Research Report 1197

EFFECTIVENESS OF A MAP INTERPRETATION AND TERRAIN ANALYSIS COURSE ON NAP-OF-THE-EARTH NAVIGATION TRAINING OF CREWCHIEF/OBSERVERS

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U. S. Army
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This report documents the training effectiveness of a map interpretation and terrain analysis course (MITAC) in enhancing the nap-of-the-earth (NOE) navigation skills of scout helicopter crewchief/observers in Europe. A two-group transfer of training study showed that MITAC trained enlisted crewchief/observers could navigate a scout helicopter while flying NOE with almost twice the speed and 35% fewer errors as untrained crewchief/observers. These data are compared with similar data from student aviators obtained in the U.S.

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It was concluded that MITAC could be used effectively to train crewchief/ observers to navigate NOE and that MITAC could be used to train both aviators and nonaviators in Europe.

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Methods

FOREWORD

The U.S. Army Research Institute (ARI) Field Unit at Fort Rucker, Ala., provides support to the U.S. Army Aviation Center (USAAVNC) in the area of aviation training research and development. The research reported here and in Research Reports 1198 and 1199 was performed as part of the ARI Field Unit's nap-of-the-earth (NOE) research efforts to design and conduct studies to determine the training requirements for NOE flight and to develop and evaluate prototype training programs.

The entire aviation training research and development program is responsive to the requirements of Army Project 2Q763743A772, Aircrew Performance Enhancement in the Tactical Environment, and the Directorate of Training Developments, USAAVNC, Fort Rucker, Ala.

Special thanks are due to the 3rd Combat Aviation Battalion (CAB) stationed at Harvey Barracks Army Airfield, Kitzingen, Germany. The 3rd CAB provided the experimental participants, aircraft, instructor pilot, and other resources required for the study.

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EFFECTIVENESS OF A MAP INTERPRETATION AND TERRAIN ANALYSIS COURSE ON NAP-OF-THE-EARTH NAVIGATION TRAINING OF CREWCHIEF/OBSERVERS

BRIEF

Requirement:

To evaluate the effectiveness of a course of instruction entitled Map Interpretation and Terrain Analysis Course (MITAC) in training scout helicopter crewchief/observers to navigate while flying nap-of-the-earth (NOE). It also sought to determine the value of MITAC in teaching NOE navigation using German maps while flying over German terrain.

Procedure:

MITAC was evaluated for training effectiveness in a two-group transfer of training study conducted in Germany. One group of crewchief/observers received MITAC training. The second group received no special training. Both groups were given an inflight evaluation of NOE navigation skills in a scout helicopter flying NOE.

Findings:

By all measures of NOE navigation performance (accuracy, speed, fatal errors, and a composite score), the MITAC-trained group was superior to the control group. The MITAC group navigated with almost twice the speed and with 35% fewer errors as the control group. MITAC was also effective in training these navigation skills for use with German maps while flying NOE over German terrain.

Utilization of Findings:

It is recommended that MITAC be used to teach NOE navigation skills to all nonaviators that have an NOE requirement. Furthermore, it is recommended that MITAC be used to train NOE navigation with European maps for use over European terrain.

EFFECTIVENESS OF A MAP INTERPRETATION AND TERRAIN ANALYSIS COURSE ON NAP-OF-THE-EARTH NAVIGATION TRAINING OF CREWCHIEF/OBSERVERS

CONTENTS

LIST OF TABLES

EFFECTIVENESS OF A MAP INTERPRETATION AND TERRAIN ANALYSIS COURSE ON NAP-OF-THE-EARTH NAVIGATION TRAINING OF CREWCHIEF/OBSERVERS

INTRODUCTION

This report documents the training effectiveness evaluation of a map interpretation and terrain analysis course (MITAC) in teaching nonaviators to navigate while flying nap-of-the-earth (NOE). MITAC was originally developed by the U.S. Army Research Institute (ARI) for training Army aviators to learn NOE navigation and to operate in a high threat environment.

MITAC is a course of instruction comprised of 13 exercises that are studied in sequence from an easy introductory lesson through lessons requiring all actual NOE navigation skills. Each unit presents instructional material for the exercise, the exercise itself, and a debriefing. The exercises require that students maintain orientation on a map while viewing a wide-angle motion picture film of an NOE flight.

MITAC is studied at the U.S. Army Aviation Center (USAAVNC) by all undergraduate student aviators and many graduate aviators. An evaluation of MITAC demonstrated its usefulness in teaching the skills required for NOE navigation to aviators and student pilots.

Although nonaviators can be taught to navigate NOE, it is not clear that MITAC would be useful in such an attempt. It is quite likely that nonaviators must learn many prerequisite skills taught to student pilots early in their training and before they receive NOE navigation training. Also in doubt is the training value of MITAC in European terrain with European maps. MITAC is based on maps made by the U.S. Defense Mapping Agency and uses CONUS terrain in the exercises.

OBJECTIVES

The study had two objectives:

1. To evaluate the training effectiveness of MITAC in teaching crewchief/observers NOE navigation.

2. To evaluate the training effectiveness of MITAC in teaching NOE navigation in European terrain with European maps.

METHOD

This study was a two-group transfer of training experiment. The subjects were 13 OH-58 scout helicopter crewchiefs stationed in Germany. The control group consisted of 6 crewchiefs randomly chosen from this group. Except for the inflight navigation test, the control subjects were given no special treatment and went about their duties as usual. The experimental group consisted of 7 randomly chosen crewchiefs who received MITAC training. Approximately 20 hours were spent in studying the 13 MITAC lessons.

At the conclusion of MITAC training, both groups were given an inflight NOE navigation test. Each crewchief was given a map marked with a standard NOE route. The crewchief was then given time to study and prepare for the inflight evaluation. The NOE navigation test was conducted in an OH-58 scout helicopter flown by an instructor pilot (IP). The crewchief navigated the helicopter while the IP flew it nap-of-the-earth as instructed by the crewchief. The IP recorded all navigation errors, reoriented the crewchief after noncorrected errors, recorded the time taken to fly the route, and insured flight safety.

RESULTS AND CONCLUSIONS

MITAC is an effective training program to train scout helicopter crewchief/observers to navigate while flying NOE. This conclusion is based on the direct comparison of NOE navigation performance between MITAC-trained crewchiefs and untrained crewchiefs and the indirect comparison between these two groups of crewchiefs and similarly trained student aviators.

The MITAC-trained group navigated the NOE route at almost twice the speed and with 35% fewer errors as the untrained control group. The control group averaged two fatal errors per crewchief. Fatal errors were defined as navigation errors (deviations from the selected route) of more than 1,000 m that almost certainly would not have been corrected and would have resulted in mission failure. Only 1 of the 7 MITAC-trained crewchiefs made a single fatal error. All the differences mentioned above were statistically significant by analysis of variance at $p < .01$.

MITAC is an effective training program for use in Europe. This conclusion is based on the evaluation of its use in Germany.

This study does not provide a direct comparison of the relative training value of MITAC in Europe and America. However, the NOE navigation flight tests were conducted over German terrain using German tactical maps. The results show that MITAC was effective in training NOE navigation skills even though the training material (American) and test conditions (German) were different.

RECOMMENDATIONS

1. MITAC should be used to train both aviators and crewchief/observers to navigate while in NOE flight.

2. MITAC should be used in Europe as well as in CONUS.

TECHNICAL SUPPLEMENT

Nap-of-the-earth (NOE) flight is a tactic that takes advantage of the masking effect of terrain and vegetation to prevent the enemy from detecting a helicopter. NOE flight is conducted as close to the earth's surface as is possible. Speeds varying from a hover to the maximum speed of the aircraft are used over a route selected to maximize masking behind terrain features and vegetation.

NOE flight requires two pilots: one to fly the aircraft at minimum altitude while avoiding obstacles by direct visual means, and the second to navigate by pilotage from a 1:50,000 scale tactical map. The second pilot also monitors engine instruments and performs any other tasks requiring that the first pilot shift attention inside the aircraft.

Early researchers of nap-of-the-earth flight discovered that in-flight navigation was a serious problem (Saathoff, 1974; Wright & Pauley, 1971) and that the problem was due to the lack of specific skills. Fineberg, Meister, and Farrell (1978) identified these skills as map interpretation and terrain analysis skills which are not taught in the usual Army map reading courses. These special skills are required for NOE navigation due to the difference in perspectives between the map presentation and the point of view of the NOE aviator, and the need to interpret in detail both the map and many natural terrain features while flying NOE.

The map is a representation of the world as it would appear from an altitude of several thousand feet. However, the NOE navigator is not looking down on the terrain from the perspective of the map. Rather, the navigator looks at the terrain from an almost ground level perspective. Properly relating features on the map to features on the ground despite this difference in perspective is one of the special skills required for NOE navigation.

Another skill is to recognize quickly a feature along the route of flight from its map representation. This requires training and practice in relating land forms such as hills, ridges, and other slopes to their proper map depiction in terms of contour lines and intervals. Likewise, recognition of vegetation, hydrographic, and other features must be learned.

The Army Research Institute (ARI) has developed a course of instruction entitled Map Interpretation and Terrain Analysis Course (MITAC) to teach Army aviators advanced map interpretation and terrain analysis skills. The course is designed to teach the critical skills required for successful NOE navigation. MITAC has been implemented at the U.S. Army Aviation Center (USAAVNC) and is an integral part of NOE training of all Initial Entry Rotary Wing (IERW) students and certain graduate aviators. Holman (1978) evaluated MITAC at the U.S. Army Aviation Center

(USAAVNC) and found it to be effective in teaching the skills required for NOE navigation. For example, a group of IERW students trained with MITAC navigated NOE routes with twice the speed and one-third the errors when compared with an equivalent group of IERW students not trained with MITAC.

The MITAC program consists of 13 instructional units studied in sequence. The program begins with an easy introductory lesson and continues through exercises requiring all actual NOE navigation skills. The exercises follow a pattern in which the student studies and prepares for the exercise, receives a preflight briefing, actively performs a navigation exercise, and is debriefed. A typical exercise requires the student to maintain orientation and perform some navigation task on a map while being "flown" over an NOE route using wide-angle motion pictures. A complete description of MITAC is contained in the Appendix.

Although MITAC is effective in teaching aviators to navigate while flying NOE, other Army personnel need these skills. The most obvious example is the crewchief of the OH-58 scout helicopter who flies with a pilot and acts as the scout observer and navigator. Other examples are helicopter-mounted battle captains and various ground commanders.

OBJECTIVES

A previous study has shown that MITAC is effective in teaching NOE navigation to aviators while flying over U.S. terrains. This study evaluated the effectiveness of MITAC in teaching NOE navigation to non-aviator, crewchief/observers in a European setting.

METHOD

This study was a two-group transfer of training experiment. The subjects were OH-58 crewchiefs, some with and some without MITAC training. The data were measures of inflight NOE navigation skill collected immediately after training.

Subjects

The subjects participating in this study were 13 OH-58 crewchiefs stationed at Harvey Barracks Army Airfield at Kitzingen, Germany. The experimental group consisted of 7 crewchiefs randomly chosen from the group of 13. The remaining 6 subjects made up the control group. None of the subjects was an aviator, but all were familiar with helicopter and NOE flight, the general terrain in the local area, and tactical maps. None of the subjects had received any special instruction in NOE navigation or in map interpretation.

Independent Variables

The main factor in this experiment was MITAC instruction compared to no instruction. The experimental group spent approximately 20 hours studying the 13 MITAC lessons. Control group subjects received no special treatment and performed their usual duties.

A second point of interest was the European terrain. Although a direct comparison between European terrain and maps and American terrain and maps was not possible, demonstrating the effectiveness of MITAC in Europe was an important part of this experiment.

Performance Measures

Current Army doctrine (Department of Army FM 1-1, Terrain Flying, 1975) requires that a navigator navigate a helicopter NOE within 100 m of a selected course line and be able to locate the aircraft's position to within an accuracy of 100 m. The NOE flight should be carried out at the highest possible speeds, consistent with navigation, masking, safety, and mission objective.

The data recorded inflight were the number and magnitude of course deviations over 100 m, errors in locating the endpoint of the NOE route, the length of the route that was flown, and the elapsed time spent navigating the route. These data were recorded by the check pilot on each subject's map.

Derived measures were average speed, errors per kilometer, mean error magnitude, number of fatal errors per subject, and a composite measure of terrain navigation skill (TENAV). The TENAV score combines the number of errors, their magnitudes, speed of flight, and the length of the route into a single score according to the following equation:

$$\text{TENAV Score} = \frac{\Sigma E^{1.3} + 100^{1.3}}{D \times S^{.8}} . \qquad (1)$$

E = a navigational error (course deviation, endpoint, error) in meters.

D = the length of the course navigated in kilometers.

S = the average speed of the NOE flight in kilometers per hour.

The exponents were derived from the results of a magnitude estimation study using NOE instructor pilots as subjects (Holman, 1978b).

Fatal errors were errors that almost certainly would not have been corrected and would have resulted in mission failure. An error was considered fatal when the crewchief directed the aircraft off course by 2 km and continued to so direct the aircraft without realizing that the aircraft was off course. Because the same route was used by all subjects in this test, fatal errors are summarized as a mean over subjects in each group.

Operational Procedures

MITAC. The MITAC training program was presented to the seven experimental crewchief/observers over a period of 4 days. Actual instruction required approximately 20 hours.

Inflight Data Collection. Each of the 13 participating crewchiefs was given an inflight NOE navigation test at the end of the MITAC training program. An 18 km NOE route was selected and surveyed for hazards and suitability for the test. The test was conducted and data collected by an NOE instructor pilot flying an OH-58.

The crewchiefs were given a map with the NOE route marked on it the day before their flight test to give them ample time to study the map and route. At the time of the test, the check pilot flew each subject to the initial point of the route and made certain the subject was oriented. The check pilot then flew NOE along a course and at the speed directed by the crewchief being tested. If the crewchief directed the aircraft off the route by 1,000 m to 2,000 m, the check pilot would return to the route, reorient the crewchief, and continue the test. At the end of the test, the check pilot would mark the crewchief's actual course on the map, record the elapsed time on route, and make any other appropriate comments. The map was then collected for data analysis.

RESULTS

The data were analyzed using the Statistical Package for the Social Sciences (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975). This package contains the required subprograms for the descriptive statistics and analysis of variance.

Table 1 summarizes the results in terms of means and standard deviations of each navigation performance measure. Before performing an analysis of variance, each measure was subjected to the F max test for homogeneity of variance. The TENAV scores were found to be heterogeneous. A log transformation was performed and homogeneity was achieved (Kirk, 1968). Tables 2 through 6 summarize the analysis of variance for each of these measures. A significant effect was found on each measure ($p < .05$). The coefficient of determination, R^2, indicates the proportion of the variance in the data that is accounted for by the difference between control and experimental group means.

Table 1

Means and Standard Deviations of Inflight Performance Measures for MITAC-Trained and Control Crewchief/Observers

Performance measure	MITAC		CONTROL	
	Mean	S.D.	Mean	S.D.
Speed (km/hr)	58	9.9	37	9.6
Errors per km	0.18	0.08	0.51	0.08
Error magnitude (m)	381	142	583	95
Fatal Errors	0.14	0.38	2.0	0.89
TENAV scores	17	8.8	140	74

Table 2

Analysis of Variance for Speeds

Source	df	MS	F	$p<$	R^2
Groups	1	1362	14	.003	.57
Error	11	95			

Table 3

Analysis of Variance for Number of Errors per Kilometer

Source	df	MS	F	p<	R^2
Groups	1	.335	48	.001	.82
Error	11	.007			

Table 4

Analysis of Variance for Error Magnitude

Source	df	MS	F	p<	R^2
Groups	1	131625	8.7	.013	.44
Error	11	15121			

Table 5

Analysis of Variance for Fatal Errors

Source	df	MS	F	p<	R^2
Groups	1	11.14	25.2	.001	.70
Error	11	0.44			

Table 6

Analysis of Variance for Log TENAV Scores

Source	df	MS	F	p<	R^2
Groups	1	2.56	73.8	.001	.87
Error	11	.035			

DISCUSSION

Speed

The MITAC-trained group navigated the NOE test route at slightly over 50% faster than the control group (58 km/hr vs. 37 km/hr). Table 2 shows that the large difference in performance between groups accounts for 57% of the variance in the speed data. This difference in speeds is due to the increased certainty of orientation on the part of the MITAC-trained crewchiefs. The less extensively trained NOE navigator is frequently unsure about aircraft position and spends more time on route. This is due to time spent flying slowly or hovering while trying to interpret the tactical maps and scanning the terrain in an attempt to recognize some feature. Additional time is also spent backtracking to known points and correcting navigational errors. The well-trained NOE navigator is seldom unsure of aircraft position, can interpret the map while the aircraft travels at higher speeds, and rarely searches for recognizable features since most of the surrounding terrain can be easily related to the map.

Number of Errors

The MITAC-trained group made 35% fewer errors than the control group (.18/km vs. .51 km). Table 3 shows that this difference in error rates is significant and accounts for 82% of the variance in the data. Again, this is due to the increased map interpretation and terrain analysis skills of the MITAC-trained crewchiefs. It is also what one would expect from better oriented navigators.

Error Magnitude

The number of errors made by the MITAC-trained group averaged two-thirds less than the number of errors made by the control group (381 m vs. 583 m). Table 4 shows that this difference is significant and accounts for 44% of the variance in the data. The magnitude of errors is a measure less sensitive to training in these test conditions for two reasons: most errors are small, 100 m to 500 m, with the more poorly trained navigators responsible for more errors; very large errors, those over 2,000 m, are limited in size because in the training or testing situation, the instructor pilot stops the student and returns to the course for reorientation at that point.

Fatal Errors

Fatal errors are defined as errors that almost certainly would not have been corrected and would result in mission failure. The control group averaged 28 times as many fatal errors as the MITAC-trained group. The crewchiefs in the control group averaged two fatal errors each, whereas only 1 of the 7 MITAC-trained crewchiefs made a single fatal error. Table 5 shows that the group difference accounts for 70% of the variance in the data.

TENAV Scores

The TENAV score is a composite score compiled from the number of errors, error magnitude, and speed averaged over the length of the route, as seen in equation 1. The mean TENAV scores for the MITAC and control groups were 17 and 140, respectively. The following examples will help put these scores in perspective.

A 15-km NOE route flown at 60 km/hr with no errors is a superior performance and receives a TENAV score of 1.0. A relatively good score of 4.8 could be obtained by flying the same course at 40 km/hr and making one error of 200 m. A marginally acceptable score of 9.0 is produced by navigating the 15-km route at 50 km/hr with one error of 435 m. This is the average score earned by a large group of initial entry rotary wing students at Fort Rucker after having received MITAC training in ground school plus 9 or 10 hours of inflight NOE navigation training. A score of 17, averaged by the MITAC-trained crewchiefs, could have been earned by navigating a 15-km course at 50 km/hr with errors of 250 m, 300 m, and 400 m. Although this is not an operationally acceptable skill level, it was obtained with no inflight training.

A large group of initial entry rotary wing students at Fort Rucker with 8 or 10 hours of NOE navigation flight training, but without MITAC training, averaged a TENAV score of 50. This score could be obtained by flying a 15-km NOE route at 26 km/hr while making errors of 250 m, 350 m, 450 m, and 550 m.

To complete the examples, the control group in the present experiment averaged a TENAV score of 140. This could have been earned by flying the route at 35 km/hr and making errors of approximately 200 m, 300 m, 400 m, 500 m, 600 m, 700 m, 800 m, and 1,200 m.

Table 6 shows that the difference in log TENAV scores accounts for 87% of the variance in the data. This accounts for a larger percentage of the variance than is accounted for by any of the three individual measures. This is due to the fact that the TENAV score was designed to compensate for differences in navigation style and to provide an equivalent score for navigation performance of different styles. For example, one navigator who navigates slowly and makes few or small errors can score the same as another navigator who navigates faster and makes more or larger errors.

European Terrain and Maps

This study does not provide a direct comparison of the relative training value of MITAC in Europe and America. However, the NOE navigation flight tests were conducted over German terrain using German 1:50,000 scale topographic maps. The results show that MITAC was effective in improving NOE navigation performance even though the training material (American) and test conditions (German) were different. The skills learned in MITAC can be generalized to other maps and other types of terrain.

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APPENDIX A

COURSE DESCRIPTION

Following is a summary of the training materials and procedures that were developed for this course. The facilities and equipment required to implement the course are also specified.

INSTRUCTIONAL AIDS

TEXT: Map Interpretation in Nap-of-the-Earth Flight

A monograph on map interpretation as it applies to Army aviation was especially prepared for this course and serves as a basic text. The instructional content of this text will not be found in any existing manual. It is not intended to replace existing manuals, but supplements them by focusing on the use of maps in the specific application of visual pilotage during terrain flight.

The special text was needed mainly because cartographers apply a great many conventions and selection criteria in compiling any kind of map, and they have a direct impact on the Army aviator's ability to interpret the information shown on the map. However, few map users, even highly experienced aviators, have any idea of what these conventions and criteria actually are. For example, the basis for the selection and classification of roads, the coding criteria for vegetation cover, the ground rules followed by the cartographer in delineating relief and drainage, the conventions used for grouping cultural features under standard symbols, the generalization and displacement practices in cartographic drafting, the geodetic accuracy limitations, the seasonal base, and many other factors that enter into the process of compiling a topographic map are all largely unknown to Army aviators. None of this information will be found in map legends or existing texts on map reading. Yet, without such knowledge, accurate map interpretation cannot be performed. Furthermore, the factors that influence how the map is designed must then be related to the factors that influence the visibility and appearance of features seen on the ground during terrain flight. The text supplied with this course is designed to fulfill this need.

Copies of the text should be distributed for assigned reading at the very outset of the course. The instructor can then review and amplify the main points in his initial lectures.

Lecture Aids

A series of 131 35-mm color transparencies are provided for use as teaching aids in lectures on map interpretation. These may be supplemented by slides from the school's files and by slides made from the figures contained in the instructional text.

The slides were selected mainly to illustrate the variations in actual appearance of features which are portrayed by standard symbols on topographic maps. They also illustrate some of the factors that influence the visibility of certain kinds of features and which provide cues to their detection and identification. Some of the slides are included to illustrate the manner in which certain features are portrayed on topographic maps.

The slides cover the following subjects:

- hydrography (Part 1: streams),
- hydrography (Part 2: ponds and reservoirs),
- vegetation,
- railroads,
- roads,
- buildings, and
- miscellaneous cultural features.

The selection of slides should by no means be considered a complete set of visual aids for map interpretation lectures. This collection of slides can be supplemented by additional photography or from existing slides and map samples.

A suggested narrative is included with the slides. The instructor may either use it directly or as a frame of reference from which he prepares his own narrative.

It should be noted that these lecture aids do not deal with the subject of contour analysis or other aspects of the interpretation of terrain relief. That subject is covered in the text and is amplified in the special exercise described below.

Contour Analysis (Route H-1)

This exericse is designed to supplement instructional lectures on contour analysis by exercising the student's skill in correlating landforms in the visible terrain with the contour-line portrayal on conventional topographic maps. A 35-mm slide showing the forward visual field as seen from a helicopter at NOE altitude is presented on one screen. A vu-graph transparency of a map of the general area is presented on an adjacent screen. Five alternative positions are marked on the map, one of which is the correct position from which the photograph was made. The students are told the heading and MSL altitude of the aircraft. Their task is to study the landforms appearing in the slide presentation, correlate them with the contour portrayal on the map, and decide which of the five choices marks the correct position. Each student in the class independently makes his choice and marks it on a response sheet. After all five items are completed, the choices are compared, and students who reached different conclusions discuss or defend their choices. The instructor guides the discussion, gives the correct answer, and presents the main map-interpretation points (if these have not already been raised by the students themselves) that should lead the student to the correct answer or to the rejection of the wrong answers. The five alternative positions are selected so as to illustrate basic principles of contour interpretation. A tape-recorded commentary is provided for each item, which describes the general principles illustrated by the item and the specific contour analysis cues that apply to that item. The tape can be directly played in the feedback session or can be used by the instructor to guide his own commentary.

Five sets of contour interpretation problems have been prepared for this exercise. The 35-mm slides are blowups of individual frames from a 16-mm film of a flight over the area. At the conclusion of the feedback session, a vu-graph is presented in which the five correct answers are connected with a course line and, on the adjacent screen, the 16-mm film of the entire flight is presented to illustrate how the contour interpretation task fits into the dynamic mission context. The time required to run the exercise is a direct function of the amount of time allotted for each problem set.

PRACTICAL EXERCISES

The bulk of the program consists of materials and procedures for developing map interpretation skills through practical exercises using simple cinematic simulation methods. After an introductory session, the practical exercises proceed through four stages. The first deals with the skills involved in preflight map study, the second introduces the student to enroute orientation by requiring him only to maintain orientation along a prescribed route of flight and to identify pre-selected checkpoints along that route, the third escalates the orientation task to a more difficult level by requiring the student to recognize when, and by how much, the simulated flight deviates from a planned route, and the final level presents the student with the more formidable map-interpretation task of maintaining orientation within a corridor of operations, a task that approaches the operational requirement. Following are brief descriptions of these exercises.

Introductory Film and Practice Session (Routes H-3 and H-4)

An introductory film has been prepared which should be presented before the practical exercises are undertaken. This film consists of two short flights over routes that are only a few hundred meters apart in lateral separation. The film and a tape-recorded commentary that accompanies it illustrate how the terrain can appear totally different at very low altitudes as a consequence of small navigational errors, and should reinforce the student's appreciation of the need for precise, continuous orientation during terrain flight. In addition, the film introduces the student to the field-of-view and resolution characteristics of the films themselves, since these are important considerations in some of the subsequent training exercises.

Preflight Terrain Analysis (Routes R-29 and H-10)

The first series of exercises is designed to develop the student's ability to select useful checkpoints and orientation cues during preflight planning. It is especially aimed at teaching the student to predict, on the basis of map study, which of the portrayed features will be visible and which will not be visible from a helicopter flying NOE along a specified route.

The student is given a map plate on which is drawn a planned route. Various features portrayed on the map in the vicinity of the route are designated by means of a numbered overlay. The student is required to study the map, paying particular attention to the probable masking effects of terrain and vegetation, and to indicate on a checklist which of the numbered features he predicts would be visible during NOE flight along the designated route. He also selects the features that he believes would be the most reliable checkpoints for a mission along that route. Then the student is stationed in a rear-projection chamber and the film simulating flight over that route is presented. During the flight, the student marks on the map the features that he actually is able to see and identify. The instructor then scores the student's prediction checklist by means of a special template key and derives two types of scores: the percentage of features the student predicted would be visible but which were not, and the percentage of features he predicted would not be visible, but in fact were visible. In addition, the student compares his map marked with the features he actually saw and identified with his preflight predictions.

Following a discussion of his performance with the instructor, the student goes to the debriefing room, which has two projection screens. On one screen the filmed flight is replayed in slow motion and stop action; on the other screen a vu-graph of the map and inscribed route is presented. A tape-recorded commentary is played which relates the visual scene to the map portrayal and shows how the general principles of map interpretation apply to this specific mission simulation. The commentary focuses on how the visibility of various features (or lack of visibility) could have been predicted from proper map interpretation, the various physical appearances of features portrayed in standard form on the map, and the manner in which features are selected for portrayal. In the final step of this exercise, the student is returned to the rear-projection chamber and the filmed flight is presented again (in real-time simulation), so that he can reexperience the flight from an enlightened perspective.

In the terrain analysis exercise described above, geographic orientation is not an important requirement, the actual track of the flight is portrayed and exact groundspeed information is provided, the emphasis is on preflight map study and the basic objective is to teach the student to make realistic appraisals of the checkpoint features he can expect to see during terrain flight operations.

Two complete terrain analysis exercises have been prepared, one for the Fort Rucker area (R-29) and one for the Hunter Liggett area (H-10). The former can be conducted using either the pictomap or the Air Movement Data (AMD) map. The latter can be conducted using either a conventional 1:50,000-scale topographic map or various forms of orthophotomaps.

Along-Track Orientation (Routes R-28a and H-11b)

The student is given a map plate on which a route of flight is marked and is told that he will fly that route at a given speed, plus or minus five knots. Along the route a series of preselected checkpoints has been marked. The student first performs a preflight terrain analysis and map study, after which a tape-recorded commentary provides feedback on the adequacy of his preflight study and points out the conclusions that should be reached (and why) from the map portrayal along the planned route. Then the student is stationed in the rear-projection chamber and a film is presented which simulates flight over the designated route. The student's task is to record the projector frame count the instant the flight passes over each designated checkpoint in turn. (Some of the preselected checkpoints will not actually be visible in the film, but if the student has learned from the preceding terrain analysis exercise, he will be able to predict this and respond on the basis of associated cues or time-distance estimates of position.) The response record indicates the frame count at the moment of the student's response and, by referring to a scoring table, the instructor records the student's along-track orientation performance in terms of meters discrepancy between the actual and designated positions of each checkpoint. These discrepancies are then plotted in graphic form on a special performance score sheet.

Following the simulated flight, a knowledge-of-results and debriefing session is conducted similar to that described above for the terrain analysis exercises. The debriefing commentaries emphasize the type of features that are most useful for time checks or along-track position fixes. Two complete along-track orientation exercises have been prepared, one in the Fort Rucker area (R-28a) and one in the Hunter Liggett area (H-11b).

Cross-Track Orientation (Routes R-30a and H-14)

The student is given a map plate on which a route of flight is marked and is told to assume that it represents his planned route. He is further informed that his actual track in the simulated flight may be offset to the right or left of the planned route marked on his map, but will always be parallel to it. The student's task will be to determine as quickly and accurately as possible the cross-track deviation (if any) between his planned route and actual track. He is given an accurate groundspeed and allowed a period of preflight study. Following a feedback commentary on his preflight map study, he is stationed in the rear-projection chamber and the film is presented which simulates flight over a parallel, but offset, route. At one-minute intervals, the instructor calls for a "mark," at which time the student responds by marking on the map a numeral that indicates his estimate, in hundreds of meters right or left, of any cross-track deviation between his planned and actual routes of flight. If he should conclude that there is no deviation, he marks a zero to indicate "on course." If he is disoriented or otherwise cannot determine his actual route or flight, he marks an X on the map to indicate "no call."

When the simulated flight is completed, the instructor enters the student's responses on a graphic score sheet, which also shows the correct responses to provide knowledge of results to the student concerning his performance. Then the flight is replayed in the debriefing room, along with a tape-recorded commentary that points out the key features that should have been used for determining cross-track deviations. During the replay, a map is projected which shows both the "planned" course and the actual track of the filmed flight. Two complete cross-track orientation exercises have been prepared, one in the Fort Rucker area (R-30a) and one in the Hunter Liggett area (H-14).

Corridor Orientation (Routes R-25, R-27, H-7, and H-13)

The two preceding classes of orientation exercises are designed to introduce the student to the elements of geographic orientation by restricting the position-fixing task to only one dimension at a time. The third class, corridor orientation, is considerably more difficult and requires the student to exercise the full range of his map-interpretation skills.

The student is given a map plate on which is marked a corridor of operations 3,000 meters in width. At one end of the corridor is marked a starting vector which designates the initial position and heading of the aircraft. He is informed that the simulated flight will proceed from the starting vector through the corridor. He is given the groundspeed of the aircraft and told that the flight may go anywhere within the corridor, but will not double back on itself and will not go outside the bounds of the corridor. The student's task will be to maintain geographic orientation during the flight by means of visual pilotage and to mark, on demand, the position of the aircraft at various intervals during the flight.

A period of time is provided for the student's preflight terrain analysis and map study, during which he may mark time hacks or any other preflight annotations he wishes on the map. At the completion of his preflight map study, a briefing is presented which reviews the procedures the student should have followed and discusses the conclusions he should have reached. The briefing includes a terrain analysis, the identification of major orienting cues within the corridor, potential barrier features and funnels, probable visibility ranges of features including major terrain features outside the corridor boundary, the hierarchical ordering of potential checkpoints, and a general orientation plan.

After the briefing, the student is stationed in the rear-projection chamber and the film simulating the flight is presented. Periodically during the flight, a position mark is called for, at which time the student marks his present position on the map as accurately as he can. The student is also periodically informed of the aircraft's heading. Following the simulated flight, the instructor scores the student's performance by means of a plastic map overlay on which are inscribed concentric circles at 100-meter intervals around the actual position of the aircraft at each response-demand point. The student's performance score is the absolute discrepancy between his mark and the actual position of the aircraft. (Additional scores for along-track and cross-track orientation errors can also be measured.) A feedback session in which the instructor and student compare the student's reported positions with the actual positions is followed by the debriefing.

During this debriefing, the filmed flight is replayed in slow motion and stop action, while a tape-recorded commentary describes the main orienting cues along the route and explains how the visible features can be related to the map portrayal. Specific examples or applications of those map-interpretation principles used for precise and/or general in-flight orientation are highlighted. Following the debriefing, the student reenters the rear-projection chamber; this time with a map plate which shows the actual track and the mark points (position-demand points); and the filmed flight is presented again in real time so that the student experiences the flight under completely oriented conditions, thus reinforcing the instructional points made earlier.

Four complete exercises in corridor orientation have been prepared, two in the Fort Rucker area (R-25 and R-27) and two in the Hunter Liggett area (H-7 and H-13). The exercises can be conducted using pictomaps or AMD maps in the Fort Rucker area and with conventional topographic line maps or orthophotomaps in the Hunter Liggett area.

FACILITY AND EQUIPMENT REQUIREMENTS

Following is a specification of the facilities and equipment that would have to be supplied by the training unit to use the materials and implement the program described above.

Briefing/Debriefing Room

An ordinary classroom that can be darkened for movie and slide projection is needed for the debriefing phases of the training exercises and for the instructional sessions. The room should be equipped with two front-projection screens mounted side by side. The following equipment will be needed.

- o 35-mm slide projector with carousel and remote control cord.
- o Vu-graph transparency projector.
- o LW Photo-optical Data Analyzer 16-mm projector Model 224-A-Mk IV. This unit should be equipped with a frame-count readout and a remote control cord which permits variable frame-rate operation of the projector plus stop action and manual single-frame advance. The focal length of the lens should be sufficiently short to permit an image of at least three feet wide to be projected within the confines of the classroom. The Somco No. 6270 1" f/1.9 lens would probably be suitable.
- o Cassette tape playback unit.

The classroom should be arranged so that the group of students can view both screens, one of which will present the motion-picture film or 35-mm slide while the other presents a vu-graph of the map plate. The instructor will have to be stationed so that he can operate the control unit for the Analyst Projector and point out features on the projected map. This latter function can be performed either directly on the vu-graph transparency or by means of a flashlight pointer on the projected image.

Rear-Projection Chamber

Most of the training exercises are designed to be conducted in a rear-projection chamber of the type illustrated in Figure A-1. As noted

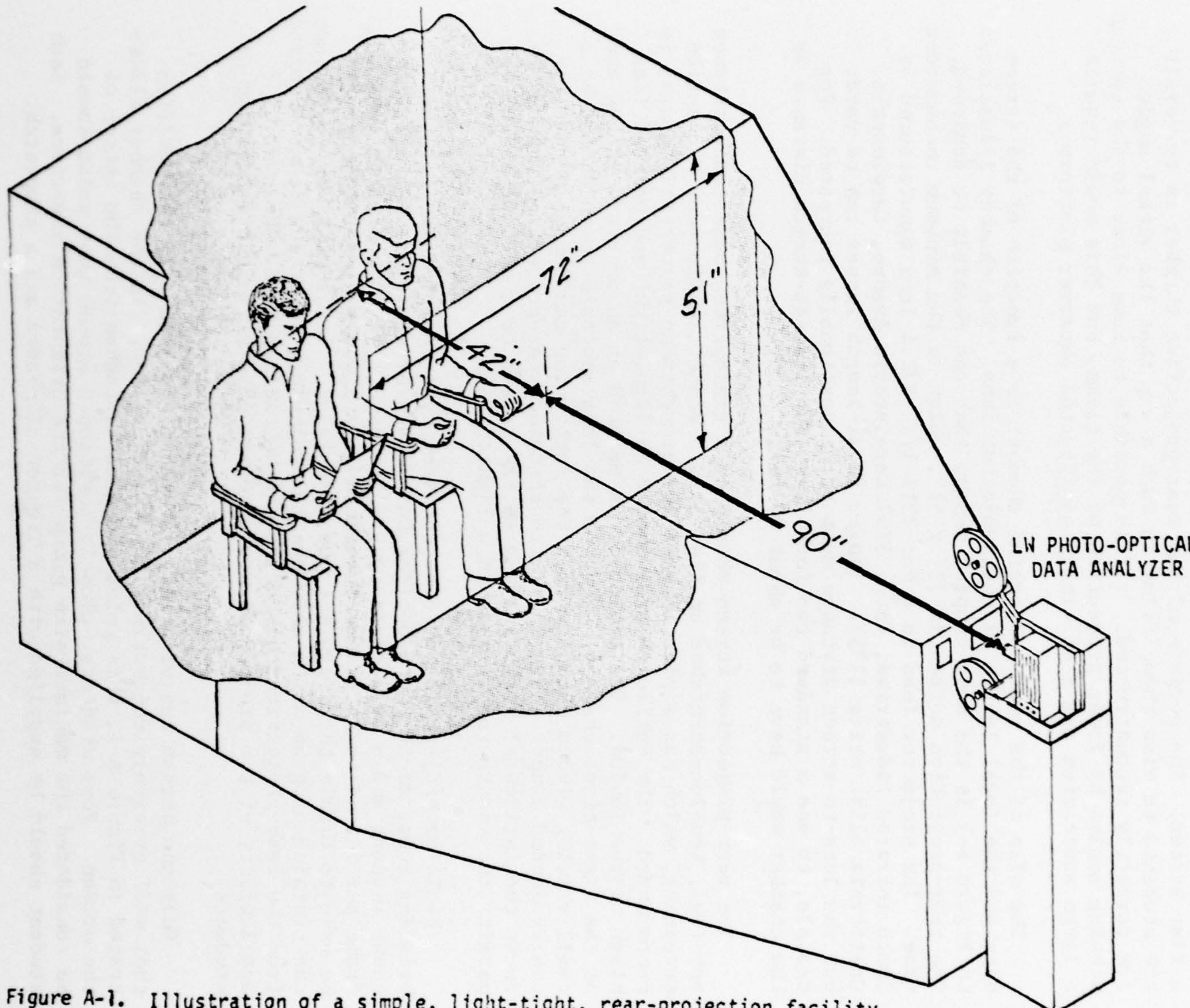

Figure A-1. Illustration of a simple, light-tight, rear-projection facility.

earlier, all of the 16-mm photography used in this program covers an 85° x 67° visual field that can be projected without distortion onto a flat screen. The purpose of the rear-projection chamber is to permit the students to view these films in such a way that the visual angles are correctly reconstructed. (It is possible to come close to the correct viewing angles by front projection of the films, but this would require a large auditorium and a specially constructed observer platform.)

The size of the rear-projection chamber is a function of the screen size and the focal length of the projector lens. The chamber illustrated in Figure A-1 is the most compact design that can feasibly be achieved. The rear-projection screen is 72" x 51", which is the minimum recommended size. The projector lens is a No. 3311 1/2" f/2.4 lens manufactured by Somco Infrared Industries, Inc., 6307 Carpinteria Avenue, Carpinteria, California (list price $135). Longer focal-length lenses can be used, but the lens-to-screen distance must be proportionally increased. For example, to use a standard two-inch lens, the lens-to-screen distance in the chamber would have to be about 30 feet.

The rear-projection screen should be a grain-free, high transmittance material, tension-stretched on its frame. Bodde transluscent projection screening, which has a plastic base and presents no perceptible grain, is recommended. The entire chamber should be light-tight and painted flat black on the inside. The projector is mounted at an aperture in the end of the light-tight chamber. Next to the lens aperture there should be a small viewing window through which the instructor can focus and monitor the projected scene. This easily constructed rear-projection chamber reduces the incidental light falling on the screen to a minimum and also permits the instructor to work in a lighted room.

The 16-mm projector should be the same type as specified for the briefing room, an LW Photo-optical Data Analyzer equipped with a frame-count readout and a frame-rate control to permit variations from one frame per second to 24 frames per second. A 1,000-watt PFD lamp should be used to obtain the brightest possible image. It is possible to conduct the training program using only one LW projector, switching it as required from the rear-projection chamber to the debriefing room. However, the availability of two projectors would permit more efficient processing of students.

Only one person can view the rear-projected film from the position that will precisely reconstruct the visual angles. In the chamber illustrated in Figure A-1, this point would be 40 inches from the center of the screen. Four students, closely positioned around that point should be considered the maximum-size group for the orientation exercises. Each student should be supplied with a lighted clipboard and a stopwatch.

The rear-projection chamber should also be supplied with a cassette tape playback unit and a projector frame counter for the along-track orientation exercises.

Film-Handling Station

A facility will be needed for storing and handling the motion-picture films. This should be located near the rear-projection chamber and should include storage racks, rewind table, a hot splicer, and film cleaning supplies. Spare projection lamps should also be on hand.

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