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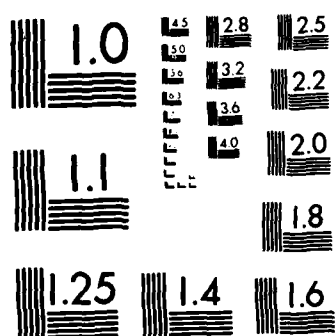
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THE USE OF FLIGHT SIMULATORS IN MEASURING AND IMPROVING TRAINING EFFECTIVENESS

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ABSTRACT

This paper studies the value of aircraft simulators as measures of training readiness. Simulator evaluations are analyzed for reserve enlisted crewmen on Navy patrol aircraft. Part-time reservists are found to have very little skill loss over time and perform as well as their full-time counterparts. Experience in the simulator produces substantial increases in subsequent flights appear to be useful measures of readiness and valuable training experience.

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1. INTRODUCTION

To what extent is the performance in the military of an individual explained by his personal characteristics, such as intelligence or education, or by the training he obtains in the service? The empirical investigation of these issues is an area of manpower research that has been underdeveloped in the past but in which some progress is being made. First, this paper briefly overviews the areas of research of interest as well as the types of approaches utilized in previous analyses. Then it turns to an empirical analysis of operational readiness and training.

2. BACKGROUND

Measuring the performance of military personnel is an important issue, but it is one that has proved to be extremely difficult. Improvements in manning levels during the last several years have coincided with increases in reported readiness throughout the military. While these trends do indicate that personnel and training policies do have an impact on the ability of the military services to perform their missions, manpower analysts are still unable to accurately measure the impact of specific factors on the performance of individuals in the military. Similar measurement difficulties impede our ability to assess the impact of individual performance on the collective effectiveness of larger units of personnel.

Substantial effort has been devoted to the issue of measuring the performance of new recruits in the military. This work has been divided into two basic areas that can be characterized as measures of survivability and trainability. Survivability is measured by successful completion of a recruit's obligated service. The dominant predictor of survival, as confirmed by numerous studies, is education [1]. In particular, having obtained a high school diploma is the best predictor of survival for enlisted personnel. While survival is an important measure of effectiveness, indeed it is a prerequisite for any contribution to the military, it does not provide any measure of the relative contribution of those personnel who do remain in the military.

Trainability measures the successful completion of the classroom training provided to incoming recruits. School pass rates or final examination scores are more refined measures of the performance of military recruits than survival rates. Scores on the military entrance exam are the best predictors of training success for new recruits. While training success is a valid measure of recruit performance, it is only a rough proxy for subsequent performance in the military.

Other, more direct, measures of performance have also been analyzed. These include supervisory ratings of recruits and advancement rates for new recruits [2, 3]. While these measures have more analytic content than previous measures, there is still an insufficient body of research to make these types of efforts influential in policy decisions.

Research on career personnel has focused less on the individual and more on the relationship of the mix of skills in a unit to its effectiveness. These types of studies have tended to use conventional measures of readiness that focus on material condition of the unit [4]. While these studies have frequently found significant relationships between personnel characteristics and readiness, they are frequently the subject of attack because they are measuring something other than war-fighting capability. There have been few studies that have tried to directly measure operational performance [5].

3. OPERATIONAL READINESS AND TRAINING: EMPIRICAL ANALYSIS

This study concentrates on three areas that have not been the subject of much research in the past. First, operational data that are realistic measures of wartime capability are analyzed. Second, in addition to estimating the effect of factors such as military experience and personnel characteristics on performance, it closely examines the effect of mid-career training on the performance of personnel. In particular, this study looks at the impact of training in flight simulators on crew performance. Finally, this study looks at a segment of the military that has not been a subject of intense interest in the past, the reserve component of the force. The reserves serve for only a limited amount of time each year and this leads to significant questions about their readiness and policies that can limit skill loss as their time away from active duty increases.

3.1 Basic Data

We gathered simulator exercise results for a sample of nine Naval Selected Reserve P-3 squadrons from 1980 through 1982. The P-3 is a long-range patrol aircraft whose primary mission is anti-submarine warfare. Crew members on ASW aircraft, both officers and enlisted, spend a substantial amount of time in simulators. These sessions, which often last several hours, are used both as training exercises and as indicators of crew readiness. The individual crew members, and the crew as a whole, are graded on their performance and results of these exercises are recorded. The sample includes 365 simulator trials and over 1000 individual exercise grades.

In addition to simulator flights, actual operational flights are graded as well. Data on grades from these flights were collected. Unfortunately, these data are too limited to be useful in these analyses. Reserve units fly a small number of operational missions each year and the data set derived from operational records was too small to be

used. This problem is exacerbated by the fact that these operational flights tend to be concentrated among a small number of crews within the squadron. As a result, only information from simulated flights are used in this study.

This study concentrates on the three enlisted sonar operators in the aircrew. Individual exercise grades were merged with personnel files which included extensive information on individual characteristics and on Navy training and experience. The information contained on these records can be categorized into four areas: personal characteristics, flight characteristics, reserve training information, and simulator experience.

3.2 The Model

Three factors fall in the category of personal characteristics. The first is the paygrade of the individual. An individual's paygrade is a measure of his experience in the Navy as well as his advancement rate. In previous studies of this type, this is the most powerful predictor of an individual's performance. The second measure is the AFQT score earned by the individual on his military entrance examination. AFQT is a composite score from several tests on the Armed Services Vocational Aptitude Battery. AFQT measures verbal and arithmetic aptitude and is normally thought of as a proxy for intelligence. The final measurable characteristic is the educational level of the crewman. In the data set for this study, many of the reservists have completed additional years of schooling after leaving the Navy so this variable does not measure their education at the time they entered the service.

The score an individual receives on his flight evaluation depends not only on his individual proficiency but also on the characteristics of the job he must perform. Certain specific tasks he must perform may be more or less difficult than others. There are three sensor positions on the aircraft. Sensor 1 and Sensor 2 operate the acoustic detection devices. Sensor 1 is the lead operator with Sensor 2 providing support. Sensor 3 operates the non-acoustic devices, and has a limited role on many flights. The analysis in the paper takes account of the individual's position on each flight. The evaluation scores also depend on the type of mission being simulated. The mission type is a factor in the analyses that follow.

The focus in this paper is on the reserve component of the total force. Information that pertains directly to the reserves is included in the analysis. A key concern in any analysis of reserve readiness is a comparison of the performance of reservists to active duty personnel. As noted above, there are not sufficient data to compare reserve to active personnel. Within the reserve community, however, there are two types of personnel. The Selected Reserves (SELRES), about three-fourths of the reserves, serve one weekend a month and two weeks a year of

active duty. The remainder of the reserves are Training and Administrative Reserves (TARs). TARs serve full time but are attached to reserve units.

For the purposes of this study, it is assumed that TARs are equivalent to active duty personnel and that data on SELRES and TARs can be used to compare the performance of reserve personnel to active duty enlisted men. In addition to exploring the differences between these two types of reservists the study examines the impact of training on the readiness of reserve personnel. The extent of skill loss of reservists and the impact of training on reducing skill loss is of great concern to the Navy. This study examines the effect of time since active duty on the performance of personnel. This may be affected by the amount of time the individual actually spent on active duty so this is considered as well. Finally, the impact of the two weeks of active duty for training that the reserves serve is analyzed. This is done by measuring the time since the last period of active duty for training for each individual.

The last strand of research in the study is the assessment of the importance of simulator training in improving performance. A large portion of this study concentrates on personnel and training issues using the simulator evaluations as a measure of performance. It is also possible, however, to analyze the effectiveness of simulators as training devices. In this context, the analysis measures the impact of simulator training on performance by measuring effectiveness of personnel as a function of the number of simulator trials they have performed during the study period. As before, effectiveness is measured by simulator scores. A more extensive study might concentrate on the time between these trials as well as a simple count of their number but the simple measure used here serves as an initial attempt to analyze this issue.

The implicit assumption throughout this paper is that performance in a simulator is a good proxy for performance in the aircraft. Evidence on this issue can be found in earlier studies on the transferability of training from simulators to actual aircraft [6, 7]. Previous studies have found a transfer ratio of 50 percent or more for cockpit simulators. The tasks being simulated in this study do not require either visual or motion cues, hence increases in performance in the simulator probably transfer at a high rate to operational effectiveness in this instance.

3.3 Results

The factors that determine simulator scores were estimated using regression analysis. Simulator trials are scored on a 100 point scale. Numerous individual tasks with different weights, are graded and added to determine an overall grade. Although the mean score is close to 90, there is still variation across the sample. Regression results are presented in table 1.

TABLE 1
DETERMINANTS OF SIMULATOR SCORES
REGRESSION RESULTS

<u>Variable</u>	<u>Coefficient</u>	<u>(t-statistic)</u>	<u>Variable mean</u>
Constant	74.5		
AFQT	.001	(0.4)	69.5
Paygrade	0.4	(1.8)	5.6
Sensor1	-3.1	(-4.9)	.34 ^a
Sensor2	-2.3	(-3.7)	.32 ^a
M1	0.9	(1.5)	.37 ^a
M2	4.7	(7.4)	.28 ^a
TAR	-1.5	(-1.9)	.23 ^a
TSACT	-.13	(-2.8)	10.9
TSTRA	-.02	(-0.3)	4.5
TRAMISS	-0.9	(-1.2)	.21 ^a
TOTAS	.25	(2.8)	5.7
TEST	1.2	(3.4)	3.4
TESTSQ	-.07	(-2.1)	17.1
YR81	5.8	(8.0)	.42 ^a
YR82	14.6	(17.8)	.38 ^a

$R^2 = .42$

Obs = 1095

Score Mean = 87.4, Std. Dev. = 10.7

^a (0,1) variables. TAR = 1 if TAR, 0 if SELRES. TSACT = Time since leaving active duty (years); TSTRA = time since last two-week active duty for training (months); TRAMISS = 1 if no record of most recent training; TOTAS = Total Active Duty (years); TEST = Number of recorded simulator trials; TESTSQ = TEST squared, M1 and M2 are variables representing the type of mission simulated.

In general, all the results are in accord with their expected signs. The magnitude of many of the effects is much smaller than would have been expected, however. This is true, in particular, for individual characteristics. The variables measuring education have been deleted entirely from the regression equation. The coefficients, whether measured in years of education or by degree status, were statistically insignificant and changed sign depending on the specification of the equation. AFQT score had a positive but miniscule impact on his simulator performance. Individuals in the higher paygrades performed better but again the differences were quite small. There is no clear

reason why these factors have so little explanatory power. The most likely explanation has to do with the nature of the reservists in our sample. They have, on average, 15 years of experience between active duty and reserve activity. The men left in the sample by that time must all be reasonably competent at their jobs to have survived that long. Therefore, it is reasonable to expect that differences in individual characteristics will be of less importance than they might have been earlier in one's career.

The variables that are included to control for differences in flight tasks all are statistically significant. These variables are included to control for the possibility that individuals are sorted into flight positions or crews into particular flights based on their personal characteristics. These variables prevent any spurious correlation between personal characteristics and simulator scores based on a nonrandom sorting of individuals based on the type of task to be performed.

The implications of these results for the readiness of reserve units is very interesting. The most important issue for reserves is whether or not reserve crewmen can perform adequately. The answer obtained from this study is a strong affirmative. These results indicate that SELRES crewmen are, in fact, slightly better than their TAR counterparts. The difference is so small, even though it is statistically significant, that for all intents and purposes SELRES and TARs can be considered equivalent. This result is important because it is often assumed that SELRES are not as effective as full-time enlisted men.

These results do imply some degree of skill loss over time, as measured by the negative coefficient on years since leaving active duty. Even though this variable is negative and statistically significant, its magnitude is quite small. For the average reservist, who has been off active duty for 11 years, his score is only about a point and a half lower than someone coming right from the active force. This finding suggests that the training of reservists, at least for the patrol aircraft squadrons, is sufficient to maintain their competence.

Two variables are included to examine skill training more specifically. Time since the last period of active duty for training has virtually no impact on the simulator score. There are two possible explanations for these findings. The first is that training has little impact on performance for experienced personnel. A more likely explanation, however, is that most reservists train on a regular basis and that the small differences in time since training are too small to have any measurable impact.¹

1. The results presented combine SELRES and TARs in a single sample. Separate estimates for each population, tables A-2 and A-3, do not show any substantial differences in results.

No record of the last training period was available for one-fifth of the individuals. This may be due simply to bad record keeping but it may also indicate that no training has been conducted for a long period. A variable to identify individuals with missing training records found that they had slightly lower scores.

3.4 Simulator Training

Flight simulators serve two functions. They can be used to measure the readiness of individual crewmen, as they have been in this analysis. They also are training devices that can be used to improve the performance of these individuals. Their usefulness as training devices can be measured by examining the impact of a session in the flight simulator on subsequent simulated flights. Figure 1 displays the mean flight score of all individuals by the number of simulated flights during the observed period. The figure clearly displays a strong upward trend. These graphical results are supported by the regression coefficients in table 1. The regression estimates predict an average increase of more than one point for each simulator flight although this effect declines slightly with each subsequent flight.

Flight simulator training leads to substantial improvements in subsequent simulated flights. Whether or not this translates into like improvements in performance during real flights remains untested. As noted before, there were too few observations on operational flights by reserve units to compare the relationship between performance in simulated and actual flights carefully. The flight simulators used in these tests are very realistic, however, and the units that use them place great confidence in them. This suggests that time in the simulator does produce improvements in the operational performance of VP crewmen. The magnitude of this effect may not exactly equal the estimates obtained here, in fact it is probably smaller, but there is evidence that simulators can be used effectively to provide training to these crewmen.

4. CREW INTERACTIONS

The research presented has concentrated on the scores each individual operator received. The individual's score is also affected by the scores of the other crew members. Table 2 presents the simple correlations between the individual scores of sensors 1, 2, and 3. It is readily apparent that the score given to the first two sensor positions is almost identical on most flights. This is not surprising as these two crewmen work as an integral team. The correlation between the score for sensor 3 and the other two positions is somewhat less but still

1. The equations also indicate that those were substantial improvements over time, independent of additional training.



FIG. 1: SIMULATOR SCORES BY EXPERIENCE

substantial. Regression analysis indicates that a one point decline in the score of sensor 3 leads to half-point decline for the other two positions, and the reverse is true as well.¹

TABLE 2
CORRELATION
CREW MEMBER SCORES

	<u>Sensor 1</u>	<u>Sensor 2</u>	<u>Sensor 3</u>
Sensor 1	1.00	--	--
Sensor 2	.95	1.00	--
Sensor 3	.61	.60	1.00

One final bit of evidence on the importance of individual performance to overall crew performance is obtained by relating the individual scores to the flight grade for the whole aircraft. The overall grade depends both on the performance of the enlisted sensor operators and the officers. As can be seen in table 3, the overall flight grade does depend on the performance of the enlisted crew members. This is true in particular for sensor 1.² An increase in the score of sensor 1 by one point increases the overall grade by .2 points. Conversely, the overall score has a substantial impact on the individual score for sensor 1 but, the score for sensor 3 seems to be independent of the rest of the crew.³

1. See tables A-3 and A-4.

2. Grades for sensor 1 and 2 are so highly correlated that separate effects cannot be estimated. Hence only sensor 1 is shown.

3. The effects of individual performance on the overall flight grade and the converse are shown in tables A-5, A-6, and A-7.

TABLE 3
CORRELATIONS
CREW AND INDIVIDUAL SCORES

	<u>Crew</u>	<u>Sensor 1</u>	<u>Sensor 3</u>
Crew	1.00	--	--
Sensor 1	.42	1.00	--
Sensor 3	.21	.61	1.00

5. CONCLUDING COMMENTS

The measurement of personnel performance is a difficult problem. This paper has examined the usefulness of using simulators to measure the readiness of personnel. The emphasis is on the impact of training on performance. The data come from Naval Reserve patrol aircraft squadrons. Training is particularly important for Reserve units who do not serve on a regular basis.

Although this paper cannot claim to be more than an initial effort in this area the results are encouraging. Enlisted reservists experience very little skill loss over time. The typical reservist, who has been out of active duty for more than 10 years, performs his job just about as well as someone coming directly off active duty. The Selected Reserve enlisted men score as well on simulated flights as their full-time counterparts. Both of these results suggest that reserve training is very good.

This study uses simulator scores both to measure performance and to analyze the value of simulators as training devices. The dramatic increase in observed flight scores with each successive trial indicates that the simulator provides a substantial amount of training. Sufficient empirical data do not exist to tie performance in the simulator to success in actual operational flights. Solid empirical evidence on this question remains a topic for further research. Observational and anecdotal evidence, however, suggest that this link does exist.

The final question in this study concerned the interaction between the performance of the individual crewmen. The results are far from conclusive but they suggest that this may be important for some positions and not for others. The first two sensor positions seemed to affect and be affected by the performance of the rest of the crew. The other position, on the other hand, appeared to be largely unaffected by the rest of the aircrew.

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APPENDIX A
REGRESSION RESULTS

TABLE A-1

DETERMINANTS OF SIMULATOR SCORES
SELRES REGRESSION RESULTS

<u>Variable</u>	<u>b</u>	<u>(t)</u>	<u>$\bar{X}$</u>
Constant	73.9		
AFQT	.02	(1.2)	72.2
Paygrade	0.3	(1.0)	5.7
Sensor1	-3.7	(-5.3)	.36 ^a
Sensor2	-2.5	(-3.5)	.28 ^a
M1	0.8	(1.2)	.37 ^a
M2	4.6	6.5	.28 ^a
TSACT	-.01	(-2.1)	10.9
TSTRA	-.04	(-0.5)	4.5
TRAMISS	-1.1	(-1.3)	.27 ^a
TOTAS	0.4	(2.4)	3.9
TEST	1.0	(2.5)	3.5
TESTSQ	-.05	(-1.4)	17.8
YR81	6.7	(8.2)	.42 ^a
YR82	15.3	(16.1)	.38 ^a

$R^2 = .44$

Obs = 849

Score Mean = 88, Std. Dev. = 10.7

^a (0,1) variables. TSACT = Time since leaving active duty (years); TSTRA = time since last two-week active duty for training (months); TRAMISS = 1 if no record of most recent training; TOTAS = Total Active Duty (years); TEST = Number of recorded simulator trials; TESTSQ = TEST squared.

TABLE A-2

DETERMINANTS OF SIMULATOR SCORES
TAR REGRESSION RESULTS

<u>Variable</u>	<u>b</u>	<u>(t)</u>	<u>$\bar{x}$</u>
Constant	68.6		
AFQT	-.02	(-0.7)	60.0
Paygrade	1.5	(1.8)	5.3
Sensor1	-1.3	(-0.8)	.27 ^a
Sensor2	-1.7	(-1.3)	.46 ^a
M1	1.2	(0.9)	.36 ^a
M2	5.2	(3.7)	.28 ^a
TOTAS	0.1	(0.6)	9.6
TEST	1.5	(2.1)	3.1
TESTSQ	-0.1	(-1.6)	14.4
YR81	3.7	(2.3)	.42 ^a
YR82	12.9	(7.6)	.39 ^a

$R^2 = .35$

Obs = 246

Score Mean = 87.0, Std. Dev. = 10.5

^a (0,1) variables. TSACT = Time since leaving active duty (years); TSTRA = time since last two-week active duty for training (months); TRAMISS = 1 if no record of most recent training; TOTAS = Total Active Duty (years); TEST = Number of recorded simulator trials; TESTSQ = TEST squared.

TABLE A-3
REGRESSION RESULTS, SENSOR 1 SCORES

<u>Variable</u>	<u>b</u>	<u>(t)</u>
Constant	28.4	
Paygrade	0.5	(1.6)
TAR	0.5	(0.4)
M1	3.0	(2.6)
M2	1.2	(1.0)
Sensor 3	.60	(15.2)
$R^2 = .38$		

TABLE A-4
REGRESSION RESULTS, SENSOR 3 SCORE

<u>Variable</u>	<u>b</u>	<u>(t)</u>
Constant	36.2	
Paygrade	.04	(0.1)
TAR	0.2	(0.2)
M1	-3.8	(-3.3)
M2	1.3	(1.0)
Sensor 1	.62	(15.1)
$R^2 = .40$		

TABLE A-5
REGRESSION RESULTS
CREW SCORE

<u>Variable</u>	<u>b</u>	<u>(t)</u>
Constant	75.4	
M1	1.6	(2.5)
M2	0.6	(0.9)
Sensor 1	.22	(7.6)
Sensor 3	-.02	(-0.7)

$R^2 = .19$

Mean crew score = 93.1, Std. Dev. = 6.0

TABLE A-6
REGRESSION RESULTS, SENSOR 1 SCORE

<u>Variable</u>	<u>b</u>	<u>(t)</u>
Constant	-1.98	
M1	1.7	(1.5)
M2	0.6	(0.6)
Paygrade	.39	(1.5)
TAR	-0.1	(0.9)
Crew Score	.59	(7.5)

$R^2 = .46$

TABLE A-7
REGRESSION RESULTS, SENSOR 3 SCORE

<u>Variable</u>	<u>b</u>	<u>(t)</u>
Constant	41.0	
M1	-3.7	(-3.2)
M2	1.4	(1.1)
Paygrade	.02	(0.1)
TAR	0.3	(0.8)
Crew score	-.06	(-0.7)

$R^2 = .40$

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