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TIME TO JOB PROFICIENCY: A PRELIMINARY INVESTIGATION OF THE EFFECTS OF APTITUDE AND EXPERIENCE ON PRODUCTIVE CAPACITY

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This paper documents the Time to Proficiency (TTP) Study, which is part of a large-scale research and development (R&D) effort to develop a measurement technology for obtaining job performance data. TTP utilizes time-based supervisor rating forms to build an aptitude/experience performance model. The model is described and the solution is presented for one Air Force specialty (Avionic Communications Specialist, 328X0). A sensitivity analysis is presented and recommendations for further R&D are discussed.

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SUMMARY

In the current environment of high deficits and pressure to reduce spending, it is critical that the Air Force use its resources as efficiently and effectively as possible. Foremost among these resources are Air Force personnel, and the skills, talents, experience, and capacities they possess. In order to minimize the "costs" of competing activities, the Air Force must assess individuals' abilities to complete the requirements of jobs within occupational specialties and establish criteria for allowing access to certain jobs or specialties.

The Time to Proficiency (TTP) Project had two major objectives:

1. to determine the feasibility and validity of using supervisor estimates of relative performance and supervision time as measures of performance and to estimate the extent to which mental aptitudes affect job performance

2. to develop and apply a prototype analytical model to evaluate how changing aptitude requirements based on job performance information would affect occupational capability; manpower, personnel, and training (MPT) policies; MPT programs; and MPT costs.

In order to achieve these objectives, one specialty, Avionic Communications Specialist (AFS 328X0), was selected and data were collected from supervisors concerning the relative proficiency of their subordinates. Data were also collected on the airmen's experience and mental aptitude (as measured by the Armed Services Vocational Aptitude Battery - ASVAB). These data were then analyzed using multivariate regression techniques to estimate the effects of aptitude on productivity, controlling for experience. Attrition information obtained from the Defense Manpower Data Center (DMDC) was used to model the likelihood of remaining in service as a function of aptitude and time. First-term costs were modeled using average recruiting and training costs and military pay. These models were integrated to arrive at an objective model which minimizes cost per productive unit with respect to aptitude.

The objective model, as well as its components, yielded significant findings for AFS 328X0:

1. Higher quality people achieve a specified level of productivity more rapidly.

2. The quality/experience trade-off is approximately 16 ASVAB electronics score points per 10 months of experience.

3. The attrition model confirms that the loss rate during training is higher for the lower aptitude groups.

4. Using a simplified cost model which assumes no differences in recruiting, training or sustainment costs over the first term as a function of quality, high quality people are more cost effective over the first term.

The present findings suggest that TTP is a potentially viable performance measurement technique which is relatively easy to administer and provides sufficient information for the modeling of productivity. The project also demonstrated how an objective model can be formulated and solved to arrive at an optimum level of aptitude; however, further refinement is needed.

The implication of these results, for the one AFS studied, is that it would be cost effective for the Air Force to recruit people at the highest possible quality level. To make Air Force-wide conclusions, larger samples and more AFSs should be examined.

PREFACE

The Time to Proficiency (TTP) study is part of a large-scale research and development (R&D) effort to develop a measurement technology for systematically obtaining job performance data. This R&D effort was undertaken by the Air Force Human Resources Laboratory (AFHRL) to satisfy three primary requirements:

1. Assist the manpower, personnel and training (MPT) community in the evaluation of training and selection programs,

2. Develop criteria for other MPT R&D projects, and

3. Test the feasibility of validating the Armed Services Vocational Aptitude Battery (ASVAB) against job performance measures.

TTP utilizes time-based supervisor rating forms to build an aptitude/experience performance model.

We wish to express our appreciation to those who contributed to this project. In particular we wish to thank Dr. Craig Moore of the Rand Corporation for his conceptual work prior to this effort. We also wish to thank Captain Mark Reid of the Defense Manpower Data Center for his assistance in the acquisition of demographic information for the measured incumbents and attrition data for the 1982 cohort group.

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TIME TO JOB PROFICIENCY: A PRELIMINARY INVESTIGATION OF THE EFFECTS OF APTITUDE AND EXPERIENCE ON PRODUCTIVE CAPACITY

I. INTRODUCTION

Evaluating the influence of mental aptitude on job performance in individual specialties is an important issue facing the Air Force. This evaluation would facilitate identifying aptitude requirements for each specialty. These requirements should balance the work force's operational capability and the practicality of managing the work force's manpower, personnel, and training costs in an efficient, albeit optimal, manner. This objective is constrained by the distribution of mental aptitudes among the pool from which new members are recruited.

The Time to Proficiency (TTP) project is based on a unique approach to the balancing of aptitude requirements and cost and productivity requirements. The approach features the notion of "time to proficiency," the length of time it takes to bring people with different attributes (especially mental aptitude) to targeted levels of task performance. The hypothesis is simple: The higher the levels of aptitude required for entry into a specialty, the faster the recruits will achieve job proficiency and the greater the capacity of the work force emplaced.

However, if aptitude requirements are raised, recruiting and retention costs may also increase. The Air Force's objective is to find those levels of aptitude requirements which best balance work force capabilities and costs. Thus, in addition to collecting performance data, this project contains an analytic approach that integrates performance measurement results with manpower, personnel, and training (MPT) and economic modeling techniques. The resulting analytic structure and data can be used to predict the effects of changes in aptitude requirements in three critical areas:

1. the average growth in individuals' task proficiency;
2. the overall productive capacity, personnel structure, and costs of the specialty; and
3. the productive capacity of individual units that employ a mix of members of the specialty.

The performance data for the TTP project were collected using a promising, yet fundamentally unique, technique. This technique uses supervisors' assessments of their subordinates' relative performance within homogeneous sets of tasks in a particular specialty. This data collection method, while not perfected, has the potential to be unobstrusive, efficient, and comprehensive. Thus, this technique represents an improvement over many data collection and performance assessment techniques that are currently being used or have been used in the past.

This study evaluated only one specialty (Avionic Communications Specialist, AFS 328X0) and concentrated on the evaluation of first-term airmen. This paper describes (a) the development of the TTP approach and the acquisition of data, (b) the evaluation of the TTP measures as compared to other performance measures, (c) the formulation of a model which is used to minimize first-term cost per productive unit through the selection of an optimum level of aptitude, and (d) the solution of that model.

II. DEVELOPMENT OF THE TTP APPROACH AND ACQUISITION OF DATA

Development and Methodology

Both practical needs and political pressures are increasing for the Air Force to develop efficient and effective ways of:

1. evaluating the influence of mental aptitudes on job performance in individual specialties, and

2. identifying for each specialty the minimum aptitude requirements that would optimally balance its work force's operational capabilities and the practicality of managing that work force.

One of the most crucial practical matters, of course, is the recruitment of sufficient personnel with the requisite aptitudes.

There has been much research conducted on a variety of performance measurement methods (see Landy & Farr, 1983). This includes scores from written tests in training school, paper-and-pencil job knowledge tests, hands-on work sample tests, and a variety of behaviorally anchored rating scales.

A fundamentally different technique now appears promising. This approach uses supervisors' assessments of their subordinates' relative performance within homogeneous sets of tasks. It has the potential to be less obtrusive than hands-on measures, yet efficient and comprehensive. The data collection method was developed originally to ascertain the effects of accumulated experience on task performance, in order to identify alternative complements of personnel that could accomplish specific amounts and mixes of work in individual work centers.

The TTP project is composed of a sequence of three research and development (R&D) phases that are based on differentiation of individuals' productive efficiency, considering both the quantity and the quality of job performance. Productive efficiency is a readily interpreted concept that enables:

1. estimation of the time required for individuals with differing mental aptitudes to achieve proficiency in different types of work,

2. trade-offs between an occupation's productive capability and its entrance requirements, and

3. evaluation of the effects on unit performance of altering entrance requirements.

In practice, the approach rests on subjective data provided by supervisors. These data are collected in a controlled and systematic manner, and can be compared with objective data collected via direct observation.

During Phase 1, both subjective and objective data are collected and compared for selected tasks within a single Air Force specialty (AFS). This comparison serves as a validation of the accuracy of the subjective data. Both the subjective approach and its results are also compared with alternative performance measurement methods in this first phase. In Phase 2, an analytic structure is developed for assessing, in an integrated manner, the effects of changing an AFS's aptitude requirements on its productive potential, career structure, and MPT costs. In Phase 3, performance measurement data collected in Phase 1 are integrated into the model developed in Phase 2.

The prime objectives of Phase 1 are to establish the validity of supervisors' subjective evaluations of their subordinates' relative productive efficiencies, to validate the relationships these evaluations imply between job performance and mental aptitudes, and to compare this new subjectively based approach to other performance measurement methods. Since the approach requires supervisors to evaluate subordinates' relative performance only with respect to groups of tasks, the initial study uses a thoroughly representative set of task groups. That is, insofar as possible, the task groups, for which both objective and subjective data were collected, span the range of work performed by enlisted personnel (e.g., they include groups that represent fairly simple technical tasks, complex technical tasks, clerical work, and management tasks).

Phase 2 develops and implements (in a prototype computer code) a conceptual model for evaluating the effects of changing the minimum mental aptitudes required for entry into an AFS. This model uses the notions of productive potential and time to proficiency, and can be used with the corresponding data obtained through the data collection and analysis efforts of Phase 1 or some other mechanism external to this project.

Phase 3 exercises the model developed in Phase 2 using the data and relationships developed in Phase 1, systematically altering the requirements for AFS entry with the patterns identified. Examples of questions to be examined include:

1. How much would overall productive capability and costs change with specified aptitude requirement changes?

2. How much would the average time required to achieve proficiency change?

3. How much difference would there be in the average amount of fully proficient time the USAF would realize from each recruit?

A critical component of the TTP project is assessing the relationship between individual characteristics (most notably cognitive ability and job experience) and job performance. This requires that a performance measurement procedure be developed and validated. The performance measurement technique which will be employed is built around supervisors' assessments of subordinates' performance in each of several homogeneous task groups drawn from the job responsibilities of the Avionic Communications Specialty (AFS 328X0). For the purpose of this study, it was desired that the developed task groupings have the following characteristics:

1. *Each group should be composed of tasks which are coperformed.* Since supervisors will be rating performance on the task groups as a whole, it is essential that the group consist

of tasks which logically relate to one another and accordingly can be viewed as a coherent whole.

2. *The tasks in each group should be homogeneous with respect to difficulty.* It is likely that tasks that require little ability and training will not distinguish low from high ability personnel since this ability will confer no advantage in task mastery or performance. Conversely, since demanding tasks require considerably more training and experience for mastery, the ability to learn and retain complex skills will play a more important role in job performance. Therefore, task difficulty is likely to moderate the relationship between ability and experience on the one hand and job performance on the other. It is therefore important that each task group sample a relatively narrow range on the task difficulty continuum to permit an unconfounded estimate of the ability/performance relationship.

3. *The task groups should be manageable in size to facilitate the rating process.* The rating task which the supervisors will be asked to perform in this study will involve a fairly complex judgment in which the performance efficiencies of two individuals will be compared across several tasks (and, through recall, across many situations) and expressed through the assignment of a single rating. If the task groups are very large (e.g., consisting of 50 tasks), it will be difficult, if not impossible, for the rater to give equal consideration and weight to all tasks in the group while performing the rating. Only those tasks which the rater views as the most important or most representative of the group would actually be considered in the rating. Since the selection of a subset of tasks would probably vary from rater to rater, this would introduce a considerable degree of error variance in the performance measures. Although no single number of tasks can be firmly established and unequivocally defended as an absolute criterion of task group size, it was considered desirable to limit the task group size to 15 tasks or less.

4. *Taken together, the task groups should sample as broad a range of task difficulty levels as possible.* Although each group was developed to be internally homogeneous with respect to task difficulty, efforts were taken to ensure that the groups were distinct from one another on this dimension. The between-group variance in task difficulty allows statistical determination of the effect of this variable on the ability/performance relationship.

These criteria define the desired features of the task groupings to be established. Though the criteria are not mutually exclusive, it was recognized that it would be improbable that a set of task groupings would be defined which perfectly met all of them. Trade-offs would inevitably arise through which one of the criteria would need to be relaxed in order to achieve another. In making these trade-offs, the relative priority of the criteria paralleled the order in which they are listed above.

Steps in Defining Task Groups

The development of the task groupings occurred in a series of stages in which they were first established with regard to task Coperformance and then iteratively refined to minimize within-group variance in Task Difficulty. The first step in defining the task groups consisted of a cluster analysis of all tasks in the Occupational Research Data Bank (ORDB) for the 328X0 AFS. Only data from respondents with between 1 to 48 months of service were used in this analysis, consistent with the focus of the larger study. This analysis, performed on the basis of task Coperformance, produced a total of 44 acceptable task clusters. This number was reduced to 10 by eliminating from further consideration those task groups in Duty Areas A through F (i.e., maintenance management, administration, and training tasks) or in duty areas performed by less than 20% of the first-term personnel in this AFS. The first criterion was applied to be consistent with this study's focus on production-like work; the second sought to eliminate low-density task areas for which sufficient individual performance data were unlikely to be obtainable.

Summary statistics on the task clusters defined through this procedure are displayed in Table 1. As shown, two of the clusters (Task Groups 1 and 4) contained considerably more tasks (52 and 34 tasks, respectively) than any of the others and considerably more than were thought desirable. A second problem was in the within-cluster variability in Task Difficulty. Inasmuch as the Task Difficulty is scaled to have a standard deviation of 1.00, the three task clusters with standard deviations greater than this (Task Groups 1, 2, and 9) are less homogeneous on this dimension than the overall population of tasks. The task clusters were refined to correct these problems.

Table 1. Summary Statistics on Original Task Clusters

Task group #	# of tasks	Coperformance within subgroups	Task difficulty	
			Mean	SD
1	52	51.1	4.67	1.19
2	4	36.2	3.34	1.12
3	5	21.1	4.34	0.67
4	34	64.7	5.63	0.89
5	5	44.1	4.92	0.94
6	5	36.9	3.32	0.66
7	17	61.4	5.14	0.86
8	9	30.6	4.31	0.49
9	9	25.4	3.10	1.14

The large task clusters were first reduced in size by decomposing them into the subgroups from which they were formed during the cluster analysis. This reduced Task Group 1 to two groups (designated 1A and 1B in Table 2) containing 26 tasks each, and Task Group 4 into three groups (designated Task Groups 4A, 4B, and 4C in Table 2) consisting of 9, 21, and 4 tasks, respectively.

Table 2. Summary Statistics of Second Stage Task Clusters

Task Group #	# of tasks	Task difficulty	
		Mean	SD
1A	26	4.66	1.22
1B	26	4.68	1.15
4A	9	5.39	0.84
4B	21	5.78	0.90
4C	4	5.42	0.81

Steps were next taken to improve the groups' homogeneity in terms of Task Difficulty. Since Groups 1A and 1B were still of substantial size, they were further subdivided by splitting each at their median Task Difficulty rating. This reduced the standard deviations of all task groups derived from the original Task Group 1 to substantially less than 1.00.

Futher homogeneity in Task Difficulty was achieved by eliminating from each task group any task which was an outlier in either Task Difficulty or Coperformance. This was done by reviewing scatterplots of the tasks in each task group, plotted as a function of Task Difficulty and Coperformance with the other tasks in the task group. On the basis of the scatterplot review, three tasks were eliminated from the task groups, yielding the 15 task groups summarized in Table 3.

Table 3. **Summary Statistics for Task Clusters**

Task	Task difficulty		# of	# of
group #	Mean	SD	tasks	WTPT tasks
1	3.646	0.340	14	4
2	5.858	0.678	12	5
3	4.159	0.438	11	2
4	5.542	0.640	13	7
5	4.373	0.574	7	0
6	5.391	0.836	9	1
7	6.617	0.477	10	2
8	5.010	0.372	11	3
9	5.419	0.813	4	0
10	4.919	0.935	5	1
11	3.017	0.291	4	0
12	5.794	0.597	7	2
13	4.549	0.657	10	0
14	4.313	0.486	9	0
15	2.835	0.923	8	0

Finally, the task groups were reviewed by subject-matter experts (SMEs), in this case 328X0 supervisory personnel. A prime concern was whether the task groups developed were truly distinct, meaningful, and identifiable components of the 328X0 job responsibilities. The task groups were modified in light of the SME input to yield the final 10 groups which were used in the TTP questionnaire. The final task groups are contained in Appendix A.

Summary data indicate that the task groups, in general, possess the desired characteristics. Coperformance among each group's tasks was established by the cluster analysis that originally defined the groupings. In addition, the within-group standard deviations in task difficulty show that the task groups are homogeneous, with no group having a standard deviation greater than 1.00, and most having standard deviations substantially less. Across the task groups, however, there is a considerable range in Task Difficulty. The task group mean Task Difficulty ratings vary from 3.7 to 6.0. This variation in Task Difficulty was sufficient for this project's analytic requirements. The task group size goals were also achieved. All of the groups are composed of less than 15 tasks, and half of the groups have less than 10 tasks.

Though not an explicit criterion, an additional desired feature was that the tasks in the task groups of the TTP Questionnaire overlap with the tasks contained in the Walk-Through Performance Test (WTPT). This allows a direct comparison of hands-on job performance information collected in the WTPT to the supervisory ratings of job performance collected with the TTP methodology. Fortunately, this overlap was satisfactory. Overall, 9 of the 10 derived task groups contain WTPT tasks, and a total of 25 tasks overlap between the two data collection methodologies (see Appendix A).

Questionnaire Development

After the task groups were defined, a questionnaire was developed to collect the required information. This included background data on the responding supervisor and corresponding subordinates, relative time required to perform a fixed amount of work at a specified level of quality in each task group, the relative supervision time required by each subordinate for task instruction or inspection, and how often each subordinate actually works on a task in each group. The response grid from the unpublished Aerospace Ground Equipment (AGE) Performance Differences Questionnaire was adapted to collect the data. Each task group was given its own response grid, which was accompanied by a list of benchmark performance times for each task within the cluster. The benchmark times were determined by averaging estimates provided by six experienced 328X0 SMEs for the typical first-term Avionic Communications Specialist.

The draft questionnaire was then reviewed by both Air Force Human Resources Laboratory (AFHRL) personnel and practicing supervisors in the appropriate work centers prior to field use. This provided opportunities to refine instructions, individual questions, and response formats, and to further revise task groups to improve within-group homogeneity.

The questionnaire was then pretested by having each part completed by supervisors at three Air Force bases: Seymour Johnson, Norton, and Beale. The supervisors were instructed to make judgments in a systematic manner using a consistent frame of reference. Members of the research team were present to observe difficulties, provide assistance, ascertain whether the forms were completed correctly, and obtain feedback regarding instructions, difficulties, and completion time requirements. Based on the pretest results, the questionnaire and instructions were revised. At this point the revisions consisted chiefly of clarification of instructions. The final version of the TTP Questionnaire is contained in Appendix B.

III. COMPARISON OF PERFORMANCE MEASUREMENT METHODS

Air Force Job Performance Measurement System (JPMS)

The Job Performance Measurement (JPM) project involves the development of a variety of measurement techniques for collecting valid, accurate, and reliable hands-on job performance information. This comprehensive approach to measuring job performance is based on the rationale that the various methods--while to some extent overlapping--measure different aspects of the criterion space with differing levels of accuracy (Kavanagh, Borman, Hedge, & Gould, 1987). Less expensive, easier-to-administer interview tests and performance ratings will then be compared and evaluated as substitutes for the more expensive, labor-intensive, hands-on performance measures. A brief description of the JPMS follows. A more thorough description is provided in Hedge and Teachout (1986).

Walk-Through Performance Testing (WTPT)

The WTPT is founded on the work sample philosophy but expands the testing domain by including an interview testing component (Hedge, 1984). The hands-on component resembles a traditional hands-on work sample test designed to measure task proficiency. The interview component is conducted at the work site in a "show and tell" fashion that allows the incumbent to "visually and verbally" describe how a step should be accomplished. For each component, a test administrator uses a checklist to record whether the steps necessary for successful performance on a task are correctly performed or described. A 5-point overall proficiency rating is recorded by the administrator after the completion of each task. Additional information concerning time required to complete each task and specific amounts of task experience required is also collected.

Rating Forms

Rating forms range in detail from the very micro to the very macro in order to provide a thorough coverage of the performance evaluation continuum. Four rating forms--task, dimensional, global, and Air Force-wide--are completed by three separate rating sources (supervisor, peer, and self). All forms employ a 5-point adjectivally anchored rating scale, and specific behavioral descriptions are included to provide detailed information to assist raters in making accurate judgments.

Task Rating Form. The task rating form provides the most specific rating data. This form contains approximately 40 Avionic Communications Specialist tasks, including all those in the WTPT.

Dimensional Rating Form. The dimensional rating form provides the second most specific rating data. Technical proficiency is rated across important areas of the job. For AFS 328X0 these areas include: Avionics Administrative Functions, Troubleshooting, Remove/Replace, Bench Check/Operational Check, and General Avionics Maintenance.

Global Rating Form. The global rating form is designed to collect overall ratings of proficiency. Two items are used to assess the technical proficiency and interpersonal proficiency of job incumbents.

Air Force-Wide Rating Form. The Air Force-Wide rating form is designed to be representative of all specialties in the Air Force. The form focuses on eight performance factors important for all first-term Air Force personnel. These factors consist of: Technical Knowledge/Skill, Initiative/Effort, Knowledge of and Adherence to Regulations/Orders, Integrity, Leadership, Military Appearance, Self-Development, and Self-Control.

In sum, the WTPT and rating forms constitute the JPMS. This multiple measurement approach allows the identification of a measure or combinations of measures to be used as a criterion in selection, classification, and training R&D. In addition, surrogate measures can be identified and substituted for the more expensive and time-consuming hands-on procedure.

Comparing TTP to the Job Performance Measurement System

The TTP Questionnaire was completed by supervisors who indicated the relative performance and supervisory times required by each of their subordinates for 10 task clusters. The task clusters were constructed to form logical groupings of tasks which are homogeneous with respect to Task Difficulty and have a relatively high rate of Coperformance within the cluster as described in Section II of this paper.

The supervisor was provided with benchmark performance time for each task within each cluster. The supervisor then chose a benchmark worker who performed closest to the pace represented by the benchmark times for each cluster. The benchmark worker concept was used to control for differences in evaluation across supervisors. The supervisor then estimated how long it would take each subordinate to complete the amount of work that the benchmark worker could perform in 1 hour. The supervisor also estimated the supervision time required for each worker to complete that amount of work.

Data Collection. The TTP Questionnaire was administered concurrently with the JPMS at 18 Air Force Bases. These bases are listed in Appendix C.

The questionnaire was completed by 18 supervisors for 83 job incumbents in AFS 328X0. Of these, 58 were matched with the JPMS data file for AFS 328X0. A full set of data was not available for some of the 58 matched cases. For some cases, fewer than 10 TTP task clusters were completed or data from one or more WTPT tasks were missing. The number of complete cases available for comparison varied by task. There were as many as 58 and as few as 5 pairwise complete cases.

TTP Versus Global Ratings

The TTP Questionnaire was designed to measure the relative rate at which individuals in an AFS perform tasks within selected task clusters and the time required to supervise that performance. The global technical proficiency rating measures the extent to which the individual meets or exceeds an acceptable level of technical proficiency over all the tasks he or she performs. Since higher levels of proficiency are reflected in faster performance times, aggregated TTP performance and supervision times should be negatively correlated with global technical proficiency. The TTP Questionnaire was not designed to measure interpersonal proficiency. Any observed correlation between the TTP measures and global interpersonal proficiency would be spurious. In summary, it is hypothesized that the TTP measures are negatively correlated with technical proficiency ratings and uncorrelated with (independent of) interpersonal proficiency ratings.

Table 4 displays the correlation coefficients for comparing the TTP measures to the global ratings. The TTP times are weighted averages of the 10 performance or supervision times. The average percent time spent by first-term 328X0s in each task cluster was obtained from the Comprehensive Occupational Data Analysis Programs (CODAP) data base and used to weight the averages. Both of the global ratings were tested for correlation with the aggregate performance and supervision times from the TTP questionnaire. A significant correlation with the TTP measures was observed for the technical proficiency ratings. A significant correlation was not observed when comparing the TTP measures to the interpersonal proficiency ratings. These findings support the above hypotheses by confirming the relationship between the TTP measures and technical proficiency while showing no statistical correlation with interpersonal proficiency.

Table 4. **Correlation Coefficients for TTP Performance and Supervision Times by Global Ratings**

Global rating	Performance time	Supervision time
Supervisor Technical Proficiency	-0.5246**	-0.4232**
Peer Technical Proficiency	-0.4064**	-0.4523**
Self Technical Proficiency	-0.4997**	-0.4331**
Supervisor Interpersonal Proficiency	-0.1851	-0.1179
Peer Interpersonal Proficiency	-0.1739	-0.1959
Self Interpersonal Proficiency	-0.0687	-0.0079

Note. Based on 58 observations.
*Significant at the 0.01 level.
**Significant at the 0.001 level.

TTP Versus Dimensional Ratings

The TTP task clusters span the range of the dimensional ratings. Again, since higher ratings are expected to be associated with faster performance times and less supervision, aggregated TTP measures should be negatively correlated with the five dimensional ratings as well as with the average of the five ratings. Table 5 displays the correlation coefficients for the TTP measures compared to the dimensional ratings for self, supervisor, and peer. The supervisor and peer ratings showed statistically significant correlations with the TTP measures for all five dimensions. The self ratings were significantly correlated with four of the five dimensions; however, no statistical significance was found for correlations between either TTP measure and Avionics Administrative Functions nor between TTP supervision time and Remove/Replace for the self ratings. Thus, the TTP measures show a moderate correlation with the majority of the dimensional ratings.

TTP Versus Air Force-Wide Ratings

The TTP measures were expected to be negatively correlated with the Technical Knowledge/Skill component of the Air Force-Wide Rating Form and uncorrelated with the other Air Force-Wide components. This was expected because higher levels of technical knowledge and skill should be associated with faster performance time and less supervision. Table 6 displays the correlation coefficients for the TTP measures compared to the eight Air Force-Wide ratings. As expected, the Technical Knowledge/Skill component was significantly correlated with both TTP measures across all raters. Supervisor and peer Leadership ratings were also significantly correlated with the TTP measures, as was the supervisor rating of Integrity. The Self-Development component was significantly correlated with both TTP measures for the self and peer ratings and with supervision time for the supervisor ratings. A few other pairs of measures were significantly correlated as indicated in the table.

Table 5. Correlation Coefficients for Dimensional Ratings Versus Aggregate TTP Performance and Supervision Times

Dimensional attributes	TTP time	Rater: Self Corr coef	Self N	Supervisor Corr coef	Supervisor N	Peer Corr coef	Peer N
Avionics Administrative Functions	Performance	-0.2155	58	-0.4400**	58	-0.3900**	58
	Supervision	-0.1787	58	-0.4037**	58	-0.4038**	58
Troubleshooting	Performance	-0.4412**	58	-0.6260**	58	-0.4396**	58
	Supervision	-0.4272**	58	-0.6831**	58	-0.3255*	58
Remove/Replace	Performance	-0.2845*	57	-0.5887**	58	-0.4426**	58
	Supervision	-0.1423	57	-0.6005**	58	-0.3956**	58
Bench Check/Operational Check	Performance	-0.3318*	58	-0.2905*	58	-0.4779**	57
	Supervision	-0.2754*	58	-0.3124*	58	-0.4793**	57
General Avionics Maintenance	Performance	-0.4452**	58	-0.3461**	58	-0.4703**	58
	Supervision	-0.3767**	58	-0.3042*	58	-0.4991**	58
Average Dimensional	Performance	-0.4882**	58	-0.6073**	58	-0.5518**	58
	Supervision	-0.3977*	58	-0.6143**	58	-0.5075**	58

*Significant at the 0.05 level.
**Significant at the 0.01 level.

Table 6. **Correlation Coefficients for Air Force-Wide Rating Form Versus Aggregate TTP Performance and Supervision Times**

		Rater					
		Self		Supervisor		Peer	
Air Force-wide attribute	TTP time	Corr coef	N	Corr coef	N	Corr coef	N
Technical Knowledge/Skill	Performance	-0.4568**	55	-0.5464**	55	-0.6610**	55
	Supervision	-0.4495**	55	-0.5345**	55	-0.6563**	55
Initiative/Effort	Performance	-0.3418*	54	-0.1871	55	-0.2416	55
	Supervision	-0.3097*	54	-0.1885	55	-0.3041*	55
Knowledge of and Adherence to Regulations/Orders	Performance	0.0115	55	-0.2714*	55	-0.1103	55
	Supervision	-0.1055	55	-0.2523	55	-0.1271	55
Integrity	Performance	0.1083	55	-0.3643**	55	-0.1263	55
	Supervision	0.0648	55	-0.4057**	55	-0.1388	55
Leadership	Performance	0.1036	55	-0.5018**	55	-0.4800**	55
	Supervision	-0.0002	55	-0.4003**	55	-0.4688**	55
Military Appearance	Performance	-0.0204	55	-0.1676	55	-0.2294	55
	Supervision	-0.1425	55	-0.1732	55	-0.2847*	55
Self-Development	Performance	0.3476**	55	-0.2427	55	-0.3056*	55
	Supervision	0.2738*	55	-0.2819*	55	-0.3218*	55
Self-Control	Performance	0.2631	55	-0.1141	55	-0.1594	55
	Supervision	0.2372	55	-0.2083	55	-0.1934	55

*Significant at the 0.05 level.
**Significant at the 0.01 level.

TTP Versus Task Ratings

The TTP measures for each task cluster should be negatively correlated with the task ratings for that cluster. This was expected because a high task rating should be associated with a low performance time and a low supervision time. Table 7 gives the correlation for the TTP measures compared to aggregated self, supervisor, and peer task ratings within each task cluster. In Cluster 1, both TTP times were significantly correlated with the peer ratings, as was supervision time with the supervisor ratings. In Cluster 2, the TTP measures were significantly correlated with the supervisor and peer ratings. TTP performance time was significantly correlated with the supervisor and peer ratings in Cluster 3. No significant correlations were observed for Cluster 4. In Cluster 5, both TTP measures were significantly correlated with the peer ratings, as was performance time with the supervisor ratings. Only supervision time and the supervisor ratings were significantly correlated in Cluster 6. Only performance time and the peer ratings were significantly correlated in Cluster 7. The peer ratings for Cluster 8 were significantly correlated with both TTP measures. No task ratings were obtained for Cluster 9. In Cluster 10, both TTP measures were significantly correlated with the supervisor ratings, as was performance time with the peer ratings. The self rating was not significantly correlated with either TTP measure in any cluster.

TTP Versus Walk-Through Performance Tests

Appendix A displays the assignment of specific tasks to TTP task clusters. The tasks which correspond to WTPT tasks for which data were available are indicated by an asterisk (*). A total of 25 of the TTP tasks were common to the WTPT. At least one WTPT task was included in all but one of the TTP clusters. Each cluster contained some tasks which were not among the WTPT tasks.

An aggregate WTPT score (measured by number of steps correctly completed), overall rating, and performance time were computed for each of the 10 TTP task clusters. The number of steps correctly completed was summed over all tasks in the cluster. To adjust for WTPT differences in testing (i.e., Phase 2, or major command-specific tests), the sum was divided by the total number of steps on which the individual was tested for that cluster. This ratio was used as a cluster-level measure of WTPT performance. When both interview and hands-on overall ratings were available, these ratings were averaged to obtain an overall rating for the task. Otherwise, whichever rating was available was used as the overall rating for the task. Interview time was believed to be inappropriate because the time required to complete an interview is not expected to be related to the time required to actually complete a task. Thus the hands-on time, when available, was used as the overall time for each task. Cluster-level WTPT ratings were computed by averaging the overall WTPT ratings for each task in the cluster, weighting by average percent time spent on each task. These weights were obtained from the CODAP data base as mentioned previously. This weighting of tasks by average percent time spent simulates how a supervisor might form a composite rating for a cluster in the TTP Questionnaire. It is expected that a task on which the average individual spends a greater proportion of his or her time would have a stronger influence on the supervisor's composite assessment than tasks which make up a smaller proportion of the average individual's productive time. Similarly, cluster-level WTPT hands-on performance times were computed using weighted averages.

Table 7. Correlation Coefficients for Task Ratings (Self, Supervisor, and Peer) Versus TTP Performance and Supervision Times

TTP task cluster	TTP time	Rater: Self Corr coef	Self N	Supervisor Corr coef	Supervisor N	Peer Corr coef	Peer N
1. Maintenance Administration and Inspection	Performance	-0.1733	55	-0.1512	55	-0.4276**	55
	Supervision	-0.0748	55	-0.2736*	55	-0.3109*	55
2. Flightline Maintenance	Performance	-0.1718	55	-0.3447**	55	-0.4779**	55
	Supervision	-0.1437	55	-0.3002*	55	-0.4789**	55
3. Flightline Troubleshooting	Performance	-0.1424	52	-0.2881*	52	-0.3828**	52
	Supervision	-0.1732	52	-0.2617	52	-0.2153	52
4. Shop Maintenance	Performance	-0.1093	49	-0.2206	49	-0.1689	49
	Supervision	-0.1411	49	-0.1978	49	-0.0807	49
5. UHF Shop Maintenance	Performance	-0.1659	48	-0.3071*	48	-0.3065*	48
	Supervision	-0.1636	48	-0.2426	48	-0.3222*	48
6. Flightline HF Maintenance	Performance	-0.1262	24	-0.4005	24	-0.1056	24
	Supervision	0.1769	24	-0.4063*	24	-0.1496	24
7. HF Control Box In-Shop Maintenance	Performance	0.1128	21	-0.1792	21	-0.6229**	21
	Supervision	0.1890	21	-0.2719	21	-0.3354	21
8. Receiver-Transmitter/HF Coupler Shop Maintenance	Performance	-0.1498	39	-0.1660	39	-0.4022*	39
	Supervision	-0.1878	39	-0.1983	39	-0.3758*	39
10. Shop VHF Maintenance	Performance	0.0518	19	-0.5458*	19	-0.4991*	19
	Supervision	0.0682	19	-0.4791*	19	-0.3890	19

*Significant at the 0.05 level.
**Significant at the 0.01 level.

The TTP Questionnaire collected only cluster-level data. Thus, direct task-level correlation between TTP and WTPT could not be examined. However each TTP cluster could be compared to each WTPT task within that cluster. In order to compare TTP and WTPT at the same level of aggregation, WTPT measures were aggregated to the cluster level. Correlation at this level was expected to be strongest when a large proportion of the TTP cluster is represented by WTPT tasks. At the task level, correlations of each TTP cluster with each WTPT task in that cluster were examined. At the aggregate level, correlations between TTP clusters and WTPT measures aggregated to the cluster level were examined. Since each WTPT task represents only a small portion of the TTP cluster, failure to find significant task-level correlation may be due to masking effects by other tasks (TTP and WTPT) in the cluster. Aggregation of WTPT measures to the cluster level could cause weaker correlation if the tasks to be combined are negatively correlated. However, this was not expected since the clusters were constructed to maximize homogeneity within clusters.

Table 8 displays the correlation coefficients for the TTP performance and supervision times with task-level and cluster-level WTPT measures. A significant correlation was found between the TTP performance time for Cluster 1 and the WTPT hands-on time for the only WTPT task in the cluster. For Cluster 2, significant correlations were observed for both TTP performance time and supervision time when compared to the interview performance and rating for the tasks: "Safety-Wire or Bond System Components" and "Inspect Parts Received from Supply or Manufacturer." For Cluster 3, significant correlations were observed for several individual tasks as well as at the cluster level. No significant correlations were observed for Cluster 4. For Cluster 5, significant correlations were observed for the hands-on time for several tasks as well as at the cluster level. A significant correlation was observed between the TTP performance time and the interview performance and rating for the only WTPT task in Cluster 6. The TTP performance time was significantly correlated with the hands-on time for the only WTPT task in Cluster 7. For Cluster 8, TTP performance time and the hands-on rating for the task "Isolate Malfunctions in HF Receiver-Transmitters" were significantly correlated. Cluster 9 contained no WTPT tasks. No significant correlations were observed for Cluster 10.

The TTP measures were estimated to have negative correlation coefficients when paired with the interview and hands-on performance and ratings, and positive correlation coefficients when paired with hands-on time. TTP performance and supervision time for Clusters 3 and 5, in which over half of the TTP tasks are represented by WTPT, show significant correlation with aggregate WTPT performance time. This supports the expectation that clusters with greater WTPT representation show stronger correlation. A control cluster in which all tasks are represented by WTPT would be useful to verify this assumption. Although the individual task correlation analysis does not convincingly verify the TTP measures as a surrogate for hands-on measures, the TTP measures offer some promise. Further analysis on a larger sample with more than one AFS is necessary to verify the relationship between TTP and hands-on performance.

Summary of Comparisons

In summary, the TTP measurement system is a unique approach in assessing the performance of workers. While relationships with hands-on measures and others JPMS measures are moderate, the TTP approach has potential for generating modeling data to use in estimating the effects of changing aptitude requirements on productive capacity.

Table 8. **Correlation Coefficients for TTP Performance and Supervision Times Versus WTPT Task Measures**

Task	WTPT measure	N	TTP time Performance	TTP time Supervision
Task Cluster 1 - Maintenance Administration and Inspection				
Make Entries on Maintenance Data Collection Record Forms. (AFTO Forms 349)	Interview Performance	58	-0.0628	-0.0161
	Interview Rating	58	-0.0741	-0.1740
	Hands-on Performance		-0.0532	-0.0749
	Hands-on Rating	58	-0.1158	0.0657
	Hands-on Time	58	0.2909*	0.1474
Aggregate Task Cluster 1	Performance	58	-0.0709	-0.0758
	Rating	58	-0.1393	-0.0585
	Time	58	0.2909*	0.1474
Task Cluster 2 - Flightline Maintenance				
Safety-Wire or Bond System Components	Interview Performance	58	-0.4106**	-0.3385**
	Interview Rating	58	-0.3461**	-0.3031*
	Hands-on Performance	58	0.0321	0.0506
	Hands-on Rating	58	-0.1055	-0.0404
	Hands-on Time	58	-0.0106	0.1916
Remove or Replace UHF Receiver-Transmitters	Interview Performance	58	0.0341	-0.0236
	Interview Rating	58	-0.0779	-0.0399
Remove or Replace Inter-phone Station Control Units	Interview Performance	22	-0.0533	-0.0986
	Interview Rating	22	-0.1360	-0.2279
Inspect Parts Received from Supply or Manufacturer	Interview Performance	58	-0.3888**	-0.3039*
	Interview Rating	58	-0.2847*	-0.2737*
Aggregate Task Cluster 2	Performance	58	-0.3721**	-0.3035*
	Rating	58	-0.2469	-0.2123
	Time	58	-0.0106	0.1916

Table 8. (Continued)

Task	WTPT measure	N	TTP time Performance	TTP time Supervision
Task Cluster 3 - Flightline Troubleshooting				
Repair Avionic System Wiring or Cables	Hands-on Performance	9	0.2978	-0.1032
	Hands-on Rating	9	-0.1919	-0.2521
	Hands-on Time	9	0.0475	0.1520
Remove or Replace Radio Frequency (RF) Coaxial Connectors	Hands-on Performance	55	-0.3959**	-0.3737**
	Hands-on Rating	55	-0.2991*	-0.2798*
	Hands-on Time	54	0.2607	0.3544**
Isolate Malfunctions in UHF Systems	Interview Performance	55	-0.1977	-0.1240
	Interview Rating	55	-0.1152	0.0022
Trace Circuits or Signals Using Wiring Diagrams or Schematics	Hands-on Performance	55	-0.3321*	-0.1981
	Hands-on Rating	55	-0.2723*	-0.1532
	Hands-on Time	55	0.2591	0.3031*
Remove or Replace Multiple Wire Plugs	Hands-on Performance	9	-0.7021*	0.0226
	Hands-on Rating	9	-0.5289	0.0092
	Hands-on Time	9	0.6213	0.0726
Aggregate Task Cluster 3	Performance	55	-0.4448**	-0.0261
	Rating	55	-0.3431*	-0.2042
	Time	55	0.3257*	0.4276**
Task Cluster 4 - Shop Maintenance				
Isolate Malfunctions in Interphone Cords	Interview Performance	51	-0.0658	-0.1087
	Interview Rating	51	-0.1084	-0.1736
Isolate Malfunctions in Interphone Monitor Control Units	Interview Performance	22	-0.0644	0.1693
	Interview Rating	22	-0.0876	0.0464
Aggregate Task Cluster 4	Performance	51	-0.1062	-0.0604
	Rating	51	-0.1116	-0.1584

Table 8. (Continued)

Task	WTPT measure	N	TTP time Performance	TTP time Supervision
Task Cluster 5 - UHF Shop Maintenance				
Bench Check UHF Receiver-Transmitters	Hands-on Performance	49	-0.3327*	-0.2805
	Hands-on Rating	49	-0.2373	-0.2787
	Hands-on Time	49	0.3361*	0.3252*
Isolate Malfunctions in UHF Receiver-Transmitters	Interview Performance	49	-0.1768	-0.0234
	Interview Rating	49	-0.2180	-0.1584
Bench Check UHF Control Units	Hands-on Performance	5	-0.4226	0.2182
	Hands-on Rating	5	0.7906	0.4082
	Hands-on Time	5	0.7946	-0.2052
Remove or Replace UHF Receiver-Transmitter Components	Interview Performance	49	-0.2516	-0.3063*
	Interview Rating	49	-0.1380	-0.2304
	Hands-on Performance		-0.1398	-0.1175
	Hands-on Rating	49	-0.2541	-0.2805
	Hands-on Time	49	0.3441*	0.2788
Set Up UHF System-Peculiar Test Equipment	Hands-on Performance		0.1026	0.0753
	Hands-on Rating	49	0.0584	0.0376
	Hands-on Time	49	0.2868*	0.2394
Perform Time Compliance Technical Order (TCTO) Modifications on Avionic Systems	Interview Performance	5	0.3101	-0.4804
	Interview Rating	5	0.0000	-0.5601
Aggregate Task Cluster 5	Performance	49	-0.2671	-0.2022
	Rating	49	-0.2466	-0.2657
	Time	49	0.4249**	0.3815**
Task Cluster 6 - Flightline HF Maintenance				
Remove or Replace HF Receiver-Transmitters	Interview Performance	25	-0.5413**	-0.0678
	Interview Rating	25	-0.4276*	-0.1073
Aggregate Task Cluster 6	Performance	25	-0.5413**	-0.0678
	Rating	25	-0.4276*	-0.1073

Table 8. (Continued)

Task	WTPT measure	N	TTP time Performance	TTP time Supervision
Task Cluster 7 - HF Control Box In-Shop Maintenance				
Bench Check HF Control Boxes	Hand-on Performance	22	0.0273	0.3106
	Hands-on Rating	22	-0.1788	0.0554
	Hands-on Time	22	0.4484*	0.3410
Aggregate Task Cluster 7	Performance	22	0.0273	0.3106
	Rating	22	-0.1788	-0.0554
	Time	22	0.4484*	0.3410
Task Cluster 8 - Receiver-Transmitter/HF Coupler Shop Maintenance				
Remove or Replace HF Receiver-/Transmitter Subassemblies	Interview Performance	22	-0.2434	-0.0763
	Interview Rating	21	-0.2928	-0.0725
	Hands-on Performance	22	-0.2056	-0.1771
	Hands-on Rating	22	-0.3784	-0.2610
	Hands-on Time	22	-0.1646	-0.3329
Set Up HF System-Peculiar Test Equipment	Hands-on Performance	40	-0.0190	-0.1186
	Hands-on Rating	40	-0.0114	-0.1169
	Hands-on Time	40	-0.2262	0.0406
Isolate Malfunctions in HF Receiver-Transmitters	Hands-on Performance	22	-0.1672	-0.1101
	Hands-on Rating	19	-0.5659*	0.3901
	Hands-on Time	19	-0.3221	-0.3299
Aggregate Task Cluster 8	Performance	40	-0.0973	-0.1768
	Rating	40	-0.0386	-0.1922
	Time	40	-0.1493	0.0662

Table 8. (Concluded)

Task	WTPT measure	N	TTP time Performance	TTP time Supervision
Task Cluster 10 - Shop VHF Maintenance				
Align VHF AM Receiver-Transmitters	Hands-on Performance	19	-0.2032	-0.1461
	Hands-on Rating	19	-0.0829	-0.0429
	Hands-on Time	19	0.1221	0.1520
Bench Check VHF AM Receiver-Transmitters	Hands-on Performance	19	-0.1749	-0.2417
	Hands-on Rating	19	-0.1397	-0.1957
	Hands-on Time	19	0.2504	0.2989
Aggregate Task Cluster 10	Performance	19	-0.2202	-0.1745
	Rating	19	-0.1258	-0.1246
	Time	19	0.1683	0.2065

Note. N - Number of Observations.
*Significant at the 0.05 level.
**Significant at the 0.01 level.

IV. TIME TO PROFICIENCY MODEL DEVELOPMENT

Overview of the TTP Model

The objective of the TTP model is to identify an optimum method of selecting airmen for entry into an AFS which minimizes cost per productive unit. The model uses the Armed Services Vocational Aptitude Battery (ASVAB) electronics score, a measure of aptitude, as a selection variable. The model is used to find the electronics score requirement associated with the smallest cost per productive unit over the first term. The model consists of four components:

1. Productive Capacity Model
2. Attrition Model
3. Cost Model
4. Distribution of Aptitudes

The productive capacity model represents productivity as a function of experience and aptitude. It is generally hypothesized that airmen with higher aptitudes are more productive than are airmen with lower aptitudes, and that productivity increases with experience. The attrition model represents the likelihood of remaining in service for each month in the first term as a function of aptitude. The data show that airmen with lower aptitude are more likely to leave the Air Force early than those with higher aptitude. The cost model represents monthly training costs and military pay through the first term and includes the cost of recruiting. Ideally, the cost model would be broken down by aptitude. Unfortunately this level of discrimination could not be obtained at this time. The cost model is therefore independent of aptitude. The distribution of aptitude is a model of the probability density function (PDF) for Electronics Aptitude Index (AI) scores for the population of airmen. From this model, the PDFs for subpopulations defined by selecting airmen on the basis of electronics score are computed.

An objective model is derived by examining the functional and logical relationships of the four components (production, attrition, cost, and aptitude). Production and cost are accumulated over the first term and adjusted for attrition to yield expected first-term productive capacity and expected first-term cost. The ratio of expected cost to expected productive capacity is then computed for each of five groups of airmen defined by electronics score. The distribution of electronics scores among airmen is then used to identify the subpopulation with the smallest average cost per productive unit for the first term.

Productive Capacity Model

A mathematical model can be formulated to express productive capacity (inverse (In) of performance time) as a function of experience (time in AFS) and mental aptitude (electronics score). Research has shown that learning curves often follow S-shaped functions such as $y=1/(1+\exp(-x))$. This is known as the logistic function. The domain of this function is the interval $(0,\infty)$. The range is (0,1). Our model for productive capacity is:

$$P = 1/(1+\exp(-b_0 - b_1X_1 - b_2X_2))$$

Where P = productive capacity

X_1 = experience (months in AFS)

X_2 = mental aptitude index (ASVAB electronics score)

b_0, b_1, b_2 are parameters to be estimated.

To ensure that productive capacity, P, is contained in the interval (0,1), the performance time must be normalized. The productive capacity, P, is defined as t^*/t where t is the TTP performance time in minutes and t^* is 1 minute less than the minimum observed performance time for the respective cluster ($t^* = \min(t) - 1$). Thus t^* is an estimate of the fastest possible performance time. If t^* is the smallest possible time interval in which a defined unit of work can be completed at an acceptable quality, it follows that $1/t^*$ is the maximum number of work units that can be completed per unit of time. For any individual worker, t is the time required for that worker to complete the defined unit of work at an acceptable quality, and 1/t is the number of work units that the individual can complete per unit of time. Thus, $P = t^*/t = (1/t)/(1/t^*)$ is the proportion of maximum productivity that the individual has obtained. For example, P = 0.75 indicates that the individual performs at a rate which is 75% of the maximum achievable productivity. Note that when t is very close to t^*, P approaches 1.0 (maximum productivity); and when t is much larger than t^*, P approaches zero (no productivity).

The next objective is the estimation of b_1, b_2, and b_0. The logistic function is nonlinear with respect to b_0, b_1, and b_2. Algebraic manipulation and a log transformation yield the following function:

$$\ln (P / (1-P)) = b_0 + b_1X_1 + b_2X_2.$$

The parameters b_1, b_2, and b_0 can now be estimated using multiple linear regression with $\ln (P/(1-P))$ as the dependent variable and experience and electronics score as explanatory variables. Table 9 lists the estimated parameters b_1, b_2, and b_0 for the above regression model

Table 9. **Regression Models for TTP Performance Time as a Function of Experience and Aptitude**

Task cluster	Explanatory variables: Experience b1	Experience P	Aptitude b2	Aptitude P	Intercept bo	Intercept P	Model statistics n	R-Squared	P
1	0.0316	0.000	0.0048	0.576 NS	-1.2789	0.072 NS	67	0.3652	0.000
2	0.0246	0.000	0.0024	0.770 NS	-0.7636	0.252 NS	66	0.2821	0.000
3	0.0269	0.000	0.0187	0.029	-2.7107	0.000	60	0.3942	0.000
4	0.0165	0.006	0.0238	0.007	-2.5020	0.001	55	0.3116	0.000
5	0.0208	0.003	0.0179	0.075 NS	-2.4080	0.005	54	0.2643	0.000
6	0.0318	0.001	0.0055	0.678 NS	-0.7752	0.474 NS	47	0.2467	0.002
7	-0.0065	0.543 NS	0.0141	0.309 NS	-0.6979	0.536 NS	35	0.0361	0.556 NS
8	0.0249	0.057 NS	0.0365	0.041	-3.1450	0.034	37	0.2432	0.009
9	0.0188	0.023	0.0179	0.015	-1.5245	0.130 NS	37	0.2472	0.008
10	-0.0008	0.961 NS	0.0048	0.845 NS	-0.0781	0.967 NS	27	0.0017	0.980 NS
Aggregate	0.0273	0.000	0.0167	0.025	-1.9945	0.001	67	0.4424	0.000

b1 = Regression Coefficient for Experience.
b2 = Regression Coefficient for Aptitude (Electronics Score).
bo = Regression Coefficient for the Intercept.
n = Number of Observations.
R-Squared = Coefficient of Determination.
P = Significance Level.
NS = Nonsignificant.

for each of the 10 task clusters and for the aggregate. The overall model (F-test) was significant for all but two of these clusters. (The data did not fit the model well for Task Clusters 7 and 10. This may be due to the small number of observations available for the clusters.) For those clusters with significant F-tests, experience was a significant explanatory variable. AI as measured by the ASVAB Electronics score was statistically significant for four of those clusters. The aggregate model, in which the dependent variable is calculated from a weighted average of performance times, was significant in the overall F-test as well as the two predictors. The coefficient of determination was 0.4424, which, given the sample size and the nature of the data, indicates a reasonably good fit.

Figures 1 through 9 graphically represent the estimated production curves for 8 of the 10 task clusters and for the aggregated clusters. (Clusters 7 and 10 were omitted due to lack of fit. A larger sample size is needed to evaluate the significance of these models.) The curves are shown with productive capacity on the vertical axis and experience (months in AFS) on the horizontal axis. The three curves represent the function at Electronics AI scores of 70, 80, and 90. In all graphs the lowest curve represents an electronics score of 70 while the highest curve represents a score of 90. The effect of electronics score on productive capacity decreases as the curves get closer together. For example, electronics score has a weaker effect in Task Cluster 1 than in Task Cluster 4. The effect of experience on productive capacity increases as the curves become steeper. For example, experience has a stronger effect in Task Cluster 1 than in Task Cluster 4. These observations may occur because the tasks in Cluster 1 are administrative whereas Cluster 4 tasks involve electronics skills. Administrative tasks are not expected to be as sensitive to electronics scores as are tasks directly involving electronics skills. However, administrative tasks may be more sensitive to experience than are electronics tasks.

In addition to the logistic model, a log-linear model was tested and yielded a comparable fit. The log-linear model does not, however, confine predicted values to the interval (0,1). Negative productive capacity or productive capacity greater than 1 could be predicted. This inadequacy was the primary reason for the selection of the logistic model over the log-linear model.

Production Isoquants

Another interpretation of the productive capacity model involves the concept of production isoquants. That is, all pairs of values of experience and aptitude which yield a fixed level of productive capacity can be determined. By solving the productive capacity equation for experience (or, alternatively, for aptitude), the relationship between experience and aptitude can be determined for a fixed level of productive capacity:

$$X_1 = [\ln (P/(1-P)) - b_0 - b_2X_2]/b_1.$$

Figure 10 graphs this function for selected values of productive capacity using the estimated regression parameters. The horizontal line at 48 months indicates the end of the first term. From the isoquants one can determine the rate of substitution between aptitude and experience to yield a given level of productive capacity. For example, the average airman with an electronics score (E-score) of 90 and 15 months of experience can perform at a rate equal to that of the average airman with an electronics score of 60 and 35 months of experience. On the average, a difference of about 1.6 points in E-score is equivalent to 1 month of experience. Thus, one airman who scores 16 points higher than another airman will reach a given level of productive capacity an average of 10 months sooner than the airman with the lower electronics score.

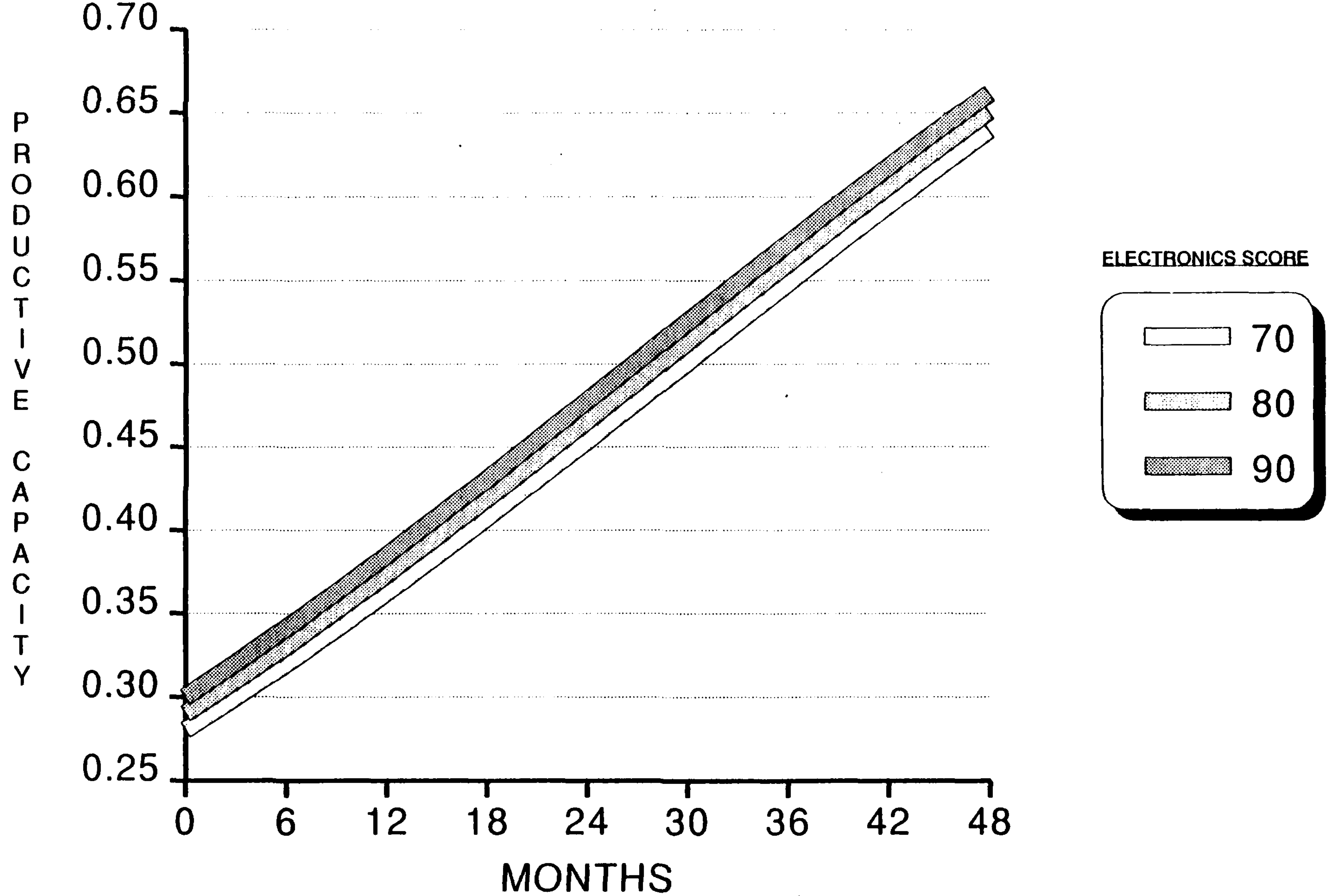

Figure 1. Estimated Production Curves for Task Cluster 1

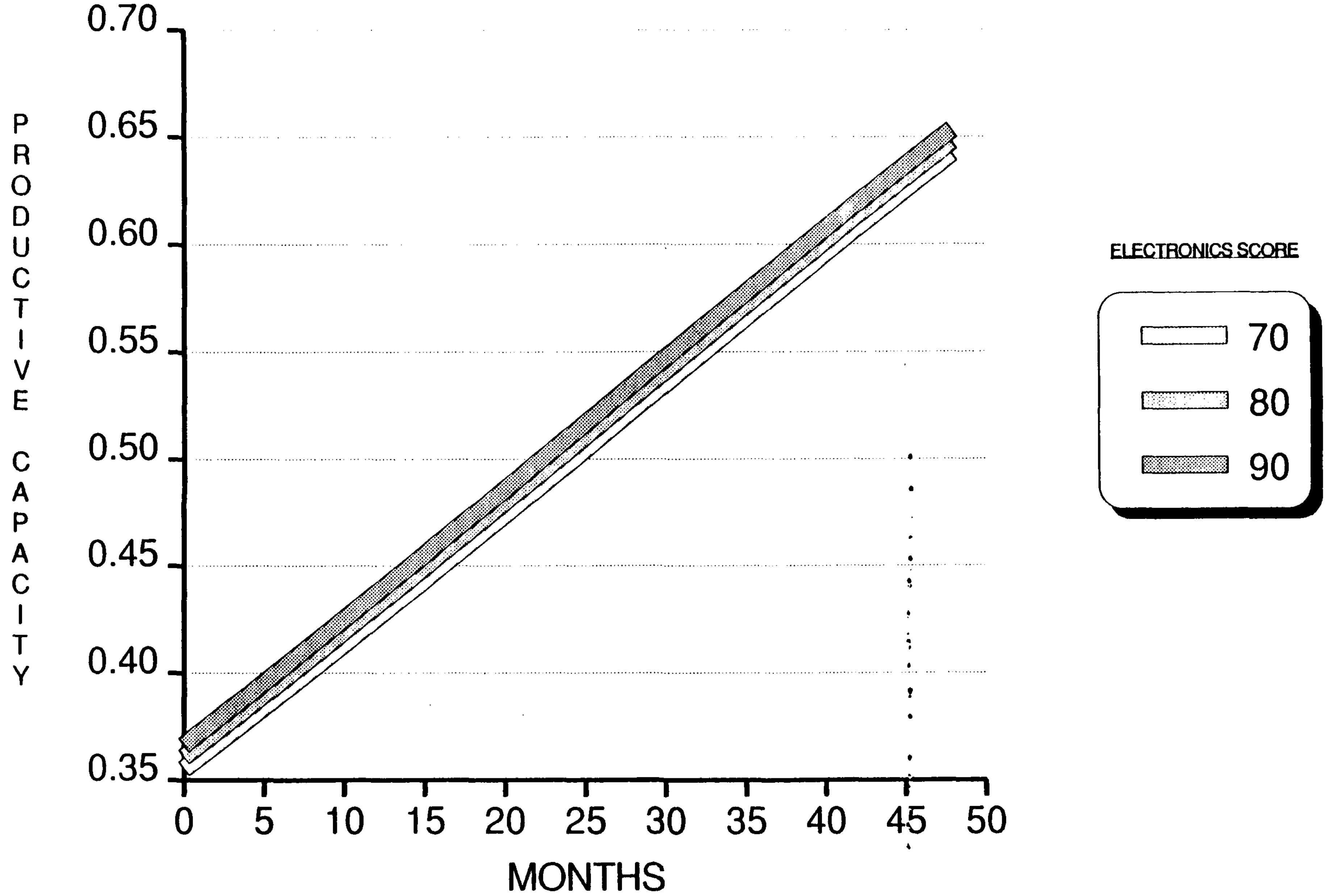

Figure 2. Estimated Production Curves for Task Cluster 2

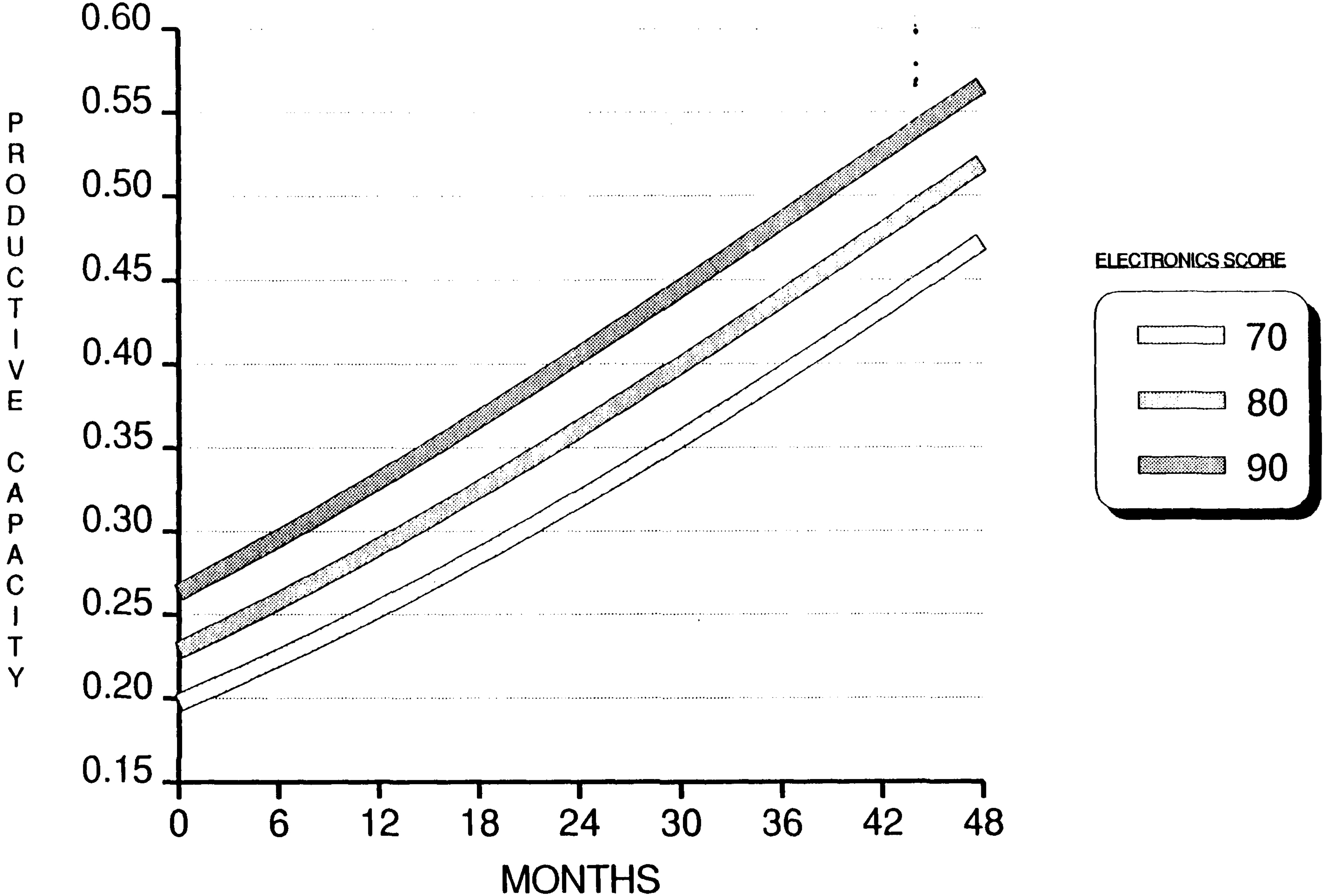

Figure 3. Estimated Production Curves for Task Cluster 3

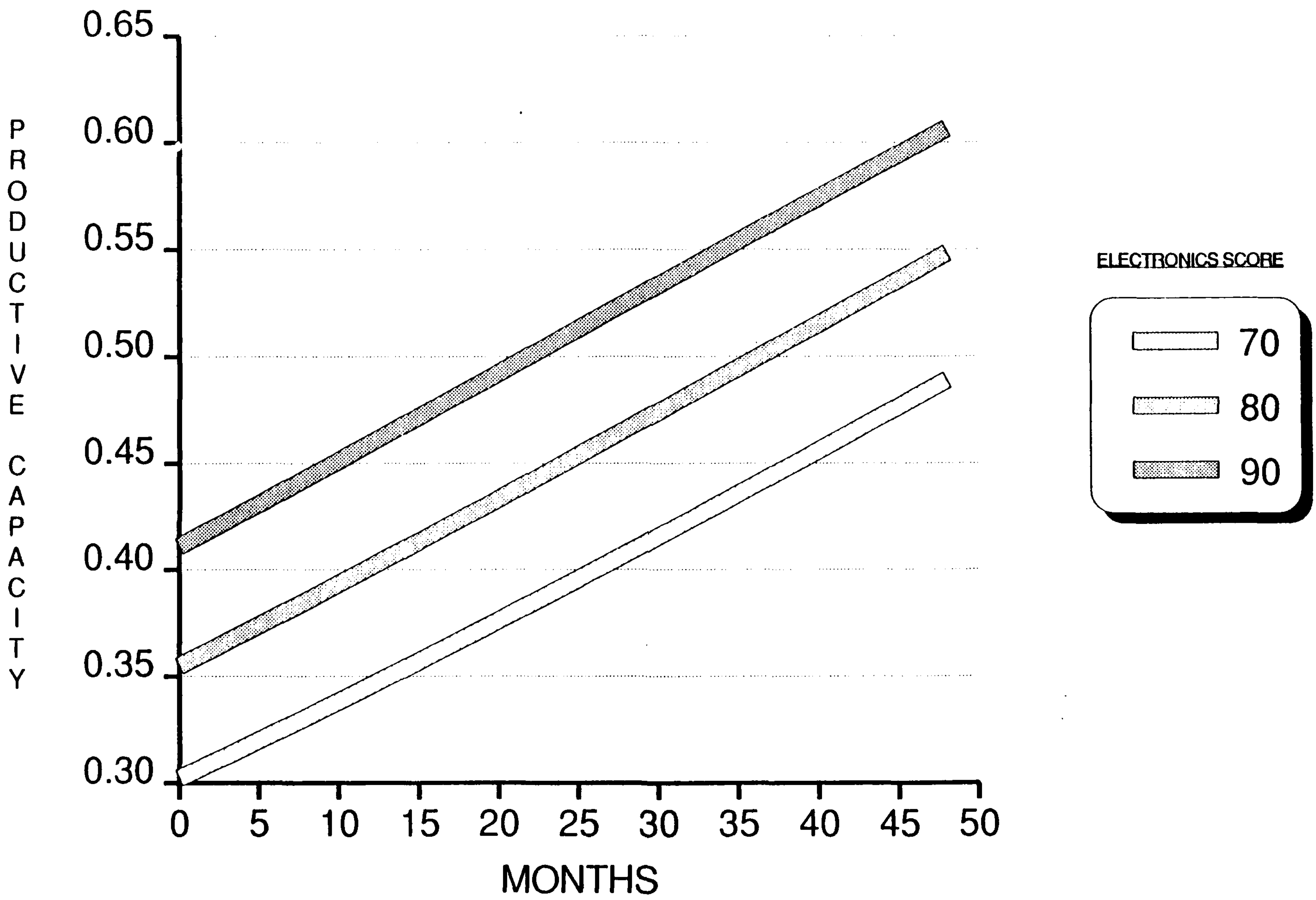

Figure 4. Estimated Production Curves for Task Cluster 4

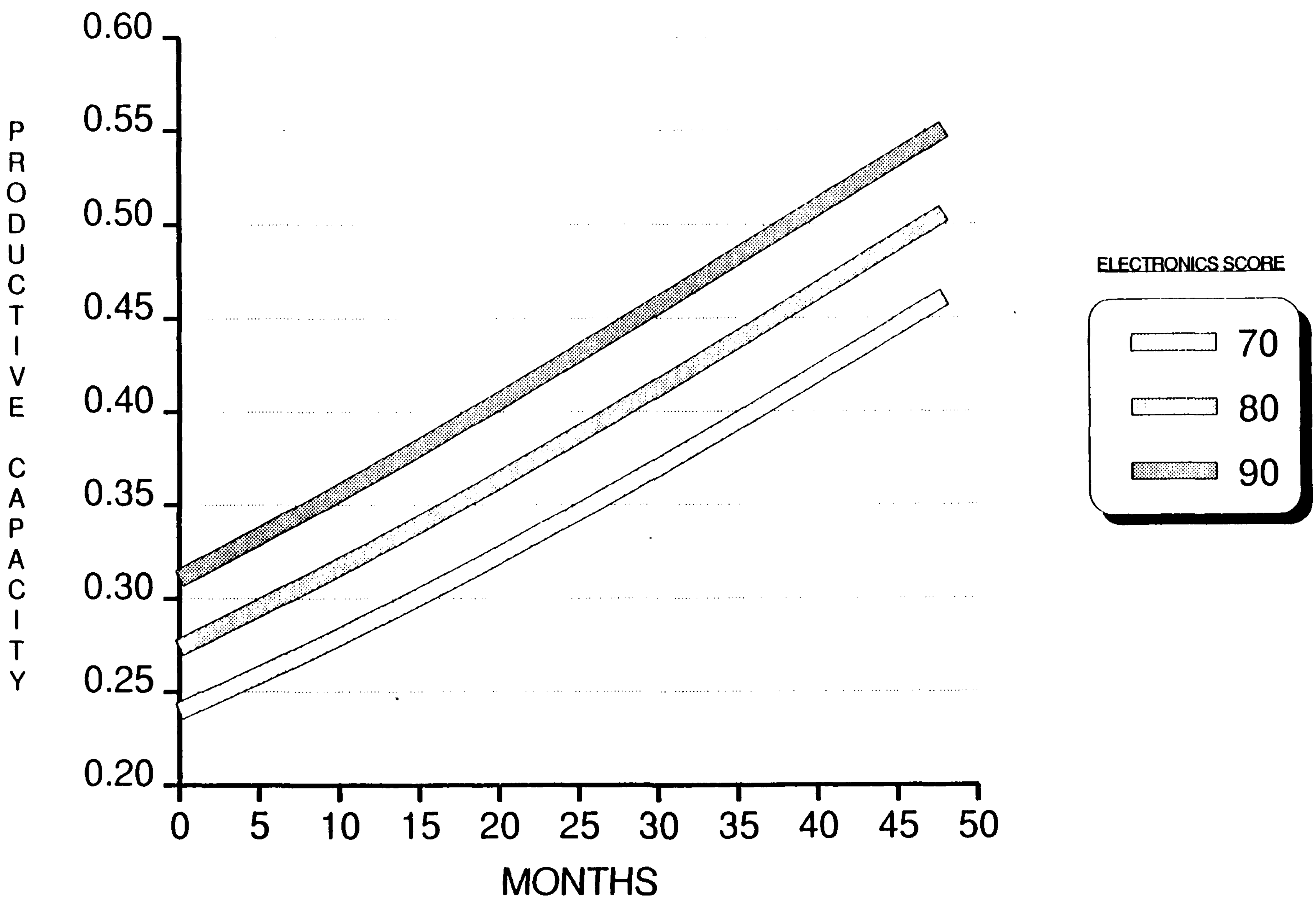

Figure 5. Estimated Production Curves for Task Cluster 5

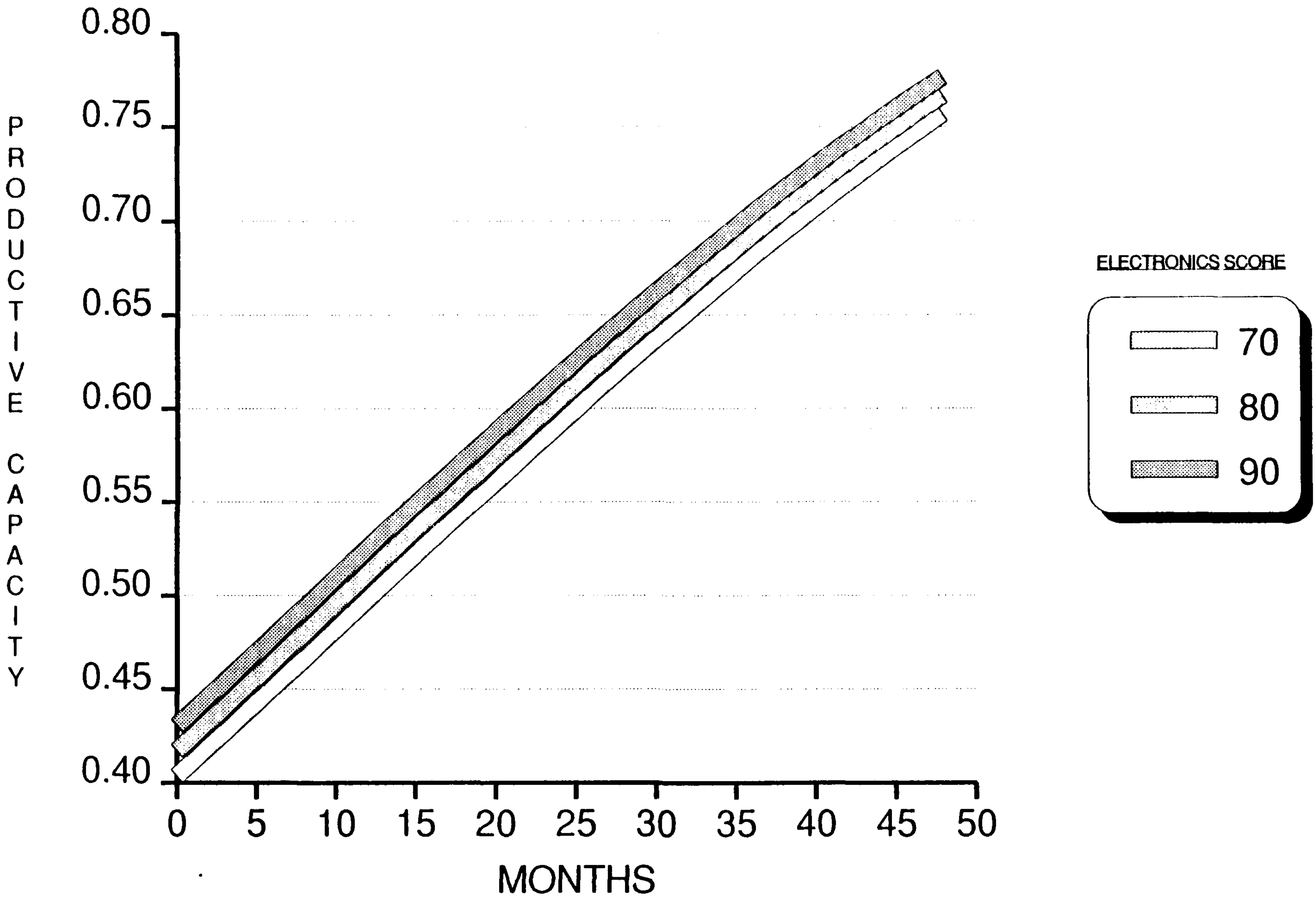

Figure 6. Estimated Production Curves for Task Cluster 6

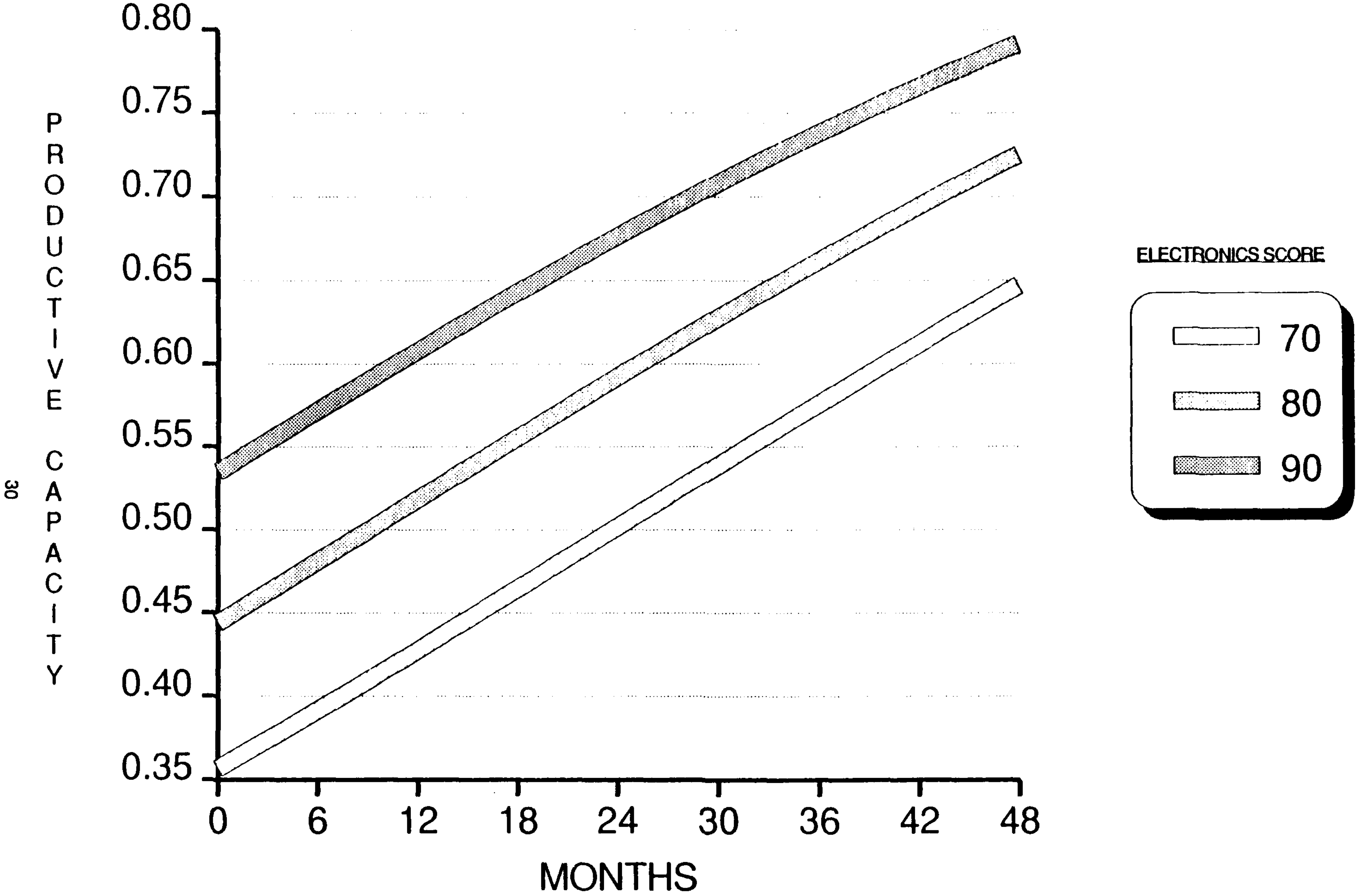

Figure 7. Estimated Production Curves for Task Cluster 8

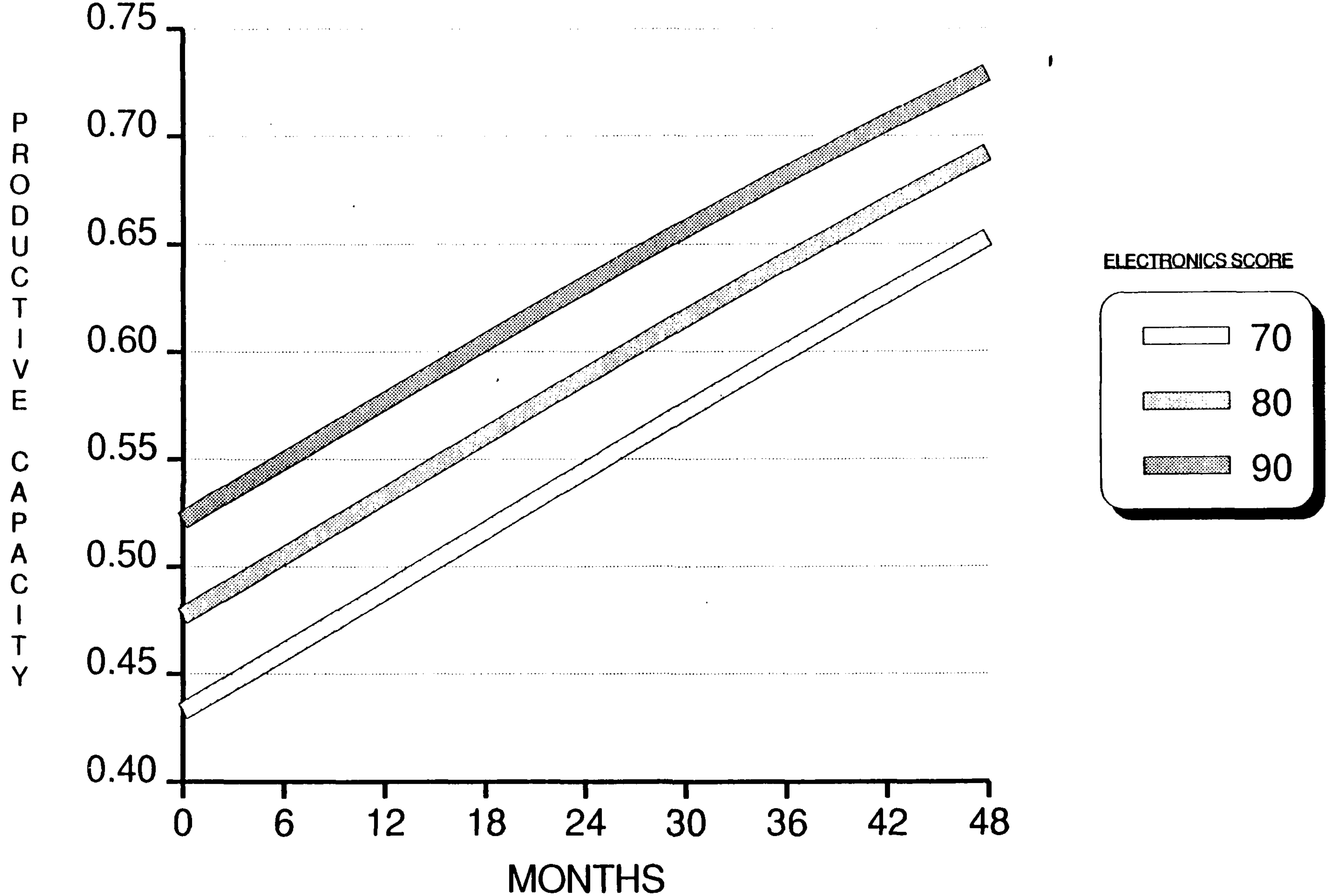

Figure 8. Estimated Production Curves for Task Cluster 9

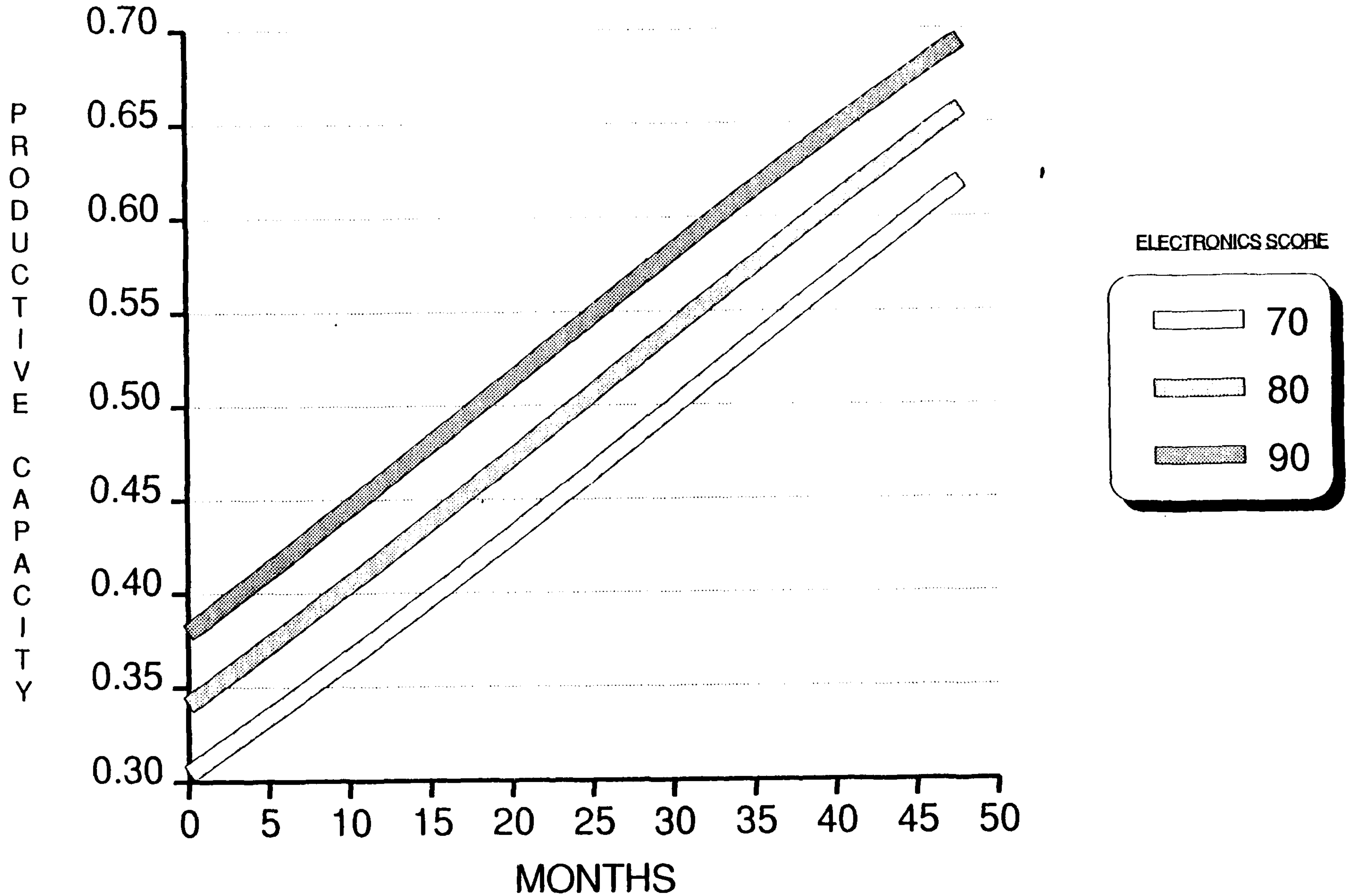

Figure 9. Estimated Production Curves for Aggregated Task Clusters

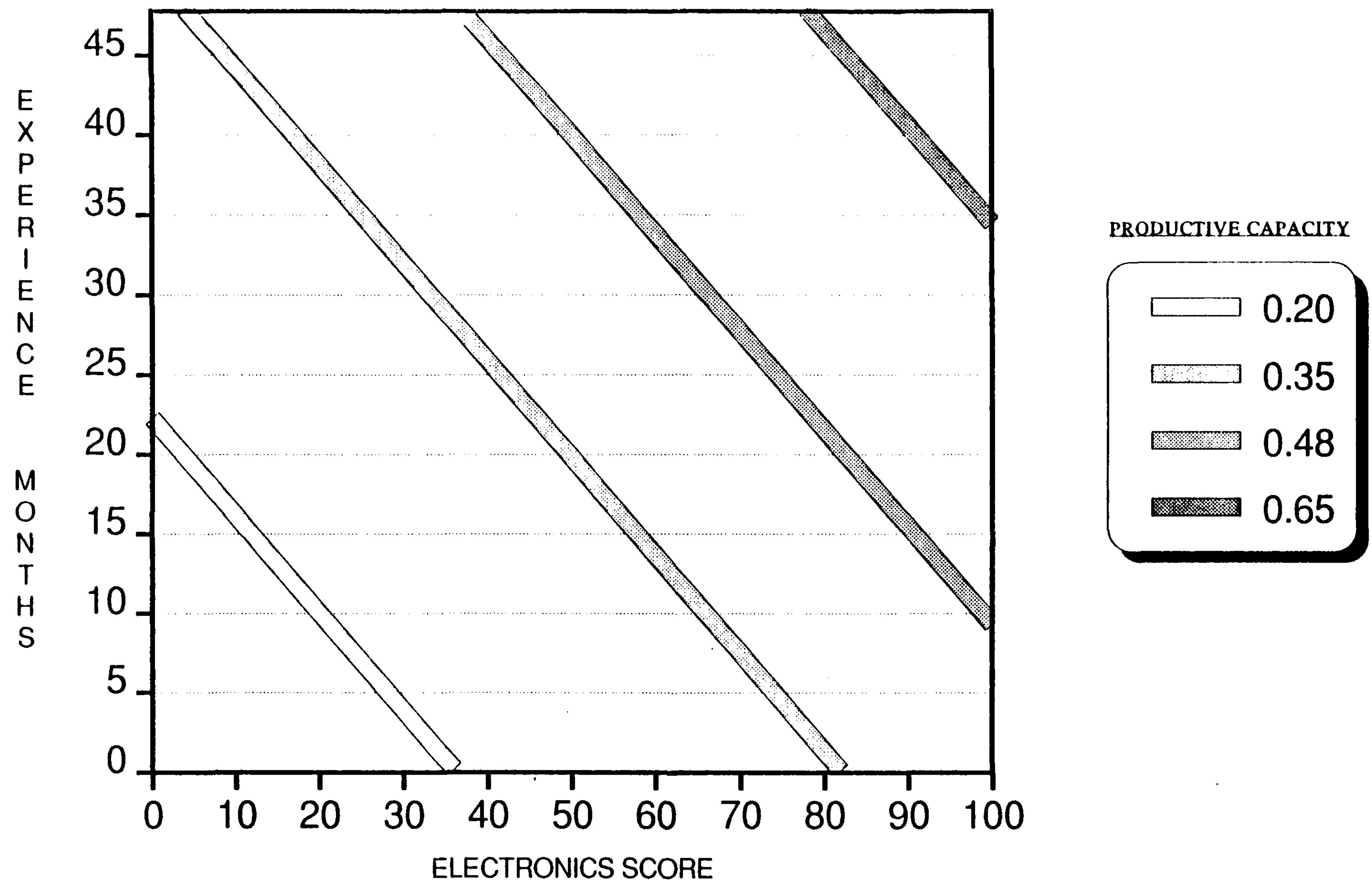

Figure 10. Estimated Production Isoquants for Aggregated Task Clusters

The isoquant graph can also be utilized to estimate the expected productive capacity of an individual with a given electronics score at a given point in his or her career. For example, at the end of the first term (48 months) an airman with an electronics score of 40 would reach an average productive capacity of 0.5 (i.e., 50% of the maximum productive capacity estimated for the 328X0 work force). An individual with an electronics score of 79 would reach an average productive capacity of 0.65 at the end of the first term. If the first-term productivity objectives are defined, the isoquant graph can be used to select minimum enlistment standards. For example, if it is desired that all airmen reach a productive capacity of 0.65 by the end of the first term, only airmen scoring 79 and higher should be admitted into the AFS. Airmen with electronics scores less than 79 are not expected to reach a productive capacity of 0.65 until after the end of the first term.

The productive capacity model is not only an essential component of the TTP integrated model, but also provides a useful method for examining the relationships among experience, aptitude, and productivity. As illustrated above, isoquants can be used to estimate the rate of substitution between experience and aptitude to yield a constant level of productivity. The model can be used to predict the productive capacity of an individual with a given level of aptitude at a given point in his or her career. Airmen can then be selected based on aptitude to ensure that they will meet a required level of productivity by a given point in their career.

Attrition Model

Attrition can be modeled as the probability of an individual remaining in service after a given number of months. This probability may be conditional upon the mental aptitude of the individual. Data were obtained from the Defense Manpower Data Center (DMDC) to estimate the attrition model. Members of the 1982 cohort group were tracked over 48 months to determine their time of separation. The data include Air Force specialty (AFS), Electronics Score, and months of service at separation for the cohort group under study. To model attrition for the AFS 328X0, a subset of the DMDC data was taken. This subset included all individuals in any AFS beginning with 32. There were not enough data points to build a model using only AFS prefix 328. The authors believe that extending the scope of the model to all AFS 32's will improve the model's confidence and still represent the specialty under study.

The airmen in AFS 32 were stratified into groups defined by Electronics Score (60-69, 70-79, 80-89, 90-99). For each group, the number and proportion of airmen remaining at the end of each month during the first term were accumulated. Figure 11 graphs the percent remaining in each of the four aptitude groups over the first 48 months of service. The graph shows that in the early months, the loss rate is higher for the lower aptitude groups. The loss rates converge at the end of the term and are virtually the same across aptitude groups in the 48th month. The loss in the last month represents airmen who chose not to re-enlist.

A mathematical model was developed to describe the probability of remaining in service as a function of aptitude and time. This model has the general form:

$$r(x,t) = b_0 + b_1 \ln [(t + s(x)) / (48 - t)] + b_4 x$$

$$s(x) = \exp(b_2 + b_3 x)$$

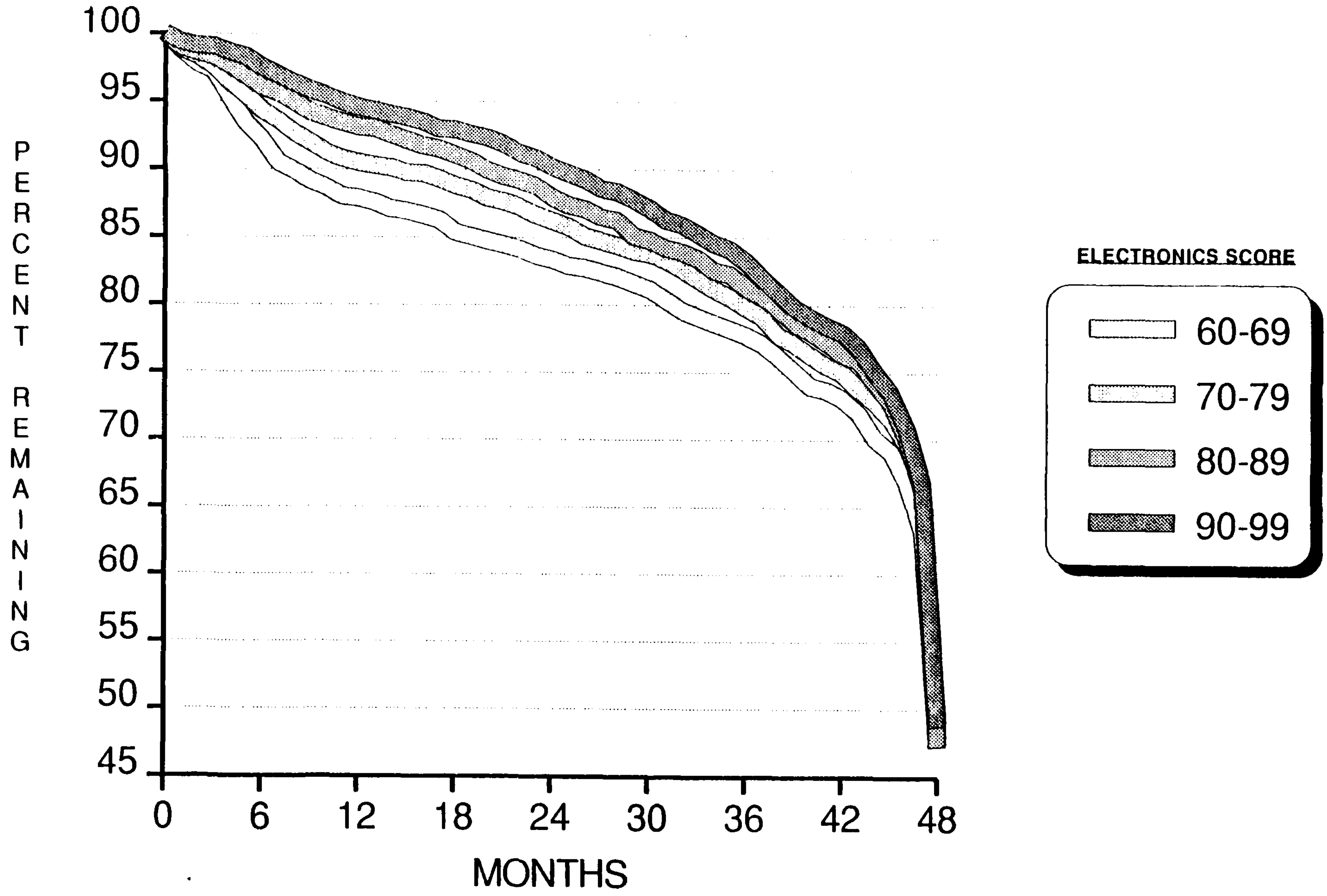

Figure 11. Actual Attrition by Electronics Score

where r(x,t) is the probability of an airman within an aptitude index of x remaining in service after t months (t = 1 to 48)

x is the aptitude index (electronics score)

t is the number of months in service

b_0, b_1, b_2, b_3, b_4 are parameters to be estimated

The above model can be described as a logistic function (in terms of t) with a phase shift. This phase shift, which depends on aptitude, is represented by s(x). The modeled phase shift increases exponentially as aptitude (measured by electronics score) increases linearly. Since the model is not implicitly linear, a gradient search technique was used together with multiple regression to estimate the parameters:

Parameter	Estimate	R^2 = 0.9898
b_0	66.0881	
b_1	-5.5569	
b_2	-3.8500	
b_3	0.0654	
b_4	0.2679	

As indicated by the R^2, a remarkably good fit was obtained. Figure 12 graphs the predicted attrition for the four aptitude groups, along with the extrapolated curve for the 50-59 aptitude group.

The percent remaining has a steeper decline early and late in the term. During training, the decline is steeper for lower aptitude levels. The percent remaining in the 48th month was not predicted since expected productivity and cost for any given month are affected by the force remaining at the end of preceding month.

Cost Model

Cost can also be modeled as a function of time in service and mental aptitude. Military pay increases as time in service increases, due to both promotions and longevity increases. The rate at which salaries increase may also depend upon mental aptitude (e.g., more rapid promotion may be linked to higher aptitude). Training costs occur during the first 10 months. These training costs may be extended over a longer period of time if some individuals must repeat training courses. Recruiting costs occur just before the term begins. This initial cost may vary by mental aptitude.

Information on costs broken down by aptitude could not be obtained. Recruiting Service had no recruiting cost information identified by mental categories or aptitude levels. Similarly, Air Training Command did not have information on training costs broken down by aptitude. Although "ATC Cost Factors" (June 1987) showed average training costs broken down by AFS, the information was useful, but did not provide the level of distinction necessary to adequately model cost as a function of aptitude. The cost model is consequently constant across aptitude groups. The cost model includes initial recruiting costs and training costs in the first 10 months.

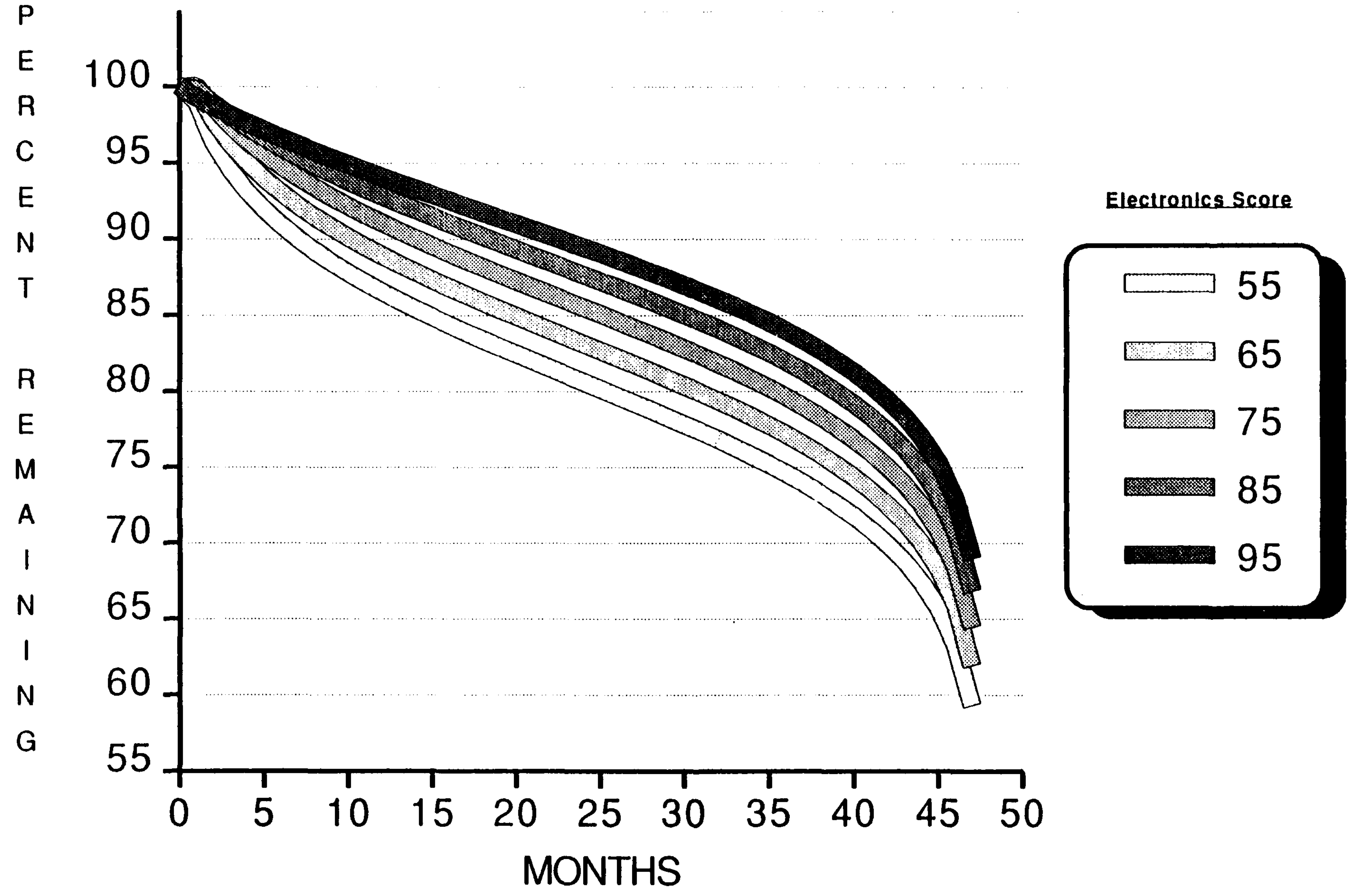

Figure 12. Predicted Attrition by Electronics Score

Military pay is included throughout the first term, with increases following an average promotion schedule. Figure 13 graphs the cost model derived from the cost data extracted from "Air Training Command Cost Factors" (June 1987).

Distribution of Aptitude

For reasons discussed under Model Integration, the distribution of aptitudes among airmen must be estimated. The data obtained from DMDC for the attrition model were used to estimate this distribution. Figure 14 graphs the relative frequency for each of six aptitude groups.

To see the effects of excluding airmen who score below a given value on the electronics component of the ASVAB, a truncated distribution can be computed. If f(x) is the relative frequency associated with an electronics score of x, then $f_m(x) = f(x)/(1-\sum_{i<m} f(i))$ is the relative frequency associated with that electronics score within the subpopulation defined by excluding those with E-scores less than m. Figure 15 displays the relative frequencies with the full population for each of six aptitude groups, together with the relative frequencies obtained by truncating the population at various minimum electronics scores. These relative frequencies will be used to estimate average cost per productive unit for various minimum electronics score cutoffs.

V. MODEL INTEGRATION AND SOLUTION

Integration

Once estimated, the models must be integrated into a meaningful objective function. To develop this function, it is helpful to consider two intermediate functions: expected productive capacity and expected cost. Expected first-term productive capacity for an individual with a given E-score (x) can be described by the following equation:

$$P(x) = \sum_{t=0}^{48} r(x,t)\ p(x,t)$$

where P(x) = Expected first-term productive capacity for an individual with E-score of x

x = E-score

t = Time in service (months)

r(x,t) = Probability that an individual with E-score of x is still in service after t months

p(x,t) = Productive capacity for an individual with an E-score of x and t months of experience.

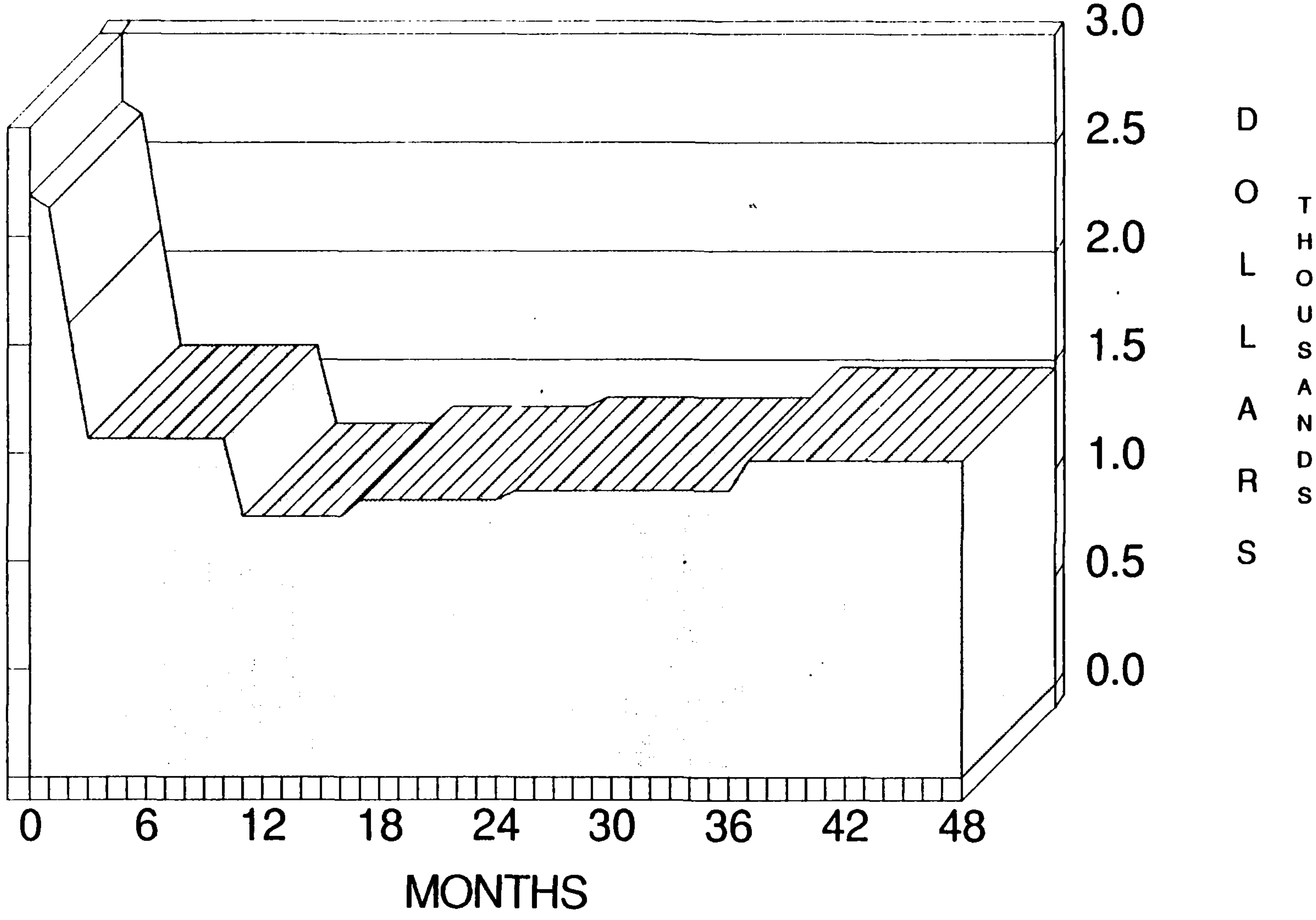

Figure 13. Average Cost per Month

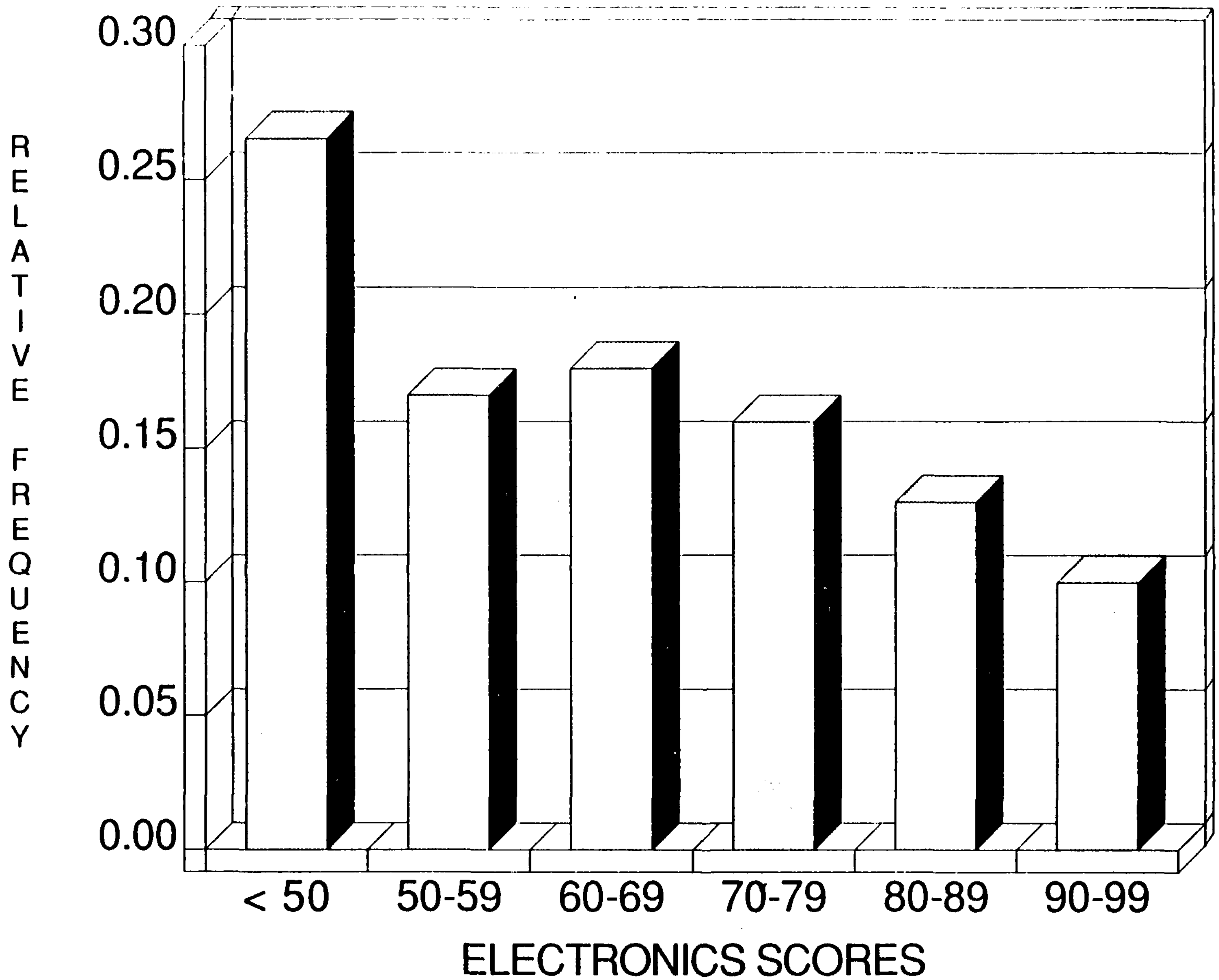

Figure 14. Distribution of Electronics Score for the Full Population

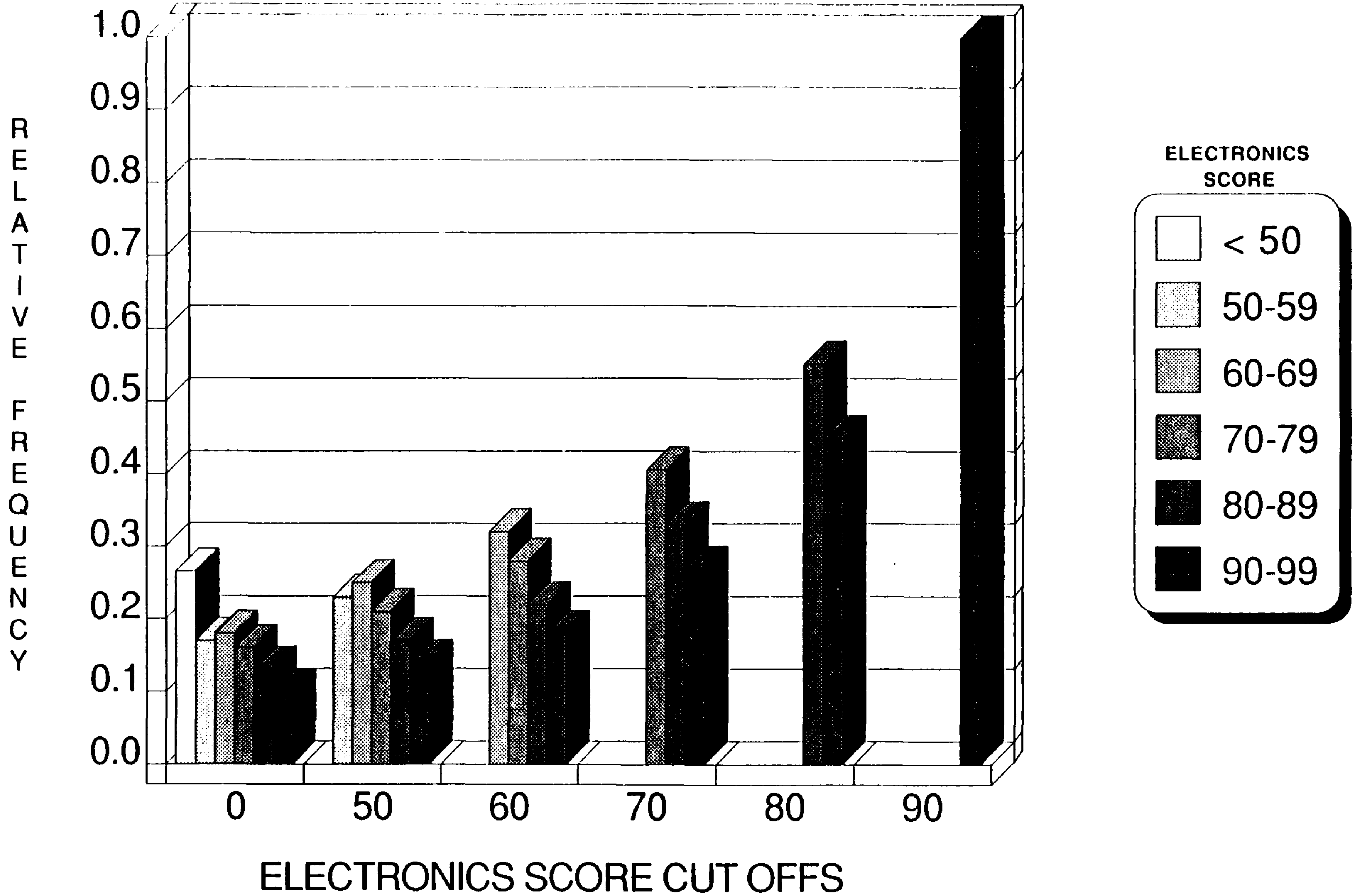

Figure 15. Truncated Distributions of Electronics Scores at Selected Cut Offs

Figure 16 graphs the expected productive capacity for the first term for an average airman in each of five aptitude groups. The productive capacity is zero for all aptitude levels until the eleventh month. The height of the curve increases as aptitude increases. The curves for any two levels of aptitude do not intersect in the first term. This implies that the cumulative expected productive capacity will increase as level of aptitude increases. For any aptitude level, the expected productive capacity function increases until about the middle of the final year of the first term. At that point, it reaches a maximum and decreases until the end of the term. Up until the maximum point, productive capacity increases at a rate greater than that of attrition. Beyond that point, the attrition rate increases faster than productive capacity. That is, productivity does not increase fast enough to compensate for attrition late in the term. This may be caused by "early outs" which some airmen choose to take at this time.

Figure 17 presents a bar chart representing the total expected productive capacity for the first term for five aptitude groups. The total expected productive capacity ranges from 12.62 for the 50-59 group to 19.43 for the 90-99 group. In the first term, the average airman with an E-score between 50 and 59 produces an amount equivalent to a worker performing at the maximum achievable level for 12.62 months. Similarly the average airman in the 90-99 group produces the equivalent to 19.43 months. This implies that over the first term, the average airman in the 90-99 E-score group is over 50% more productive than the average airman in the 50-59 group.

Expected first-term cost for an individual with a given E-score can be described by:

$$C(x) = \sum_{t=0}^{48} r(x,t)\ c(x,t)$$

where $C(x)$ = Expected first-term productive capacity for an individual with E-score of x

x = E-score

t = Time in service (months)

$r(x,t)$ = Probability that an individual with E-score of x is still in service after t months

$c(x,t)$ = Cost to the Air Force of an individual with E-score x in month t.

Figure 18 graphs the expected monthly cost over the first term (beginning with the third month) for each of five aptitude levels. Since the cost model does not vary by aptitude, differences in expected cost among aptitude levels are due to differences in attrition rates. At month zero, the recruiting cost is the same for all aptitude levels. Attrition has not yet taken effect. The first month includes the cost of basic training. Attrition still has no effect. The second month's costs include basic training during the first half and technical training during the second half. Attrition has a small effect in the second month. Costs in months 3 through 10 include technical training. Expected costs are lower for lower aptitude levels because of their higher attrition rates. After training, expected cost for any fixed aptitude level decreases until the point of pay increase. It then jumps to compensate for the pay increase and declines until the next pay increase, and then the process is repeated.

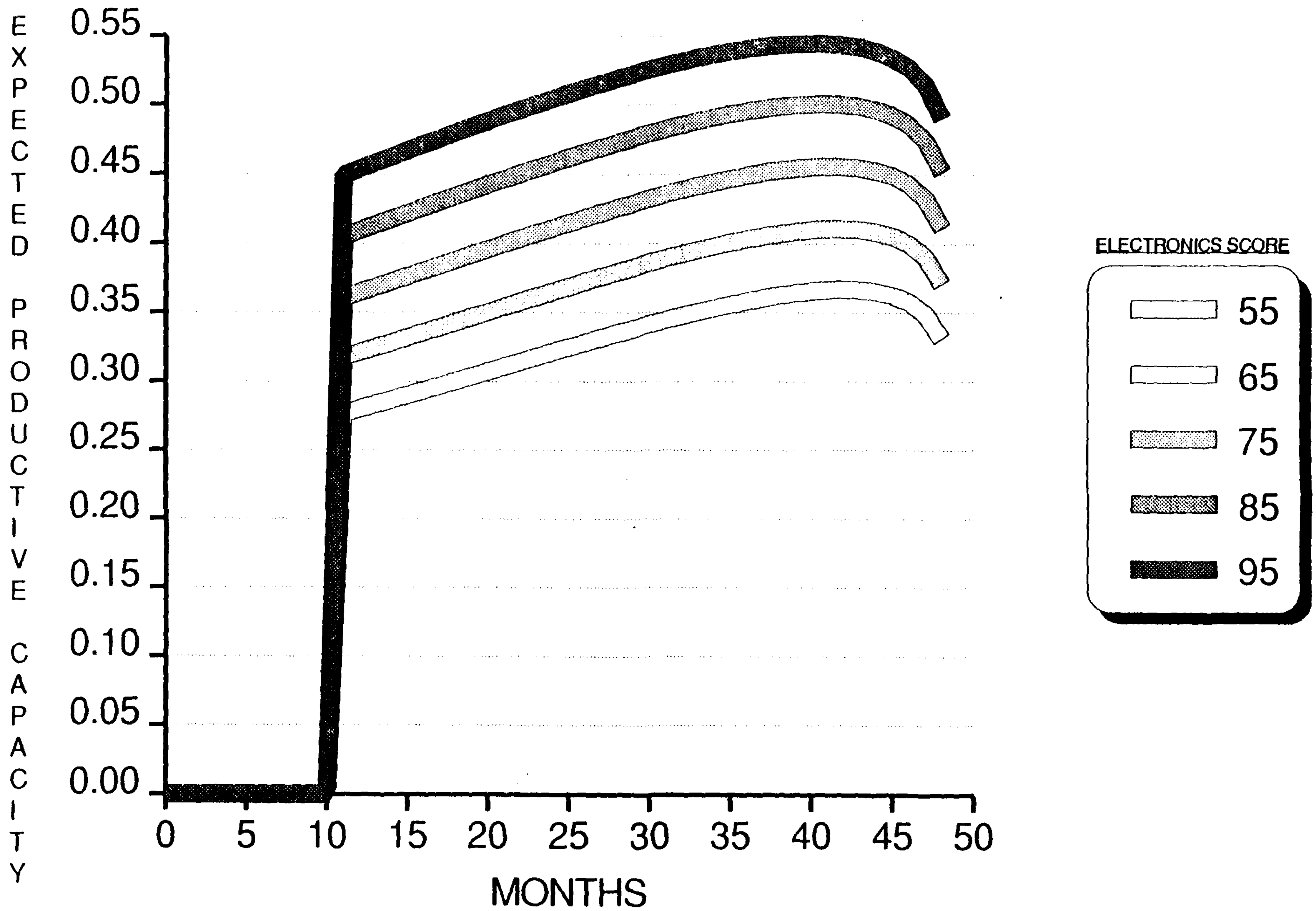

Figure 16. Expected Productive Capacity for an Entry Cohort

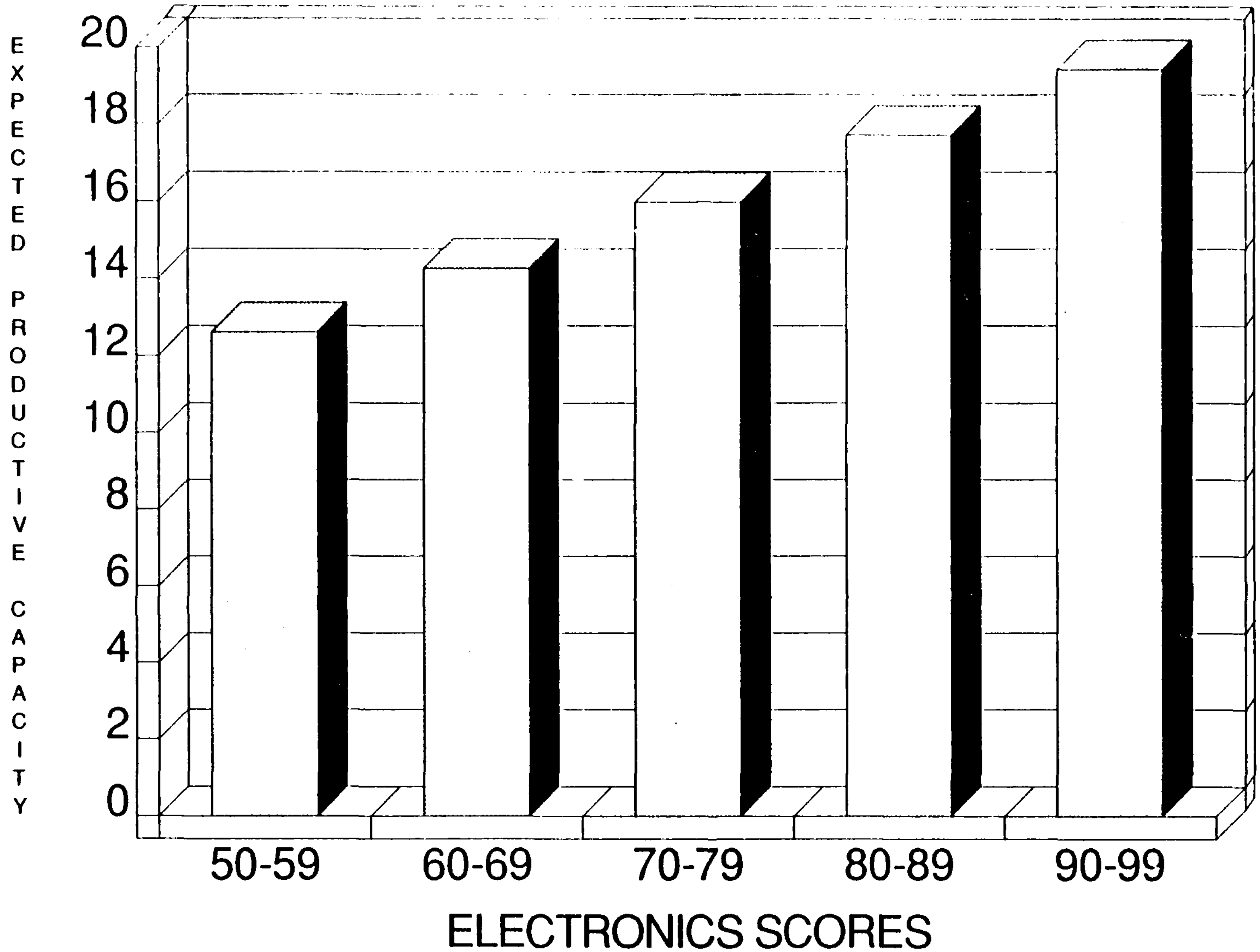

Figure 17. Expected First-Term Productive Capacity

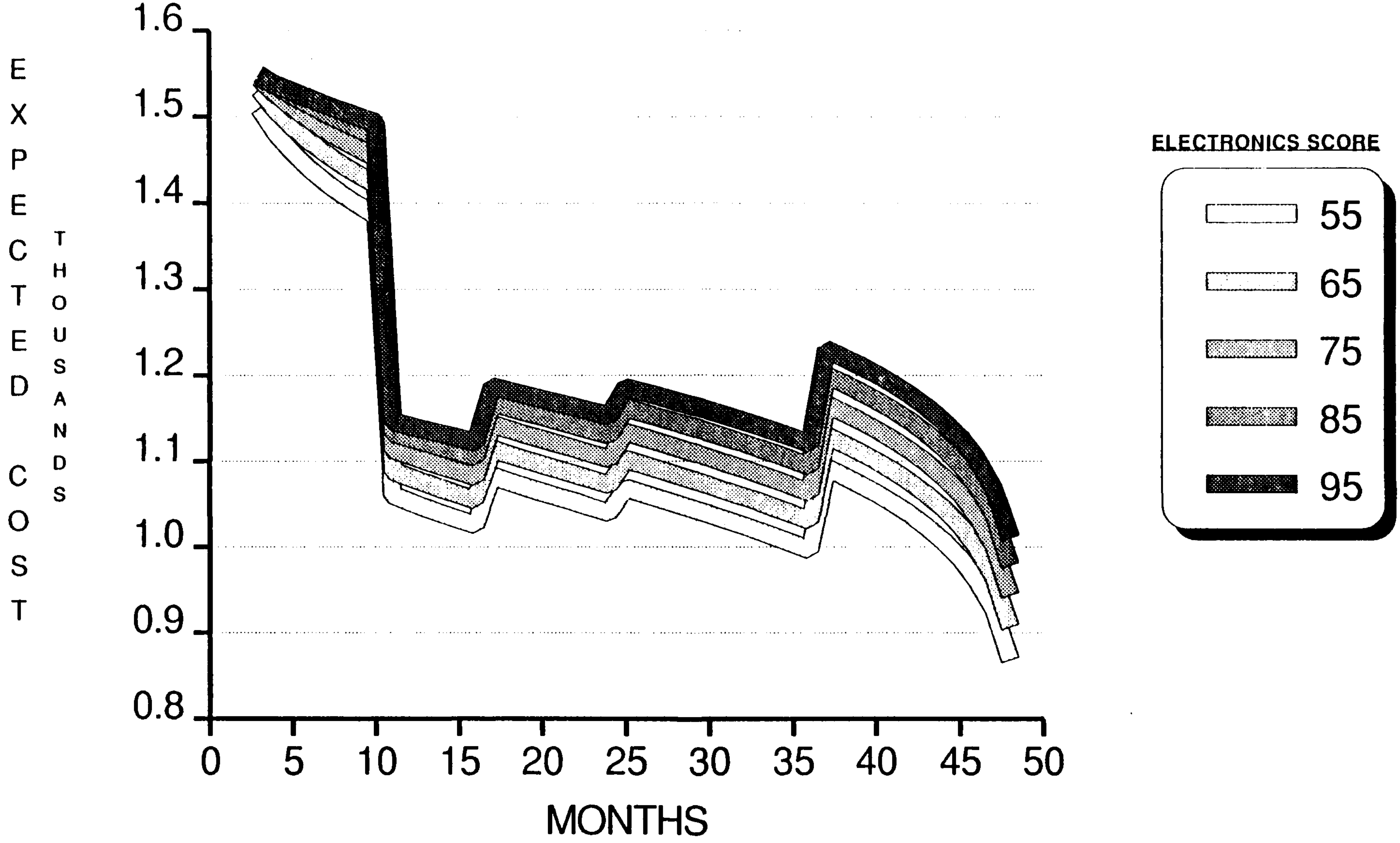

Figure 18. Expected Cost per Month for an Entry Cohort

Figure 19 presents a bar chart representing the total expected first-term cost for the five aptitude groups. The total expected cost ranges from $58,239.00 for the 50-59 E-score group to $63,436.00 for the 90-99 E-score group. Total expected cost is higher for higher aptitude groups because airmen with higher aptitude are more likely to remain in service than airmen with lower aptitude.

The ratio C(x)/P(x) represents the expected cost per productive unit over the first term. By minimizing this ratio with respect to x (E-score), one can obtain the optimum E-score to minimize cost per productive unit. Figure 20 presents a bar chart representing the expected cost per productive unit for each of five aptitude groups. The expected cost per productive unit ranges from $3,264.00 for the highest aptitude group to $4,614.00 for the lowest group displayed. Thus, to produce the same amount of work in the first term, it would cost over 40% more to employ airmen with E-scores between 50 and 59 than airmen with E-scores between 90 and 99.

The solution of this minimization problem would imply that all new recruits should be selected with an E-score equal to the optimum value of x. It would be impractical to impose such a constraint on the selection of new AFS members. The distribution of the pool from which new recruits are selected must be considered. If f(x) is the probability density function of E-scores for the population of potential recruits, then $f_m(x) = f(x)\backslash 1-\sum_{i<m} f(i))$ is the conditional probability density function for the population of potential recruits with an E-score of at least m. Productive capacity and cost can then be modeled as functions of a minimum allowable E-score.

$$E[P(m)] = \sum_{x>=m} f_m(x)\ P(x)$$

$$E[C(m)] = \sum_{x>=m} f_m(x)\ C(x)$$

Where: m is the minimum allowable E-score

E[P(m)] is the expected (average) first-term productive capacity for the subpopulation of potential recruits with E-scores of at least m

E[C(m)] is the expected (average) first-term cost for that subpopulation

$f_m(x)$ is the conditional probability density function of E-scores for the subpopulation of potential recruits with E-scores of at least m

P(x) and C(x) are as defined earlier.

By minimizing the ratio E[C(m)]/E[P(m)] with respect to m, one can find the optimum minimum E-score standard for a given distribution of E-scores among a recruiting pool. The solution is given in the next section.

Optimal Solution

The optimal solution is obtained by comparing the computed expected cost per productive unit among the subpopulations obtained by imposing different E-score cutoffs.

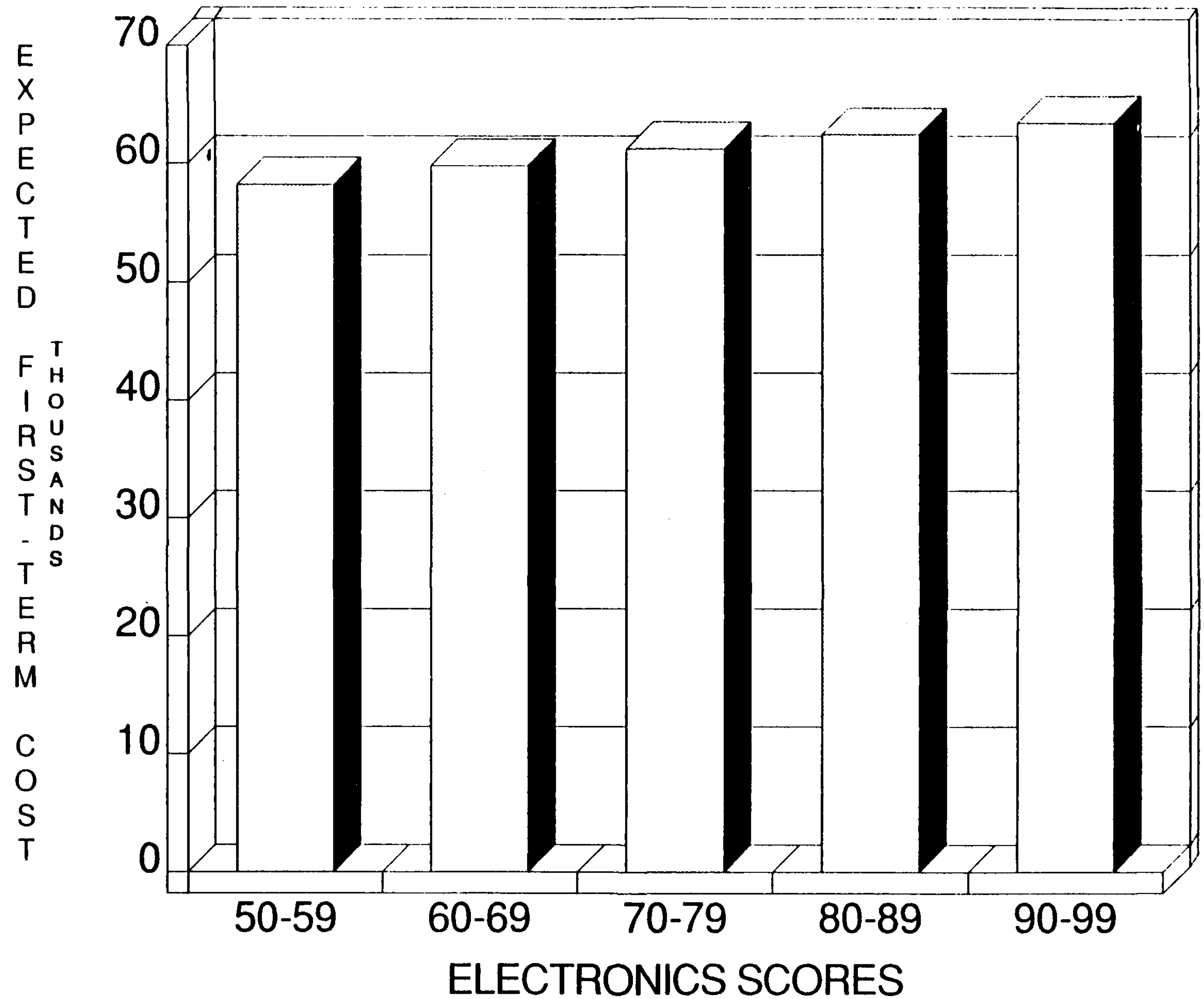

Figure 19. Expected First-Term Cost by Electronics Score

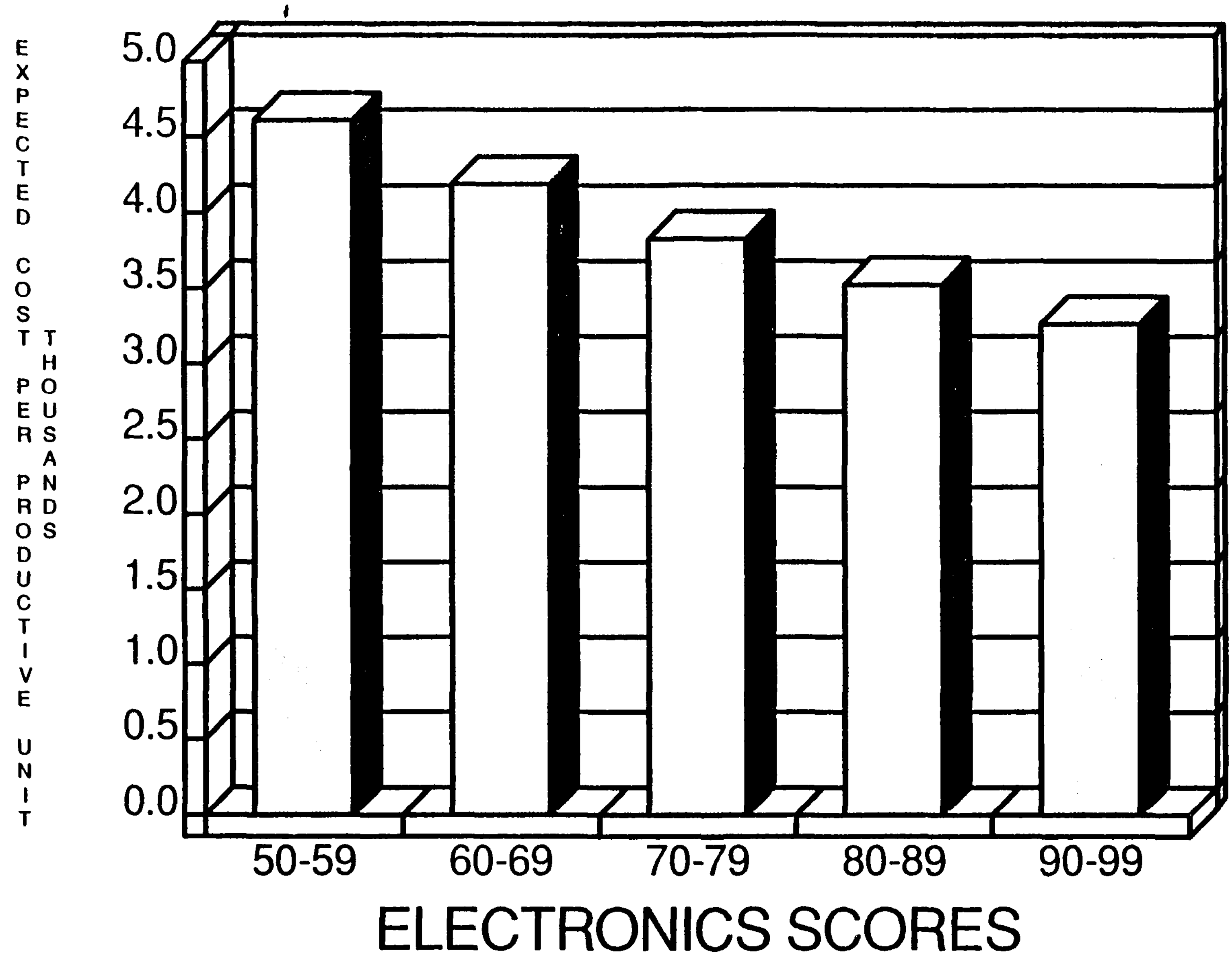

Figure 20. Expected First-Term Cost per Productive Unit

Figure 21 presents a bar chart representing the average first-term cost per productive unit for the subpopulations obtained by imposing minimum electronics score requirements of 50, 60, 70, 80 and 90. The average cost per productive unit ranges from $3,264.00 when a minimum electronics score of 90 is imposed to $3,968.00 when the cutoff is 50. Thus, the lowest average cost per productive unit is obtained when the minimum required electronics score for admission to the AFS is 90. Under a different cost model the solution might change.

Sensitivity Analysis

Since the cost model does not depend on aptitude, the optimum aptitude group is the group with the highest expected productive capacity. Sensitivity analysis allows an investigation as to how this solution might change if a different cost model was appropriate. Of particular interest is the limit to which the costs associated with the optimum aptitude group can be increased without changing the current solution.

If the total expected cost for the 90-99 group were increased by $5,035.00 (roughly 8%), the average cost per productive unit for the subpopulation defined by truncating at an electronics score of 80 would be approximately the same as the cost per productive unit for the subpopulation truncated at 90 (i.e., the difference in productive capacity between the two cutoffs would not compensate for the difference in cost). Any increase beyond this would select members with less than the highest category of aptitude scores. Such a difference is not implausible, which suggests that a more accurate cost model should be developed to reduce the uncertainty of the cutoff decision.

Increased training costs for lower aptitude groups would evoke a stronger argument for selecting from the highest aptitude groups. Increased recruiting costs and military pay for higher aptitude groups would influence the solution in the direction of choosing lower aptitude individuals. Other modifications to the cost model would yield varied results, thus stressing the need for greater accuracy and reliability in the cost model.

VI. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This work has demonstrated how a model can be formulated and solved to arrive at an optimum aptitude standard (measured by electronics score) which minimizes cost per unit of production. The objective model consists of four components:

1. Productive Capacity Model
2. Attrition Model
3. Cost Model
4. Distribution of Aptitudes

The objective model, together with its components, yields significant findings:

1. Higher quality people achieve a specified level of productivity more rapidly; e.g., the average airman with an electronics score of 80 and 18 months of experience is estimated to perform at a rate equal to that of the average airman with an electronics score of 50 and 36 months of experience.

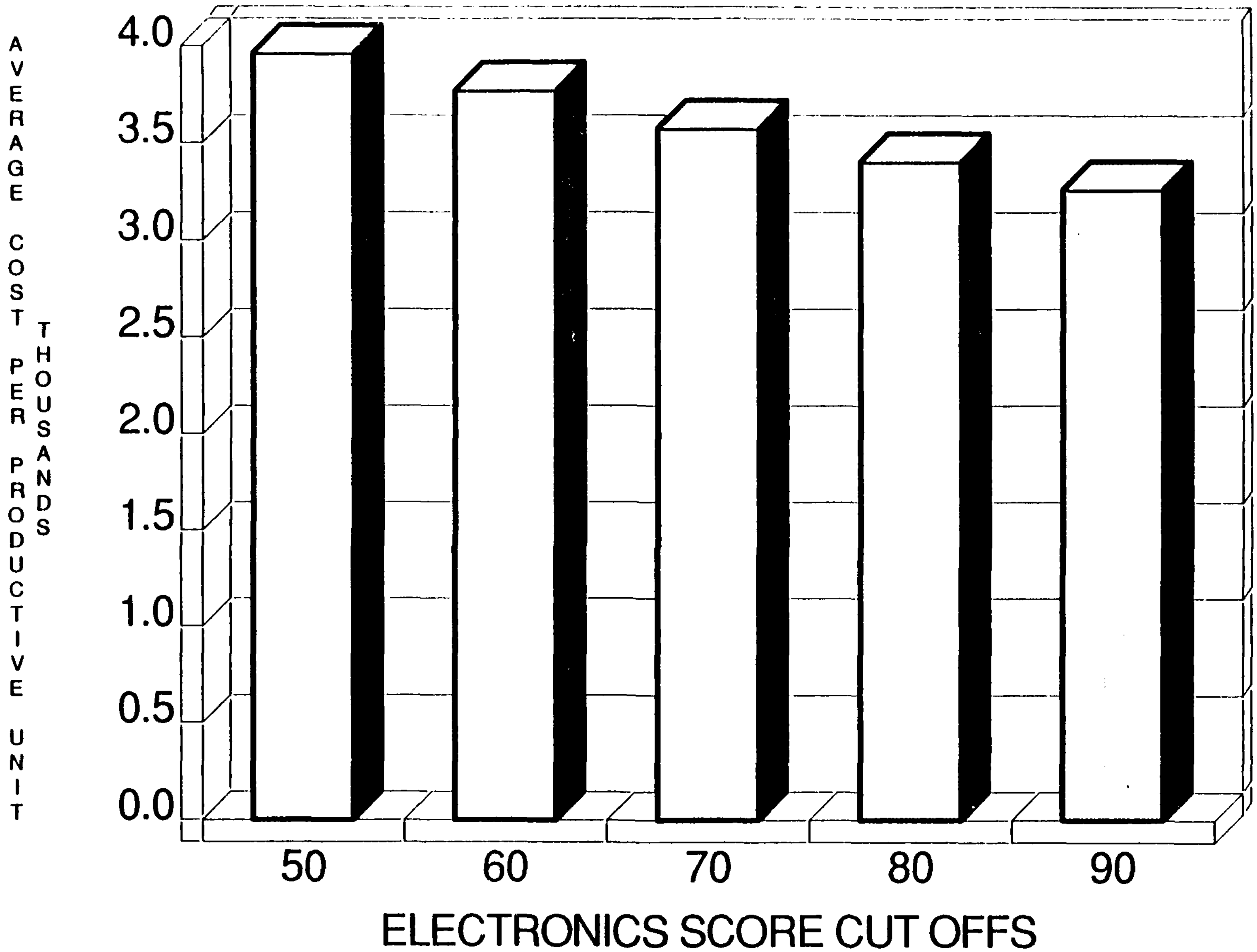

Figure 21. Average Cost per Productive Unit for Electronics Score Cut Offs

2. The quality/experience trade-off is approximately 16 points per 10 months; i.e., if one airman scores 16 points higher than another, he will reach a given level of productive capacity an estimated 10 months sooner than the airman with the lower electronics score.

3. The attrition model demonstrates that the loss rate during training is higher for the lower aptitude groups.

4. Adjusting for attrition, it is estimated that the average airman in the 90-99 electronics score group is over 50% more productive than the average airman in the 50-59 group during the first term.

5. Using a simplified cost model which assumes no differences in recruiting, training or sustainment costs over the first term as a function of quality, high quality people are more cost effective over the first term. For example, it costs an estimated 40% more for a group of airmen with electronics scores between 50 and 59 than a group of airmen with electronics scores between 90 and 99 to produce the same amount of work in the first term.

The results of this research must be caveated by the fact that the study is limited to production-oriented tasks in only one Air Force specialty. These results would not be expected to hold true either in the same direction or degree for all specialties. However, it is reasonable to believe that these results are typical for the majority of specialties requiring a high degree of skill and aptitude and dominated by production-oriented tasks over the first term.

It is also cautioned that these results apply only to the first-term "life cycle." If the selection model were to consider the loss rates after the first term and the resulting production over the second and subsequent terms, the results might be different. In addition, the development of and requirement for leadership and administrative skills beyond the first term would create another dimension to investigate when considering the cost-efficiency of skilled personnel.

Nevertheless, with these caveats in mind, it is fair to conclude that this research indicates that as long as recruiting and sustainment costs are not significantly higher for higher quality personnel, the Air Force and the taxpayers are best served by setting their quality standards as high as possible for AFSs that are directly similar in work and requirements to Avionic Communications Specialists, 328X0.

Recommendations for Further Research

Additional research is required to replicate Phases 1 and 3 for additional AFSs in order to test the method's broader applicability and confirm its practical, economic, and operational potentials. Naturally, one should expect that different specialties will bring different analytic complexities, and several applications will have to be completed before the approach's generality and cost-effectiveness can be judged as satisfactory.

Further applications of the approach would also offer opportunities to develop different and perhaps more efficient protocols for collecting objective data of the types needed to validate the subjective data, to select tasks for direct observation that could improve the statistical properties of estimates and hypothesis tests, and to devise improved formats and mechanisms for collecting subjective assessments from supervisors.

In order to fully evaluate the TTP measurement approach and adequacy of the related models, data are needed for more individuals in more Air Force specialties. These data include the information collected on the TTP Questionnaire, as well as sufficient information on attrition and costs broken down by experience and mental quality and other attributes that might augment the model. Larger sample sizes will allow the testing of more complex regression models while preserving sufficient degrees of freedom to evaluate the significance of the models. Repeating the process for several Air Force specialties will help to verify the validity of the TTP process and the resulting models.

A more accurate cost model is needed to replace or confirm the solution found here. Recruiting and training costs must be broken down by aptitude. Promotion schedules must similarly be disaggregated. If such data are not available in aggregate form, the itemized costs per individual could be merged with demographic data (including aptitude measures) from DMDC and aggregated into a usable form. This assumes that records are kept on each individual airman.

The TTP model should be extended beyond a single Air Force specialty. The models developed here should be validated using two or three additional AFSs, obtaining an optimal solution for each independently. Then all specialties within a certain classification (e.g., Electronics AI) could be analyzed together, assuming a limited number of recruits. A mathematical programming algorithm could be used to optimally allocate recruits to the specialties based on electronics scores and availability and practicality constraints. Finally, all Air Force specialties could be considered. A more complex algorithm could be used to optimally allocate the recruits to the specialties based on the vector of Mechanical, Administrative, General, and Electronics AI scores.

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APPENDIX A: FINAL TASK CLUSTERS

Task Group #	Task difficulty Mean	SD	# of Tasks	# of WTPT tasks
1	4.047	0.683	5	1
2	3.655	0.370	13	4
3	5.997	0.759	9	5
4	4.496	0.370	10	2
5	5.642	0.677	11	6
6	5.412	0.817	7	1
7	5.349	0.707	5	1
8	5.977	0.928	11	3
9	4.273	0.707	5	0
10	5.487	0.656	11	2

APPENDIX A (Continued)

DEFINITION OF TTP TASK CLUSTERS

Task Cluster 1 - Maintenance Administration and Inspection

Locate Part or Stock Numbers in Technical Publications (Form 781)
* Make Entries on Maintenance Data Collection Record Forms (AFTO Forms 349)
Make Entries on Reparable Item Processing Tag Forms
Inspect Avionic Equipment for Corrosion and Perform Corrosion Control
Locate Maintenance Information in Technical Publications

Task Cluster 2 - Flightline Maintenance

* Safety-Wire or Bond System Components
Test Continuity of Coaxial Cables
Preset Frequencies in UHF Control Units
Remove or Replace UHF Control Units
* Remove or Replace UHF Receiver-Transmitters
Operationally Check Interphone Systems
Remove or Replace Interphone Cord Components
Remove or Replace Interphone Cords
* Remove or Replace Interphone Station Control Units
Remove or Replace Interphone Monitor Control Units
Remove or Replace UHF Antennas
Operate AGE, such as Power Units, Heaters, or Light Carts
* Inspect Parts Received from Supply or Manufacturer

Task Cluster 3 - Flightline Troubleshooting

Isolate Malfunctions in Avionic Systems Wiring or Cables
* Repair Avionic System Wiring or Cables
* Remove or Replace Radio Frequency (RF) Coaxial Connectors
Solder Avionic System Wiring
* Isolate Malfunctions in UHF Systems
* Trace Circuits or Signals Using Wiring Diagrams or Schematics
Isolate Malfunctions in Interphone Systems
Operationally Check Systems Using Flightline Test Equipment
* Remove or Replace Multiple Wire Plugs

Task Cluster 4 - Shop Maintenance

Remove or Replace Receiver-Transmitter Subassemblies
Remove or Replace UHF Control Unit Subassemblies
Bench Check Interphone Monitor Control Units
Bench Check Interphone Station Control Units
Remove or Replace Interphone Control Subassemblies
Remove or Replace Interphone Control Components
* Isolate Malfunctions in Interphone Cords
* Isolate Malfunctions in Interphone Monitor Control Units
Isolate Malfunctions in Interphone Station Control Units
Bench Check UHF Remote Channel Indicators

Task Cluster 5 - UHF Shop Maintenance

Diagnose Mockup Malfunctions
Align UHF Control Units
Align UHF Receiver-Transmitters
* Bench Check UHF Receiver-Transmitters
* Isolate Malfunctions in UHF Receiver-Transmitters
* Bench Check UHF Control Units
Isolate Malfunctions in UHF Control Units
Remove or Replace UHF Control Unit Components
* Remove or Replace UHF Receiver-Transmitter Components
* Set Up UHF System-Peculiar Test Equipment
* Perform Time Compliance Technical Order (TCTO) Modifications of Avionic Systems

Task Cluster 6 - Flightline HF Maintenance

Isolate Malfunctions in HF Systems
Remove or Replace HF Control Units
Remove or Replace HF Couplers
* Remove or Replace HF Receiver-Transmitters
Operate Associated Systems Checking HF Systems
Operationally Check HF Systems Using FTE
Remove or Replace HF Antennas

Task Cluster 7 - HF Control Box In-Shop Maintenance

Align HF Control Boxes
Isolate Malfunctions in HF Control Boxes
Remove or Replace HF Control Box Components
Remove or Replace HF Control Box Subassemblies
* Bench Check HF Control Boxes

Appendix A (Concluded)

Task Cluster 8 - Receiver-Transmitter/HF Coupler Shop Maintenance

Remove or Replace HF Coupler Components
Remove or Replace HF Coupler Subassemblies
Remove or Replace HF Receiver-Transmitter Components
* Remove or Replace HF Receiver-Transmitter Subassemblies
* Set Up HF System-Peculiar Test Equipment
Align HF Couplers
Isolate Malfunctions in HF Couplers
Bench Check HF Couplers
Align HF Receiver-Transmitters
Bench Check HF Receiver-Transmitters
* Isolate Malfunctions in HF Receiver-Transmitters

Task Cluster 9 - Flightline VHF Maintenance

Remove or Replace Very High Frequency (VHF) Amplitude Modulated (AM) Radio Antenna
Remove or Replace VHF Control Units
Remove or Replace VHF AM Receiver-Transmitters
Operate Associated Systems Checking VHF AM Systems
Operationally Check VHF AM Systems Using Flight Test Equipment

Task Cluster 10 - Shop VHF Maintenance

Align VHF AM Control Units
Bench Check VHF AM Control Units
Remove or Replace VHF AM Control Unit Components
Remove or Replace VHF AM Receiver-Transmitter Subassemblies
Remove or Replace AM Receiver-Transmitter Components
Isolate Malfunctions in VHF AM Systems
* Align VHF AM Receiver-Transmitters
* Bench Check VHF AM Receiver-Transmitters
Isolate Malfunctions in VHF AM Receiver-Transmitters
Isolate Malfunctions in VHF AM Control Units
Set Up VHF AM-Peculiar Test Equipment

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*Overlaps the Walk-Through Performance Test

APPENDIX B:

TIME TO PROFICIENCY QUESTIONNAIRE

TIME TO PROFICIENCY (TTP) QUESTIONNAIRE

Purpose of Questionnaire:

The purpose of this study is to collect information on how work experience affects a worker's efficiency. For the purposes of this study, efficiency is defined as having two parts: the amount of time the worker requires to perform the task satisfactorily, and the amount of time needed to spend supervising the worker. This questionnaire asks for estimates of both performance time and supervision time for each of the task areas which are included in this AFS. This information is confidential and for study purposes only, and will not be used for formal evaluations.

Instructions For Completing The Questionnaire:

Overview:

In order to complete this questionnaire you will first need to identify the workers, whom you supervise, who have a 328X0 AFS. After providing information on each worker (Step One below), you will complete five steps (Steps 2 through 6 below), for each of ten Task Groups. In these steps you will be evaluating the performance of your workers in each of these Task Groups. Each Task Group represents an area of responsibility within the 328X0 AFS.

The steps you will complete are outlined briefly below, and are then described in detail. An example of a completed questionnaire follows the detailed instructions.

Step One: Complete Worker Identification Information

In Step One you will complete information which will identify the workers under your supervision who perform the tasks listed. You will complete this step only once.

Step Two: Review Task Group Description

In Step Two you will familiarize yourself with the various tasks within the Task Group you will evaluate. You will also need to be familiar with performance benchmarks for selected tasks for the Task Group. You will repeat this step for each Task Group rating.

Step Three: Complete Task Group Data Column One

In Step Three you will indicate how often each worker performs the tasks in the Task Group you are evaluating. You will repeat this step for each Task Group rating.

Step Four: Complete Task Group Data Column Two

In Step Four you will select a Benchmark Worker against which you wil compare the other workers. You will repeat this step for each Task Group rating.

Step Five: Complete Task Group Data Column Three

In Step Five you will rate each worker against the Benchmark Worker you selected in Step Four. In Step Five you will rate the workers for performance time. You will repeat this step for each Task Group rating.

Step Six: Complete Task Group Data Column Four

In Step Six you will indicate the amount of time you supervise the workers. You will repeat this step for each Task Group rating.

Detailed Instructions:

Step One: Complete Worker Identification Information

In order to complete Step One begin by turning this questionnaire to page 26 (the last page). You will notice that this page has a flap along the right side of the page. Please unfold the flap. Notice that this page asks for basic information on each of the workers you supervise. The information asked for on this page is: the length of time (years and months) that each worker has been in the 328X0 AFS (not including Technical School),each worker's Social Security Number (SSN), and each worker's name. Once you have completed the information on this page turn to page 6. When you turn to page 6 LEAVE THE FLAP ALONG THE RIGHT SIDE OF PAGE 26 EXTENDED. Leaving the flap extended will help you to complete the performance and supervision information later in the questionnaire.

Step Two: Review Task Group Description

In order to complete Step Two please turn to page 6. On this page you will notice information at the top of the page which identifies the particular Task Group for which you will rate the workers identified in Step One. Following the Task Group identification there is a list of tasks included in the Task Group. To the right of the tasks are performance benchmarks. The performance benchmarks are typical times to complete the tasks. You will use the performance benchmarks to select a Benchmark Worker in Step Four. Please familiarize yourself with the information on this page and begin thinking about the performance of your workers in the tasks on this page.

Step Three: Complete Task Group Data Column One

Indicate at the top of the next page of the questionnaire if any of the tasks you have just read are performed by any of the workers you supervise. If you indicate "NO" (none of the workers you supervise perform any of the tasks on the previous page) then turn the page and begin Step Two for the next Task Group. If you indicate "YES" (at least one of the workers you supervise perfoms at least one of the tasks on the previous page) then continue on with Step Three.

Next please indicate in Column One how often each of the workers you supervise performs the tasks in the Task Group you are evaluating. Please use the following codes:

"R" - the worker performs the tasks REGULARLY,
"O" - the worker performs the tasks OCCASIONALLY, or
"N" - the worker NEVER performs the tasks.

Step Four: Complete Task Group Data Column Two

In order to complete Step Four you will need to select a Benchmark Worker against which you will compare all of the other workers for the tasks in this Task Group. Please select the worker who generally performs closest to the performance benchmarks listed on the previous page. The worker you select should perform closest to the times listed, while completing the work to an acceptable quality level. Please indicate which worker you select by checking one worker in Column Two. Please note that the worker you select as the Benchmark Worker pertains to only the Task Group you are evaluating. You may select that worker as the Benchmark Worker for another Task Group, but you do not necessarily have to do so.

Step Five:Complete Task Group Data Column Three

You will complete this step for each worker . To do this you will compare each of these workers' performance, on average, to that of the Benchmark Worker you selected in Step Four.

Recall the amount of work (in this Task Group) that the Benchmark Worker can complete correctly in one hour. Now indicate in Column Three the amount of time each of the workers requires to complete the same amount and quality of work. The amount of time you indicate in Column Three can be greater than, less than, or equal to one hour. For example, the work that the Benchmark Worker completes in one hour might take Worker 1 one hour and 15 minutes to complete , while Worker 2 can complete the work in forty minutes.

Step Six: Complete Task Group Data Column Four

In order to complete Step Six please indicate in Column Four how much time you would require to supervise each worker while he or she completes the work you evaluated in Column Three. Please note that the times you indicate in Columns Three and Four are independent. A worker who requires more time to perform the work may or may not require more supervision time. Supervision time can include quality checks of the completed work as well as direct "over the shoulder" supervision while the work is being performed. Supervision time also includes any delegated supervision.

AFTER YOU HAVE COMPLETED STEP SIX FOR THE FIRST TASK GROUP PLEASE TURN THE PAGE AND COMPLETE STEPS TWO THROUGH SIX FOR THE REMAINING TASK GROUPS.

THANK YOU VERY MUCH FOR YOUR COOPERATION.

Example:

As you can see below this is an example of the Worker Identification Information page that has been completed correctly.

Worker	How long in AFS?		Social Security Number (SSN)	Name (Last, First, MI)	Worker
	Years	Months			
1	2	8	111-11-1111	ADAMS, John, J.	1
2	0	9	222-22-2222	BURNS, LAURIE, M.	2
3	3	1	333-33-3333	CASTLE, PAUL, J.	3
4	1	6	444-44-4444	DARNELL, JENNIFER, J.	4
5					5
6					6
7					7
8					8
9					9
10					10
11					11
12					12
13					13
14					14
15					15

After reviewing the Task Group Description Information, the supervisor has completed the Task Group Data. The supervisor has: completed Column One for each worker, selected a Benchmark Worker in Column Two, compared the performance of the other workers to that of the Benchmark Worker in Column Three, and indicated the required supervision time for each worker in Column Four.

Worker	COLUMN ONE How Often Performs Jobs In This Group (R/O/N)	COLUMN TWO Benchmark Worker (Check One)	COLUMN THREE Performance Time		COLUMN FOUR Supervision Time		Name (Last, First, MI)	Worker
			Hours	Minutes	Hours	Minutes		
1	O		1	15	1	00	ADAMS, John, J.	1
2	R		∅	40	∅	20	BURNS, LAURIE M.	2
3	R	✓	1	00	0	30	CASTLE, PAUL, J.	3
4	N		—	—	—	—	DARNELL, JENNIFER, J.	4
5								5
6								6
7								7
8								8
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MAINTENANCE ADMINISTRATION AND INSPECTION

This Task Group includes the following tasks and performance benchmarks:

	Time
Locate Part or Stock Numbers in Technical Publications (Form 781)	11 Mins.
Make Entries on Maintenance Data Collection Record Forms (AFTO Form 349)	10 Mins.
Make Entries on Reparable Item Processing Tag Forms	9 Mins.
Inspect Avionic Equipment for Corrosion and Perform Corrosion Control	22 Mins.
Locate Maintenance Information in Technical Publications	9 Mins.

TASK AREA DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Area.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
1						
2						
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Page _ 7

FLIGHTLINE MAINTENANCE

This Task Group includes the following tasks and performance benchmarks:

	Time
Safety Wire or Bond System Components	10 Mins.
Test Continuity of Coaxial Cables	23 Mins.
Preset Frequencies in UHF Control Units	11 Mins.
Remove or Replace UHF Control Units	11 Mins.
Remove or Replace UHF Receiver-Transmitters	14 Mins.
Operationally Check Interphone Systems	29 Mins.
Remove or Replace Interphone Cord Components	18 Mins.
Remove or Replace Interphone Cords	16 Mins.
Remove or Replace Interphone Station Control Units	12 Mins.
Remove or Replace Interphone Monitor Control Units	12 Mins.
Remove or Replace UHF Antennas	26 Mins.
Operate AGE, Such as Power Units, Heaters, or Light Carts	11 Mins.
Inspect Parts Received from Supply or Manufacturer	5 Mins.

TASK AREA DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Area.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
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FLIGHTLINE TROUBLESHOOTING

This Task Group includes the following tasks and performance benchmarks:

	Time
Isolate Malfunctions in Avionic Systems Wiring or Cables	1 Hr. 23 Mins.
Repair Avionic System Wiring or Cables	23 Mins.
Remove or Replace Radio Frequency (RF) Coaxial Connectors	25 Mins.
Solder Avionic System Wiring	15 Mins.
Isolate Malfunctions in UHF Systems	38 Mins.
Trace Circuts of Signals Using Wiring Diagrams or Schematics	20 Mins.
Isolate Malfunctions in Interphone Systems	26 Mins.
Operationally Check Systems Using Flightline Test Equipment	31 Mins.
Remove or Replace Multiple Wire Plugs	37 Mins.

TASK AREA DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Area.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
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Page _ 11

SHOP MAINTENANCE

This Task Group includes the following tasks and performance benchmarks:

Task	Time
Remove or Replace Receiver-Transmitter Subassemblies	18 Mins.
Remove or Replace UHF Control Unit Subassemblies	18 Mins.
Bench Check Interphone Monitor Control Units	35 Mins.
Bench Check Interphone Stations Control Units	35 Mins.
Remove or Replace Interphone Control Subassemblies	17 Mins.
Remove or Replace Interphone Control Components	21 Mins.
Isolate Malfunctions in Interphone Cords	8 Mins.
Isolate Malfunctions in Interphone Monitor Control Units	22 Mins.
Isolate Malfunctions in Interphone Station Control Units	22 Mins.
Bench Check UHF Remote Channel Indicators	14 Mins.

TASK AREA DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Area.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
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UHF SHOP MAINTENANCE

This Task Group includes the following tasks and performance benchmarks:

Task	Time
Diagnose Mockup Malfunctions	50 Mins.
Align UHF Control Units	22 Mins.
Align UHF Receiver-Transmitters	46 Mins.
Bench Check UHF Receiver-Transmitters	1 Hr. 58 Mins.
Isolate Malfunctions in UHF Receiver-Transmitters	38 Mins.
Bench Check UHF Control Units	26 Mins.
Isolate Malfunctions in UHF Control Units	33 Mins.
Remove or Replace UHF Control Unit Components	27 Mins.
Remove or Replace UHF Receiver-Transmitter Components	15 Mins.
Set-Up UHF System Peculiar Test Equipment	11 Mins.
Perform Time Compliance Technical Order (TCTO) Modifications on Avionic Systems	1 Hr. 15 Mins.

TASK AREA DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Area.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
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FLIGHTLINE HF MAINTENANCE

This Task Group includes the following tasks and performance benchmarks:

	Time
Isolate Malfunctions in HF Systems	45 Mins.
Remove or Replace HF Control Units	11 Mins.
Remove or Replace HF Couplers	1 Hr. 19 Mins.
Remove or Replace HF Receiver-Transmitters	16 Mins.
Operate Associated Systems Checking HF Systems	12 Mins.
Operationally Check HF Systems Using FTE	34 Mins.
Remove or Replace HF Antennas	1 Hr. 55 Mins.

TASK AREA DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Area.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
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HF CONTROL BOX IN-SHOP MAINTENANCE

This Task Group includes the following tasks and performance benchmarks:

	Time
Align HF Control Boxes	20 Mins.
Isolate Malfunctions in HF Control Boxes	35 Mins.
Remove or Replace HF Control Box Components	24 Mins.
Remove or Replace HF Control Box Subassemblies	16 Mins.
Bench Check HF Control Boxes	56 Mins.

TASK AREA DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Area.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
1						
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RECEIVER-TRANSMITTER/HF COUPLER SHOP MAINTENANCE

This Task Group includes the following tasks and performance benchmarks:

	Time
Remove or Replace HF Coupler Components	33 Mins.
Remove or Replace HF Coupler Subassemblies	19 Mins.
Remove or Replace HF Receiver-Transmitter Components	23 Mins.
Remove or Replace HF Receiver-Transmitter Subassemblies	17 Mins.
Set-Up HF System Peculiar Test Equipment	11 Mins.
Align HF Couplers	38 Mins.
Isolate Malfunctions in HF Couplers	34 Mins.
Bench Check HF Couplers	47 Mins.
Align HF Receiver-Transmitters	2 Hrs. 32 Mins.
Bench Check HF Receiver-Transmitters	1 Hr. 48 Mins.
Isolate Malfunctions in HF Receiver-Transmitters	43 Mins.

TASK AREA DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Area.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
1						
2						
3						
4						
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FLIGHTLINE VHF MAINTENANCE

This Task Group includes the following tasks and performance benchmarks:

Task	Time
Remove or Replace Very High Frequency (VHF) Amplitude Modulated (AM) Radio Antenna	31 Mins.
Remove or Replace VHF AM Control Units	11 Mins.
Remove or Replace VHF AM Receiver-Transmitters	13 Mins.
Operate Associated Systems Checking VHF AM Systems	8 Mins.
Operationally Check VHF AM Systems Using FTE	34 Mins.

TASK AREA DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Area.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
1						
2						
3						
4						
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SHOP VHF MAINTENANCE

This Task Group includes the following tasks and performance benchmarks:

	Time
Align VHF AM Control Units	21 Mins.
Bench Check VHF AM Control Units	26 Mins.
Remove or Replace VHF AM Control Unit Components	28 Mins.
Remove or Replace VHF AM Receiver-Transmitter Subassemblies	17 Mins.
Remove or Replace AM Receiver-Transmitter Components	24 Mins.
Isolate Malfunctions in VHF AM Systems	30 Mins.
Align VHF AM Receiver-Transmitters	54 Mins.
Bench Check VHF AM Receiver-Transmitters	1 Hr. 3 Mins.
Isolate Malfunctions in VHF AM Receiver-Transmitters	39 Mins.
Isolate Malfunctions in VHF AM Control Units	18 Mins.
Set-Up VHF AM Peculiar Test Equipment	14 Mins.

TASK GROUP DATA

Are any of the tasks on the previous page performed by any of the workers you supervise?

YES _____ (Please complete the table below.)

NO _____ (Please turn to the next Task Group.)

	COLUMN ONE	COLUMN TWO	COLUMN THREE		COLUMN FOUR	
Worker	How Often Performs Jobs In This Group (R/O/N)	Benchmark Worker (Check One)	Performance Time		Supervision Time	
			Hours	Minutes	Hours	Minutes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

WORKER IDENTIFICATION INFORMATION

Worker	How long in AFS?		Social Security Number (SSN)	Name (Last, First, MI)	Worker
	Years	Months			
1					1
2					2
3					3
4					4
5					5
6					6
7					7
8					8
9					9
10					10
11					11
12					12
13					13
14					14
15					15

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APPENDIX C: TTP DATA COLLECTION SITES

Military Airlift Command

- Norton AFB CA
- McGuire AFB NJ
- Charleston AFB NC
- Travis AFB CA
- McChord AFB WA
- Altus AFB OK

Strategic Air Command

- March AFB CA
- Minot AFB ND
- Beale AFB CA
- Loring AFB ME
- Blythesville AFB AK
- Castle AFB CA

Tactical Air Command

- Homestead AFB FL
- Moody AFB GA
- Bergstrom AFB TX
- Seymour Johnson AFB NC
- Shaw AFB NC
- George AFB CA