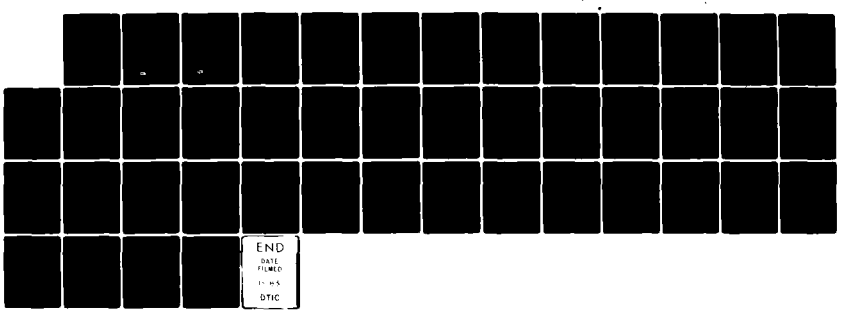
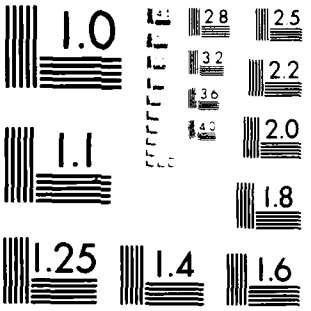
AD-A122 420 PERSONNEL SUBSTITUTION AND NAVY AVIATION READINESS(U) 1/1
CENTER FOR NAVAL ANALYSES ALEXANDRIA VA NAVAL STUDIES
GROUP A J MARCUS OCT 82 CNA-PP-363 N00014-76-C-0001
UNCLASSIFIED F/G 5/9 NL





PROFESSIONAL PAPER 363 / October 1982

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Naval Studies Group

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PERSONNEL CHARACTERISTICS AND NAVY AVIATION SQUADRON PERFORMANCE: A PRODUCTION FUNCTION APPROACH

BACKGROUND

The Navy's ability to carry out its peacetime and wartime missions depend heavily on the quality of its enlisted force. Thirty percent of the Navy's annual budget is spent on personnel compensation. Depite the large expenditure on personnel each year it is still an open question whether current personnel requirements provide an efficient allocation of manpower resources. The work reported here is one of a series of analyses underway to determine whether manpower requirements can be developed that will lead to increases in the Navy's level of readiness.

Navy manning documents for classes of ships and aviation squadrons list manpower requirements by rating, NEC and paygrade. These documents are derived from industrial engineering surveys of individual work centers. The required workload is determined for specific tasks, then for each work center as a whole. Minimum manning requirements are calculated based on an approved Navy work week. These requirements are aggregated to create a manning document for the ship or squadron, taking account of time required for training, leave, and other non-productive activity. Shore billets are determined in a similar manner through the SHORSTAMPS System.

This requirements determination process provides detailed descriptions of manning levels and experience mixes by paygrade. In an independent process, the Navy also sets minimum requirements for education and mental ability for incoming recruits. They are based on the probability of successfully completing the first enlistment and on estimates of probable A-school success. Neither process considers directly the possibilities for substitution that exists among personnel with different experience levels and other characteristics or the cost. This paper analyzes the tradeoffs among personnel with different characteristics with respect to their productivity and cost.

The effects of experience, education, mental ability and skill level of enlisted personnel on the performance of aviation squadrons are estimated. The degree of substitutability among various categories of squadron maintenance personnel is analyzed as well. This information can be combined with cost data on different types of personnel to determine a cost-minimizing force mix.

Most research on personnel productivity in the military has relied either on survey information about the relative performance of individuals with different personnel characteristics, or on written tests that attempt to measure an individual's ability to perform his job. Few studies have attempted to relate personnel resources to larger measures of military readiness. Several studies of readiness have been conducted at CNA, but they have not concentrated on manpower

requirements or substitution possibilities. (For a review of this research, see [1].)

MODEL

We estimate a production function that relates labor inputs to measures of the output of aviation squadrons. Since we have no strong priors about the shape of this production function or the ability of specific types of labor inputs to substitute for each other, a flexible production function is desired.

We have chosen the generalized Leontief production function suggested by Diewert (2). This function has the form:

$$Q = \sum_{i=1}^{n} a_i X_i + \sum_{i=1}^{n} \sum_{\substack{j=1 \\ j \neq i}}^{n} b^1_{ij} (X_i X_j)^{1/2} \qquad (1)$$

where Q is output and X_i, X_j are input quantities. Equality of b_{ij} and b_{ji} is required for estimation.* If one ignores the cross-product terms, (1) becomes a linear production function.

The marginal product of input X_i is:

$$f_i = \frac{\partial Q}{\partial X_i} = a_i + \sum_{\substack{j=1 \\ j \neq i}}^{n} b_{ij} (X_j / X_i)^{1/2} \qquad (2)$$

* The coefficient estimated by the regression analysis is $b^1_{ij} = b_{ij/2} = b_{ji/2}$.

A well-behaved production function satisfies two conditions.

It should be characterized by monotonic increases in output for increases in any input, i.e., that $f_i > 0$. Clearly, over certain ranges of X the generalized Leontief production functions can possess uneconomic regions where $f_i < 0$. This monotonicity condition can be tested with the parameter values estimated at appropriate input levels.

The second requirement is that the isoquants determined by the production function be convex. Convexity requires that the bordered Hessian matrix of first and second partial derivatives is negative definite. Again, the bordered Hessian must be evaluated for the appropriate parameter and input values.

The own second derivatives and cross-partial derivatives of the generalized Leontief function are respectively:

$$f_{ii} = \frac{\partial^2 Q}{\partial X_i^2} = -1/2 \sum_{\substack{j=1 \\ j \neq i}}^{n} b_{ij}(X_j/X_i^3)^{1/2} \qquad (3)$$

and

$$f_{ij} = \frac{\partial^2 Q}{\partial X_i \partial X_j} = 1/2\ b_{ij}(X_i X_j)^{-1/2}. \qquad (4)$$

These derivatives are calculated and inserted into the Hessian matrix to test the convexity condition.

From estimation of the production function it is possible to derive the appropriate demand requirements. Conditions for the optimal relative demand requirements are that the ratio of marginal product to price are equal for all inputs. Marginal products are derived from (2) and given information on the relative cost of each category of labor inputs one can solve for the optimal mix of labor groups. In practice this procedure is cast as a cost-minimizing problem subject to an output constraint and solved by non-linear methods.

The production function approach generates estimates of substitution elasticities. They provide insight about tradeoffs among inputs. If two types of labor are good substitutes then the Navy can respond to a reduction in one input by increasing the number of the second type. If the inputs are not good substitutes then this type of tradeoff becomes more difficult.* The Allen partial elasticity of substitution is

$$\sigma_{ij} = \left(\sum_{i=1}^{n} f_i X_i / X_i X_j \right) \left(|\bar{F}_{ij}| / |\bar{F}| \right) \quad i, j = 1, n \qquad (5)$$

* For a more developed discussion of these issues see [3].

where $|\bar{F}|$ is the determinant of the bordered Hessian matrix and $|\bar{F}_{ij}|$ is the cofactor of f_{ij} in $|\bar{F}|$. As equations (2) to (4) indicate, the values of the elements of $|\bar{F}|$ and σ_{ij} depend on the levels of X_i.

DATA

Flight Activity of Naval Aircraft, OpNav Notice C3700 (6/77 - 12/80), provided the following quarterly information on deployed squadrons:

- Type and number of aircraft
- Atlantic or Pacific Fleet
- Carrier on which deployed
- Total squadron flying hours in the quarter
- Total squadron flights and landings in the quarter
- Average hours flown per operating aircraft
- Mission capable rates.

Once the squadrons were identified, their Unit Identification Codes (UIC) were matched to the squadron number. Given the UIC, the enlisted personnel attached to the squadron were identified from the Enlisted Master Records for the corresponding dates. To be sure that these personnel were aboard the carrier, we examined their Onboard Accounting Category Codes and transfer dates. The following characteristics of the squadron's enlisted personnel were calculated:

- o Number of high school graduates and non-graduates,
- o Numbers in each paygrade,
- o Number by years of experience,
- o Number in each mental group category,
- o Number by training completed,
- o Number by tenure in the squadron,
- o Number by occupational group, and
- o Combinations of various categories.

Observations were obtained for 292 quarterly squadron deployments. Squadrons have an average of approximately 230 enlisted personnel. Within squadrons enlisted men are assigned to numerous occupations requiring very different levels of training and ability. To control for occupational differences, enlisted men were assigned to three categories based on the average skill level of their rating.* Rating group 1 includes personnel in highly technical ratings. Group 2 contains technical ratings and group 3, non-technical ratings. Estimation of the squadron production function was conducted for the squadron as a whole and separately within each rating group.

* See table A-1 for the assignment algorithm.

RESULTS

Preliminary analysis indicated that relationships between labor inputs and measures of effectiveness were significantly different for the three types of aircraft squadrons, F-4, F-14 and A-7. Analysis was conducted separately for the different aircraft types. Sample sizes were very small for F-4 and F-14 aircraft and results were unreliable. As a result, only analysis of the 180 attack squadron deployments is reported.

PAYGRADE

Most enlisted manpower requirements are defined in terms of experience and paygrade. Estimates of a production function with labor input measured by the number of personnel in specific experience and paygrade levels can confirm whether or not the current mix of junior and senior personnel is appropriate. Analysis of paygrade was conducted first. Personnel were grouped into three paygrade categories, E1-E3, E4-E6, and E7 - E9. The following equation was then estimated in two versions, the first using Number of Flights and the second using the quarterly Mission Capable Rate (MCR) as the measure of output.

$$Q = a_1X_1 + a_2X_2 + a_3X_3 + a_4P + b_{12}(X_1X_2)^{1/2} + b_{13}(X_1X_3)^{1/2} + b_{23}(X_2X_3)^{1/2} + b_{14}(X_1P)^{1/2} + b_{24}(X_2P)^{1/2} + b_{34}(X_3P)^{1/2}. \quad (6)$$

where X_1 = Personnel in grades E1-E3

X_2 = Personnel in grades E4-E6

X_3 = Personnel in grades E7-E9

P = Average number of operating aircraft.

Regression results are shown in table A-2. Results for each of the three rating groups, separately are displayed in table A-3. Estimates of the marginal product of each input are calculated as in (2), using estimated parameter values and mean levels of the independent variables. Table 1 presents the marginal products calculated from these regressions.

These results are highly consistent and display the appropriate pattern of increasing output at higher grade levels. The major exception is row 4, which has a perverse result, along with the value for mid-grade personnel in row 6. The most striking finding is the extremely high marginal productivity of the most senior personnel. This suggests that substantial improvements in readiness can be obtained by increasing the number of top-grade enlisted men.

Table 2 summarizes the substitution elasticities among inputs for each of the three rating groups. Positive (negative) signs indicate that the inputs are substitutes (complements). The actual substitution elasticity estimates are provided in table A-4.

TABLE 1

MARGINAL PRODUCTS OF PAYGRADE GROUPS

		E1-E3	E4-E6	E7-E9	Aircraft
	Mean Level	[82]*	[132]	[14]	[13.2]
(1)	Flights	-1.2	2.9	30.7	13.9
	[846]	(29.1)	(1.6)	(9.4)	
(2)	MCR	.08	.15	.72	1.98
	[59]	(.08)	(.10)	(.40)	
			Rating Group 1		
		[10]	[42]	[5]	
(3)	Flights	7.2	8.0	26.5	25.8
(4)	MCR	1.07	.36	-.07	2.56
			Rating Group 2		
		[25]	[52]	[5]	
(5)	Flights	4.9	11.2	50.5	-7.8
(6)	MCR	.56	.39	1.67	1.38
			Rating Group 3		
		[46]	[39]	[4]	
(7)	Flights	-4.8	11.7	44.8	35.9
(8)	MCR	-.07	.64	.68	2.9

* Bracket terms are mean values of variables. MCR is measured on a scale from 0 to 100. Standard errors for marginal products involve tedious calculations. They are presented, in parentheses, for the entire squadron sample as an indication of the relative precision of the estimate.

TABLE 2

SUBSTITUTION ELASTICITIES BY PAYGRADE
FOR RATINGS GROUPS 1, 2, 3
(Flight Equations)

	E1-E3	E4-E6	E7-E9
E4-E6	+++		
E7-E9	++-	-+-	
Aircraft	-++	+++	---

At this point, the value of a flexible functional form for the production function becomes apparent. Although analysis below argues that a more senior force is desireable the increase in senior personnel is somewhat less than might be expected from an examination of table 1. The first reason is that the marginal productivity of senior personnel is high in part because of their very small numbers and this production function allows the marginal product to decline as input levels increase. Thus as the number of senior personnel is increased their marginal product will fall quite quickly. Secondly , as is seen in table 2, this form allows E7-E9 personnel to be complements with more junior personnel which reduces the relative value of substituting senior for junior personnel.

LEAST COST FORCE

In order to test the applicability of results from the estimation conducted, a least-cost force mix by paygrade was constructed. Costs

for personnel in each paygrade category were derived from the Enlisted Billet Cost Model [4] and the minimum cost force for a 12-plane squadron was determined subject to the condition that output be at least equal to the current level. This is the constrained-minimization problem presented below:

$$\text{Min}_{X_1,X_2,X_3} \sum_{i=1}^{3} P_i X_i + \lambda(Q_0 - Q(X)) \qquad (7)$$

where P_i ≡ Average cost of personnel in category i

X_i ≡ Number of personnel in category i

Q_0 ≡ Current number of flights

$Q(X)$ ≡ Number of flights predicted from equation (1).

The solution of this minimization problem is shown in table 3 using parameter values from the regression of flights on paygrade categories for all personnel (table A-2).

TABLE 3

CURRENT AND LEAST-COST FORCE BY PAYGRADE
FOR 12-PLANE A-7 SQUADRONS

	E1-E3	E4-E6	E7-E9	$ Cost (10^3)
Current	75	120	12	4,190
Least-cost	57	107	19	3,860
Difference	-18	-13	+7	330

Cost/Man (10^3): E1-E3 (14.4), E4-E6 (22.4), E7-E9 (34.5)

The results imply that a shift in resources from the bottom six paygrades to the top three would result in an eight percent cost savings while maintaining the current effectiveness level. This solution assumes constant marginal costs. The true marginal cost will rise with increased manning in any specific manpower category and therefore the solution overstates the optimal tradeoffs. These results are suggestive of efficient substitution possibilities, however. Although all results point in the same direction, similar analysis within rating groups produced unsatisfactory results.

The categories of paygrades chosen are essentially arbitrary. As a check on the sensitivity of the analysis to the grouping of paygrades, the same analysis was conducted using different paygrade groups. Because many personnel reach the E-4 level within their first term, a second set of estimates was derived that assigned them to the most junior group. Marginal product estimates from this specification are displayed in table 4. This set of results show a higher marginal product for the mid-level group, as expected. As with the first set of estimates, results based on quarterly flights are more consistent than those using MCR as the measure of performance.

The estimates based on different manpower categories produce somewhat different marginal product estimates. In order to test the effect of this on the policy implications of the model, a least-cost

TABLE 4

MARGINAL PRODUCTS OF PAYGRADE GROUPS

	E1-E4	E5-E6	E7-E9	Aircraft
Mean level	[141]	[71]	[13]	[13.1]
(1) Flights	-0.5	6.2	29.1	9.9
(2) MCR	.046	.339	.342	2.114
		Rating Group 1		
	[29]	[23]	[5]	
(3) Flights	19.2	-4.1	19.5	21.8
(4) MCR	.184	.323	.084	3.538
		Rating Group 2		
	[50]	[26]	[5]	
(5) Flights	3.0	18.2	36.7	8.1
(6) MCR	.418	.462	1.341	1.689
		Rating Group 3		
	[63]	[22]	[4]	
(7) Flights	-3.3	20.7	45.8	34.5
(8) MCR	-.017	1.508	.658	2.234

force is shown in table 5. Again the optimal solution implies that a dramatic increase in the number of top-grade personnel and a substantial drop in the number of the most junior personnel would lead to significant savings. A final test, including the E-7s in the mid-grade group, was conducted. In this case the marginal product for the E-8, E-9 group dropped dramatically. An average squadron had only three or four men in this category, however, so confidence in this finding must

be limited. On balance then, this analysis finds consistent evidence that a more senior force is an efficient change from current manning.

TABLE 5

CURRENT AND LEAST-COST FORCE BY PAYGRADE
FOR 12-PLANE A-7 SQUADRONS

	E1-E4	E5-E6	E7-E9	$ Cost (10^3)
Current	129	65	12	4,304
Least-cost	86	60	23	3,796
Difference	-43	-5	+11	508

Cost/Man (10^3) E1-E4 (16.6), E5-E6 (24.5), E8-E9 (34.5)

EXPERIENCE

Promotion to higher ranks is dependent on both time in service and performance. Therefore, it is not surprising that output is related to higher paygrade personnel. Related analysis was conducted based on experience alone, as measured by years in service. Personnel were assigned to three experience categories, 1-4 years, 5-8 years, and 9 or more (corresponding to first term, second term and career personnel). Regression results are displayed in tables A-5 - A-6.

Table 6 presents the calculated marginal products for the experience categories. Again, the estimates are consistent and indicate

significant improvement with experience. Anomalous results are limited to low estimates for second term personnel (rows 1, 3, 4) and one wrong sign for aircraft in row 5.

TABLE 6

MARGINAL PRODUCTS OF EXPERIENCE GROUPS

DV		1-4 Years	5-8 Years	9+ Years	Aircraft
	Mean Level	[146]	[29]	[53]	[13.2]
(1)	Flights	1.3	-2.8	14.5	.5
(2)	MCR	.01	.12	.44	2.25
		Rating Group 1			
		[32]	[10]	[15]	
(3)	Flights	17.0	-4.4	2.0	24.2
(4)	MCR	.14	.01	.34	3.66
		Rating Group 2			
		[52]	[10]	[20]	
(5)	Flights*	5.8	9.6	3.41	-18.1
(6)	MCR	.30	.59	1.15	.83
		Rating Group 3			
		[62]	[9]	[18]	
(7)	Flights	.3	1.7	37.9	14.8
(8)	MCR	.02	.55	1.53	1.90

* Convexity condition not satisfied.

Estimates of substitution elasticities are more varied for the experience variable than for paygrade. They are, however, generally reasonable. Table 7 presents the elasticity estimates. Cost minimization experiments have not been conducted for experience groups due to difficulties in deriving appropriate prices. A glance at table 6 makes it clear, however, that a more experienced enlisted force is probably desireable.

TABLE 7

SUBSTITUTION ELASTICITIES FOR EXPERIENCE GROUPS,
RATING GROUPS 1, 2, 3
(Flight Equations)

	1-4 Years	5-8 Years	9+ Years
5-8 years	- + +		
9+ years	+ - -	+ - -	
Aircraft	+ + +	+ - +	- - 0

Current manpower requirements are defined basically by experience and paygrade. As such, they were the central variables in this analysis. The Navy does impose minimum educational and ability requirements on incoming recruits, however. It is of interest to know the effects of these characteristics on productivity as an input into the current popular debate on whether or not the military requires higher "quality" personnel.

EDUCATION AND AFQT

In order to estimate the effects of education on productivity, personnel were assigned to three categories. The first includes high school non-graduates and those with General Educational Development Certificates (GED). The second and largest category is made up of high school graduates. The final category contains personnel with education beyond high school. As with the earlier work analysis was conducted for the squadron as a whole and separately within occupational categories. Regression estimates are found in tables A-7 and A-8.

Table 8 presents the estimated marginal products for each educational category evaluated at current mean levels of the inputs. When output is measured by total flights an appropriate pattern is found, personnel with more education are more productive. Only the estimate for non-graduates in row (5) is inconsistent with the expected result. Results with MCR as an alternative measure of output are generally unreasonable.

In addition to educational categories, estimates of the effects of mental ability, as measured by mental group categories, were obtained. Three categories, MG 1 and 2, MG3, and MG 4 and 5, were included in the production function regressions, as presented in tables A-9 and A-10. Table 9 provides the marginal product estimates. These results are disappointing. Previous studies at CNA have found tenuous and

conflicting results on the value of mental ability in predicting performance [5, 6]. We hesistate to accept the proposition that intelligence has no relation to performance, but we cannot measure the relationship with any confidence.

TABLE 8

MARGINAL PRODUCTS OF EDUCATIONAL GROUPS

		NHS/GED	HSG	HS+	Aircraft
	Mean Level	[53]	[158]	[18]	[13.2]
(1)	Flights	-.5	1.9	10.6	26.8
(2)	MCR	.30	.06	-.04	2.20
			Rating Group 1		
		[7]	[42]	[7]	
(3)	Flights	4.8	9.0	12.9	22.4
(4)	MCR	.21	.44	-.64	3.01
			Rating Group 2		
		[21]	[57]	[3]	
(5)	Flights	19.1	9.9	17.6	-15.9
(6)	MCR	.68	.33	.78	1.67
			Rating Group 3		
		[24]	[58]	[7]	
(7)	Flights	-14.6	7.8	8.8	53.1
(8)	MCR	-.02	-.01	.37	4.30

TABLE 9

MARGINAL PRODUCTS OF MENTAL GROUPS

		MG1-2	MG3	MG4-5	Aircraft
	Mean Level	[77]	[100]	[50]	[13.2]
(1)	Flights	7.7	.5	2.1	13.7
(2)	MCR	.21	-.03	.39	1.49
			Rating Group 1		
		[37]	[17]	[3]	
(3)	Flights	6.4	7.7	25.1	29.2
(4)	MCR	.06	.52	1.53	3.15
			Rating Group 2		
		[20]	[41]	[21]	
(5)	Flights	18.7	9.6	6.5	-2.7
(6)	MCR	.44	.37	.89	1.18
			Rating Group 3		
		[20]	[43]	[26]	
(7)	Flights	6.1	-2.5	.9	67.2
(8)	MCR	.20	.12	-.02	3.97

SUMMARY

The analysis in this study has examined the relationship between the characteristics of enlisted personnel and unit performance. The results confirm that unit performance is affected by the quality of personnel. The most consistent findings are the effects of more senior personnel on performance. The results for education and mental ability

as predictors of performance are generally reasonable although much less consistent.

Personnel in the upper paygrades were found to be substantially more productive than junior personnel. Estimates of substitution elasticities imply that E1-E3 personnel are substitutes for E4-E6 enlisted men but that E7-E9 personnel may be complements for both groups. The results were used to derive a simulated least-cost force. This simulation indicates that a shift in resources to the top three paygrades could result in significant savings in personnel cost while maintaining current effectiveness levels.

Measures of experience based on length of service rather than rank were employed as well. Similar results were obtained to those using paygrade. Productivity was found to increase substantially with additional years of experience. Again, this finding is particularly striking for the most senior personnel. Productivity studies based on individual performance measures have had great difficulty in estimating productivity for this group due to the administrative nature of their jobs. This result lends support to the argument that measures of unit performance provide insights unavailable in research which examine individual performance.

Estimates of the relationship between unit performance and levels of education and mental ability display mixed results. Increases in

productivity at higher levels of education are observed when performance is measured by quarterly flights but not when MCR is used. The effects of mental ability on performance cannot be established with any confidence.

PROSPECTS

Current efforts are underway at CNA that will provide estimates of the relative cost of personnel with different levels of education and mental ability. They will allow for estimates of the optimal mix of men with varying personal characteristics. However, regression estimates for these equations do not seem to be very stable, and it may be difficult to place a great deal of confidence in the resulting mix predictions. Nonetheless, these estimates have potential as a first step in attacking these issues.

Data are available on other characteristics of aviation squadrons that could improve the precision of estimates of output. Measures of length and location of deployments, activities conducted, and material readiness, for example, would all be useful as explanatory variables. Unfortunately, none of these data are in condition to be used without extensive effort. For the immediate purpose of determining manpower requirements, it is unlikely that further data development will provide dramatic improvements. For studying readiness issues in general and personnel requirements in particular, however, production function

analysis using flexible functional forms, such as the generalized Leontief, offer considerable promise.

This CNA study is one in a series of projects aimed at measuring personnel productivity and analyzing manpower requirements. In addition to this study, and others that have measured unit performance as a function of labor inputs, studies based on surveys, proficiency exam scores, time to promotion and simulation models are being used to measure the performance of personnel in the Navy. (See [7] for a review of current work and future plans.) These measures of performance are being integrated with our continuing supply analyses. As final products, we seek models which parameterize both supply and demand. These models can be used to analyze a wide variety of policy issues such as alternative force structures, contract length and optimal bonus levels.

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APPENDIX A

EMPIRICAL RESULTS

TABLE A-1

ASSIGNMENT PROCEDURE FOR RATINGS[a]

Rating Group 1	Rating Group 2	Rating Group 3
Highly Technical	Technical	Semi-Technical
Air Traffic Controller (AC)	Aviation Machinist's Mate (AD)	All Others
Aviation Electricians Mate (AE)	Aviation Structural Mechanic (AM)	
Aviation Fire Control Technician (AQ)	Aviation Ordnanceman (AO)	
Aviation Electronics Technician (AT)	Aviation Support Equipment Technician (AS)	
Aviation Antisubmarine Warfare Technician (AY)	Aircrew Survival Equipmentman (PR)	

[a] Assignments based on skill classification by Op-110C.

TABLE A-2

COEFFICIENT ESTIMATES: PERFORMANCE ON PAYGRADE

Variable	Flights	MCR
(X_1) E1-E3	-59.1 (27.0)[a]	-3.16 (1.26)
(X_2) E4-E6	-49.4 (34.8)	-4.06 (1.62)
(X_3) E7-E9	43.1 (68.8)	-1.91 (3.21)
(P) Aircraft	-513.1 (359.2)	-42.9 (16.7)
$(X_1X_2)^{1/2}$	-24.1 (42.4)	-1.30 (1.98)
$(X_1X_3)^{1/2}$	9.6 (73.0)	4.51 (3.40)
$(X_2X_3)^{1/2}$	158.8 (92.7)	5.91 (4.32)
$(X_1P)^{1/2}$	355.0 (179.7)	15.7 (8.4)
$(X_2P)^{1/2}$	230.2 (174.1)	23.9 (8.1)
$(X_3P)^{1/2}$	-551.8 (338.1)	-24.6 (15.8)

[a] Std. errors in parentheses.

TABLE A-3

COEFFICIENT ESTIMATES: PERFORMANCE ON PAYGRADE BY RATING GROUP

Variable	Rating Group 1		Rating Group 2		Rating Group 3	
	Flights	MCR	Flights	MCR	Flights	MCR
(X_1) E1-E3	-3.8	2.83	-40.6	-1.11	-48.9	-4.10
	(71.2)	(3.22)	(48.3)	(2.23)	(30.9)	(1.41)
(X_2) E4-E6	-91.2	-8.12	40.1	-4.45	-30.5	-1.02
	(68.1)	(3.08)	(51.4)	(2.38)	(79.7)	(3.63)
(X_3) E7-E9	-175.0	-8.05	-84.6	2.52	31.8	-1.46
	(143.8)	(6.51)	(138.9)	(6.42)	(53.7)	(2.45)
(P) Aircraft	-36.6	-2.93	154.0	-7.96	-171.5	-32.67
	(177.2)	(8.02)	(345.5)	(15.98)	(284.0)	(12.95)
$(X_1X_2)^{1/2}$	8.9	-1.07	-3.9	-0.78	40.1	-3.18
	(114.2)	(5.17)	(68.4)	(3.17)	(70.4)	(3.21)
$(X_1X_3)^{1/2}$	119.9	9.66	1.77	10.26	-97.2	-5.84
	(152.4)	(6.90)	(103.4)	(4.78)	(77.5)	(3.53)
$(X_2X_3)^{1/2}$	236.6	17.94	160.9	4.75	46.9	-5.33
	(208.1)	(9.42)	(144.0)	(6.66)	(127.5)	(5.81)
$(X_1P)^{1/2}$	-69.0	-7.04	132.6	-0.17	147.4	21.00
	(228.7)	(10.36)	(202.3)	(9.36)	(172.5)	(7.86)
$(X_2P)^{1/2}$	200.6	20.15	-208.5	17.27	45.3	14.47
	(193.8)	(8.78)	(236.1)	(10.92)	(251.1)	(11.45)
$(X_3P)^{1/2}$	-281.2	-30.65	-153.5	-24.64	115.4	12.98
	(430.3)	(19.48)	(344.3)	(15.93)	(263.2)	(12.00)

TABLE A-4

SUBSTITUTION ELASTICITIES BY PAYGRADE
FOR RATING GROUPS 1, 2, 3
(Flight Equations)

	E1-E3	E4-E6	E7-E9
Rating Group 1			
E4-E6	.4		
E7-E9	2.3	-.1	
Aircraft	-1.3	.1	-.4
Rating Group 2			
E4-E6	.1		
E7-E9	.3	.4	
Aircraft	.6	.1	-.1
Rating Group 3			
E4-E6	1.5		
E7-E9	-4.7	-1.7	
Aircraft	1.5	1.1	-2.3

TABLE A-5

COEFFICIENT ESTIMATES: PERFORMANCE ON EXPERIENCE

	Flights	MCR
(X_1) LOS 1-4	-60.5 (29.4)	-3.62 (1.30)
(X_2) LOS 5-8	-16.1 (28.9)	3.58 (1.28)
(X_3) LOS 9+	-18.6 (54.6)	-1.13 (2.42)
(P) Aircraft	-634.7 (513.9)	-77.04 (22.79)
$(X_1X_2)^{1/2}$	28.3 (51.4)	-5.81 (2.28)
$(X_1X_3)^{1/2}$	-11.2 (52.9)	-.25 (2.35)
$(X_2X_3)^{1/2}$	48.0 (53.9)	-3.49 (2.39)
$(X_1P)^{1/2}$	391.1 (215.7)	33.22 (9.57)
$(X_2P)^{1/2}$	-150.6 (151.8)	16.00 (6.73)
$(X_3P)^{1/2}$	98.1 (285.3)	12.30 (12.65)

TABLE A-6

COEFFICIENT ESTIMATES: PERFORMANCE ON EXPERIENCE RATING BY GROUP

Variable	Rating Group 1		Rating Group 2		Rating Group 3	
	Flights	MCR	Flights	MCR	Flights	MCR
(X_1) LOS 1-4	-3.4	-3.45	-7.5	.05	-45.6	-3.58
	(113.6)	(5.21)	(73.4)	(3.37)	(34.0)	(1.52)
(X_2) LOS 5-8	22.7	3.34	65.0	8.40	-13.1	3.71
	(29.3)	(1.34)	(52.7)	(2.42)	(49.4)	(2.70)
(X_3) LOS 9+	-102.3	-3.12	-25.9	.94	-131.9	2.01
	(104.3)	(4.78)	(97.8)	(4.49)	(134.2)	(5.98)
(P) Aircraft	-288.0	-24.01	-107.1	-6.45	-581.4	-32.53
	(320.6)	(14.7)	(352.6)	(16.2)	(390.4)	(17.4)
$(X_1X_2)^{1/2}$	-71.5	-4.09	110.8	-8.64	60.4	-4.16
	(129.6)	(5.94)	(95.3)	(4.37)	(51.1)	(2.28)
$(X_1X_3)^{1/2}$	-78.3	-3.19	-168.0	2.26	-70.8	-2.75
	(166.9)	(7.66)	(106.8)	(4.90)	(92.1)	(4.11)
$(X_2X_3)^{1/2}$	67.4	-7.39	204.7	-2.29	-75.7	-6.10
	(97.5)	(4.47)	(103.4)	(4.75)	(96.2)	(4.29)
$(X_1P)^{1/2}$	208.1	18.06	160.9	5.85	230.7	22.28
	(338.5)	(15.52)	(296.6)	(13.61)	(192.2)	(8.57)
$(X_2P)^{1/2}$	-7.4	8.58	-569.2	6.06	-18.4	10.83
	(171.4)	(7.86)	(230.3)	(10.57)	(179.3)	(7.99)
$(X_3P)^{1/2}$	287.4	18.66	296.1	-1.93	610.2	9.94
	(262.2)	(12.02)	(273.0)	(12.53)	(440.5)	(19.64)

TABLE A-7

COEFFICIENT ESTIMATES: PERFORMANCE ON EDUCATION

	Flights	MCR
(X_1) NHS/GED	40.9 (74.7)	4.07 (3.34)
(X_2) HSG	7.4 (29.5)	2.19 (1.32)
(X_3) HS+	16.9 (61.5)	-1.99 (2.75)
(P) Aircraft	-460.5 (427.9)	-49.97 (19.12)
$(X_1X_2)^{1/2}$	-161.6 (76.2)	-11.16 (3.40)
$(X_1X_3)^{1/2}$	132.1 (77.0)	2.40 (3.44)
$(X_2X_3)^{1/2}$	21.4 (65.4)	-4.59 (2.92)
$(X_1P)^{1/2}$	241.0 (285.4)	20.85 (12.75)
$(X_2P)^{1/2}$	260.2 (158.4)	12.97 (7.08)
$(X_3P)^{1/2}$	-352.1 (237.7)	15.59 (10.62)

TABLE A-8

COEFFICIENT ESTIMATES: PERFORMANCE ON EDUCATION BY RATING GROUP

Variable	Rating Group 1		Rating Group 2		Rating Group 3	
	Flights	MCR	Flights	MCR	Flights	MCR
(X_1) NHS/GED	103.5	6.61	44.0	-.66	10.2	1.36
	(68.6)	(3.05)	(64.9)	(3.00)	(70.4)	(3.15)
(X_2) HSG	-10.4	1.80	38.1	.94	-70.2	2.22
	(47.8)	(2.12)	(59.5)	(2.76)	(68.3)	(3.05)
(X_3) HS+	22.3	1.35	-8.7	1.96	56.2	.76
	(72.9)	(3.25)	(55.3)	(2.56)	(71.6)	(3.20)
(P) Aircraft	-5.6	-10.65	116.2	-10.68	-310.8	-49.19
	(183.8)	(8.18)	(373.7)	(17.30)	(288.0)	(12.87)
$(X_1X_2)^{1/2}$	-146.3	-9.61	-56.1	-2.25	-104.5	-16.62
	(103.2)	(4.61)	(105.8)	(4.90)	(100.0)	(4.47)
$(X_1X_3)^{1/2}$	85.0	2.42	94.3	-1.17	-52.6	-1.42
	(111.5)	(4.96)	(84.1)	(3.89)	(83.0)	(3.71)
$(X_2X_3)^{1/2}$	89.7	-8.44	59.8	-6.03	173.9	-11.77
	(107.9)	(4.80)	(88.2)	(4.08)	(99.2)	(4.43)
$(X_1P)^{1/2}$	51.8	5.90	5.3	8.69	189.4	32.17
	(215.7)	(9.60)	(277.5)	(12.84)	(213.5)	(9.54)
$(X_2P)^{1/2}$	109.5	8.56	-76.7	3.41	345.9	21.44
	(138.1)	(6.15)	(255.9)	(11.84)	(232.8)	(10.41)
$(X_3P)^{1/2}$	236.5	10.28	-217.4	12.83	-361.1	26.09
	(237.3)	(10.56)	(200.7)	(9.29)	(221.1)	(9.88)

TABLE A-9

COEFFICIENT ESTIMATES: PERFORMANCE ON MENTAL GROUP

	Flights	MCR
(X_1) MG 1-2	-37.6 (31.5)	-2.53 (1.43)
(X_2) MG 3	-34.7 (45.1)	-3.84 (2.05)
(X_3) MG 4-5	4.9 (52.2)	3.30 (2.37)
(P) Aircraft	-339.7 (375.9)	-28.93 (17.09)
$(X_1X_2)^{1/2}$	-28.5 (61.0)	.30 (2.78)
$(X_1X_3)^{1/2}$	174.2 (61.3)	4.71 (2.79)
$(X_2X_3)^{1/2}$	-85.9 (76.3)	-3.69 (3.47)
$(X_1P)^{1/2}$	-40.4 (131.7)	3.28 (5.99)
$(X_2P)^{1/2}$	429.7 (238.5)	28.0 (10.84)
$(X_3P)^{1/2}$	-195.8 (224.4)	-12.51 (10.20)

TABLE A-10

COEFFICIENT ESTIMATES: PERFORMANCE ON MENTAL GROUPS
BY RATING GROUP

Variable	Rating Group 1		Rating Group 2		Rating Group 3	
	Flights	MCR	Flights	MCR	Flights	MCR
(X_1) MG 1-2	-35.4	-1.32	-5.2	.06	-25.8	.82
	(39.4)	(1.77)	(44.8)	(2.08)	(63.1)	(2.81)
(X_2) MG 3	51.6	.74	-19.9	.59	125.0	-6.25
	(107.6)	(4.84)	(57.1)	(2.64)	(63.7)	(2.83)
(X_3) MG 4-5	59.8	2.89	32.3	2.65	-139.9	-.62
	(47.9)	(2.16)	(44.6)	(2.07)	(72.7)	(3.23)
(P) Aircraft	11.4	-4.19	184.9	-5.80	-509.4	-46.18
	(201.7)	(9.08)	(328.6)	(15.23)	(288.1)	(12.80)
$(X_1X_2)^{1/2}$	70.3	.26	55.7	-3.59	-1.2	-4.60
	(69.3)	(3.12)	(62.4)	(2.89)	(97.0)	(4.31)
$(X_1X_3)^{1/2}$	-37.7	-8.09	95.0	3.12	33.6	-.47
	(84.3)	(3.80)	(67.6)	(3.13)	(96.9)	(4.30)
$(X_2X_3)^{1/2}$	-120.4	3.70	2.5	-3.13	36.5	-7.16
	(107.9)	(4.86)	(67.2)	(3.11)	(109.7)	(4.87)
$(X_1P)^{1/2}$	79.3	8.25	-157.7	3.32	33.6	7.43
	(144.0)	(6.48)	(181.3)	(8.40)	(185.1)	(8.23)
$(X_2P)^{1/2}$	-157.7	-2.70	31.5	7.60	393.0	38.70
	(283.3)	(12.71)	(245.4)	(11.4)	(214.7)	(9.54)
$(X_3P)^{1/2}$	164.2	8.08	-187.1	-2.80	287.1	15.18
	(213.1)	(9.59)	(191.7)	(8.88)	(223.9)	(9.95)

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