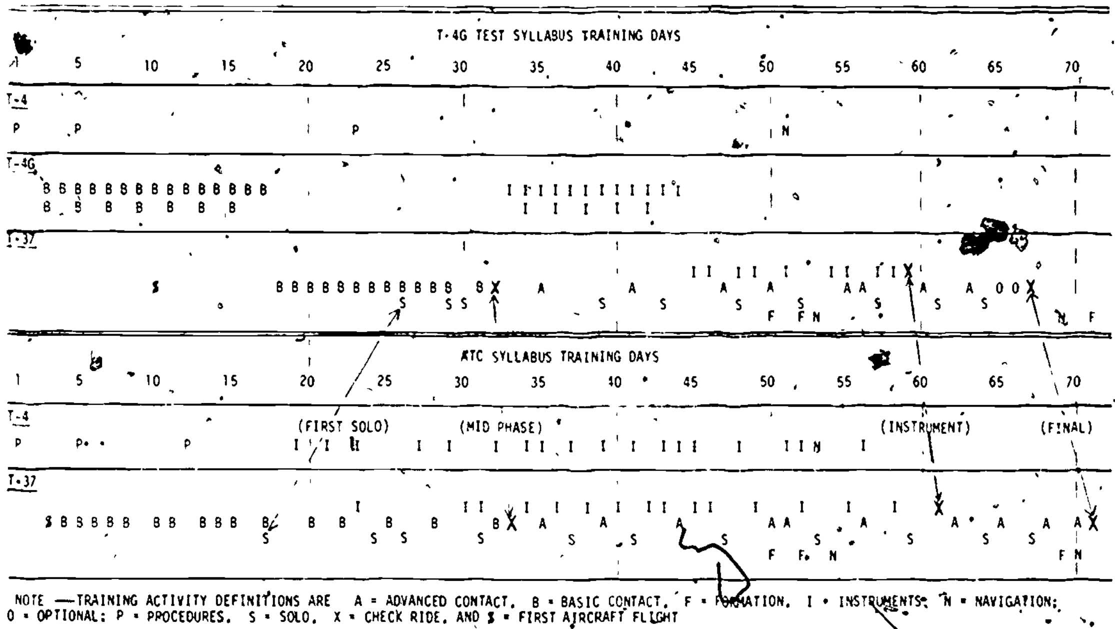

Figure 1. Comparison of experimental and regular UPT syllabi flow by day, period, device and type of training.

Table 1. Training Objectives/Maneuvers Taught in Contact Training Using the T-4G Visual System

	Scene Used		Scene Used
Emergency Procedures		**Fundamental A/C Control**	
Aborted TO	F	Control response	S[a]
One eng failure on TO	F	Trim	S[a]
Two eng failure on TO	F	Straight and level	S[a]
Low altitude restart	F & S	Pitch, bank and power	S[a]
One eng apch	F	CAS straight and LVL	S[a]
Hydraulic failure	F & S	CAS CL and DST	S[a]
		CAS CL turn	S[a]
Basic Aircraft Maneuvers		CAS DST turn	S[a]
Slow flight	S	Level offs	S[a]
Takeoff	F[a]	Level turns	S[a]
Straight-in touch and go	F	Change of A/S	S[a]
Go-around	F	Steep turns	S[a]
TO climb	S[a]	Traf pat steep turns	S & F
Landing	F		
Traf pat stall	S		

Note. — Symbol Definitions. F = film source, S = sky mode, TO = takeoff, apch = approach, CAS = constant airspeed, LVL = level; CL = climb; DST = descent; and A/S = airspeed.

[a]Composite contact and instrument instruction used.

landings were limited to specified maximum amounts. Although such training was certainly of value, neither emergency procedures nor composite tasks were included in the T-37 mid-phase contact checkride and, therefore, could not contribute directly to a reduction in aircraft flying hours required, the primary objective of this study. Emergency procedures were included originally to demonstrate the utility of the T-4G but were discontinued when it was determined that this longer syllabus tended to overload the student schedule. Simulator landings were limited to straight-in patterns because the visual system field of view (44° X 28°) did not display peripheral cues necessary for overhead patterns. Practice on straight-in landings in the simulator was of limited value since landings were practiced frequently while learning the traffic pattern in the T-37.

Results

Table 2 lists average T-4G and T-37 hours used and saved by UPT classes. The amount of T-4G training time used in Phase I (Table 2) was reduced by more than 25% for Phases II and III. This reduction in T-4G time did not cause degradation in training efficiency as shown by comparing aircraft flying hours saved for Phases I and II; i.e., 3.9 hours vs 5.1 hours, respectively. Table 2 also shows that Phase III Ss saved an average of only .3

Table 2. Average Hours Per Student Used and Saved in UPT Contact Flight Training Using a T-4G Trainer and T-37 Aircraft

Class Number	n	T-4G trainer used	T-37 aircraft Used	T-37 aircraft Saved
7306	6	16.9	23.2	3.9
7309	7	11.8	25.3	5.1
7403	8	12.9	27.0	.3
Summary	21	13.7	25.0	3.0[a]

Note. — Summed aircraft hours used and saved equals average hours per student for respective control group. Raw data per student is provided in Appendix B.

[a]Represents 10% savings in contact flight hours over current program.

aircraft hours (1%). This significant difference from the two previous groups resulted from untimely bad weather combined with the rigidity inherent in the blocked training approach. Poor flying weather forced delays which interferred with continuity and as a result, more aircraft refresher training was required.

IV. INSTRUMENT FLIGHT TRAINING

Training Procedure

Ss did not receive any instrument training (except for initial composite practice) until the midphase contact check was passed. The Ss then returned to the simulator for training on the 26 instrument maneuvers which could be taught in trainers· two maneuvers, wing over and aileron roll were taught only in the aircraft. After finishing simulator training, the S and his IP flew the T-37 until the S was ready for his instrument check. Table 3 provides a list of simulator maneuvers/learning objectives included in instrument training.

During Phase I it was decided that students would benefit from increased instruction in the areas of VOR and GCA. Therefore, the number of permissible simulator sorties was increased by five for class 7403.

Preliminary inspection of results, obtained during Phase I, indicated a high probability of achieving significant savings in aircraft hours during instrument training, and it appeared worthwhile to determine what portion of those savings could be attributed to the training device versus the revised training methodologies and syllabus. To provide insight into this area of interest, the treatment of Phase II and III Ss was changed: approximately half of the Ss for these phases were given instrument training in the T-4G and the remainder were trained in the T-4. Since the T-4G and T-4 trainers were identical with respect to cockpit and instrument displays, and because the T-4G visual system contributed only in a supplementary role to instrument training (low visibility approaches are not a part of the conventional T-37 instrument syllabus), the only remaining difference between the two devices was the T-4G motion system. By conducting half the Ss through each device using the same syllabus and treatment, it was possible to estimate savings

Table 3. Learning Objectives/Maneuvers Taught in T-37 Instrument Training Phase of UPT

Review	Radar
Straight and level[1]	Surveillance APCH to LNDG
Change of A/S	Precision APCH to LNDG[2]
CAS CL and DST[1]	
Level-Off[1]	Mission Profile
30° bank turn to HDG[1]	ITO and IFR departure
	All check items
Basic instruments	Procedures
ITO[1]	Radio calls
TO CL	Straight and level
Vertical S	Change of A/S
Rate DST	CAS CL and DST
Unusual attitudes	Turns to headings
Steep turns	Steep turns
Confidence maneuvers	Unusual attitudes
	Vertical S
VOR usage	RMI APCH to PHX VOR
Equip understanding/operation	Norton holding and pentration
Homing	Low and missed APCH[3]
Intercepts	Radar and missed APCH[3]
Departures and approaches	
Holding	Instrument check ride review

Note. — Symbol definitions: A/S = airspeed; CL = climb; DST = descent; HDG = heading; ITO = instrument takeoff; LNDG = landing; CAS = constant airspeed; and; APCH = approach.

[1] Visual presentation used at times to enable student to compare attitude instrument indications with outside view.

[2] Visual presentation used for landing after breakout.

[3] Variable crosswinds, ceiling and visibility used for realism.

attributable to special handling (T-4 and revised syllabus VS T-4 and conventional syllabus) and contributions of the T-4G motion systems (T-4G VS T-4 performance using the same syllabus).

Results

*S*s (N = 21) who successfully completed instrument training with T-4G or T-4 training used an average of 9.4 fewer flying hours (45%) than did their classmates in the regular program. These savings were achieved using varying amounts of simulator training; however, in all cases simulator time was less than that used in the conventional program. T-4G *S*s saved an average of 10.1 aircraft hours (48%) and T-4 *S*s saved and average of 8.1 aircraft hours (39%). Table 4 lists training hours (used and saved) in the T-4G, T-4 and T-37. The difference between hours saved in the T-4G and the T-4 is not statistically significant.

V. MANEUVER ANALYSIS

During the course of each dual training sortie, whether in the simulator or in the aircraft, *S*s practiced various maneuvers under the guidance of the IPs. Using a specially designed card, IPs recorded and scored (pass/fail) each trial on each maneuver. Thus, at the end of training a complete record of all dual maneuver practice repetions in both simulators and aircraft was available for each participating *S*. An analysis of these records provides insight into the utilization and effectiveness of T-4G and T-4 trainers. Since *S*s were trained to proficiency on each maneuver before leaving the simulator or before receiving a checkride in the aircraft, the total number of practice repetitions required for each maneuver represents the total training requirement in the simulators and aircraft.

Table 4. Average Hours Per Student Used and Saved in UPT Instrument Flight Training Using T-4G and T-4 Trainers and T-37 Aircraft

Class		T-4G	T-37 Aircraft		T-4	T-37 Aircraft	
Number	n	Used	Used	Saved	Used	Used	Saved
7306	6	14.9	9.7	11.1			
7309	4	16.7	11.4	9.4			
	3				19.4	12.8	8.0
7403	4	22.2	11.8	9.2			
	4				21.4	12.8	8[illegible]
Summary	14	17.5	10.8	10.1[a]			
	7				20.6	12.8	8.1[b]

Note. – Summed aircraft hours used and saved equals average hours per student for respective control group. Raw data by student is provided in Appendix B.

[a]Represents a 48% savings in aircraft hours normally used in instrument training.

[b]Represents a 39% savings in aircraft hours normally used for instrument training.

Maneuver repetition data were examined in several ways. First, 14 contact and 24 instrument maneuvers common to aircraft and simulators were ranked for each of the three classes according to the total number of practice repetitions. Table 5 lists coefficients of concordance computed for contact and instruments in both the aircraft and the simulator; the equivalent average Spearman rank correlations are also shown. Agreements among the three classes for instrument maneuvers were significant for both the simulator and the aircraft with $p < .001$, agreements for contact maneuvers were also both significant with $p < .01$. These agreements among the three classes on the amounts of practice required in the simulator and aircraft per maneuver indicate consistency in utilization of the T-4G and T-4 by a variety of IPs and students.

Table 5. Coefficients of Concordance

	Type of Training	
Device	Instruments	Contact
Aircraft	W=.83[a] (r_s=.74[b])	W=.81 (r_s=.71)
Simulator	W=.90 (r_s=.86)	W=.80 (r_s=.70)

[a]Kendall coefficients of concordance as illustrated by Siegel (1956).

[b]Equivalent average Spearman rank correlations are presented in parentheses.

Table 6 provides a summary of all maneuver trials recorded (see note at bottom of Table 6) during the contact flight training phase of the T-4G study. The maneuvers are listed in order of total trials attempted. Also included are: percentage of total trials attempted in the T-4G, percentage of T-4G trials scored as failing, and percentage of T-37 trials scored as failing. With some qualifications, the percentage of total trials recorded in the T-4G reflects the ability of the simulator to satisfy total training requirements as well as its intrinsic capability as a training device. Total training requirements include the following in addition to training to impart flying skill. (a) overtraining on some maneuvers because of their importance to safety, (b) extra practice of some maneuvers because they are always performed in connection with or as a part of other maneuvers, and (c) training for continuity (that is, continued practice of a maneuver after proficiency has been achieved to maintain satisfactory performance).

Table 6. Summary of Trials on Contact Maneuvers[a]

MANEUVER	TRIALS PRACTICED				TRIALS FAILED			
	T-4G		T-37		T-4G		T-37	
	Total	%	Total	Sum	Number	%	Number	%
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1 LANDING	568	40	858	1426	277	49	333	39
2 LEVEL OFF[b]	570	49	603	1173	280	49	105	17
3 TAKE OFF[b]	538	47	608	1146	241	45	95	16
4 FINAL APPROACH	692	77	207	899	348	50	87	42
5 STEEP TURN[b]	356	53	318	674	185	52	90	28
6 GO-AROUND	233	39	359	592	101	43	128	36
7 TECH ORDER CL[b]	224	40	340	564	102	45	44	13
8 LEVEL TURN[b]	417	81	100	517	201	48	11	11
9 TPS, LANDING	161	38	265	426	63	39	36	14
10 TPS, NOSE LOW	196	48	212	408	108	55	78	37
11 TPS, PITCH OUT	199	49	205	404	109	55	68	33
12 TPS, NOSE HIGH	178	49	185	363	77	43	56	30
13 STRAIGHT & LVL[b]	258	71	103	361	114	44	2	2
14 SLOW FLIGHT	195	55	157	352	90	46	22	14
SUM	4785		4520	9305	2296		1155	
PERCENTAGE	51		49	--		48		26
% RANGE	38-81		19-62	--		39-55		2-42
T-4G ONLY MANEUVERS								
--CONSTANT A/S Dc[b]	253		--	253	115	45	--	--
--CONSTANT A/S CL[b]	223		--	223	96	43	--	--
SUM AV%	476		--	476	211	44	--	--
T-37 ONLY MANEUVERS								
--PATTERN, OVERHD	--		752	752	--	--	385	51
--PATTERN, CLOSED	--		375	375	--	--	117	31
--PATTERN, ONE ENG	--		311	311	--	--	119	38
--LANDING, ONE ENG	--		250	250	--	--	58	23
--DIVE RECOVERY	--		187	187	--	--	43	23
--INV RECOVERY	--		176	176	--	--	18	10
--VERT RECOVERY	--		169	169	--	--	52	30
--ST PWR STALL	--		160	160	--	--	80	50
--TURN PWR STALL	--		138	138	--	--	62	45
--SPIN	--		123	123	--	--	45	37
--SPIN PREVENT	--		121	121	--	--	29	24
--APRCH, NO FLAP	--		29	29	--	--	16	55
--LNDG, NO FLAP	--		22	22	--	--	12	55
SUM/AV %			2813	2813			1036	37

NOTE.—(N=21) Definitions: TPS=Traffic Pattern Stall; CL=Climb; LVL=Level; A/S=Airspeed; Dc=Decent; INV=Inverted; Vert=Vertical; ST=Straight; and LNDG=Landing. Letters in parenthesis identify columns for reference in text. [a]Data reflect all trials recorded: T-4G data is complete but T-37 data is based on data cards from 80% of total sorties. [b]Contact maneuvers in which simultaneous instrument-contact references were taught when teaching composite crosscheck.

Column (c) of Table 6 provides the percentage of the total trials completed in the T-4G and shows the effect of limited peripheral cues, e.g., all maneuvers in which these cues are important required proportionally more practice in the aircraft. Using these percentages, the contact maneuvers appear to fall in three groups as follows: (a) level turns, final approaches, straight and level, slow flight and steep turns (53% to 81%); (b) level offs, traffic pattern stalls, pitchout, nose low and nose high, and takeoffs (47%—49%); and (c) landings, tech order climbs, go-arounds and landing traffic pattern stalls (38%—40%). These data support the requirement for additional peripheral cuing in simulators if more contact training is to be achieved. There are some reversals, but these are believed explained by the comments made earlier concerning total training requirements.

Columns (b) and (d) of Table 6 show the total trials on each maneuver by training device. A Spearman correlation coefficient (Siegel, 1956) was computed for these data to estimate the degree to which the rankings in these two columns agree. The obtained estimate, $r_s = .37$, is considerably lower than agreement of the three classes within the simulator or aircraft. This correlation suggests that emphasis given to the various maneuvers was not the same in the aircraft and the simulator. The difference may be attributed to either or both of two factors: the simulator was different from the aircraft and/or learning which occurred in the simulator differentially altered the amount of training required in the aircraft. The truth is probably a combination of these two factors. The fact that learning occurred in the simulator is evidenced by the flying hour savings realized, but more learning occurred on some maneuvers than on others.

Because repetition data for some maneuvers are inflated by total training requirements, analysis of total repetitions does not reveal training effects of the simulators' characteristics per se. However, analysis of failing repetitions alone (rather than total repetitions), provides revealing information. Failing repetitions by themselves reflect only the students' progress since training requirements for continuity, as part of other maneuvers, and for maneuver importance are usually not failed. Thus, training, which is performed for reasons other than the student's rate of achieving flying skill, is eliminated and the effect of equipment characteristics on student progress can be seen more clearly. (IP emphasis is probably not eliminated since IPs tend to be more demanding when they consider a maneuver important.) It may be assumed that the more frequently a maneuver is failed, the more slowly consistent proficient performance is attained.

Data in Table 6 show the percent of practice trials failed for both simulator (column g) and aircraft (column i). An average of 48% of all T-4G trials were failed as compared with 26% in the aircraft. The higher percentage of trial failures in the T-4G is probably due to the sequence of instruction wherein learning began in the simulator and continued until criterion performance was reached. When these same maneuvers were then practiced in the aircraft they were already understood and, in some cases, mastered. Contributing factors can also be speculated. For example, the instructor pilots indicated the T-4G was somewhat more difficult to fly than the aircraft. Also, failing scores could be recorded in the simulator without supporting administrative paper work (i.e., pink slips) as required in the aircraft. In any event, the reduction in failure rate appears to reflect learning in the simulator, since the average failure rate for non-T-4G maneuvers was 37% as compared with 26% for T-4G/T-37 maneuvers.

The percent of failed trials for T-4G maneuvers ranges from 39 to 55% (Table 6, column (g)); the range for aircraft trials on the same maneuvers is 2 to 42% (column (i)). An inspection of this 2 to 42% range reveals two distinct distributions, neither of which include the mean; their ranges are 2 to 17% and 28 to 42%. Identification of the specific maneuvers included in each of these ranges reveals that, with one exception (maneuver 5, steep turns), all the maneuvers in which simultaneous instruments and contact training was used fall into the low aircraft error group (02—17%). While these maneuvers are probably easier to learn than those in the higher error range group, the size of the differences seems to support the efficacy of early instrument training.

Table 7 provides a summary of all maneuvers trials recorded during the instrument training phase of the T-4G study. Again, the maneuvers (column (a)) are listed in order of total trials attempted (column (e)). Trials for both T-4G and T-4 trainers were combined since for purpose of instrument training the trainers are considered equivalent.

In Table 7 the difference between the percent of maneuver trials practiced in the trainers and the aircraft (67% versus 33%, respectively) and the

Table 7. Summary of Trials on Instrument Maneuvers[a]

MANEUVER	TRIALS PRACTICED					TRIALS FAILED			
	T-4G		T-37		T-4G		T-37	
	Total	%	Total	Sum	Number	%	Number	%
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1 LEVEL OFF	764	74	274	1038	215	28	26	09
2 TURN TO HEAD	579	63	344	923	98	17	32	09
3 UNUSUAL ATT	546	67	267	813	133	24	26	10
4 CHANGE A/S	590	74	202	792	144	24	10	05
5 STEEP TURN	429	58	315	744	99	23	36	11
6 CONSTANT A/S CL	410	73	151	561	95	23	14	09
7 TAKEOFF	364	73	135	499	96	26	8	06
8 TECH ORDER CL	314	68	148	462	80	26	14	09
9 VERTICAL S-A	311	69	138	449	133	43	15	11
10 VERTICAL S-D	288	70	141	429	115	40	16	11
11 VOR MIS APRCH	230	54	197	427	118	51	31	16
12 STRAIGHT & LVL	327	81	78	405	56	17	1	01
13 RADAR FINAL	269	68	124	393	158	59	17	14
14 VOR INTCPT, OUT	231	59	161	392	42	18	12	07
15 CONSTANT A/S Dc	254	66	131	385	47	19	13	10
16 RMI INBND	246	65	132	378	61	25	10	08
17 VOR PNTRATN	212	60	139	351	122	58	28	20
18 VOR LOW APRCH	211	61	137	348	117	55	26	19
19 VOR HOLDING	209	60	137	346	79	38	20	15
20 VOR INTCPT, IN	187	59	131	318	44	24	15	11
21 RMI OUTBND	125	66	65	190	39	31	8	12
22 RATE DSCNT	100	60	68	168	36	36	9	13
23 VERTICAL S-B	69	68	33	102	34	49	5	15
24 VERTICAL S-C	41	79	11	52	17	41	3	27
SUM	7306		3659	10965	2178		395	
PERCENTAGE	67		33			30		11
% RANGE	54-81		19-46			17-59		01-27
T-4G ONLY MANEUVERS								
--RADAR MISS APRCH	201		--	201	106	53	--	--
--IFR LNDG	65		--	65	17	26	--	--
T-37 ONLY MANEUVERS								
--WINGOVER	--		174	174	--	--	25	14
--AILRN ROLL	--		172	172	--	--	15	09
ΣΣ	7572		4005	11577	2301		435	
PERCENT	65		35	--	--	30	--	11

NOTE.—(N=21) Definitions: A/S=Airspeed; CL=Climb; Dc=Decent. Letters in parenthesis identify columns for reference in text. [a]Data reflect all trials recorded; T-4G data is complete but T-37 data is based on 80% of total sorties.

relatively low failure rate for aircraft trials (11%) reflects the effectiveness of ground devices in achieving instrument flight training objectives. In addition, a Spearman correlation coefficient to determine the agreement between columns f and h (r_s = .73) is much higher than for contact training and approaches that of the three classes within the simulator or aircraft.

Inspection of the errors recorded by type of maneuver provides additional insight into training emphasis. For example, the instrument maneuvers may be grouped into three general categories. These are. (a) basic airwork, (b) more complex vertical S maneuvers, and (c) radio and radar navigation and approach maneuvers. Summation of the failed trials by this categorization reveals the following percentage of total trials failed by device (columns g and i) (a) 23% versus 9%. (b) 42% versus 12%, and (c) 40% versus 14%, respectively. for trainers versus aircraft. These comparisons indicate that, as a result of practice on similar type contact maneuvers, basic instrument maneuvers were learned to a high level in ground trainers and few errors were made in the aircraft. However, category (b) and (c) maneuvers were learned to a lesser level in the trainer with a resultant increase in failing aircraft trials. Since there is no reason to reason to suspect trainer fidelity is any less in radio work than basic airwork. these data indicate that more time spent in the trainer on radio navigation, low approaches and vertical Ss might have resulted in improved transfer of training.

A comparison between the percentage of total trials by device in contact (Table 6) and instrument training (Table 7) leads to a similar conclusion with respect to utilization of trainer time. These data indicate that if training time on contact maneuvers had been continued until higher criteria and less variability in performance had been achieved (such as the 67.33 ratio of trainer to aircraft trials reported in instrument training), more efficient transfer would have been achieved in contact training.

Additional support for the suggestion that more practice in ground trainers would be expected to decrease requirement for aircraft training is provided by examining the average number of practice trials per maneuver by device. Data from Table 7 indicate that for instrument maneuvers practiced in both simulators and aircraft, 304 trials were used in the simulators and 153 trials in the aircraft. Similar data from Table 6 for contact maneuvers show 343 trials for the simulators and 232 trials for the aircraft. However, for maneuvers reported in Table 6 practiced only in aircraft. the figure is 251 trials. From these figures, it appears logical that if a ratio between total simulator and aircraft trials of 2.1 had been achieved in contact training (as in the instrument phase, i.e., 304.153) the average errors per maneuver could have been reduced from the 323 achieved to some figure less than that achieved for aircraft only maneuvers (251) and perhaps close to the 153 trials per maneuver reported in the instrument phase.

VI. DISCUSSION

Visual System

A specific objective of this project was to evaluate the effectiveness of the electronic perspective transformation (EPT) visual system in UPT contact flight training. The film portion of the EPT did not prove effective within the context of UPT as defined for this study. Data obtained in this project indicate that beginning students did learn to perform straight-in landings, takeoffs, and touch and go landings, three of the first four students trained were able to land the aircraft successfully on the first try. However, no savings were demonstrated in landings or takeoffs (Table 6). These data suggest that flying the 360° overhead pattern (excluding landings and takeoffs) is at least as difficult as learning to land the aircraft and that potential savings were masked by the relatively high amount of T-37 time required to learn the pattern. (Intuitively, we believe that even if such a data base had been available, a relatively low transfer would have been obtained since the essential cues for precise contact traffic pattern flying do not occur in the forward field-of-view.)

The horizon scene proved to be effective in teaching basic air work and is responsible for most of the hourly savings reported in contact training. The utility of this visual scene was limited by its field-of-view since only maneuvers in which the horizon was visible could be practiced: for example, complete stalls could not be practiced since no peripheral cues (directional or wings level references) were available in the visual display, and at the highest pitch position the horizon disappeared from the forward view.

The capability to enrich instrument training by providing reduced ceilings and/or visibilities at the end of an instrument approach could not be evaluated since low approach breakouts are not performed in T-37 aircraft by pilot trainees.

Subjectively, it was the opinion of the IPs, the project supervisors, and numerous visitors that this capability provided a realistic scene of great training potential.

Motion

Comparison of student performance during instrument training, as presented in Table 4, shows that *Ss* using the T-4G saved two aircraft hours more than those using the T-4 (10.1 hours versus 8.1 hours: not statistically significant). This suggests that motion cueing of the level provided by the T-4G (a relatively limited system) was not a significant factor in increasing instrument training transfer. The possible contribution of motion to transfer of contact training was not addressed. (However, an IP in the first study reported that when a student's performance on final approaches was below a previously learned level and it was learned the motion system had been inadvertently left off; when it was activated his performance rapidly improved to the previous level.) Motion sickness in simulators sometimes occurs when visual cues depicting apparent motion are presented without normally expected motion cues (Puing, 1970). Since no sickness by IPs or students occurred, the presence of motion may have been beneficial in contact training.

Instrument Training

Two questions were of interest relative to the use of the T-4G in instrument training. (1) could T-37 aircraft hours be saved through use of the T-4G; and (2) could quality of the UPT graduate be increased. Results of this study indicate that the T-4G and its associated revised training package can be used to save aircraft hours. Obviously, were the "saved" hours applied to further training, quality would be improved; e.g., practice on new problems such as strange field approaches and low minimum approaches would provide a more polished input to T-38 training.

Training Package

Evaluation of the T-4G provided an opportunity to incorporate into a total training package many training methods known to be of value in increasing training efficiency, and the results were very effective. However, of even more practical significance were results obtained using students from classes 73-09 and 74-03 in which similar savings were achieved using the same training methodologies with existing UPT T-4 instrument trainers. From these data, it is apparent that the basis for having achieved significant savings in instruments was the training package and that similar savings could be expected with any device possessing fidelity equal to that of the 15-year-old T-4.

Administrative Problems

While the results of this project were highly successful, its conduct was not without problems IP manning was one of these. We considered it necessary to use an IP/*S* ratio of 1:1 in this study. The usual IP/student ratio is about 1:3. If the program used in this study is to be implemented operationally, manning may be a problem. Current experience has shown that T-4G type training can be integrated into the UPT syllabus with less than a 1:1 IP/student ratio. However, it has also shown that ratios larger than those commonly used are required.

Determination of student class standing is another administrative problem. Since to a great extent, class standing determines who gets first choice of assignments, students are concerned about how it is derived. When progression on a proficiency basis is incorporated in a training program, the student who reaches criterion first (as indicated by a passing checkride score) will always wonder what he could have achieved had he flown more time. In this study, a mathematical scheme based on aircraft hours saved, was used to reward students who completed training in reduced hours (Cyrus & Woodruff, 1974). Table 8 provides a summary of raw and revised check scores received by subjects in this study. This controversial issue would have to be addressed in an operational program using proficiency advancement.

It has been suggested that the blocked training concept used in this study might be impractical at a bad weather base. While some problems did occur because of rigid adherence to the study schedule, it is believed this problem can be circumvented through a combined use of more blocks, less rigidity and administrative authority to provide flexibility in student entry and exit dates.

There is also the problem of indoctrinating an inexperienced instructor into a program which requires use of judgment as to when a student should progress. The buddy-IP system (used in the latter phases of this project) proved effective in reducing this problem.

Table 8. Comparison of Experimental and Control Group Average Check Scores

Class Number	Contact — Midphase: Control Group	Contact — Midphase: Experimental Raw	Contact — Midphase: Experimental Revised[a]	Instruments — Final: Control Group	Instruments — Final: Experimental Raw	Instruments — Final: Experimental Revised[a]
7306	76.1	77.7	78.1	87.1	84.2	87.1
7309	76.1	74.7	75.4	84.9	84.5	85.8
7403	77.9	77.6	78.0	88.2	87.8	89.0

[a]Revised in accordance with technique reported in AFHRL-TR-74-91, in press.

VII. SUMMARY AND CONCLUSIONS

The objective of this study was to determine if the use of T-4G technology (using a T-37 simulator incorporating a film base visual system and a two DOF motion system-device A/F37A-T4G) in UPT would result increased training efficiency. A revised syllabus and a special treatment incorporating suitable training methodologies were developed. Three samples of beginning UPT students were trained using the revised program and their performance was compared with the remainder of their UPT classes using the conventional syllabus.

Combined results from the three classes involved demonstrated that T-4 methodology resulted in T-37 flying hours savings of an average of three hours per student in basic contact, and an average of 10.1 hours per student in instrument training.

As a result these findings (obtained with the first of the three classes involved), it was decided to also investigate to what extent similar savings could be achieved in the instrument phase using the newly developed training program with conventional T-4 instrument trainers. An average savings of 8.1 hours of T-37 instrument training was achieved.

The most significant of the above findings is that application of the revised training program with existing equipment can achieve an average savings of eight T-37 aircraft hours per student. Whether or not these hours are eliminated to reduce cost, and conserve energy or used to teach other training objectives, thereby turning out a better product to using commands, is a prerogative of ATC and Air Force management. However, the implication is clear, a more efficient training program using existing equipment is possible. only administrative action to implement the changes is required.

With respect to evaluation of the T-4G visual system: it is concluded that a production model of such a visual system could be used on a modest or better fidelity simulator to achieve savings of three to four aircraft hours in early contact flight training in UPT. A determination as to whether these projected savings would justify procurement of such devices command-wide would require a detailed cost comparison.

The use of this type visual system to enhance instrument training can only be addressed subjectively, since constraints in UPT did not permit quantative evaluation in this role. Subjectively, people who have flown, or observed, the device agree that the capability to provide realistic bad weather instrument approach breakouts does exist and could provide significant training value.

VIII. IMPLICATIONS

The implications of these study results are:

1. Significant increases in instrument training efficiency in UPT can be achieved in the current program by incorporating the revised syllabus and training methodologies developed in this project. The resultant savings could be converted to dollar and/or energy reduction, or training in other learning objectives to improve the product.

2. The major thrust of the findings of this study concerns syllabus revision and revised instructional strategies for which additional research is not required to justify adoption. Similar actions should be initiated to revise the T-26 instrument training phase of T-38 UPT training and to review any other USAF instrument training program which has evolved over the years and not through modern instructional system development (ISD) efforts. The potential for cost savings in such programs (where the cost

differential between aircraft and simulator is much larger than in T-37 aircraft) is significantly higher.

3. All instrument and procedures training programs developed using ISD techniques should be reviewed to insure maximum use of training strategies demonstrated in this project.

4. Planning for procurement of new ground training devices incorporating visual systems should include an extensive examination of the training objectives expected to be assigned to the visual system before system definition is completed. In these efforts, utility in training should be the overruling consideration.

5. The electronic perspective transformation (EPT) visual system as it currently exists has been demonstrated to have practical value in landings and takeoffs. Consideration should be given to developing additional capabilities which would permit teaching the remainder of the traffic pattern.

REFERENCES

Air Training Command, *Syllabus of training*, NO. P-V4A-A, November 1971.

Cyrus, M.L., & Woodruff, R.R. *Grading system for T-4G simulator students in UPT Studies.* AFHRL-TR-74-91. Williams AFB, Ariz.: Flying Training Division, Air Force Human Resources Laboratory, November 1974, in press.

Puig, J.A. *Motion in flight training: A human factors view.* Technical Report NAVTRADEVCIN IH-177. Orland, Florida, October 1970.

Ritchie, M.L., & Hanes, L.F. *An experimental analysis of transfer effects between contact and instrument flight training.* AD-816 553. Washington, D.C.: Federal Aviation Agency, (Ritchie, Inc., Dayton, Ohio) June 1964.

Rust, S.K., Smith, J.F., & Woodruff, R.R. *Syllabus and syllabus development techniques used in evaluating the A/F-37A/T-4G Flight simulator.* AFHRL-TR-74-44. AD-786 412. Williams AFB, Ariz.: Flying Training Division, Air Force Human Resources Laboratory, June 1974.

Siegel, S. *Nonparmetric statistics for the behavioral sciences.* New York: McGraw-Hill, 1956.

Woodruff, R.R., Smith, J.F., & Morris, R.A. *Use of the T-4G simulator in USAF undergraduate pilot training (UPT), Phase I.* AFHRL-TR-74-61, AD-786 413. Williams AFB, Ariz.: Flying Training Division, Air Force Human Resources Laboratory, July 1974.

The T-4G is an updated ME-1 trainer modified to accommodate a Singer SPD Electronic Perspective Transformation (EPT) visual system. The ME-1 itself is essentially a T-4 instrument trainer mounted on a two degree-of-freedom motion base. Figure A1 is an artist's concept of the T-4G.

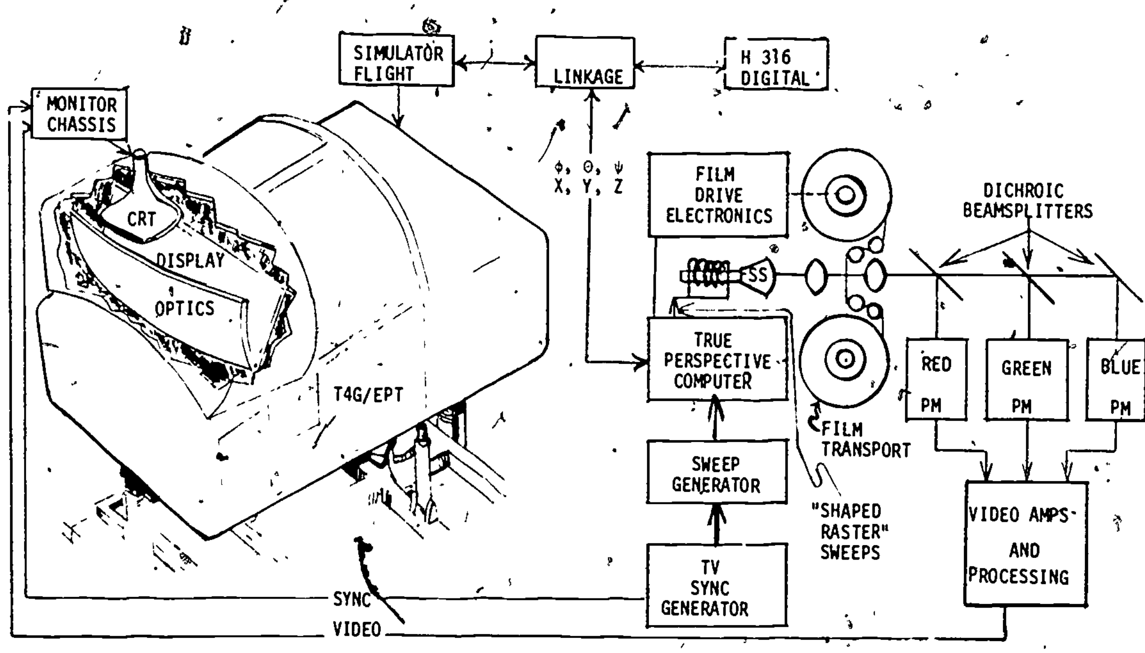

Figure A1. **Artist's concept of the T-4G.**

Following is a list of the major simulator components:

- Modern Microelectronic Computer
- T-4 Cockpit
- Two DOF Motion
- EPT Visual System
- External Operator Station
- Internal Instructor Station

The motion system moves ± 5.5° pitch, ± 8.5° in bank, and vertically +6" and –4". The visual display field of view in 44° x 28°, and the image is provided in full color at infinity. Image generation for the visual display is obtained from two sources: color movie film, and an electronically generated horizon display. An approach, landing, and takeoff movie sequence filmed at Williams AFB projected on the visual display tracks student pilot control inputs. Changes in aircraft speed are achieved by changes in film speed, vertical and lateral deviations from the path of the film are produced by the EPT system. The EPT visual system provides. normal straight-in approached from four miles out, no flap and simulated single engine configurations; touchdown, landing roll; and takeoff to 500′ AGL.

The electronically-produced visual scene showing a horizon defined by blue sky and a cloud deck is provided for airwork, horizontal translation is not provided. Display image motion capability of 360° continuous motion in pitch, roll, or heading permits acrobatic practice in the simulator, however, the limited motion cues and field of view detract from realism.

In addition to motion and visual cues, the T-4G includes a complete nav/comm system and the capability to produce aural cues such as wind, engine sound, landing gear warning, system operations, etc.

Aids for instruction included at both operator and instructor station are the capability to freeze the simulator during a mission, and to reset to a preselected position within a matter of seconds.

APPENDIX B. T-4G/T-4/T-37 DEMONSTRATIONS

Table B1. Summary of Hours Used or Saved/Device/Student in Three T-4G/T-4/T-37 Demonstrations

		CONTACT AIRWORK			INSTRUMENTS					
DEVICE		T-4G	T-37	T-37	T-4G	T-37	T-37	T-4	T-37	T-37
HOURS		USED	USED	SAVED	USED	USED	SAVED	USED	USED	SAVED
CLASS 7306	S1	17.3	25.5	1.7	10.4	6.9	13.9			
	S2	15.0	21.7	5.5	13.7	9.7	11.1			
	S3	17.3	22.7	4.5	14.5	11.4	9.4			
	S4	17.3	22.3	4.9	17.5	12.1	8.7			
	S5	17.3	25.1	2.1	16.2	11.5	9.3			
	S6	17.3	22.2	5.0	17.0	6.7	14.1			
	Σ	101.5	139.5	23.7	89.3	58.3	66.5			
	M	16.9	23.2	3.9	14.9	9.7	11.1			
			(27.2)[a]					(27.0)	(20.8)	
CLASS 7309	S1	12.8	23.7	6.7	15.8	10.9	9.9			
	S2	12.8	21.5	8.9	16.6	10.1	10.7			
	S3	11.4	31.1	-.7	17.9	12.9	7.9			
	S4	12.1	24.4	6.0	16.6	11.7	9.1			
	S5	12.1	29.0	1.4				23.7	13.2	7.6
	S6	12.1	23.8	6.6				17.0	14.5	6.3
	S7	9.3	23.3	7.1				17.5	10.7	10.1
	Σ	82.6	176.8	36.0	66.9	45.6	37.6	58.2	38.4	24.0
	M	11.8	25.3	5.1	16.7	11.4	9.4	19.4	12.8	8.0
			(30.4)					(27.0)	(20.8)	
CLASS 7403	S1	12.8	24.6	2.7	21.6	15.1	5.9			
	S2	12.8	25.5	1.8	22.9	13.6	7.4			
	S3	12.8	25.7	1.6	22.0	7.2	13.8			
	S4	12.8	27.9	-.6	22.5	11.4	9.6			
	S5	12.8	25.5	1.8				20.0	13.4	7.6
	S6	12.8	31.8	-4.5				20.8	13.6	7.4
	S7	13.5	27.6	-.3				22.5	11.5	9.5
	S8	12.8	27.2	.1				22.5	12.8	8.2
	Σ	103.1	215.8	2.6	89.0	47.3	36.7	85.8	51.3	32.7
	M	12.9	27.0	.3	22.2	11.8	9.2	21.4	12.8	8.2
			(27.3)					(27.0)	(21.0)	
TOTAL	ΣΣ	287.2	532.1	62.3	245.2	150.2	140.8	144.0	89.7	56.7
	M	13.7	25.3	3.0	17.5	10.8	10.1	20.6	12.8	8.1
RANGE	LO	9.3	21.5	-4.5	10.4	6.7	5.9	17.0	10.7	6.3
	HI	13.5	31.8	8.9	22.9	15.1	14.1	23.7	14.5	10.1

[a](0.0) = Average hours used by non experimental students by class.