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TAEG REPORT NO. 63

THE EFFECTS OF SIMULATOR LANDING PRACTICE AND THE CONTRIBUTION OF MOTION SIMULATION TO P-3 PILOT TRAINING

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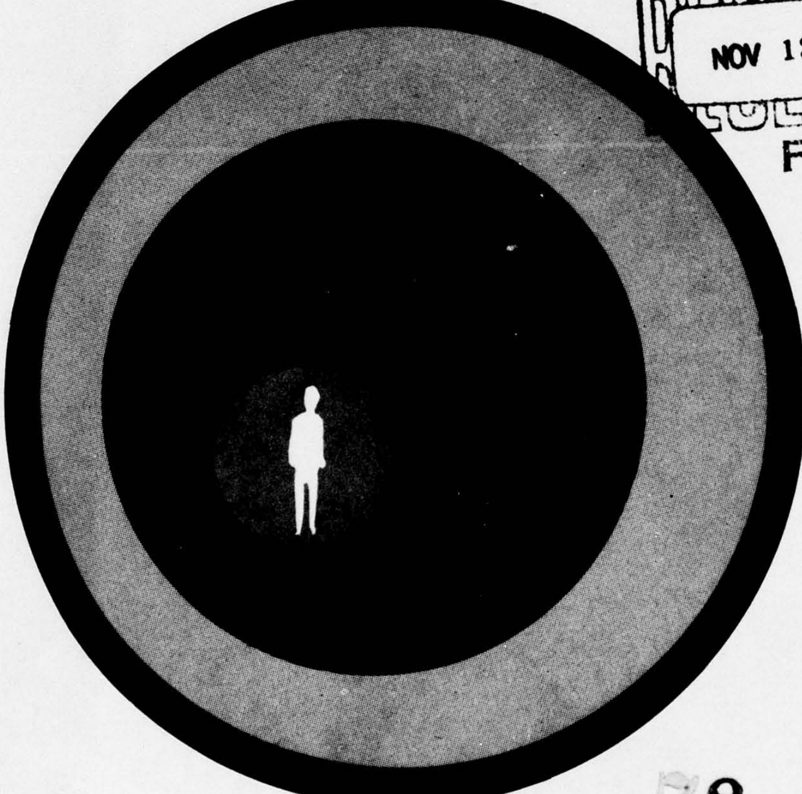

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SEPTEMBER 1978

TRAINING ANALYSIS AND EVALUATION GROUP
ORLANDO, FLORIDA 32813

TAEG Report No. 63

THE EFFECTS OF SIMULATOR LANDING PRACTICE AND THE CONTRIBUTION OF MOTION SIMULATION TO P-3 PILOT TRAINING

Leonard E. Ryan
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Robert F. Browning

Final rept.

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Training Analysis and Evaluation Group

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This report examines (1) the effectiveness of Device 2F87F for training the final portion of the landing task, (2) the contribution of cockpit motion to specific objectives in the curriculum, and (3) the incidence of motion sickness in the simulator when training was given with the cockpit motion system off and the visual system operating.

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20. Abstract (continued)

The analyses considered:

- overall flight hours
- flight hours to proficiency
- P-3 landings required
- transfer effectiveness ratios
- student qualification based on undergraduate pilot training
- the incidence of motion sickness.

Device 2F87F was found to provide effective training for the final portion of the landing task. Transfer effectiveness ratios show that landing practice in the simulator provides a training benefit under the three different training conditions examined.

Training in the simulator without cockpit motion did not significantly affect subsequent trials required to attain proficiency in the aircraft.

Simulator training with and without cockpit motion produced little evidence of motion sickness either during or after simulator flights.

ACKNOWLEDGMENT

We are indebted to Dr. Fred E. Guedry and Dr. J. Michael Lentz of the Naval Aerospace Medical Research Laboratory, Pensacola, Florida, for their assistance and contributions in assessing the issue of motion sickness. Dr. Guedry and Dr. Lentz modified a motion sickness questionnaire for this study and analyzed and interpreted the questionnaire data.

The encouragement and substantial technical guidance of Dr. Alfred F. Smode, Director of the Training Analysis and Evaluation Group, is gratefully acknowledged. His many fruitful discussions on organizing the findings have contributed significantly to the report.

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SECTION I

INTRODUCTION

This report is the third in a series of three reports concerned with the evaluation of the training effectiveness of Device 2F87F, P-3C Operational Flight Trainer (OFT).

The first study[1] evaluated the effectiveness of the newly installed Device 2F87F OFT at the Fleet Readiness Squadron (FRS), VP-30. The study determined the training and cost effectiveness of the 2F87F as a replacement for the earlier generation 2F69D OFT when used in combination with the P-3 aircraft.

The second study[2] continued the investigation of the training effectiveness of the device by examining additional factors that influence device utilization. The specific objectives of the study were to determine the:

- performance of a group trained in the aircraft without previous simulator training to permit comparison with performance of matched groups having correlative simulator training,
- value of training trials for providing an index of student performance and device effectiveness,
- correlation of performance in Device 2F87F with performance in the P-3 aircraft,
- effect of undergraduate pilot training (UPT) performance on subsequent performance in FRS,
- performance of VP-30 trained students in subsequent operational assignments.

The above two studies provided data on the positive benefits of landing practice in Device 2F87F. However, due to the less than exact handling characteristics of the simulator during the final phase of landing, the consensus of the VP-30 pilots was that little benefit could be gained by practicing this phase of the task in the simulator. This attitude was expressed in a message from VP-30 to the Commander, Patrol Wings Atlantic dated 6 June 77,[3] which reads in part "Training experience in the 2F87F has revealed optimum training

[1] R. F. Browning, L. E. Ryan, P. G. Scott, and A. F. Smode. Training Effectiveness Evaluation of Device 2F87F, P-3C Operational Flight Trainer. TAEG Report No. 42. 1977. Training Analysis and Evaluation Group, Orlando, FL. AD A035771.

[2] R. F. Browning, L. E. Ryan, and P. G. Scott. Utilization of Device 2F87F OFT to Achieve Flight Hour Reductions in P-3 Fleet Replacement Pilot Training. TAEG Report No. 54. 1978. Training Analysis and Evaluation Group, Orlando, FL.

[3] PATRON THREE ZERO Message 072200Z Jun 77

transfer in all areas except for groundhandling and final landing phases. The suspected lack of transfer in these phases is due to overly responsive aileron control, lack of peripheral vision, poor depth perception and poor flight simulation when landing flaps are selected. The fact that some landing pattern training does transfer from 2F87F to the aircraft is not in question. However, the amount of transfer and the reinforcement realized is neither documented, nor substantiated at this point in time." The extent of pilot concern coupled with the importance of the issue, led VP-30 to request that the Training Analysis and Evaluation Group (TAEG) conduct a study of the final phase of the landing task.

In response to the above request, a study was conducted evaluating the effectiveness of simulator training on the final phase of the landing task (i.e., from the "Select Land Flap" position in the landing pattern). The results of that study are contained in section II of this report. In addition, the results of a second study which examined the contribution of simulator platform motion to student performance is presented in section III.

Both studies were conducted using the simulator "as is." No changes were made to the flight equations or to the motion or visual systems. Although it is possible that certain of these changes could result in the simulator more closely approximating the flying characteristics of the P-3 during the final portion of landing, the engineering data to make these changes were not available. The merit of this approach is that the study was conducted under the precise conditions wherein the informed opinion held the simulator to be ineffective for training the final portion of the landing task. Although this study provided no information related to trainer improvement, it did assess adequately the contribution of the visual simulation to training the landing task under the exact conditions voiced in the pilot opinions.

The objective of the second study in this report was to compare flight performance of students who were trained in the simulator with or without platform motion. The results presented apply only to training conducted in Device 2F87F with its presently programmed motion algorithm. With minor exceptions, this motion algorithm was programmed into Device 2F87F prior to simulator acceptance at VP-30.

Within the second study, an additional effort was devoted to assessing the incidence of motion sickness in the simulator when training was given with the cockpit motion system off and the visual system operating. This effort is described in section IV of this report.

SECTION II

EVALUATION OF SIMULATOR LANDING PRACTICE

This section presents the first of the two studies described in the introduction of this report. The study reported here is an evaluation of the effectiveness of the 2F87F simulator for training the final phase of the landing task. This segment of the landing task begins with the "Select Land Flap" position in the landing pattern and culminates in the touchdown of the aircraft on the runway.

STUDY DESIGN

The study was designed to compare the number of landing trials in the P-3 aircraft required by experimental (E) and control (C) groups to achieve proficiency as a function of variation in landing training in the 2F87F simulator. The study plan is shown in table 1. One group (C-1) received block simulator training followed by aircraft training. A second group (C-2) received an integrated simulator/flight syllabus (the present operational syllabus), and the third group (C-3) received only aircraft training without simulator training. The E group received the same sequence of simulator/aircraft training as group C-2. However, the E group received no flare or touchdown practice during landing training in the simulator. All groups received identical preliminary training in the cockpit familiarization trainer (CFT) and cockpit procedures trainer (CPT).

TRAINING TASKS. The familiarization/instrument (FAM/INST) phase provides training in 45 tasks. In this study, three tasks served as the basis for comparing the performance of the E and C groups. These were: (1) Normal Landings, (2) Approach Flap Landings, and (3) Three Engine Landings.

SUBJECTS. All subjects were newly designated first-tour Naval aviators. The subjects used for Group C-1 were from classes 7608, 7609, and 7610. Subjects for Group C-2 were drawn from classes 7703, 7704, and 7705. Subjects for Group C-3 came from class 76T03 and those for the E group from classes 7710 and 7801. All groups were matched on the basis of Undergraduate Pilot Training basic and advanced flight scores. Based on these averages the E group score (52.7) is equivalent to the combined C groups score (53.3). All subjects had recently completed undergraduate multiengine training and possessed Standard Instrument Cards.

INSTRUCTORS. Squadron FAM/INST instructors conducted all simulator and flight training. Each instructor was briefed by TAEG personnel on the purpose of the study, the grading requirements, and the data recording requirements.

TABLE 1. STUDY PLAN

Control Groups			Experimental Group
C-1 (N=27)	C-2 (N=39)	C-3 (N=10)	E (N=19)
4 CFT	4 CFT	4 CFT	4 CFT
6 CPT	6 CPT	6 CPT	6 CPT
6 OFT (Device 2F87F)	6 OFT (Device 2F87F)	-	#6 OFT (Device 2F87F)
4 P-3 Flights	4 P-3 Flights	6 P-3 Flights	4 P-3 Flights

The trainer was frozen or a waveoff initiated at the Select Land Flap position on the final approach in the landing pattern. The E group received no flare or touchdown practice in the simulator.

Groups C-2 and E received integrated simulator/aircraft training. The sequence was as follows:

Sim 1, Sim 2, Sim 3, Sim 4, Fly 1*, Sim 5, Fly 2**, Sim 6, Fly 3***, and Fly 4.

NOTE: Due to aircraft availability:

* Fly 1 followed Sim 5 for some students
** Fly 2 followed Sim 6 for some students
*** Fly 3 preceded Sim 6 for some students

TRAINING DEVICES. Two part-task trainers and the OFT were employed in the study. They are described below.

Cockpit Familiarization Trainer, Device 2C23A. The CFT provides a static simulation of the pilot, copilot, and flight engineer positions. It is used to facilitate the learning of the nomenclature, location, and function of the various controls, instruments, switches, and annunciator lights. The device is well suited to the learning of repetitive tasks such as normal and emergency operations.

Cockpit Procedures Trainer, Device 2C45. The CPT was developed from a modification of an obsolete P-3 OFT. The motion simulation, most of the flight dynamics, and unneeded systems were removed or disabled. The device in its present configuration provides training in power plant management and systems procedures for both normal and emergency operations. Some CPT training was conducted in Device 2F69D which is now used solely for that purpose.

Operational Flight Trainer, Device 2F87F. This state-of-the-art device simulates the flight stations (pilot, copilot, and flight engineer) of the P-3 Orion, a four-engine turboprop aircraft used to support land-based ASW and other long range surveillance and data gathering missions. The high fidelity digital device is equipped with a 6 degrees of freedom motion system and a narrow-angle visual (50^{o} horizontal, 38^{o} vertical) television rigid model system. A broad range of environmental conditions varying from full daylight color to darkness with variable visibility, ceiling, and wind conditions can be simulated. The model board simulates an area of approximately 15 X 5 nautical miles on a scale of 2000 to 1 for the low altitude maneuvers associated with takeoff, landing, and instrument approaches. Low altitude on-top conditions are simulated electronically, and high altitude simulation is provided by a high altitude model board.

PROCEDURE

GROUND SCHOOL, CFT, AND CPT TRAINING. The E and C groups received identical ground school, CFT, and CPT training (i.e., the present syllabus).

CONTROL GROUP TRAINING. Groups C-1 and C-2 received the same training syllabus in the simulator and in the aircraft. The difference between the two groups was that the simulator syllabus for C-1 was accomplished in a block period whereas an integrated simulator/aircraft syllabus was used for C-2. Both control groups received full landing practice in the simulator; i.e., touchdown of the aircraft on the runway. Group C-3, the fly only group, received no simulator training. The aircraft syllabus content was the same for all groups.

EXPERIMENTAL GROUP TRAINING. The E group received the same training and training sequence as the C-2 group. However, for the E group the trainer was frozen or a waveoff was initiated at the "Select Land Flap" position on the final approach in the landing pattern (see figure 1). Since this group was not allowed to land the trainer, no flare or touchdown practice was received.

GRADING SYSTEMS. The C-1, C-2, and E groups were graded as follows: During aircraft flights students were assigned grades based on the conventional grading system used in Navy pilot training. In this system, referred to as the "U, BA, A, AA" (UBAA), the letter U denotes unsatisfactory performance and is equated to a numerical grade of 0, BA denotes below average and a grade of 2.5, A denotes average and a grade of 3.0, and AA denotes above average and a grade of 3.5. The numerical scores of all students were compiled and averages obtained for individuals and for the group.

In addition to the UBAA grades, a proficiency (P) grade was also assigned. P was defined as performance estimated to be equivalent to that required to demonstrate competence (a grade of AA or A) on that task on the conventional flight check. For groups C-1 and C-3, instructors recorded the number of trials and determined the flight on which the student attained proficiency.

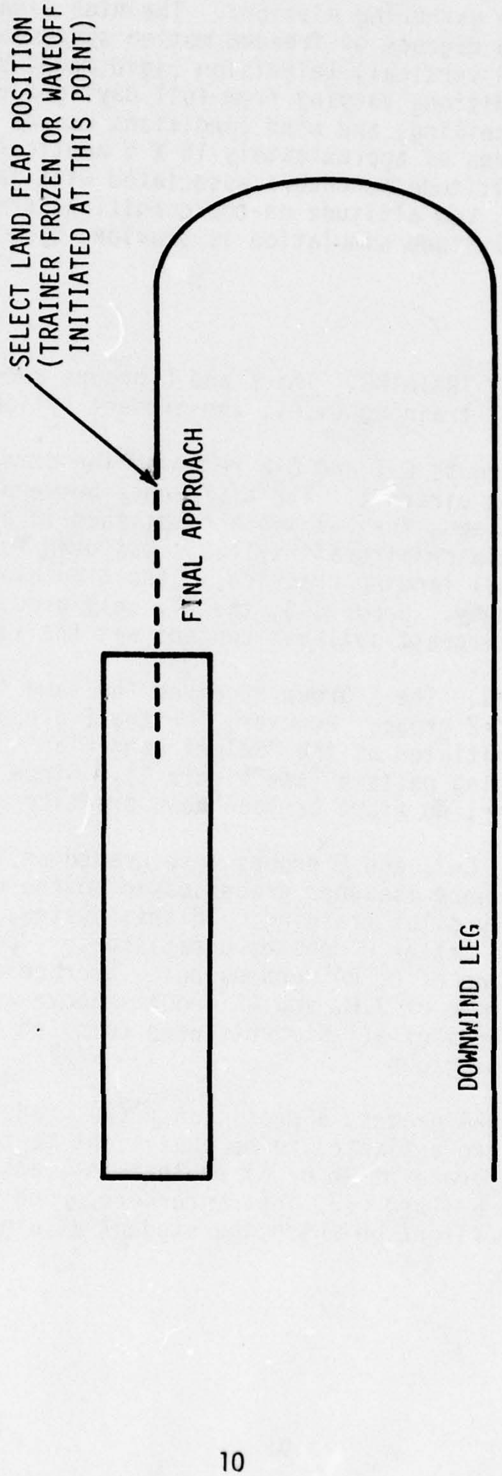

Figure 1. P-3 Simulator Landing Pattern.

For groups C-2 and E, trial performance was recorded by the instructor, and TAEG determined the point at which P was attained for each task. This was done to standardize proficiency grades. The procedure for making this determination is as follows: The trial performance was recorded by the instructor as either "1" (meaning one trial) or "P" (meaning one trial that was proficient). For example, normal landings on any flight may have been graded 11P11PP111. That indicates that 10 trials were conducted--7 which were not proficient and 3 which were proficient. The rule used for determining the point when P was attained is as follows: (1) Over 50 percent of the trials (for a given task) on any flight had to be P and (2) at least 50 percent of the trials were P on all subsequent flights. An exception to (1) and (2) could occur on the check flight. If on the check flight a "UBAA" grade of A or AA was assigned by the instructor, then P was assigned by TAEG no matter how the individual trials were graded.

RESULTS

The results are presented under three main topics: (1) Summary Data, (2) Simulator and Aircraft Landings, and (3) Transfer Effectiveness Ratios (TERs). The summary data present the average flight grades in UPT and performance in VP-30 of the four groups in the study. The simulator and aircraft landing data compare the number of aircraft landings with the simulator training received. Transfer effectiveness ratios are also computed using the performance of the fly only group (C-3) as the baseline.

SUMMARY DATA. Table 2 presents the number of students in each group, the group UPT flight average, VP-30 average flight hours, and the VP-30 check flight average grade.

TABLE 2. AVERAGE FLIGHT HOURS AND FLIGHT GRADES OF CONTROL AND EXPERIMENTAL GROUPS

	C-1	C-2	C-3	E
Number of Students	27	39	10	19
Average Flight Grade (UPT)	54.2	52.3	55.0	52.7*
VP-30 Flight Hours Per Student	8.6	9.6	15.1	10.4
VP-30 Check Flight Average Grade	3.03	3.00	3.01	2.99

*Estimated from partial UPT raw score grades

The data of most interest in table 2 are the number of flight hours and the check flight average grades. The E group averaged slightly more VP-30 flight hours than the C-1 and C-2 groups. The additional time was attributed to the increased number of landings required by the E group to achieve proficiency.

The E group check flight average grade was slightly lower than the check flight average grades for the C groups. The lower check flight average grade of the E group was due primarily to two students whose poor performance eventually resulted in their being "set back" to a following class. The UPT flight averages of these two students were 45 and 38, well below the historical mean of 53. The positive correlation between UPT flight averages and VP-30 performance has been discussed in an earlier study.[4] In that study the data showed an inverse relationship between UPT flight grades and UPT flight hours--the lower the flight grade in UPT, the greater the number of UPT flight hours. The same relationship exists for UPT flight average and FRS performance at VP-30. The UPT flight average and FRS flight average are highly correlated ($p = < .01$ level).

SIMULATOR AND AIRCRAFT LANDINGS. Table 3 presents the average number of simulator landings and the average number of aircraft landings required to attain proficiency.

TABLE 3. AVERAGE SIMULATOR LANDINGS RECEIVED AND AIRCRAFT LANDINGS REQUIRED TO ATTAIN PROFICIENCY

Group	Simulator Landings	Aircraft Landings to Proficiency
C-1 (N=27)	28	17
C-2 (N=39)	28	28
C-3 (N=10)	0	50
E (N=19)	23*	37**

* Trainer frozen or waveoff initiated at Select Land Flap position in the landing pattern.

** E group is significantly different from the C-2 and C-3 groups ($p < .05$) and from the C-1 group ($p < .01$).

A comparison of the E, C-1, and C-2 groups indicates that students who received no flare or touchdown practice during landing trials in the simulator (E group) required significantly more aircraft landings to attain proficiency than students who received full landing practice in the simulator (groups C-1 and C-2). Also, students who received <u>no</u> simulator training (group C-3) required

[4] Browning, Ryan, and Scott, op. cit.

significantly more aircraft landings to attain proficiency than the E group. The data in table 3 support the conclusion that practicing landing pattern airwork in the simulator transfers positively to landing performance in the P-3 aircraft even though actual touchdown was not performed.

The differences between the average number of landings for the C-1 and C-2 groups (17 vs 28) may be attributed to the order of presentation; i.e., block versus integrated syllabus and/or differences in grading criteria. This issue is described in some detail in an earlier P-3 study.[5] The differences between the C-3 and the other control groups are attributed to the lack of any training in the simulator by the C-3 group.

TRANSFER EFFECTIVENESS RATIOS. Another way of depicting effectiveness of landing practice in the simulator is via the computation of the TER.[6] The following computations are based on using the fly-only group (C-3) landings as a baseline:

1. $$\text{TER} = \frac{\text{P-3 Landing Trials (C-3) - P-3 Landing Trials (C-1)}}{\text{Simulator Landing Trials (C-1)}}$$

$$\text{TER} = \frac{50 - 17}{28} = 1.18$$

2. $$\text{TER} = \frac{\text{P-3 Landing Trials (C-3) - P-3 Landing Trials (C-2)}}{\text{Simulator Landing Trials (C-2)}}$$

$$\text{TER} = \frac{50 - 28}{28} = .79$$

3. $$\text{TER} = \frac{\text{P-3 Landing Trials (C-3) - P-3 Landing Trials (E)}}{\text{Simulator Landing Trials (E)*}}$$

$$\text{TER} = \frac{50 - 37}{23} = .57$$

* Does not include flare or touchdown landing practice.

[5] Browning, Ryan, and Scott, op. cit.

[6] H. K. Povenmire and S. N. Roscoe. "An Evaluation of Ground Based Flight Trainers In Routine Primary Flight Training." Human Factors. 13. 2. April 1971. pp. 109-116.

The TER[7] value indicates the aircraft landing trials saved for every landing trial in the simulator.

TER examples 1 and 2 show that the value of one landing trial in the simulator ranges from 1.18 to .79 landing trials in the P-3 aircraft. These different TER values are most likely the result of a combination of the variables listed below:

1. C-1 training was conducted using a block syllabus; C-2 used an integrated syllabus.

2. A more stringent criterion was imposed on C-2.

3. C-2 had several poor performers who increased the group average.

Despite the differences, however, the data show that transfer of landing practice in the simulator is high.

A comparison of the landing trials of the C-3 and E groups (TER example 3 above) indicates the value of landing pattern airwork. Under training conditions which did not permit flare or touchdown practice in the simulator, a training benefit did occur. In this example one landing trial in the simulator saved .57 landing trials in the aircraft.

The study results indicate that simulator practice in landing pattern airwork and the final phase of landing transfers positively to the aircraft. This transfer occurs even though VP-30 instructor and student pilots universally agreed that the 2F87F does not "handle" like the aircraft during the final phase of landing. The question of greater training effectiveness as a function of improved fidelity was not addressed in this study. It is a topic worthy of further investigation.

EFFECT OF LIMITED FIELD OF VIEW ON LANDING PERFORMANCE. A major concern of pilots is the limited field of view of the rigid model board. They suspect this reduces the training value of landing practice in the simulator since visual cues in the periphery are absent. However, the belief that a wide angle visual capability is required for effective training is not supported by the data in the present study nor by a number of other studies. For example, Armstrong[8] employed a Varsity aircraft configured such that the field of view of the pilot was limited to 50°. Armstrong reported that landing performance in the aircraft was almost unaffected by loss of peripheral vision, even

[7] The reader is cautioned not to interpret the TER as a constant; it is not necessarily linear with increased training, and it varies as a function of previous practice.

[8] B. D. Armstrong. Flight Trials to Discover Whether Peripheral Vision is Needed for Landing. Royal Aircraft Establishment Technical Report 70205. 1970. Ministry of Aviation Supply, Farnborough Hants.

under poor visibility conditions. Roscoe[9] configured a Cessna T-50 such that the windshield of the airplane was replaced by an aluminum sheet through which a periscope was installed. An image was projected from the periscope to an 8 inch screen with a field of view from the pilot's eye of a maximum of 30 degrees horizontally and vertically. Roscoe found that both experienced and inexperienced pilots could make safe takeoffs and landings by periscope using a variety of techniques and under a variety of conditions. Based on these aircraft data and the data from this study, it is reasonable to conclude that high fidelity simulators do not require "wide" angle visual systems to provide effective landing training.

SUMMARY OF FINDINGS

The findings of this study are summarized below:

1. The E group who received no flare or touchdown practice during simulator landing trials required significantly more landing trials in the aircraft to attain proficiency than did the C-1 and C-2 groups who received full landing training in the simulator (37, 17, and 28 landings, respectively).

2. The group that received no simulator training, C-3 (the fly only group), required significantly more landing trials in the aircraft to attain proficiency than did the E group. Practicing landing pattern airwork in the simulator contributes positively to landing performance in the P-3 aircraft.

3. The C-1 group required fewer total simulator and aircraft landings to attain proficiency than did the aircraft-only trained group (C-3). This suggests that the task learned in the simulator transfers significantly to subsequent aircraft landing performance.

4. The TERs computed from the landing data show that landing practice in the simulator provides a training benefit under the three different training conditions examined.

[9] S. N. Roscoe, S. G. Hasler, and D. G. Dougherty. "Flight by Periscope: Making Takeoffs and Landings; The Influence of Image Magnification, Practice, and Various Conditions of Flight." Human Factors. 8. 1. February 1966. pp. 13-40.

SECTION III

SIMULATOR COCKPIT MOTION AS A TRAINING VARIABLE

This section presents the second study of this report which examined the effects of simulator cockpit motion on the training of prospective P-3 pilots. The specific objectives of the effort were to determine: (1) the training tasks that benefit most from cockpit motion, (2) whether lack of cockpit motion makes the simulator more difficult to "fly," and (3) the need for major syllabus adjustments in the event that the cockpit motion system should become inoperative for a protracted period of time.

At the outset, it should be made clear that the data from this cockpit motion study are only suggestive due to several concerns. To begin with, the number of students in the sample was small and all did not receive advanced undergraduate pilot training in the same aircraft type. In addition, an undetermined number of experimental group students received some training trials with the motion system engaged. This was a departure from the study design. Instructor pilots also voiced a reluctance to conduct training with the motion system off. Their feeling was that realism was compromised. In an effort to overcome these limitations, the TAEG requested that the motion study be extended to minimally include an additional sample of 15 students. Unfortunately, squadron training commitments precluded this initiative. Nevertheless, the findings of the study are considered to be of sufficient value to multiengine pilot training communities to be reported here.

DESIGN OF THE STUDY

The study was designed to compare training trial data of groups trained in the simulator with or without cockpit motion. The plan is shown in table 4.

TABLE 4. STUDY PLAN

Control Group C (N=39)	Experimental Group E (N=11)
4 CFT	4 CFT
6 CPT	6 CPT
6 OFT	6 OFT*
4 P-3 Flights	4 P-3 Flights

* Cockpit motion system off

Note: The simulator/aircraft sequence was as shown in table 1.

SUBJECTS: The C group was comprised of students from classes 7703, 7704, and 7705. This was the control group C-2 in the study described in section II. The E group consisted of 11 students from class 7803. Six of these eleven students received the new undergraduate pilot curriculum which provides advanced flight training in the T-44 twin turboprop aircraft. All C group students and five subjects from the E group received their advanced flying training in the S-2, a small twin reciprocating engine aircraft.

INSTRUCTORS. VP-30 flight instructors provided both simulator and flight training. Each instructor was briefed on the purpose of the study, the grading requirements, and the data recording requirements.

TRAINING DEVICES. See section II of this report for a description of the training devices.

PROCEDURE. The training provided and the measurement technique employed are as follows:

CONTROL GROUP TRAINING. The C group received the present ground school, CFT, CPT, 2F87F, and aircraft syllabus.

EXPERIMENTAL GROUP TRAINING. The E group received the present ground school, CFT, CPT, and aircraft syllabus. During 2F87F simulator training, cockpit motion was not provided.

MEASUREMENT. The measurement technique described in section II of this report was used in this study. "UBAA" and P grades were assigned to all check tasks.

DATA ANALYSIS

Data analysis centers on two major topics: (1) the lack of cockpit motion on simulator training and (2) the lack of simulator cockpit motion on subsequent training in the aircraft. Summary data of the C and E groups are presented in table 5.

TABLE 5. AVERAGE FLIGHT HOURS AND FLIGHT GRADES OF CONTROL AND EXPERIMENTAL GROUPS

	C	E		
		T-44	S-2	Combined
Number of Students	39	6	5	11
Flight Average (UPT)	52.3	46.3	57	51.2
VP-30 Flight Hours Per Student	9.6	10.2	10.7	10.4
VP-30 Check Flight Average Grade	3.00	3.01	3.03	3.02

The data indicate that the VP-30 check flight grade and the UPT flight average for the combined E group is not significantly different from the C group. The VP-30 flight hour average of the E group is slightly higher than group C primarily because of "reflys" caused by bad weather. The T-44 trained students received three reflys and the S-2 trained students received five reflys. The reflys of students trained in the S-2 aircraft account for the difference in flight hours between them and students trained in the T-44 aircraft. The difference between T-44 and S-2 students is small and is mentioned here since historical data over the last 7 years indicate that UPT flight grades correlate negatively with VP-30 flight hours and positively with check flight grades. This relationship holds true in this instance for check flight grades only. VP-30 flight hours were slightly less for the group (T-44) with the lowest UPT flight average.

EFFECTS OF NO-MOTION ON SIMULATOR TRAINING. A comparison of simulator trials received and simulator trials to proficiency for 13 check tasks for the C and E groups is presented in table 6.

TABLE 6. SIMULATOR TRIALS RECEIVED AND SIMULATOR TRIALS TO PROFICIENCY

	AVERAGE TRIALS TO PROFICIENCY		AVERAGE TRIALS RECEIVED (FOR STUDENTS NOT ATTAINING PROF.)	
	C	E	C	E
Abort Four Engine	1.5	3.0	2.1	5.3
Abort Three Engine	2.9	4.9	7.5	13.0
Engine Failure After Refusal	2.4	2.7	5.1	- *
Departure	2.3	3.8	3.5	2.0
Holding	4.1	1.7	3.1	1.5
TACAN/VOR	3.5	5.3	7.8	3.4
LOC	1.8	1.0	.8	1.0
GCA	2.2	3.2	3.4	2.5
ILS	1.7	3.0	1.2	.6
Normal Landings	10.2	12.9	13.5	- *
Approach Flap Landings	4.0	4.4	7.1	4.5
Waveoff	1.8	3.1	4.5	3.5
Three Engine Landings	4.1	4.2	4.0	- *

* All students attained proficiency on this task

While there are statistical differences between the C and E groups, the practical differences are small. Simulator training time was the same for all students. For both groups, the average was about 12 hours per student as first pilot. A comparison of the C and E groups' average trials to proficiency for each task shows the largest differences to occur in Aborts, Holding, TACAN/VOR, and Normal Landings. Of these, Aborts and Holding appear to have the only true differences. TACAN/VOR and Normal Landings trials for the C group would be essentially the same as for the E group if all the C students had been trained to proficiency.

Based on these data, it appears that the lack of simulator cockpit motion may have a slight adverse effect on training in Three and Four Engine Aborts. The differences in the Holding task are difficult to explain particularly in terms of motion as a training variable.

EFFECTS OF NO-MOTION SIMULATOR TRAINING ON SUBSEQUENT AIRCRAFT PERFORMANCE. The effect of training in the simulator without cockpit motion on later student performance was examined. In the initial planning only those tasks were selected in which performance presumably would be affected by the variables of motion. The following analysis considers only those tasks. An analysis of variance (F test) with repeated measures was used. The measure employed was Aircraft Trials to Proficiency for the following tasks:

1. Abort Four Engine
2. Abort Three Engine
3. Instrument Tasks

    a. Holding
    b. Non-Prec App TACAN
    c. VOR
    d. NDB
    e. LOC
    f. Prec App GCA
    g. ILS
    h. Inst Procedures

4. Landings

    a. Normal Landings
    b. Approach Flap Landings
    c. Three-Engine Landings

5. Engine Failure After Refusal

As shown in table 7, no significant differences obtained between training methods ($F=3.21$), and no significant interaction effect occurred between training method and task ($F=1.91$). Trials to Proficiency were affected more by variance of students within groups than by training method. The only statistically significant finding was that certain tasks require more aircraft training trials than do others ($F=201.43$). This, however, is obvious.

TABLE 7. F TEST SUMMARY TABLE COMPARING THE C AND E GROUPS

	df	M.S.	F	p
Between Group Training	1	140.81	3.21	$<.05$
Subjects Within Groups	48	43.80		
Between Tasks	4	6475.91	201.43	$>.05$
Group X Task Interaction	4	61.33	1.91	$<.05$
Task X Subjects Within Groups	192	32.15		

Although the data show no major effects in simulator or aircraft performance as a function of motion in the simulator, informal discussions with pilot instructors and pilot trainees leave no doubt about their preference. Every individual in the sample favored using the motion system. It clearly enhanced their acceptance of the 2F87F as a desirable trainer.

SUMMARY OF FINDINGS

- Training in the simulator without cockpit motion increases the simulator trials required to attain proficiency in three and four engine aborts (3.0 vs 1.5 and 4.9 vs 2.9, respectively).

- Trials to proficiency in the aircraft for (1) four engine aborts, (2) three engine aborts, (3) instrument tasks, (4) landings, and (5) engine failure after refusal are not significantly affected by previous simulator training without cockpit motion.

- Individual differences among students had more effect on trials to proficiency than did training method.

- Use of the motion system greatly increases pilot acceptance of Device 2F87F.

- Both students and instructors strongly favor the use of platform motion in the simulator.

SECTION IV

CONFLICT OF VISUAL AND MOTION CUES

The addition of visual simulation to high fidelity flight simulators has produced instances of physiological discomfort during and immediately after training in the device. This has presumably resulted from cue conflict when visual motion cues are present in the absence of cockpit motion cues. This is particularly so with wide-angle visual systems. During the series of TAEG studies evaluating the 2F87F simulator, several VP-30 instructors reported nausea and general disorientation when the visual system was operative while the cockpit motion system was off. Consequently, the issue of motion sickness relating to simulator training was examined as a part of the second study in this report.

QUESTIONNAIRE ASSESSMENT

To assess the prevalence of motion sickness with the cockpit motion system off and the visual system on, a motion sickness questionnaire (MSQ) used by the Naval Aerospace Medical Research Laboratory (NAMRL) was submitted to instructor pilots and pilot trainees. This questionnaire is reproduced in appendix A.[10]

The questionnaire was administered to students and instructors of classes 7803 and 7805. Class 7803 received simulator training without cockpit motion; class 7805 received simulator training with cockpit motion.

The data from these two groups were compared with published data on student Naval flight officers[11] and with data on a group of college males.[12] Comparisons among these groups are shown in tables 8, 9, and 10.

The data in table 8 are compiled from sections A and B of the motion sickness questionnaire. Appendix B provides the scoring procedures used for sections A and B of the MSQ.

[10] The MSQ was modified for this study by Dr. F. E. Guedry of NAMRL. In addition, Dr. F. E. Guedry and Dr. J. M. Lentz conducted a computer analysis of the MSQ data collected during this study.

[11] J. M. Lentz, G. L. Holtzman, W. C. Hixon, and F. E. Guedry, Jr. Normative Data for Two Short Tests of Motion Reactivity. NAMRL-1243. 1977. Naval Aerospace Medical Research Laboratory, Pensacola, FL.

[12] J. T. Reason. An Investigation of Some Factors Contributing to Individual Variation in Motion Sickness Susceptibility. FPRC Report 1277. 1968. Ministry of Defense (Air Force Dept), London.

TABLE 8. DATA COMPILED FROM SECTIONS A AND B OF THE MOTION SICKNESS QUESTIONNAIRE (RESULTS RELATE TO HISTORY OF MOTION SICKNESS)

	Class 7803	Class 7805	NFO Group	College Group
Number of Students	26	21	552	150
Mean Motion Sickness Susceptibility Score	20.80	12.80	15.99	28.00
Standard Deviation	17.10	15.80	18.78	20.00

Table 8 shows the no-motion group (Class 7803) to be average in terms of motion sickness susceptibility as determined by MSQ methods. The scores for this group indicate less susceptibility than those of college males but more susceptibility than those of the NFO and class 7805 groups. The mean of the no-motion group was increased slightly by one student who had a score of 73.7 (highly susceptible to motion sickness).

Table 9 presents data compiled from section C of the questionnaire. For ease in interpretation, each question is stated followed by the appropriate data from classes 7803 and 7805. Question 5 also includes published data of Lentz and Collins for comparison with the VP-30 data.[13]

Responses to questions 2 and 3 suggest that the no-motion group is about average for military aviation in that the percent of individuals indicating some degree of airsickness under provocative flight conditions is average to above average. This finding is consistent with previous studies. Question 4 indicates about 10 percent of the group experience dizziness episodes in everyday life. Again, this is average or slightly above average for military aviators.

Question 5, percent taking antimotion sickness medication, is average compared with a college group. Considering the extensive exposure to motion of class 7803, this percentage is below expectations. However, the percentage for class 7805 is even lower.

Questions 6 and 7 are based upon items used by Hutchins and Kennedy.[14] The items are regarded as good predictors of airsickness. Their report, however, does not give percent of individuals replying in each answer category. A common sense look at the responses from classes 7803 and 7805 suggests that some students regard themselves as "poor risks" in motion sickness studies. Several individuals admitted experiencing sickness feelings when viewing

[13] J. M. Lentz and W. E. Collins. "Motion Sickness Susceptibility and Related Behavioral Characteristics in Men and Women." Aviation Space Environmental Medicine. 48, 4, pp. 316-322, 1977.

[14] C. W. Hutchins and R. S. Kennedy. "Relationship Between Past History of Motion Sickness and Attrition from Flight Training." Aerospace Medicine. 36, pp. 984-987, 1965.

TABLE 9. DATA COMPILED FROM SECTION C OF THE MOTION SICKNESS QUESTIONNAIRE

QUESTION 1

Please give a rough approximation of the number of flight hours you have had in military aircraft: (a) while piloting the aircraft, (b) as a crew member, (c) as a passenger.

	Class 7803 Instructors/Students				Class 7805 Instructors/Students			
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
a. While piloting the aircraft	1656	230	525	624	1634	223	360	289
b. As a crew member	1378	851	122	130	1563	833	168	198
c. As a passenger	156	149	39	46	156	157	136	381

QUESTION 2

In flight conditions that tend to produce airsickness in others, how often were you airsick in military aircraft prior to getting your wings?

Instructors and Students

	Never	Rarely	Sometimes	Often	Almost Always
Class 7803	16	6	3	0	1
Class 7805	14	6	0	0	0

QUESTION 3

In flight conditions that tend to produce airsickness in others, how often have you been airsick in military aircraft since getting your wings?

Instructors and Students

	Never	Rarely	Sometimes	Often	Almost Always
Class 7803	19	6	1	0	0
Class 7805	18	3	0	0	0

QUESTION 4

Do you ever experience episodes of dizziness or poor balance in your normal, everyday life?

Instructors and Students

	Yes	No
Class 7803	2	24
Class 7805	1	20

TABLE 9. DATA COMPILED FROM SECTION C OF THE MOTION SICKNESS QUESTIONNAIRE (continued)

QUESTION 5

Have you ever taken a medication like dramamine for motion sickness?

	Yes	No	
Class 7803	4	22	(15% Yes)
Class 7805	2	18	(11% Yes)
Comparison Group[15]	46	1260	(16% Yes)

QUESTION 6

What do you think your chances of getting sick would be in an experiment where 50% of the subjects get sick?

	Class 7803	Class 7805
I almost certainly would	3	0
I probably would	1	6
I probably would not	14	12
I almost certainly would not	8	3

QUESTION 7

Would you volunteer for an experiment where you knew that:

	Yes		No	
	7803	7805	7803	7805
85% of the subjects did get motion sick	11	1	15	20
75% of the subjects did get motion sick	14	3	12	18
25% of the subjects did get motion sick	20	12	6	9

QUESTION 8

While viewing wide-screen movies (like cinerama) involving external views from within moving vehicles, have you experienced: (a) sickness feelings, (b) disturbance.

	Never	Rarely	Sometimes	Often	Almost Always
Class 7803					
a. Sickness feelings	24	1	0	0	1
b. Disturbance	16	8	2	0	0
Class 7805					
a. Sickness feelings	19	2	0	0	0
b. Disturbance	17	4	0	0	0

15 Lentz and Collins, op. cit.

wide-screen movies involving external views from within moving vehicles (see question 8). Overall, both groups seem about average for pilots in regard to susceptibility to motion sickness. Sections A, B, and C indicate that class 7803 contains enough individuals with some history of motion sickness to serve as a reasonable test group for testing the prevalence of motion sickness with the cockpit motion system off and the visual system operating.

Table 10 presents data compiled from section D of the motion sickness questionnaire. Table 10, part A, presents (1) grouped responses of class 7803 for the six questions of part A, (2) the scoring procedure for part A, and (3) comparisons of motion sickness symptoms for class 7803, class 7805, and two groups of student Naval flight officers from a study by Lentz, et al.[16] Lentz collected normative data for these Naval flight officers on two tests of motion reactivity. These two tests were the brief vestibular disorientation test (BVDT) and the visual vestibular interaction test (VVIT).

Section D, part A, indicates that the simulator exposure produced little evidence of motion sickness either during or after simulator training. Most of the affirmative answers were in reference to tiredness or drowsiness. This may be a sign of motion sickness, but it may also be attributable to (1) prolonged simulator sessions or (2) time of day of the session. Of the symptoms that could be related to motion or the lack of it, three students reported headache and five reported mild unsteadiness.

The mean of the no-motion group is considerably lower than the mean of the BVDT and VVIT comparison groups who were exposed to "provocative stimulation." Thus, the no-motion students and instructors rated their 4-hour simulator exposure as less physiologically disturbing than the comparison groups rated their 10-minute exposure to the VVIT or their 6-minute exposure to the BVDT.

Section D, part B, which asked each individual to give his opinion of the simulator, may be the best set of questions in the questionnaire because they directly address the point of interest. If the responses from section B are converted to a four point rating scale where 1 = Not At All, 2 = Somewhat, 3 = Moderately, 4 = Very Much So, the mean for question B1 for class 7803 is 2.96 closest to "Moderately." Question B1 for class 7805 is 3.7 closest to "Very Much So." For Question B2, the mean for class 7803 was 1.77 closest to "Somewhat." The mean for class 7805 was 1.14 closest to "Not At All." For question B3 the mean for class 7803 was 3.2 closest to "Moderately." Class 7805 was not scored on question B3 since they did not fly the simulator without motion.

Based on student and instructor responses on the Pensacola Motion Sickness Questionnaire, simulator training with and without cockpit motion produced little evidence of motion sickness either during or after simulator flights. From the present results, it appears that the students and instructors both strongly favor having the motion cues available.

[16] Lentz, Holtzman, Hixon, and Guedry, op. cit.

TABLE 10. DATA COMPILED FROM SECTION D OF THE MOTION SICKNESS QUESTIONNAIRE (PART A PROVIDES STUDENT AND INSTRUCTOR SYMPTOMS OF MOTION SICKNESS. PART B PROVIDES ATTITUDES ABOUT THE SIMULATOR.)

PART A.* During or after the simulator session, I experienced:

Class 7803 Group Responses

1. Sickness feeling	26						
	None						Strong
2. Tiredness or drowsiness	17	6	1	1	1		
	None						Extreme
3. Unsteadiness	21	5					
	None						Extreme
4. Headache	23	2		1			
	None						Bad
5. Other	25				1		
	None						Strong

6. Disturbance after the simulator session lasted:

N/A	< 30 min	< 1 hr	< 2 hrs	< 3 hrs	< 4 hrs	> 4 hrs
23	3					

*To score section D, part A, sum positive responses in lines 1 through 5 (maximum score each line = 6; maximum score for 5 lines = 30) and multiply by weighted score in line 6, where N/A = 1 and 4 hrs = 6, so that maximum possible total score would be 30 x 6 = 180. Scores on part A for classes 7803, 7805, and student Naval flight officers are shown below:

	Class 7803		Class 7805		Student NFO	
	Instructors	Students	Instructors	Students	Brief Vestibular Disorientation Test Group	Visual Vestibular Interaction Test Group
N	9	17	8	13	524	300
Mean Symptom of Motion Sickness	0.7	2.8	1.5	1.6	5.5	9.1
Standard Deviation	1.0	3.8	2.1	3.3	13.9	18.4

TABLE 10. DATA COMPILED FROM SECTION D OF MOTION SICKNESS QUESTIONNAIRE (PART A PROVIDES STUDENT AND INSTRUCTOR SYMPTOMS OF MOTION SICKNESS. PART B PROVIDES ATTITUDES ABOUT THE SIMULATOR.) (continued)

PART B. Circle appropriate items to indicate your feelings about the simulator: (1) I felt at ease in flying the simulator, (2) I felt "rattled" or "uneasy" in flying the simulator, (3) I believe the lack of motion cues degraded the simulator training.

Student and Instructor Attitudes About the Simulator

	Not at All		Somewhat		Moderately		Very Much So	
	7803	7805	7803	7805	7803	7805	7803	7805
1. I felt at ease in flying the simulator	1	-	7	1	10	4	8	16
2. I felt rattled or uneasy in flying the simulator	11	19	10	1	5	1	0	-
3. I believe the lack of motion cues degraded the simulator training	1	N/A	2	N/A	5	N/A	7	N/A

APPENDIX A

MOTION SICKNESS QUESTIONNAIRE

2F87F MOTION SICKNESS QUESTIONNAIRE

Please check appropriate block: Instructor____ Student____

This questionnaire is designed to find out: (a) how susceptible to motion you are; and - (b) what sorts of motion are most likely to cause that sickness.

Section A is concerned with your childhood experience of motion sickness, that is, prior to the age of 12. Section B is concerned with your experience of motion sickness since the age of 12.

The correct way to answer each question is explained in the body of the questionnaire. Please read these instructions carefully as you go along. It is important that you should answer every question.

Your replies to these questions will be treated in the strictest confidence. Thank you for your help.

SECTION A

All questions in section A refer ONLY to your childhood experience of motion sickness (if any) where childhood is defined as the period prior to 12 years of age. It is quite possible that you will have difficulty recalling childhood motion sickness, nevertheless, please try to answer the questions to the best of your ability.

1. Indicate approximately how often you traveled on each type of conveyance or platform (before age 12) by using one of the following numbers:

0 - no experience
1 - less than 5 trips
2 - between 5 and 10 trips
3 - more than 10 trips

Cars	Buses or Coaches	Trains	Airplane	Small Boats	Ocean Liners	Swings	Merry Go Round	Roller Coasters

Considering ONLY those types of transportation that you have marked 1, 2, or 3 (i. e. those that you have traveled on), go on to answer the two questions below. Use the following letters to indicate the appropriate categories of responses: N - Never; R - Rarely; S - Sometimes; F - Frequently; A - Always

	Cars	Buses or Coaches	Trains	Airplane	Small Boats	Ocean Liners	Swings	Merry Go Round	Roller Coasters
2. How often did you feel sick while traveling, i.e., queasy or nauseated?									
3. How often were you actually sick while traveling, i.e., vomiting?									

SECTION B

Section B is concerned solely with your experience of motion sickness (and travel) <u>SINCE</u> the age of 12. Please answer the questions in exactly the same way as in Section A.

1. Indicate approximately how often you traveled on each type conveyance or platform (since age 12) by using one of the following numbers:

0 - no experience
1 - less than 5 trips
2 - between 5 and 10 trips
3 - more than 10 trips

Cars	Buses or Coaches	Trains	Airplane	Small Boats	Ocean Liners	Swings	Merry Go Round	Roller Coasters

Considering <u>ONLY</u> those types of transportation that you have marked 1, 2, or 3 (i.e. those that you have traveled on), go on to answer the two questions below. Use the following letters to indicate the appropriate categories of responses: *N- Never; R - Rarely; S - Sometimes; F - Frequently; A - Always*

	Cars	Buses or Coaches	Trains	Airplane	Small Boats	Ocean Liners	Swings	Merry Go Round	Roller Coasters
2. How often did you feel <u>sick</u> while traveling, i.e., queasy or nauseated?									
3. How often were you <u>actually sick</u> while traveling, i.e., vomiting?									

SECTION C

1. Please give a rough approximation of the number of flight hours you have had in military aircraft:

   a) while piloting the aircraft ________

   b) as a crew member ________

   c) as a passenger ________

2. In flight conditions that tend to produce airsickness in others, how often were you airsick in military aircraft prior to getting your wings?

   Never________ Rarely________ Sometimes________ Often________ Almost always________

3. In flight conditions that tend to produce airsickness in others, how often have you been airsick in military aircraft since getting your wings?

   Never________ Rarely________ Sometimes________ Often________ Almost always________

4. Do you ever experience episodes of dizziness or poor balance in your normal, everyday life? YES____ NO____

5. *Have you ever taken a medication like dramamine for motion sickness?* YES____ NO____

6. What do you think your chances of getting sick would be in an experiment where 50% of the subjects get sick?

   I almost certainly would ________
   I probably would ________
   I probably would not ________
   I almost certainly would not ________

7. Would you volunteer for an experiment where you knew that:

   85% of the subjects did get motion sick? YES_____ NO_____
   75% of the subjects did get motion sick? YES_____ NO_____
   25% of the subjects did get motion sick? YES_____ NO_____

8. While viewing wide-screen movies (like cinerama) involving external views from within moving vehicles, have you experienced:

   a) sickness feelings? Never_____ Rarely_____ Sometimes_____ Often_____ Almost always_____
   b) distrubance? Never_____ Rarely_____ Sometimes_____ Often_____ Almost always_____

SECTION D

To determine whether or not you feel that there were certain effects connected with the P-3 simulator (Device 2F87F) training, please check the appropriate blocks.

A. During or after the simulator session, I experienced:

1. Sickness feeling	None	___	___	___	___	___	Strong
2. Tiredness or drowsiness	None	___	___	___	___	___	Extreme
3. Unsteadiness	None	___	___	___	___	___	Extreme
4. Headache	None	___	___	___	___	___	Bad
5. Other*	None	___	___	___	___	___	Strong
6. Disturbance after the simulator session lasted	None	30 min or less	1 hr or less	2 hr or less	3 hr or less	4 hr or less	4 hr or more

* Explain Other:

B. Circle appropriate items to indicate your feelings about the simulator:

1. I felt at ease in flying the simulator:	not at all	somewhat	moderately	very much so
2. I felt "rattled" or "uneasy" in flying the simulator:	not at all	somewhat	moderately	very much so
3. I believe the lack of motion cues degraded the simulator training	not at all	somewhat	moderately	very much so

PLEASE WRITE ANY ADDITIONAL COMMENTS ON THE REVERSE SIDE.

APPENDIX B

SCORING PROCEDURES FOR SECTIONS A AND B OF THE MSQ

SCORING THE MSQ

Each section is scored separately and yields two subscores, which are summed for a section score. The two section scores are then summed to yield a total score, the MSQ.

Scoring is done with the aid of the following conversion table:

Experience Level	Frequency of Report R	S	F	A
1	2	4	6	8
2	3	5	7	9
3	4	6	8	10

Example: A subject has reported Section A as follows:

Question	Cars	Buses or Coaches	Trains	Airplanes	Small Boats	Ocean Liners	Swings	Merry Go-Round	Roller Coasters
A1	3	2	2	3	3	0	3	3	3
A2	S	R	R	R	N	0	N	N	N
A3	R	R	N	R	N	0	N	N	N
SCORE									
A1 & A2	6	3	3	4	0	0	0	0	0
A1 & A3	4	3	0	4	0	0	0	0	0

Determine the cell score for "nausea in cars" by determining the experience level from A1. This is 3. The frequency is S. Enter the table and read the weight 6 at the intersection of Row 3 and Column S. Repeat for the remaining cells in Lines A1 and A2. Determine the cell score for "vomiting in cars." The experience level is 3. The frequency is R. Read the weighted score 4 at the intersection of Line 3 and Column R. Enter the weight on the "Vomiting" line under "Cars" as indicated. Note that 0 experience level and/or N frequency always lead to a zero cell score.

Sum the nausea weights to obtain the "corrected frequency score" for nausea" 6 + 3 + 4 = 16. Sum the vomiting weights to obtain the "corrected frequency score" for vomiting: 4 + 3 + 4 = 11. Determine the number of types of motion experienced: 9 - 1 = 8.

The total section score is obtained as follows:

SCORING THE MSQ (continued)

$$\text{Section Score} = \frac{\text{Sum of the corrected frequency scores}}{\text{No. of types of experience}} \times 9$$

$$= \frac{16 + 11}{8} \times 9 = 30.4 \text{ (to the nearest tenth).}$$

The procedure is then repeated for Section B. Let us assume the section score for B is 12. The Motion Sickness Quotient is then obtained by summing the section scores:

$$\begin{aligned} \text{MSQ} &= \text{Section A score} + \text{Section B score} \\ &= 30.4 + 12 = 42.4 \end{aligned}$$

Source: NAMRL

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