EFFECTIVENESS OF THE C-130 WEAPON SYSTEM TRAINER FOR TACTICAL AIRCREW TRAINING

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ABSTRACT

Transfer of training from the C-130 WST to the aircraft was assessed in a Follow-on Operational Test and Evaluation (FOT&E). The study was accomplished in three phases corresponding to initial qualification (Phase I), mission qualification (Phase II) and continuation (Phase III) training. In the first phase the nature of skill acquisition and the impact of WST training were addressed using student copilots who were learning approaches, landings, and engine-out go-arounds. In the second phase, WST training effectiveness was assessed for lead and formation flight, maximum effort landings, and recoveries using mission qualification pilots. In the third phase, effectiveness for engine-out take-offs and windmill taxi starts was assessed using mission ready pilots. Training in the WST generally transferred positively to the aircraft as measured by proficiency ratings and by sorties to criterion. Recommendations for modifying the WST curriculum were made based on these results as well as other observations made during the FOT&E.

INTRODUCTION

Background

The Military Airlift Command (MAC) established a program to replace its aging C-130 training devices in order to enhance simulator training effectiveness and improve supportability. Ten C-130 operational flight trainers (OFTs) were procured from the Singer Company, Link Flight Simulation Division, as part of this program. Four were installed at Little Rock AFB, Arkansas, and the remaining six were deployed to operational C-130 units throughout MAC. One visual system was developed by the General Electric Corporation, Simulation and Control Systems Department, and integrated with the pilot production unit OFT at Little Rock AFB to form the C-130 Weapon System Trainer (WST). This paper describes the Follow-on Operational Test and Evaluation (FOT&E) of the WST which was requested by HQ MAC to evaluate the WST in its intended operational roles of initial qualification (Phase I) training, mission qualification (Phase II) training, and continuation (Phase III) training. The Air Force Airlift Center (USAFALCENT) directed this FOT&E, and the Air Force Human Resources Laboratory (AFHRL) provided assistance to evaluate WST training effectiveness. The 34th Tactical Airlift Training Group (34 TATG), which is responsible for initial qualification and mission qualification training, provided students, instructors, courseware, and on-site test management to support the evaluation of WST effectiveness for Phase I and Phase II training.

System Description

The C-130 WST is a full mission simulator designed to simulate the configuration and performance characteristics of a C-130E aircraft. As noted above, the WST was developed by integrating a C-130 OFT with a wide-field-of-view computer generated imagery (CGI) visual system. Both of these training devices are described briefly in the following paragraphs.

C-130 OFT. The C-130 OFT is an instrument flight simulator that provides a training environment for pilots, copilots, navigators, and flight engineers in a simulated C-130 cockpit that is mounted on a six-degree-of-freedom motion platform. The OFT is controlled from an onboard instructor/operator station that provides a variety of performance measurement and other features including monitoring and programming capabilities for initial conditions, demonstrations, malfunctions, and preprogrammed missions. The OFT can simulate engine electronics, autopilot, hydraulic pressurization, instrument flight, radar (using a digital radar land mass system), communication equipment, station keeping equipment (SKE), and primary and secondary flight controls. Tasks to be trained with this level of simulation include accomplishment of checklists, instrument flight (including take-off), departure, navigation, penetration, instrument approaches, normal and emergency procedures, and SKE operations including SKE formation flight, airdrop, escape and recovery.

C-130 WST. The WST is a C-130 OFT with a General Electric visual system that provides computer-generated imagery of out-of-the-window visual cues. This visual system can provide day, dusk, and night scenes, and presents the imagery using a six window, five channel color CRT display system with infinity optics. The field-of-view is approximately 230°

horizontally and 35° vertically. The visual data base used in this FOT&E portrays more than 33,000 square miles of terrain and cultural features surrounding Little Rock AFB including three airfield complexes, five airdrop/assault landing zones, and a combat training zone. The image generator is capable of generating 8000 visible edges and 4000 point lights simultaneously. Other features include surface texturing and the capability of generating seven moving models (aircraft, missiles, or land vehicles). With this visual system, simulator training has been expanded to include: visual approaches; landings; engine-out go-arounds; low level navigation; visual slow down, run in, airdrop, and escape; visual formation flying; hostile environment training; and special operations training.

C-130 WST Qualification Operational Test and Evaluation (QOT&E)

The visual system was delivered to Little Rock AFB in the spring of 1982 and integrated with the pilot production unit OFT to form the C-130 WST. HQ MAC tasked USAFALCENT to conduct a QOT&E on this device, in order to evaluate the operational effectiveness and suitability of the WST hardware, software, subsystems, and support systems; to evaluate performance, maintainability, and logistics supportability; to estimate the military utility; and to identify WST deficiencies. Eight aircrews flew scenarios in the WST designed to utilize the visual system capabilities. These crews rated the fidelity of the WST overall and the fidelity of both the OFT and the visual system separately, assessed the adequacy of the visual system data base and image generator to portray the real-world visual cues necessary to support training, and evaluated the capability of the WST to support the proposed syllabus. The final report of this QOT&E(1) concluded that the fidelity of the visual system was good, but noted the following deficiencies:

1. No taxi lines on ramp or taxi ways.

2. Lack of sufficient terrain contrast for low-level flying.

3. Lack of sufficient depth perception for landings and low altitude parachute extraction system (LAPES) airdrops.

4. Touchdown zone markers at the assault landing strip popped into view on short final.

5. Marker panels did not exist at the LAPES zone.

Finally, the report concluded that the visual system greatly enhanced simulator traning by providing the capability to train events that could not be trained in a non-visual simulator, including visual formation, taxi, windmill taxi start, drop zone run-in, assault take off and landing, LAPES, visual traffic pattern and landing, and inadvertant weather penetration without SKE. Corrective actions were taken to address most of the problems identified in the QOT&E prior to the start of the FOT&E.

Purpose

The primary purpose of this FOT&E was to determine the training effectiveness of the WST for visually-oriented events in order to provide information to help assess the value of visual systems for the nine remaining non-visual simulators. The evaluation was conducted in three distinct phases corresponding to initial qualification training (study 1), mission in qualification training (study 2) and continuation training (study 3). Visually-oriented tasks were selected for each phase of training. For most tasks one group of students received training of these specific tasks in the WST followed by inflight training. In order to ascertain transfer of training from the WST to the C-130, the performance of these crews inflight was compared to that of a second group that did not receive the simulator training.

STUDY 1 - INITIAL QUALIFICATION TRAINING

Method

Subjects. The subjects used in this study were 28 student copilots enrolled in the C-130 initial qualification course conducted by the 34 TATG at Little Rock AFB, AR. All subjects were assigned to the C-130 training program directly following graduation from undergraduate pilot training and none had prior C-130 flying experience.

Training Tasks. Phase I training tasks were conceptualized as falling into three categories. Some tasks involve no out-of-the-window visual components and presumably do not require a visual display for training. Other events have visual components but could conceivably be accomplished either with or without a visual system. Finally, some tasks are dependent on out-of-the-window cues and cannot be performed in the simulator without a visual system. This FOT&E focused on tasks in the last two categories. Student training records from several previous classes were analyzed to determine which tasks required the greatest number of sorties for students to reach criterion level performance. The events selected for evaluation in this phase of the FOT&E were those from the resulting list that were also perceived to be dependent on out-of-the-window cues. The tasks chosen were:

1. visual approaches
2. landings
3. engine-out go-arounds

Procedure. The 28 subjects were assigned to one or the other of two groups, with 14 in each. One of the groups (test) was trained in the WST and the other (control) was trained in the OFT prior to receiving training in the C-130 aircraft. Both groups went through training programs developed by the 34 TATG to meet the objectives of this phase of the C-130 WST FOT&E. In the resulting program, the control group received academic training followed by eight four-hour OFT training sessions, and

finally, flight training. The test group received the same training, except that six of the simulator training sessions were accomplished in the WST. The remaining two sessions were accomplished in OFTs because they involved operations that did not require the capabilities of the existing visual system data base. Copilots in the test group received an additional hour of training in visual approaches, landings and engine-out go-arounds following each of the WST training missions. The mean number of approaches accomplished was 57, ranging from 42 to 74 for individual students. The mean number of landings accomplished was 50, ranging from 33 to 61. For engine out approaches, the mean number of events accomplished was 6, ranging from 3 to 9 repetitions for individual students. Both groups were given a proficiency check in the simulator before advancing to flight training. The flying phase of training for both groups culminated in a MACR 60-1 flight evaluation.

Measures of Effectiveness. Data collected in this FOT&E included proficiency ratings, instructor input ratings, and selected performance parameters for each approach, landing, engine-out go-around. Proficiency ratings were the primary measures of effectiveness. The remaining information was collected to better define the nature of changes in proficiency.

a. Student Proficiency Ratings. Instructors rated student proficiency during all WST training sessions and all inflight training missions for approaches, landings, and engine-out go-arounds using the following five-point scale:

1 - Unable to accomplish

2 - Can do simple parts of the task.

3 - Can do most parts of the task.

4 - Can do all parts of the task, meeting minimum requirements.

5 - Can do the complete task quickly and accurately.

b. Instructor Inputs. The amount of assistance provided by the instructor during the training mission was rated for each of the three events of interest using the following five-point scale:

1 - Hands on assistance required.

2 - Substantial coaching required.

3 - Limited coaching required.

4 - Coaching only for technique.

5 - No input.

c. Performance Parameters. Instructors estimated deviations from desired values of specific parameters during each accomplishment of three critical tasks. For approaches, vertical and horizontal deviations at one-half mile from the runway and airspeed at threshold were recorded. For landings, roundout height as well as distance from centerline at touchdown, distance down the runway at touchdown, and crab at touchdown were recorded. For engine-out go-arounds, runway alignment and heading control were recorded.

Results

Two sets of results are presented in this section. The first set is concerned only with the performance of the test group students during WST training. It provides information with respect to the rate and level of learning demonstrated by the test group in the WST prior to transferring to the aircraft. The second set of results provides a variety of comparisons of the test and control groups during actual inflight training. The performance of the two groups is compared on each of the three critical tasks using instructor ratings of overall student proficiency, amount of instructor input during task accomplishment, and instructor estimates of individual performance parameters. In addition, relationships among the three types of measures are described.

Performance in the WST

The goal for this phase of training was to have all students meet or exceed a criterion of acceptable threshold proficiency for the three FOT&E tasks in the WST prior to progressing to the flight line phase of training. The criterion for threshold proficiency corresponds to a "4" rating on the student proficiency five-point scale. Figure 1 depicts the percentage of students that met this criterion for each task on each WST training session. The

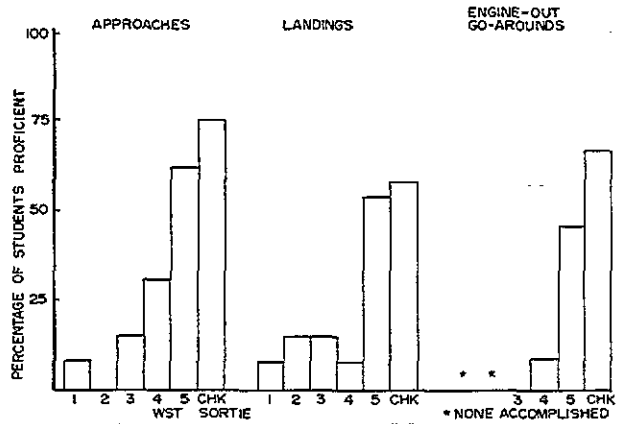

FIGURE 1. PERCENT OF STUDENTS RATED "4" OR BETTER ON EACH WST SORTIE.

percentages of students receiving criterion-level proficiency ratings during the simulator check ride are of particular interest. Although most students received ratings that met or exceeded the criterion, a substantial number did not. The shortfall was most acute for landings, where 42% of the students did not meet the desired criterion.

Inflight Performance. Mean proficiency ratings received by students during the flightline phase of training are shown in Figure 2. An analysis of approach and landing proficiency ratings showed significant improvements during the flying phase of training. Proficiency ratings for WST-trained students were significantly higher than proficiency ratings for students in the control group ($F(1, 26) = 7.764$, $p < .01$). The group by sortie interaction was not significant. Ratings for approaches were higher than ratings for landings, especially for the OFT-trained students, but the differences decreased over sorties. Both the task effects and the interaction between tasks and sorties were statistically significant ($F(1, 26) = 7.002$, $p < .014$, and $F(5, 130) = 3.496$, $p < .005$ respectively). Engine-out go-around data was not included in the analysis of variance, but the pattern of results is similar to that of the other two tasks. Mean ratings are depicted for all sorties where at least half of the students accomplished the event.

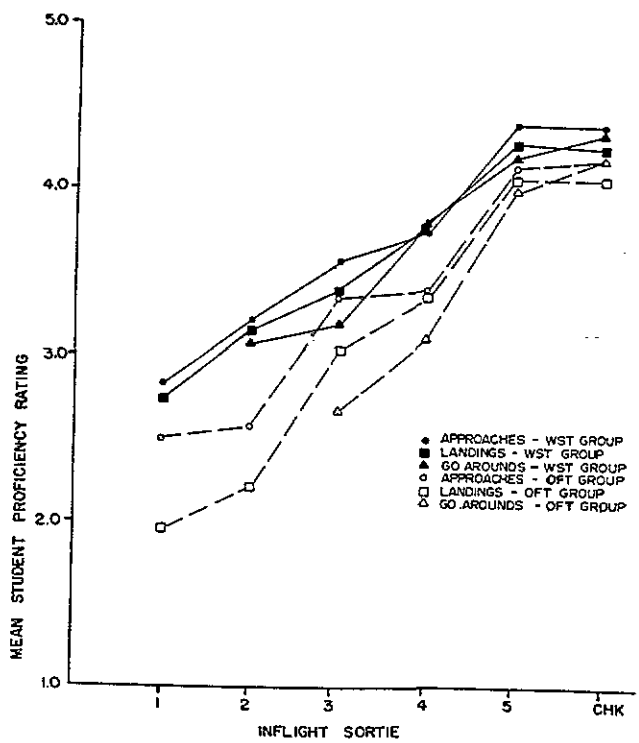

FIGURE 2. MEAN RATINGS OF STUDENT PROFICIENCY DURING PERFORMANCE OF APPROACHES, LANDINGS, AND ENGINE-OUT GO-AROUNDS IN THE C-130 AIRCRAFT.

Students who were trained in the WST received higher ratings for engine-out go-arounds throughout inflight training than did the students trained only in the OFT. As can be seen in Table 1, WST-trained students received their first criterion-level proficiency ratings earlier than did OFT-trained students, with the difference between group means exceeding one sortie for each of the three FOT&E tasks.

Table 1: Mean Number of Aircraft Sorties Required To Reach First Proficiency Rating

Task	OFT Group Mean	WST Group Mean	Difference
Approaches	4.36	3.14	1.22
Landings	4.50	3.14	1.36
Engine-out go-arounds	4.71	3.57	1.14

Mean instructor input ratings as a function of sorties are shown in Figure 3 for the three tasks studied. The pattern of results resembles the pattern observed in student proficiency ratings.

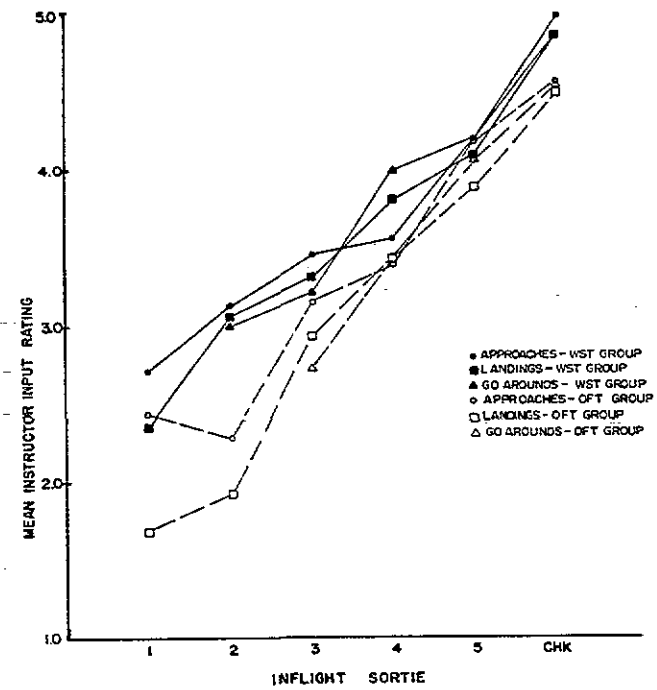

FIGURE 3. MEAN RATINGS OF INSTRUCTOR INPUTS DURING PERFORMANCE OF APPROACHES, LANDINGS, AND ENGINE-OUT GO-AROUNDS IN THE C-130 AIRCRAFT.

Instructor input ratings for OFT-trained students indicated substantially more assistance from the

instructor than did input ratings for WST-trained students through- out training including the checkride. An analysis of individual student ratings on the first sortie indicated that half of the OFT-trained pilots received hands-on assistance for landings, while only one WST-trained pilot received this level of assistance. During the checkride, almost half of the OFT-trained students received coaching for each critical task, while only one WST-trained student received coaching in landings, and another received coaching during engine-out go-arounds. Instructor inputs for both groups decreased dramatically over sorties. More instructor input was reported for landings than for approaches, especially during the first several sorties.

Instructor estimates of performance parameters were summarized by determining mean absolute deviations from the optimum value of each parameter for each subject for each sortie. Means of these values across the OFT group and the WST group are presented for each performance measure as functions of sorties. Tests of significance were two-tiered. First, a multivariate test of significance was conducted for all measures associated with each of the three tasks studied. Then each performance measure was evaluated individually. Deviations during the first five sorties were judged by the instructor pilot. Deviation scores for the final sortie represent performance during the MACR 60-1 checkride and were judged by the standardization/ evaluation pilot giving the check.

a. Approaches. The performance measures associated with approaches are horizontal deviations and vertical deviations one-half mile from the runway, and airspeed deviations at the threshold. Mean deviation scores representing horizontal deviation from an extension of the runway centerline one-half mile out (beginning of the approach lights at Little Rock AFB) are shown in Figure 4 for the WST group and the OFT group across inflight missions. Figure 5 shows means of individual scores for vertical deviation from optimum height at one-half mile from the runway. At Little Rock, where the glideslope should be 3°, the aircraft should be about 200' AGL. Figure 6 depicts means of individual deviation scores in airspeed as the aircraft crosses the threshold.

The multivariate test of significance for these three parameters showed the reduction in mean deviations across sorties to be statistically reliable ($F(15,238) = 2.269$, $p < .005$), but failed to indicate a significant difference between groups or a significant interaction between group effects and sorties. Univariate tests showed significant sortie effects for vertical deviation ($F(5.88) = 2.451$, $p < .04$) and airspeed ($F(5.88) = 4.392$, $p < .001$), but not for horizontal deviation scores.

b. Landings. The measures associated with landings were roundout height, distance down the runway at touchdown, distance from the runway centerline at touchdown, and crab at touchdown.

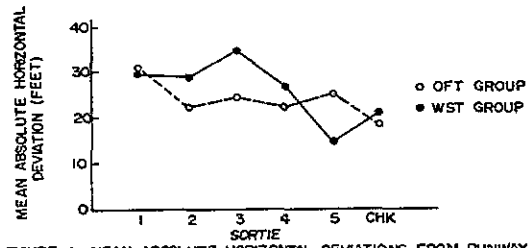

FIGURE 4. MEAN ABSOLUTE HORIZONTAL DEVIATIONS FROM RUNWAY CENTERLINE WHEN 1/2 MILE FROM RUNWAY THRESHOLD ON FINAL APPROACH.

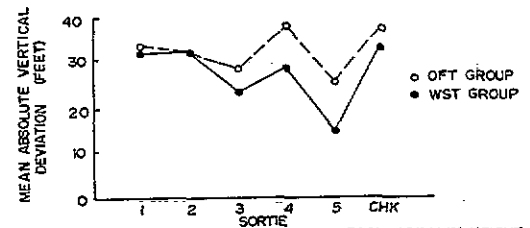

FIGURE 5. MEAN ABSOLUTE DEVIATIONS FROM OPTIMUM HEIGHT 1/2 MILE FROM RUNWAY THRESHOLD ON FINAL APPROACH.

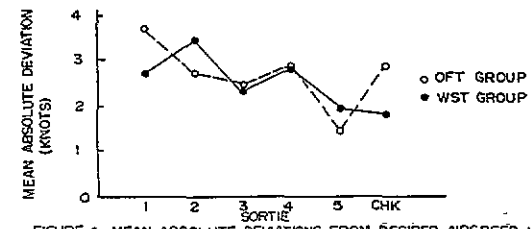

FIGURE 6. MEAN ABSOLUTE DEVIATIONS FROM DESIRED AIRSPEED WHEN CROSSING RUNWAY THRESHOLD ON LANDING APPROACH.

For the four performance measures combined, deviations decreased significantly over sorties. Group effects and the interaction were not statistically significant. Univariate analyses revealed that the decreasing deviations over sorties seen for roundout height, distance from runway centerline, and crab at touchdown were all statistically significant. Distance down the runway did not improve significantly over sorties. Although deviations tended to be smaller for the WST group than for the OFT group, this effect was statistically significant only for scores reflecting distance down the runway at touchdown.

c. Engine-Out Go-Arounds. For engine-out go-arounds, the OFT-trained students appeared to show a substantial lack of heading control in early training, and did not show stability comparable to that of WST-trained students until the fifth sortie. WST-trained students demonstrated this level of heading control from the beginning of inflight training. The relationship was reflected in a significant univariate group effect and a significant group by sortie interaction. Runway alignment deviations decreased over sorties, but neither the group effect nor the interaction were statistically reliable.

Correlations between the overall proficiency ratings and the other proficiency measures were of particular interest. Correlations between proficiency ratings and instructor input ratings were high for all three tasks, ranging from .813 to .839. These correlations are consistently

higher than any other correlations between pairs of variables.

Multiple regressions between proficiency ratings and the other variables showed that for all three tasks, instructor input alone accounted for at least two-thirds of the observed variability in proficiency ratings. For landings and engine-out go-arounds, increases in correlations from adding the other variables to the regression equation were not significant. For approaches, R squared increased from .704 to .735 when the approach performance parameters were added to instructor input as predictor variables. Among these additional parameters vertical deviation was the only statistically significant variable in the overall regression equation. In general, instructor input accounted for a considerable amount of the variability observed in proficiency ratings. Adding the other performance measures as additional variables provided little increase to these correlations, with the largest change in multiple R being .018.

Discussion

To better interpret the effects of WST training on inflight skill acquisition, the learning process for approaches, landings, and engine-out go-arounds will be described in terms of the measures collected in this FOT&E. Instructor ratings of student proficiency indicate significant improvements across sorties. Instructor inputs decreased dramatically over sorties in a manner that was highly correlated with increasing proficiency ratings. Instructor estimates of individual aircraft performance parameters for each of the three tasks, however, produce mixed results. Some individual parameters showed no significant improvement across sorties, while others showed limited improvement. In all cases sortie effects for these measures were greatly attenuated relative to the substantial changes observed in student proficiency ratings and instructor inputs. When both performance parameters and instructor inputs were used to predict proficiency ratings, instructor inputs almost completely overshadowed all other predictor variables. It appears that the primary behavioral change during inflight training for all three tasks was in the relative roles of the student and his instructor during task accomplishment. Early in training, instructors reported providing considerable assistance to their students, but inputs from instructors decreased dramatically as training progressed. The relatively small changes observed in inflight performance parameters over sorties suggest that instructors allowed very little deviation from acceptable standards during the accomplishment of these maneuvers.

Results indicated that positive transfer did occur, with differences between the test and control groups being reflective of the patterns of changes observed over sorties. WST-trained students demonstrated proficient performance earlier and required substantially less "hands-on" assistance from the instructor during early flightline training. The difference continued throughout inflight training. While students without WST training often received coaching for techique during the MACR 60-1 checkride, almost all WST-trained copilots performed the tasks with no assistance from the evaluator. Deviations from optimum values of the performance parameters tended to be smaller for the WST-trained students than for OFT-trained students, but none of the multivariate tests of significance for these parameters showed a significant difference between test and control groups. It appears that one major benefit of WST training was to better prepare students for flightline training, as seen by virtual elimination of demonstration and hands-on assistance from the instructor inflight. WST-trained students demonstrated MAC criterion-level proficiency for the trained events considerably earlier in the flightline phase of training than did students who did not receive this training, with the reduction averaging 27%. In addition, WST-trained students graduated at a higher skill level as indicated both by proficiency ratings and by ratings of instructor inputs.

STUDY II - MISSION QUALIFICATION TRAINING METHOD

Method

Subjects. The subjects used to address this objective were 26 student pilots enrolled in the C-130 mission qualification course conducted by the 34 TATG at Little Rock AFB AR. Each was a former C-130 copilot who was upgrading to aircraft commander. Mission qualification training immediately followed initial qualification training for all subjects.

Training Events. WST training effectiveness was evaluated for five training events. The events chosen were visually-oriented tasks that consumed relatively large amounts of flying resources for skill acquisition. These events were:

a. visual formation airdrop
b. lead airdrop
c. overhead recoveries
d. downwind recoveries
e. assault landings

Procedure. Fourteen pilots were assigned to the test group and received training in the WST for the five tasks identified above. The remaining 12 pilots comprised the control group. They received training for non-visual events in C-130 OFTs in lieu of the WST training received by the test group. Much of the training received by the control group concerned station keeping equipment (SKE) operations. Both groups received common academic instruction followed by simulator training, then flightline training. Students in both groups were required to pass a MACR 60-1 checkride at the end of the flying phase of training.

Measures of effectiveness. Instructors rated student proficiency during all WST training sessions and all inflight training missions for the five selected tasks using the five-point proficiency scale used in Study I.

Results

The impact of WST training on subsequent performance inflight was ascertained by comparing sortie repetitions to proficiency, mean proficiency ratings, and percent of students proficient between the test and control groups.

Sortie repetitions to criterion. Mean numbers of sortie repetitions to the first "4" proficiency rating are depicted in Figure 7. Sortie repetition values are counts of sorties where the specific task being evaluated was accomplished. For example, if formation flight was first accomplished during the second training sortie, that accomplishment would be considered to be the first sortie repetition for formation flight. In all cases, the mean number of sortie repetitions to the first "4" proficiency rating were lower for the WST group than for the OFT group. The difference between the WST group means and OFT group means was statistically significant ($F(1,24) = 5.823$, $p < .024$). Averaged across the five tasks, sortie repetitions to criterion for the WST group were reduced by nearly one-third relative to sortie repetitions to criterion for the OFT group.

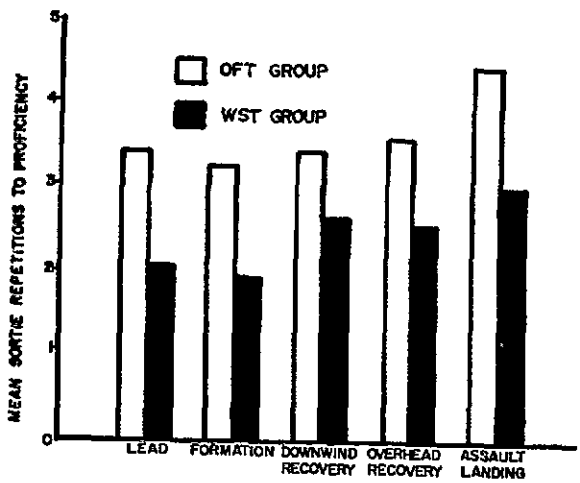

FIGURE 7. SORTIE REPETITION TO PROFICIENCY ("4" RATING OR BETTER) FOR PILOTS

Mean proficiency ratings. Mean ratings for all five tasks were higher for the WST group than for the OFT group, with the differences being greater for early sortie repetitions. Differences between groups for the first sortie repetition were statistically significant ($F(1.24) = 14.539$, $p < .001$), as were differences on the final sortie repetition ($F(1,24) = 5.970$, $p < .022$).

Percent of students proficient. Cumulative percentages of students receiving at least one "4" rating or better are shown as a function of sortie repetitions for pilots in Figure 8.

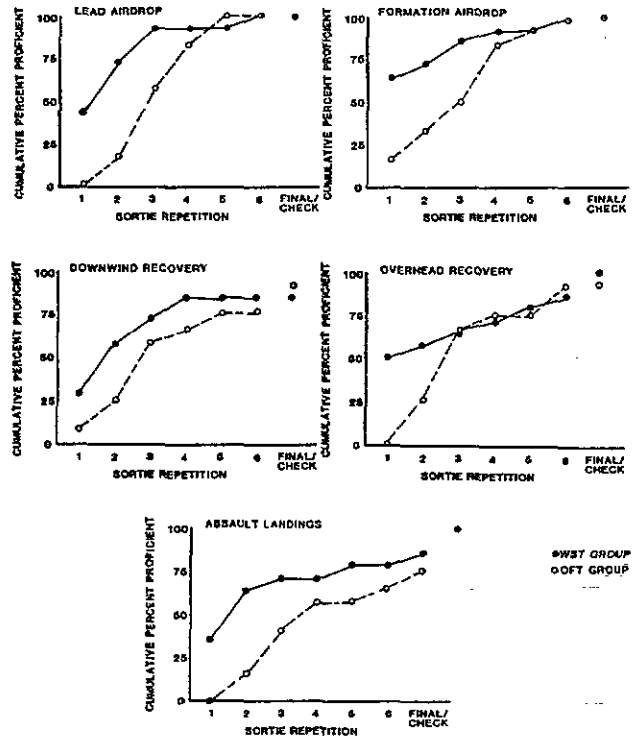

FIGURE 8. CUMULATIVE PERCENTAGE OF PILOTS RECEIVING AT LEAST CRITERION - LEVEL RATINGS ("4" OR BETTER) AS A FUNCTION OF SORTIE REPETITION

Percentages of students rated proficient were higher for the WST group than the OFT group initially, but the percentages converged toward the end of training when nearly all students had received at least one "4" rating in each task. Chi-square tests of differences on the first sortie repetition were statistically reliable for lead ($X^2(1) = 4.210$, $p < .05$), and overhead recoveries ($X^2(1) = 5.865$, $p < .025$). The differences for assault landings and downwind recoveries were not statistically significant.

Relationships between performance in the WST and the aircraft. The relationship between the number of "4" or better ratings in the WST and the number of aircraft sortie repetitions to first "4" inflight for WST-trained pilots is shown for assault landings in Figure 9. As can be seen in this plot, most pilots who required a relatively large amount of training to reach criterion inflight received few or no "4" ratings in the WST. Similar patterns exist for the other four tasks.

Discussion

Overall, mission qualification training in the WST transferred positively to the aircraft as indicated by significant improvements in mean proficiency ratings, sortie repetitions to criterion, and percentages of pilots demonstrating criterion level profinciency during early inflight sorties. As was the case

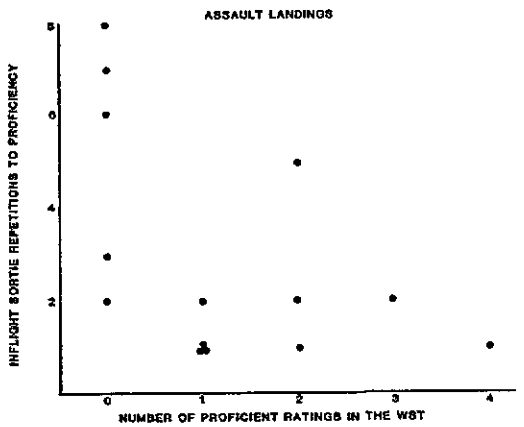

FIGURE 9. NUMBER OF INFLIGHT SORTIE REPETITIONS TO THE FIRST "4" RATING OR BETTER AS A FUNCTION OF NUMBER OF PROFICIENT RATINGS RECEIVED IN THE WST FOR ASSAULT LANDINGS.

for initial qualification training, a substantial number of students failed to demonstrate a MACR 60-1 criterion level of proficiency in the WST. Behavior in the simulator was still improving when training ended. A clear relationship was observed between the number of proficient attempts in the WST and the number of sortie repetitions to proficiency in subsequent inflight training. Given this pattern, the lack of training to proficiency appears to have limited the impact of WST training. Since proficiency in the WST was not required or aggressively pursued, the effects of WST training on subsequent inflight performance are viewed as conservative estimates of full training potential.

STUDY III - TRAINING FOR MISSION-READY PILOTS

Method

Subjects. The participants in this study were twenty-three mission-ready C-130 aircraft commanders who were students at the Tactical Airlift Instructor School.

Training events. Training effectiveness was evaluated for two tasks:

a. three-engine take-offs
b. windmill taxi starts

The general concept of a three-engine take-off is straightforward. Training for this event, however, is problematic because actual accomplishment inflight is viewed to be unacceptably dangerous. Approximations to three-engine take-offs are flown by retarding one engine to flight idle for the maneuver, providing what is viewed as somewhat attenuated, but otherwise realistic effects on handling characteristics. Windmill taxi start is a procedure that can be used to start an engine using airflow generated by taxiing down the runway 100 KIAS to rotate the prop at a speed sufficient to start the engine. These training events were chosen because they are dependent on out-of-the-window cues for successful accomplishment, and because they are currently accomplished in the aircraft during instructor training, enabling a transfer of training evaluation. These two events are viewed as being representative of the types of emergency procedures trained in simulators.

Procedure. Twelve pilots were assigned to the test (WST) group and 11 were assigned to the control (OFT) group. The test group pilots practiced both windmill taxi starts and three-engine take-offs in the WST following which they accomplished these same tasks in the C-130 aircraft. The control group practiced the procedural aspects in the OFT followed by accomplishment of the two tasks in the aircraft.

Results

The impact of the visual system on simulator training effectiveness was ascertained by comparing the inflight performance of WST-trained students to that of OFT-trained students as measured by mean proficiency ratings (using the five-point scale shown in Study I), repetitions to criterion (first "4" or better), and percent of students proficient the first time an event is accomplished inflight. The mean overall proficiency ratings for the test (WST) and control (OFT) groups on the first windmill taxi start and three engine take-off in the C-130 aircraft are shown in Table 4. An analysis of variance of these first attempt data indicated that the mean performance ratings of the WST trained pilots were significantly higher than those of their OFT trained counterparts for both tasks.

Table 2. Mean overall proficiency ratings on the first aircraft attempt following training in the C-130 WST (test) or C-130 OFT (control).

Task	Control Grp	Test Grp
Windmill Taxi Start	3.4	3.8
Three engine take-off	3.6	4.2

The percentage of pilots in each group who achieved criterion proficiency on the first attempt (i.e., a rating of 4 or better) for the two training tasks are shown in Figure 10. A chi-square analysis of the pass-fail frequency data for each task indicated that the number of test group pilots who met the required proficiency criterion on the first attempt in the aircraft was significantly higher than that of the control group for both tasks.

The mean number of repetitions to the first "4" or better rating inflight are shown in figure 11. The test (WST) group required significantly fewer task accomplishments to reach criterion in the aircraft than did the control group for both windmill taxi starts and three-engine take-offs. Windmill taxi starts were accomplished in the aircraft prior to three-engine take-offs, which may account in part for the lower number of repetitions to criterion for the WST-trained pilots.

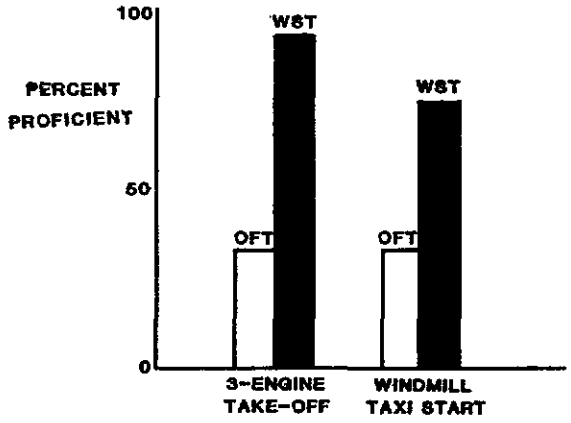

FIGURE 10. **PERCENTAGE OF PILOTS REACHING CRITERION ON THE FIRST AIRCRAFT ATTEMPT FOLLOWING TRAINING IN THE C-130 OFT OR C-130 WST.**

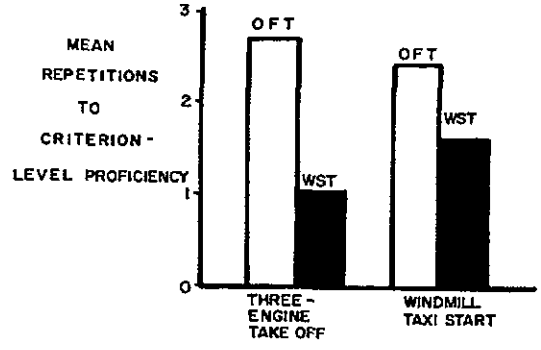

FIGURE 11. **MEAN REPETITIONS TO THE FIRST "4" PROFICIENCY RATING**

Discussion

WST training transferred positively to the aircraft as indicated by substantial differences between the performance of WST-trained and OFT-trained students with each of the measures used. With emergency procedures, ability to perform the event the first time may be the most important measure of training effectiveness. For pilots who received procedures training in the non-visual OFT, less than 30% met MAC criteria inflight even through the proficiency check followed shortly after simulator training, raising serious questions about the effectiveness of the OFT to train these tasks. Percentages were dramatically improved with WST training. This suggests that "going through the motions" for these tasks without the feedback provided by out-of-the-window visual cues was not particularly effective. With the visual system, however, a substantial percentage of pilots were trained in the WST to a point where they could demonstrate proficiency when transferred to the aircraft.

Recommendations

This section presents some interim recommendations supported by the findings and observations of the C-130 WST FOT&E. As noted in the previous section, the WST proved to be an effective training device despite the fact that it was employed in a less than optimal manner. As a consequence, most of the recommendations below are directed at actions required to exploit the as yet untapped training potential of the device in order to obtain a more cost-effective total training system for C-130 aircrews.

Simulator Training Goals

The desired outcome of simulator training needs to be defined. Assuming that simulator training "raises the learning curve" during subsequent inflight training, the difference can be translated into training to a higher level, training in a shorter time, or some combination of the two. The desired goal is a policy issue that needs to be specified by training management.

Training to Proficiency

Students should be trained to proficiency during the simulator phase of training. Until the effect of such training is evaluated, the upper limits of the C-130 WST training effectiveness will remain unknown. In the U.S. Navy's P-3 program, simulator training events are prioritized.(2) The simulator phase is of fixed duration, but proficiency is demonstrated for certain specified events before training in other areas is accomplished. This approach should allow a proficiency-based program that is manageable given current scheduling constraints.

Individualized Instruction

Training should be tailored to the needs of individual students. Highly structured training scenarios do not allow this flexibility, and therefore may limit training effectiveness. Strategic Air Command found that well-defined terminal proficiency criteria accompanied by a syllabus that allows instructors to provide the training they feel best meets the needs of individual students greatly enhanced the effectiveness of their Air Refueling Part Task Trainer (Nullmeyer and Laughery, 1980).(3) A similar concept should be considered for C-130 training.

Simulator Instructor Proficiency

Simulator instructors need to be proficient operators of the WST. In order to support individualized training in the WST, skilled simulator instructors will be needed. A cadre of dedicated simulator instructors may facilitate adequate acquisition and maintenance of simulator operating and instructing skills.

Proficiency Criteria

Instructor input may merit a more central role in training objectives and criteria.

Amount of instructor input appears to be a major index of student proficiency. One application might be to require a successful student solo in the simulator prior to flightline training. B-52 and KC-135 formal school training programs take this concept even further, with student crews flying a solo mission inflight following their checkride.

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