DLA-92-P90124

QUALITY ASSURANCE RESOURCE MODEL

May 1992

Alan R. Greve

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OPERATIONS RESEARCH AND ECONOMIC ANALYSIS OFFICE
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FOREWORD

The Quality Assurance Resource Model (QUARM) outlined in this report was a collaborative effort. Although the detailed work was performed by the Defense Logistics Agency Operations Research and Economic Analysis Management Support Office (DORO), oversight provided by the QUARM Study Advisory Group (SAG) was crucial. This group of technical professionals and experts was responsible for: establishing model specifications, identifying workload drivers, and reviewing interim results. Members of the group included personnel from: the Quality Assurance Programs and Systems Division (DLA-QR), the Program/Budget Division (DLA-CB) from the Office of the Comptroller, the five District QA Staffs, the DLA Operations Research and Economic Analysis Office (DLA-LO), the DLA Performance Standards Support Office (DPSSO), and DORO. The group's perseverance, diligence and spirit of cooperation proved vital to the successful completion of this effort.

ROGER C. ROY
Assistant Director
Policy and Plans

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EXECUTIVE SUMMARY

The Defense Contract Management Command (DCMC) is being challenged by austere funding to more effectively allocate scarce personnel resources. Quality Assurance (QA) personnel, comprising some 46 percent of DCMC, constitute an important part of that challenge. No QA workload-driven methodology currently exists for determining and allocating QA Operations resources. The Directorate of Quality Assurance (DLA-Q) and the Office of the Comptroller (DLA-C) asked the Defense Logistics Agency's (DLA) Operations Research and Economic Analysis Management Support Office (DORO) to study existing QA resourcing methodologies and build a personnel resourcing model for QA Operations. QA Operations represents almost 70 percent of total DCMC QA personnel.

Research into existing resourcing methods turned up several techniques used by the Services in their Plant Representative Offices as well as a 1989 Defense Analysis Studies Office (DASO) study titled "Staffing of Service Plant Representative Offices." All addressed total office resourcing. None addressed QA resourcing.

A Quality Assurance Resource Model (QUARM) study advisory group (SAG) was formed to: establish model specifications, identify workload drivers, and review interim results. This group included technical professionals and experts from the Programs and Systems Management Division (DLA-QR), the Program/Budget Division (DLA-CB), the Operations Research and Economic Analysis Office (DLA-LO), the DLA Performance Standards Support Office (DPSSO), the five District QA staffs, and DORO. The SAG selected 14 indicators as primary workload drivers from the QA Management Information System (MIS).

The project used regression analysis to quantify the relationship, at the QA division level, between the workload indicators and the QA Operations productive hours from the Automated Payroll Cost and Personnel System (APCAPS). Deriving separate models for Defense Contract Management Area Offices (DCMAOs) and Defense Plant Representative Offices (DPROs) proved logical and statistically sound. The DCMAO model demonstrated greater accuracy than the DPRO models.

The models were tested using October 1991 to January 1992 workload data. When applied to the test data on a fiscal year to date basis, the DCMAO model performed well and better than the DPRO models.

The QUARM models provide a uniform resourcing approach using statistically valid, logical workload indicators. Decision makers should use the models as a resourcing and allocation tool to more effectively evaluate changes in workloads, budgets, and policies. The models should be used with other analyses and field reviews, when feasible.

SECTION 1
INTRODUCTION

The Defense Contract Management Command is being challenged by austere funding to more effectively allocate scarce personnel resources. Quality Assurance personnel, comprising some 46 percent of DCMC personnel, constitute an important part of that challenge. The restructuring of nine Regions into five Districts, the consolidation of the Service Plant Representative Offices into DLA, and supervisory span of control issues are but a few of the actions that have already impacted QA resources. DLA QA management must mete out these resourcing changes in the most effective manner. No QA workload-driven methodology currently exists for allocating QA Operations resources between districts or between QA Divisions. As a result, the DLA Directorate of Quality Assurance and the DLA Office of the Comptroller asked DORO at Chicago to study existing QA resourcing methodologies and build a personnel resourcing model for QA Operations. QA Operations staffing represents almost 70 percent of total DCMC QA personnel.

1.1 SCOPE

The QUARM models cover QA Operations effort, rolled up to the Division level, with the exception of hours charged to supervisory, clerical, and leave categories. All reimbursable time is included. The workload indicator and workhour data are monthly averages for the May-June-July 1991 period. All workload data is from the QA MIS. The workhour data is from APCAPS.

1.2 OBJECTIVES

The objectives of this study are two-fold: to research current and past Department of Defense QA resourcing methodologies and to develop resourcing models for use in DLA. These models can be used both to determine suggested staffing levels and to allocate those resources that are actually provided.

The QUARM models can aid in allocating resources from DLA to the District and ultimately to the DCMAO and DPRO level. The models will help to identify imbalances and aid in the review of resource requests.

SECTION 2
METHODOLOGY

2.1 ALTERNATIVE RESOURCING METHODS

The project searched the technical literature, using several data bases, to identify existing QA resourcing methods. Previous DPRO staffing studies and models included: an Air Force Contract Management Division (AFCMD) model, a 1981 NAVAIR PRO model and the 1989 DASO study titled "Staffing of Service Plant Representative Offices." The AFCMD model used regression analysis to make an estimate of each Air Force Plant Representative Office's overall staffing. Contractor employees and contractor government sales were the principal indicators. An on-site management review set other factors in the model. The DASO study developed a regression model based on 47 DLA and Service PROs. It suggested the model be used to question staffing of activities outside a confidence interval as opposed to direct resource evaluations. These studies produced an all inclusive estimate of DPRO staffing. None addressed QA resourcing.

2.2 APPROACH

The QUARM SAG was formed to: establish model specifications, identify workload drivers, and review interim results. This group included technical professionals and experts from DLA-QR, DLA-CB, DLA-LO, DPSSO, the five District QA staffs, and DORO. Personnel participating throughout the project are listed in Appendix A. The project uses multiple linear regression to explore the relationships between QA Operations workload indicators and workhours.

2.2.1 WORKLOAD INDICATOR SELECTION

The QUARM SAG sifted through scores of candidate QA workload indicators to mutually agree on the following 14:

STUDY ADVISORY GROUP'S CANDIDATE WORKLOAD INDICATORS

- Commodity Code
- Facility Quality Provision
- Travel Hours
- QUEST Score
- Quality Assurance Letters of Instruction (QALI) on Hand
- QALIs Received
- Dollar Value of Contracts Received
- Special Programs
- Contracts Received by Quality Provision
- Facility Type (Resident or Nonresident)
- Over And Above Requests
- Product Quality Deficiency Reports (PQDR) Received
- Number of Contracts with First Article Requirements
- Contracts on Hand By Quality Provision

Workload indicator selection criteria included: no new data collection requirements imposed on field personnel, automated collection from existing data systems where possible, indicators not easily manipulated, and strong, logical appeal. In addition to those recommended by the SAG, we tested several other workload indicators from the QA MIS.

The SAG directed that the QUARM models be aimed at the lowest statistically significant organizational level. Consequently, the workload indicator-workhour relationships were examined at the facility, section, branch, and division levels.

Several measures of the work to be predicted were considered for QUARM: available or administrative hours from the QA MIS, the number of QA Operations personnel assigned, and payroll hours. The QA Operations hours reported in APCAPS were selected for several reasons. As these hours are tied into the payroll process, they are generally reliable and machine accessible. Hours for training, leave, supervision and clerical duties are easily excluded. Of all possible measures, APCAPS hours is the one most sensitive to workload changes.

One project goal was that resourcing under QUARM should be consistent with the IQUE program, a DLA performance based management initiative. An aim of IQUE is to shift resources from satisfactory contractors to poor performers. This project evaluated an indicator of contractor performance that is measured by the Quality Evaluation and Sensing Technique (QUEST). QUEST was developed at DORO Richmond. Several QUARM models use QUEST as a workload indicator.

2.2.2 REGRESSION ANALYSIS

A regression model constructs the relationship that best fits the data. It quantifies the relationship between variables thought to be logically linked, for example workhours and the dollar value of contracts received. The change in one variable is directly related to the change in the other. But the change in one does not necessarily <u>cause</u> the change in the other. For example, the dollar value of contracts received does not directly cause QA workload. The workload indicator may serve as a proxy for other variables that do cause work. These other variables may not have been included in the model due to the inability to identify, collect or quantify the real workload drivers. Regression serves to compare QA divisions with varying workloads with workhours expended. It does not compute ideal staffing levels.

In developing the models, typically one or two activities (more in the DPROs) that were at extreme variation from the trend line (outliers) were eliminated and the models were recast. The outlier variations are believed to be due, in part, to the turbulent realignments, consolidations and organizational changes in the QA environment which occurred during the study.

The nature of the models is that they will be very nearly resource neutral DCMC-wide for the time period of the data on which they were developed. Resource neutral means that the total actual hours equal the total estimated hours. The models will not be resource neutral between districts nor between DCMAOs and DPROs, especially as workloads vary over time.

2.3 MODEL TEST

After the development of QUARM models, a test was conducted by applying the models to recent data. The project plan did not specify test criteria.

SECTION 3
RESULTS

3.1 REGRESSION ANALYSES RESULTS

The project went through three iterations of data due to rapid changes in QA. These included the realignments, consolidations, and introduction of IQUE mentioned in Section 1 as well as changes in the QA MIS. While collecting the last set of data, it was decided to expedite the process by excluding the Quality Assurance Letter of Instruction (QALI), First Article provision and special program indicators. These indicators had not played a significant role in previous analyses and are not readily machine accessible. To find the most meaningful models, we grouped the data in the following ways: by quality provision, by commodity, by facility type and by organizational level. After examining the data at the facility, section, branch, and division level, the division level models showed the most promise. Deriving separate models for DCMAOs and DPROs was logical and proved to be practical statistically.

The equation for the DCMAO QUARM model is:

QA Operations Hours =		8.875E-07	UNDELIVERED DOLLAR BALANCE
	+	7.995	MIL-Q + MIL-I FACILITIES
	-	99.548	QUEST SCORE
	+	.698	CONTRACTS ON HAND
	+	3.900	PRODUCT QUALITY DEFICIENCY REPORTS
	+	1.396	OVER & ABOVE REQUESTS
	+	2.625	TRAVEL HOURS
	+	12,072	CONSTANT (in hours)

DCMAO Model statistics are shown in Appendix B. The model explains statistically significant amounts of variation in the APCAPS workhours as indicated by a high Coefficient of Determination or R^2. (See page B-3 for an explanation of R^2.) Although other DCMAO models performed better statistically, the chosen model proved the most logically appealing to the end users due to the number and breadth of workload indicators.

Appendix B also shows the DPRO models' statistics. We grouped the DPROs by number of APCAPS hours into large, medium and small. The large DPROS averaged over 2025 QA Operations hours per month. Medium DPROs ranged between 1500 and 2025 hours while small DPROs were below 1500 hours. The DPRO models are:

LARGE DPRO

QA Operations Hours =		4.682E-07	UNDELIVERED DOLLAR BALANCE
	+	146.945	MIL-Q + MIL-I FACILITIES
	+	.195	CONTRACTS ON HAND
	+	35.786	PRODUCT QUALITY DEFICIENCY REPORTS
	+	2,183	CONSTANT (in hours)

MEDIUM DPRO

QA Operations Hours =	.062	OVER & ABOVE REQUESTS
+	31.426	MIL-Q + MIL-I FACILITIES
+	.784	CONTRACTS RECEIVED
-	1.059	QUEST SCORE
+	1,695	CONSTANT (in hours)

SMALL DPRO

QA Operations Hours =	3.887E-07	UNDELIVERED DOLLAR BALANCE
+	1.867	CONTRACTS RECEIVED
+	81.332	PRODUCT QUALITY DEFICIENCY REPORTS
+	1,030	CONSTANT (in hours)

To achieve statistically significant results for the large DPROs, a number of activities, not within a statistical interval used to test for outliers, were not used to formulate the models. The explanatory power (R^2) of the large DPRO model is very good. The R^2 for the medium sized DPROs is above the DoD guideline (0.65) for such models. While the model for the small DPROs is not as good, only 2.2 percent of DPRO QA Operations personnel resources are in this category (and this is only 1.5 percent of total DCMC QA resources). Judging a model by R^2 alone is inadvisable because it may be affected by the interrelationships between workload indicators. The mean absolute percent errors (MAPEs) for all of the DPRO models (also an important measure of model quality) were acceptable. MAPE is explained in section 3.3.2.

Many other approaches were attempted to better the DPRO results including: trying new workload indicators such as the number of contractor employees working on government contracts, segregating the DPROs by commodity groupings, and using only the original DLA DPROs. The DPRO models listed proved the best available statistically.

Figure 3-1 illustrates the proportions of QA Operations hours (less supervisory, clerical, and leave time) covered by each of the QUARM models.

3.2 SIGNIFICANCE OF WORKLOAD INDICATORS

The workload indicators used in the models show good statistical correlation with APCAPS workhours. These correlations were much higher and more significant in the DCMAO model than in the DPRO models. Some indicators showed good correlation not only with the workhours but also with each other. For example, the dollar value of contracts received tended to correlate highly with the undelivered dollar balance. In cases when both variables were explaining the same variation in the workhours, only one was used in the model.

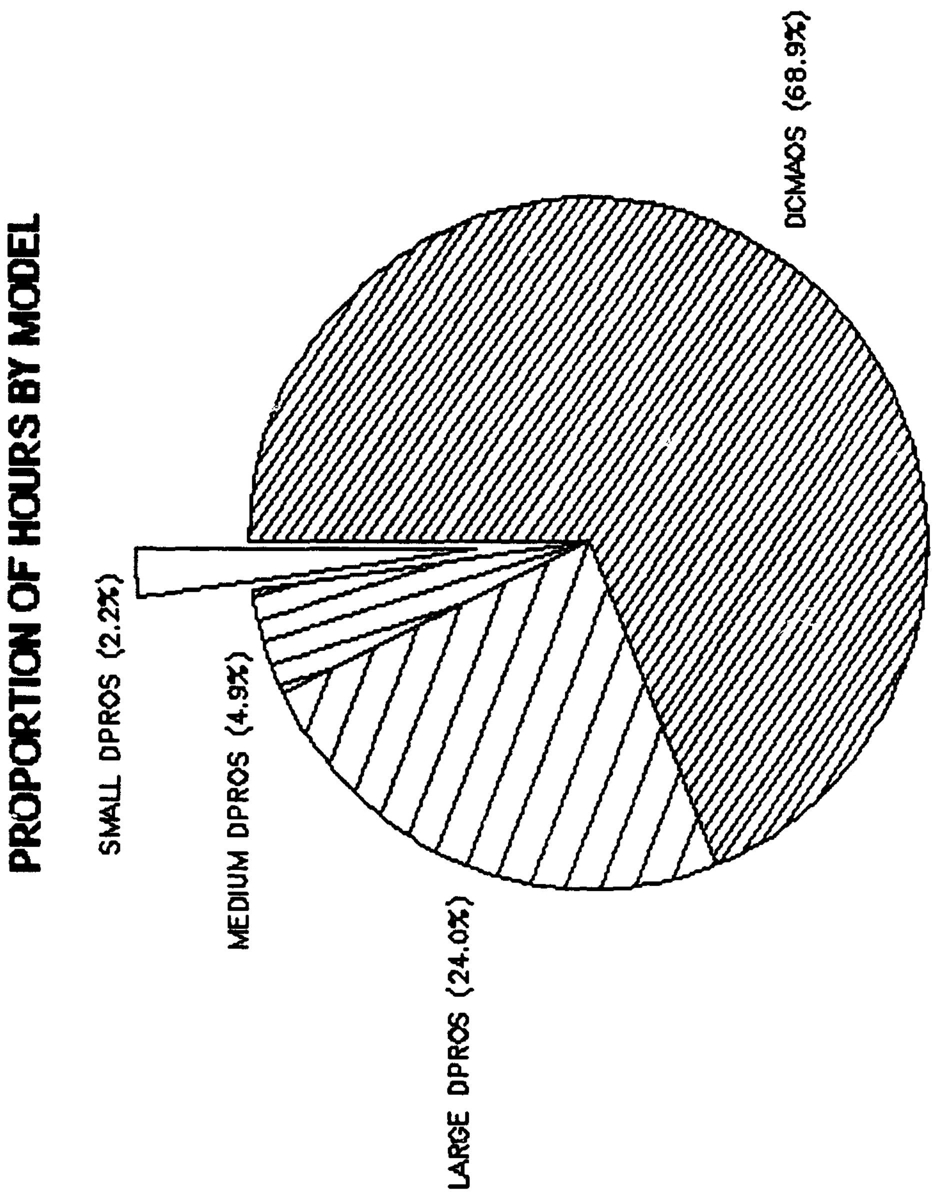

Figure 3-2. QUARM Model Coverage by QA Operations Hours

3.3 ESTIMATING ERROR

3.3.1 CAUSES OF ESTIMATING ERROR

Part of the unexplained variation in staffing (the error) is due to indicators we were unable to identify, quantify or collect. Another part is due to a number of random causes, for example, a commander's view on how QA operations should be staffed. Such views can vary markedly from person to person. Random variation is to be expected, but cannot be explained in a model. Non-random variations that could be identified were adjusted for, in the initial analysis, by excluding training, leave, clerical, and supervisory workhour data.

3.3.2 LEVEL OF ACCURACY

All measurements have an associated measurement error. For these regression models, the measurement error is presented as the MAPE. The MAPE is the average percent error (regardless of sign) between the actual and predicted workhours. Most models have a MAPE in the 10-12 percent range.

3.4 DATA PROBLEMS

The various organizational realignments, consolidations of the former service PROs and changes in the QA MIS resulted in a data collection nightmare. The data used to build these models was submitted by the SAG members directly from the QA MIS inputs for the months of May, June and July 1991. Using monthly averages dampened the peaks and valleys of QA workload. We questioned District SAG members about suspect data and errors were corrected.

DPSSO supplied the APCAPS hour data. Total APCAPS hours were reduced by the supervisory, training and clerical hours. Where hours did not correspond with the number of personnel assigned, DPSSO queried the Districts. DPSSO adjusted some division hour totals to more closely correspond with personnel on board.

In general, the former Service PROs workload data and work hours were suspect due to their recent inclusion into DLA data systems.

3.5 TEST RESULTS

We tested the models on the October 1991 to January 1992 QA MIS data. Appendix C contains a summary of the results. For each QA division, the models were applied to monthly and fiscal year to date (FYTD) data and the estimated hours compared to the actual APCAPS hours. The difference between the actual and estimated hours for each QA division were expressed as a percentage of the actual hours. The DCMAO model performed well with FYTD data and much better than the DPRO models.

The models were sensitive to the number of productive hours available in a month. Results varied slightly (2-3 percent) simply because some months were shorter or longer than others. Likewise the number of holidays or high vacation periods (i.e. December) had a slight influence on the results. For these reasons, the FYTD data proved a better measure of model performance. For future use of the models, an adjustment for the number of business days in the month may improve results.

SECTION 4
CONCLUSIONS

The QUARM DCMAO model provides a uniform resourcing approach that uses statistically valid workload indicators to baseline requirements. This model will better enable DLA-Q, DLA-C and District Commanders to allocate resources and more effectively evaluate the impact of changes in workloads, budgets and QA Operations policies. The model should be used with other analyses and field reviews, when feasible.

QUARM will provide a frame of reference, using statistical measures, for comparing workload between DCMAO QA divisions. Imbalances will become evident. Results can be used, for instance, to shift resources from a DCMAO that is significantly over-resourced to one that is under-resourced. Also, the model will make possible early identification of problem areas. For example, it could identify an accelerating weapons system program that is understaffed relative to its dollar value and complexity.

DCMAO model results should be viewed using a 6-month average due to the sensitivity to the number of productive hours described in section 3.5. Used this way, the QUARM model will give DLA-Q and DLA-C a dependable, fair, analytical tool for resourcing decisions.

The DPRO models may likewise be used for resource decisions. However, the regression statistics and test results show that the DPRO models are not as accurate as the DCMAO model. The DPRO models should also be used with other analyses and field reviews, when feasible.

SECTION 5
RECOMMENDATIONS

DLA-Q, DLA-C, District Commanders and District QA directors should use the QUARM models as a tool in resourcing decisions. Model results should be coupled with other analyses or field reviews where appropriate.

The SAG recommended displaying the model in the Labor Production Effectiveness Reporting System (LAPERS). Workload data could be automatically input into the LAPERS from the QA MIS. These links already exist but would have to be updated.

QUARM DPRO models should be recalculated after the former Service PROs are completely integrated into QA MIS reporting requirements.

Models should be updated yearly to capture, and measure, the effects of revised policies and procedures, as well as organizational changes.

APPENDIX A
STUDY ADVISORY GROUP MEMBERS

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STUDY ADVISORY GROUP MEMBERS

Mr. Richard Zerilli	DLA-QR
Mr. Donald Peterson	DLA-CB
Mr. James Russell	DLA-LO
Ms. Diane Stubblefield	DCMDS-QRS
Mr. Stephen Lapin	DCMDN-QRP
Mr. Silvio Pontarelli	DCMDC-QRS
Mr. Hal Elbeck	DCMDC-Q
Ms. Katherine Rasmussen	DCMDW-QR
Mr. Norm Kletter	DCMDM-QRS
Mr. Ted Tansey	DPSSO
Mr. Ray Butscher	DPSSO
Mr. Paul Grover	DLA-DORO
Mr. Al Greve	DLA-DORO

APPENDIX B
QUARM MODELS

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Appendix B

APPENDIX B
QUARM MODELS

B1.1 **DCMAO MODEL**

APCAPS Hours =		8.875E-07	UNDELIVERED DOLLAR BALANCE
	+	7.995	MIL-Q + MIL-I FACILITIES
	-	99.548	QUEST SCORE
	+	.698	CONTRACTS ON HAND
	+	3.900	PQDRS
	+	1.396	OVER & ABOVE REQUESTS
	+	2.625	TRAVEL HOURS
	+	12,072	CONSTANT (in hours)

R^2 = 86.8% *

NUMBER OF DCMAOS USED = 35

MEAN ABSOLUTE PERCENT ERROR (MAPE) = 12.0%

EXCLUDED AS OUTLIERS: EL SEGUNDO, SANTA ANA

* The Coefficient of Determination or R^2 is that portion of the total variation in the dependent variable (APCAPS Hours) that is explained by the regression equation. For example, the R^2 in this model shows that the regression equation explains 86.8 percent of the variation in APCAPS hours.

B-1.2 **DCMAO MAPE CALCULATIONS**

DCMAOS	DISTRICT/	QAORG	APCAPS HOURS	CALCULATED HOURS	ABSOLUTE PERCENT ERROR	ACTUAL	EARNED PERSONNEL*
ATLANTA	S	A	15540	15108.9	2.8%	107	104
BIRMINGHAM	S	B	20731	21092.0	1.7%	143	145
CLEARWATER	S	C	10118	9215.7	8.9%	70	64
DALLAS	S	D	17174	19288.0	12.3%	118	133
ORLANDO	S	F	8979	11085.0	23.5%	62	76
SAN ANTONIO	S	S	12010	13891.7	15.7%	83	96
BUFFALO	N	B	5427	6693.1	23.3%	37	46
BOSTON	N	F	15456	15538.3	0.5%	107	107
NEW YORK	N	N	8467	7367.1	13.0%	58	51
GARDEN CITY	N	Q	18547	19388.2	4.5%	128	134
SYRACUSE	N	S	9535	10262.7	7.6%	66	71
HARTFORD	N	U	14119	14926.7	5.7%	97	103
BRIDGEPORT	N	V	5100	7191.6	41.0%	35	50
TWIN CITIES	C	1	7942	9073.4	14.2%	55	63
GRAND RAPIDS	C	3	9129	8710.8	4.6%	63	60
DENVER	C	4	13037	11646.0	10.7%	90	80
WICHITA	C	6	7661	7852.1	2.5%	53	54
ST LOUIS	C	7	10618	8819.9	16.9%	73	61
CEDAR RAPIDS	C	9	5191	7328.6	41.2%	36	51
CHICAGO	C	A	11021	11958.6	8.5%	76	82
MILWAUKEE	C	D	6586	8628.7	31.0%	45	60
INDIANAPOLIS	C	E	9862	8175.1	17.1%	68	56
SEATTLE	W	N	8849	9817.5	10.9%	61	68
SAN DIEGO	W	S	7651	7678.7	0.4%	53	53
VAN NUYS	W	V	21486	20632.3	4.0%	148	142
SAN FRANCISCO	W	W	15451	15856.9	2.6%	107	109
PHOENIX	W	X	14543	14013.4	3.6%	100	97
CLEVELAND	M	1	17738	13093.6	26.2%	122	90
DETROIT	M	2	9997	8899.1	11.0%	69	61
DAYTON	M	6	18919	16060.3	15.1%	130	111
BALTIMORE	M	B	11827	12530.4	5.9%	82	86
PHILADELPHIA	M	D	19391	19959.8	0.3%	137	138
PITTSBURG	M	P	11693	9392.1	19.7%	81	65
READING	M	R	11962	10711.1	10.5%	82	74
SPRINGFIELD	M	S	20966	21330.5	1.7%	145	147
				MAPE =	12.0%		
EL SEGUNDO	W	O	25807	16818.7	34.8%	178	116
SANTA ANA	W	A	22414	16628.0	25.8%	155	115

* Actual and calculated hours were divided by 145 to derive personnel equivalents.

B-1.3 **DPRO MODELS**

All DPROS with data for the May to July 1991 period were used in our explorations. Those with no data available included:

DPRO Thiokol
DPRO Hercules
DPRO Northrop Hawthorne CA
DPRO Lockheed Sunnyvale CA

DPRO Michoud and DPRO Rockwell- Canoga Park, CA deal primarily with NASA. The resulting workload data and workhour data were extremely unusual. These activities were not used in the analysis. The Aircraft Program Management Office is not a DPRO and thus not included in these models.

The DPROs were segregated by size. Categories were determined by using the average monthly QA Operations APCAPS hours. The three size classifications were as follows:

Large DPROs - greater than 2025 hours
Medium DPROs - between 1500 and 2025 hours
Small DPROs - less than 1500 hours

LARGE DPROS

APCAPS Hours =		4.682E-07	UNDELIVERED DOLLAR BALANCE
	+	146.945	MIL-Q + MIL-I FACILITIES
	+	.195	CONTRACTS ON HAND
	+	35.786	PQDRS
	+	2,183	CONSTANT(in hours)

R^2 = 81.3%

NUMBER OF DPROS USED = 33

MEAN ABSOLUTE PERCENT ERROR (MAPE) = 11.8%

EXCLUDED AS OUTLIERS: MCDON-DOUG FL, MARTIN-MARIETTA GA, HONEYWELL, MCDON-DOUG MO, HUGHES LA, BOEING SEATTLE, GE AERO NJ

EXCLUDED GD FORT WORTH DUE TO UDB OUT OF RELEVANT RANGE

MEDIUM DPROS

APCAPS Hours =		.062	OVER & ABOVE REQUESTS
	+	31.426	MIL-Q + MIL-I FACILITIES
	+	.784	CONTRACTS RECEIVED
	-	1.059	QUEST SCORE
	+	1,695	CONSTANT (in hours)

R^2 = 67.6%

NUMBER OF DPROS USED = 16

MEAN ABSOLUTE PERCENT ERROR (MAPE) = 3.2%

EXCLUDED AS OUTLIERS: WESTINGHOUSE CA, MAGNAVOX, ALLIED SIGNAL

SMALL DPROS

APCAPS Hours =		3.887E-07	UNDELIVERED DOLLAR BALANCE
	+	1.867	CONTRACTS RECEIVED
	+	81.332	PQDRS
	+	1,030	CONSTANT (in hours)

R^2 = 36.1%

NUMBER OF DPROS USED = 12

MEAN ABSOLUTE PERCENT ERROR (MAPE) = 9.8%

EXCLUDED AS OUTLIERS: AT&T GA, LINK FLIGHT SIMULATOR

B-1.4 **DPRO MAPE CALCULATIONS**

LARGE DPROS

DPRO	DIST/ QAORG		APCAPS HOURS	EARNED HOURS	ABSOLUTE PERCENT ERROR	ACTUAL PERSONNEL	EARNED PERSONNEL
TEXAS INSTRUMENTS	S	3	5486	5596.9	2.0%	38	39
PEMCO	S	H	3081	2673.8	13.2%	21	18
LTV AEROSPACE & DEF.	S	U	3183	3406.2	7.0%	22	23
SIKORSKY	N	A	4435	4701.3	6.0%	31	32
TEXTRON LYCOMING	N	C	2369	2554.5	7.8%	16	18
GRUMMAN, BETHPAGE	N	G	5975	5402.7	9.6%	41	37
HARRIS, SYOSSET, NY	N	H	2322	2388.6	2.9%	16	16
GTE GOV'T	N	J	2968	3209.6	8.1%	20	22
HAMILTON STANDARD	N	M	2647	3514.3	32.8%	18	24
GE, LYNN	N	L	3091	3146.4	1.8%	21	22
GE PITTSFIELD, MA	N	P	2957	3792.7	28.3%	20	26
RAYTHEON, MA	N	R	8002	7836.6	2.1%	55	54
PRATT & WHITNEY, CT	N	W	4435	3439.2	22.5%	31	24
DETROIT DIESEL, IL	C	C	2192	2777.9	26.7%	15	19
MARTIN MARIETTA, CO	C	K	3375	4451.7	31.9%	23	31
BOEING WICHITA	C	N	3478	4161.6	19.7%	24	29
AEROJET, CA	W	4	2234	2781.4	24.5%	15	19
MCDON/DOUG MESA, AZ	W	8	4435	4382.5	1.2%	31	30
GEN'L DYN. SAN DIEGO	W	C	5954	4774.9	19.8%	41	33
DOUGLAS, LONG BEACH	W	D	3455	3088.4	10.6%	24	21
FMC, SAN JOSE	W	F	4245	3435.5	19.1%	29	24
GEN'L DYNAM, POMONA	W	G	2920	2481.2	15.0%	20	17
HUGHES, FULLERTON	W	H	3371	3249.5	3.6%	23	22
MCDON/DOUG HUNT. CA	W	M	4173	3837.8	8.0%	29	26
TRW REDONDO BEACH	W	T	3278	2897.4	11.6%	23	20
WESTINGHOUSE, OH	M	4	3077	2852.6	7.3%	21	20
LORAL	M	8	2894	2997.1	3.6%	20	21
BMY, OH	M	9	2530	2520.4	0.4%	17	17
BOEING, PA	M	E	3091	3379.8	9.3%	21	23
GE EVANDALE,OH	M	J	4435	4673.8	5.4%	31	32
GD WARREN, MI	M	T	2600	2423.3	6.8%	18	17
WESTINGHOUSE, MD	M	W	3629	3877.8	6.9%	25	27
GEN'L DYNAM LIMA, OH	M	Y	2817	2426.6	13.9%	19	17
				MAPE =	11.8%		
MCDON/DOUG, FL	S	K	2212	3464.0	56.6%	15	24
GE AERO NJ	M	M	10483	5613.1	46.5%	72	39
MARTIN MARIETTA, GA	S	M	4896	3149.7	35.7%	34	22
BOEING SEATTLE	W	5	5914	3251.6	45.0%	41	22
HUGHES LA	W	Z	5800	2836.0	51.1%	40	20
GD FORT WORTH,TX	S	X	5947	11186.3	88.1%	41	77
HONEYWELL, MN	C	2	8052	5127.6	36.3%	56	35
MCDON/DOUG, MO	C	S	6090	3310.0	45.6%	42	23

MEDIUM DPROS

DPRO	DIST/ QAORG		ACTUAL HOURS	EARNED HOURS	ABSOLUTE PERCENT ERROR	ACTUAL PERSONNEL	EARNED PERSONNEL
HARRIS, MELBOURNE	S	2	2013	1940.7	3.6%	14	13
DPRO LOCKHEED, GA	S	5	1995	2057.8	3.1%	14	14
PRATT WHITNEY, FL	S	7	1885	1793.0	4.9%	13	12
GRUMMAN, ST. AUG.	S	J	1967	1966.9	0.0%	14	14
ROCKWELL, INT'L	S	R	1580	1633.9	3.4%	11	11
BELL HELICOPTER, TX	S	V	1901	1828.3	3.8%	13	13
MCDON/ROCK TULSA, OK	S	Y	1660	1699.6	2.4%	11	12
UNISYS, NY	N	6	1791	1792.7	0.1%	12	12
GE BURLINGTON, MA	N	E	1735	1833.6	5.7%	12	13
SANDERS	N	K	1880	1821.5	3.1%	13	13
IBM OWEGO, NY	N	T	1723	1816.6	5.4%	12	13
FMC TWIN CITIES	C	P	1739	1680.4	3.4%	12	12
ROCKWELL, ANAHEIM	W	J	1729	1658.2	4.1%	12	11
HUGHES TUCSON	W	P	1558	1660.5	6.6%	11	11
KEARFOTT PLESSEY	M	7	1698	1697.8	0.0%	12	12
IBM MANASSAS, VA	M	I	1757	1729.3	1.6%	12	12
				MAPE =	3.2%		
WESTINGHOUSE, CA.	W	K	1984	1691.0	14.8%	14	12
ALLIED SIGNAL NY	M	3	1526	1793.1	17.5%	11	12
MAGNAVOX	C	F	1921	1672.6	12.9%	13	12

SMALL DPROS

DPRO	DIST/ QAORG		ACTUAL HOURS	EARNED HOURS	ABSOLUTE PERCENT ERROR	ACTUAL PERSONNEL	EARNED PERSONNEL
E SYSTEMS, TX	S	4	1478	1437.0	2.8%	10	10
SUNDSTRAND, IL	C	B	1422	1348.1	5.2%	10	9
ITT, OHIO	W	5	1421	1227.5	13.6%	10	8
EATON AIL	N	I	1347	1432.9	6.4%	9	10
ROCKWELL, RICH. TX	S	P	1256	1144.5	8.9%	9	8
GE BURLINGTON VT	N	Y	1221	1266.8	3.8%	8	9
FORD AERO NEWPORT CA	W	B	1213	1260.9	4.0%	8	9
TEXTRON DEFENSE MA	N	D	1210	1032.0	14.7%	8	7
NORTHROP, IL	C	H	1153	1084.8	5.9%	8	7
KAMAN AEROSPACE	N	X	1030	1186.3	15.2%	7	8
GRUMMAN, STUART	S	G	958	1089.4	13.7%	7	8
WILLIAMS INT'L MI	M	L	864	1062.4	23.0%	6	7
				MAPE =	9.8%		
LINK FLIGHT SIM.	N	O	538	1107.5	105.9%	4	8
AT&T, GA	S	W	499	1225.4	145.6%	3	8

APPENDIX C
QUARM TEST RESULTS

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Appendix C

C-1.1

SUMMARY TEST RESULTS

PERCENT OF DCMAOS WITHIN SPECIFIED LIMITS OF ACTUAL FYTD HOURS

	DEVELOPMENT DATA	TEST DATA
+/- 25%	83.8%	81.1%
+/- 20%	78.4%	67.2%
+/- 15%	67.6%	62.2%

PERCENT OF DPROS WITHIN SPECIFIED LIMITS OF ACTUAL FYTD HOURS

	LARGE		MEDIUM		SMALL	
	DEV. DATA	TEST DATA	DEV. DATA	TEST DATA	DEV. DATA	TEST DATA
+/- 25%	70.7%	56.4%	100.0%	100.0%	85.7%	71.4%
+/- 20%	65.9%	43.6%	100.0%	100.0%	78.6%	57.1%
+/- 15%	58.5%	30.8%	94.7%	73.3%	71.4%	50.0%

C-1.2 **DCMAO TEST RESULTS**

FISCAL YEAR TO DATE DATA

DCMAO	DIST/	QAORG	APCAPS HOURS	CALCULATED HOURS	ABSOLUTE PERCENT ERROR	ACTUAL PERSONNEL	EARNED PERSONNEL
ATLANTA	S	A	55304	59661.6	7.9%	95	103
BIRMINGHAM	S	B	77588	64349.5	17.1%	134	111
CLEARWATER	S	C	40763	34678.9	14.9%	70	60
DALLAS	S	D	71689	88145.9	23.0%	124	152
ORLANDO	S	F	33381	36863.6	10.4%	58	64
SAN ANTONIO	S	S	56528	45009.9	20.4%	98	78
BOSTON	N	F	75145	66229.5	11.9%	130	114
NEW YORK	N	N	41232	31033.2	24.7%	71	54
GARDEN CITY	N	Q	79095	55775.3	29.5%	136	96
SYRACUSE	N	S	54283	53373.5	1.7%	94	92
HARTFORD	N	U	60363	60620.8	0.4%	104	105
BRIDGEPORT	N	V	22178	33413.4	50.7%	38	58
TWIN CITIES	C	1	32568	37022.9	13.7%	56	64
GRAND RAPIDS	C	3	34652	36573.5	5.5%	60	63
DENVER	C	4	53305	45753.8	14.2%	92	79
WICHITA	C	6	30383	32971.4	8.5%	52	57
ST. LOUIS	C	7	40117	37487.7	6.6%	69	65
CEDAR RAPIDS	C	9	19725	29646.6	50.3%	34	51
CHICAGO	C	A	41316	44696.4	8.2%	71	77
MILWAUKEE	C	D	26721	34400.3	28.7%	46	59
INDIANAPOLIS	C	E	37154	33219.5	10.6%	64	57
SEATTLE	W	N	31763	36246.4	14.1%	55	62
SAN DIEGO	W	S	28766	31216.4	8.5%	50	54
VAN NUYS	W	V	83035	82851.9	0.2%	143	143
SAN FRANCISCO	W	W	63120	60684.7	3.9%	109	105
PHOENIX	W	X	69056	51741.3	25.1%	119	89
CLEVELAND	M	1	71948	43810.2	39.1%	124	76
DETROIT	M	2	37050	39007.0	5.3%	64	67
DAYTON	M	6	73793	64417.7	12.7%	127	111
BALTIMORE	M	B	49310	53880.5	9.3%	85	93
PHILADELPHIA	M	D	81436	82754.0	1.6%	140	143
PITTSBURG	M	P	42163	35660.3	15.4%	73	61
READING	M	R	57807	44919.2	22.3%	100	77
SPRINGFIELD	M	S	81686	90939.0	11.3%	141	157
SANTA ANA	W	A	85905	67073.9	21.9%	148	116
EL SEGUNDO	W	O	100760	73444.3	27.1%	174	127

C-1.3 **DPRO TEST RESULTS**

LARGE DPROS

FISCAL YEAR TO DATE DATA

DPRO	DIST/ QAORG		APCAPS HOURS	EARNED HOURS	ABSOLUTE PERCENT ERROR		ACTUAL PERSONNEL	EARNED PERSONNEL
MCDONNELL DOUGLAS	S	K	9061	11878.7	31.1%		16	20
LTV	S	U	12806	12353.7	3.5%		22	21
MARTIN MARIETTA, FL	S	M	17063	12137.3	28.9%		29	20
GEN'L DYNAMICS, TX	S	X	21459	46875.0	118.4%		37	81
TEXAS INSTRUM.	S	3	18882	22179.6	17.5%		33	38
E SYSTEMS	S	4	9768	11178.4	14.4%	*	17	19
PEMCO	S	H	13503	10821.8	19.9%		23	19
GTE GOV'T	N	J	12676	12542.6	1.1%		22	22
PRATT-WHITNEY, CT	N	W	14999	15737.7	4.9%		26	27
RAYTHEON	N	R	32881	30810.2	6.3%		57	53
HAMILTON STANDARD	N	M	11437	13780.6	20.5%		20	24
GRUMMAN, BETHPAGE	N	G	25933	20304.9	21.7%		45	35
TEXTRON, LYCOMING	N	C	9235	10980.7	18.9%		16	19
GE PITTSFIELD, MA	N	P	11535	14604.4	26.6%		20	25
GE LYNN, MA	N	L	14954	19353.5	29.4%		26	33
SIKORSKY	N	A	11310	21337.8	88.7%		20	37
HONEYWELL	C	2	31972	22163.6	30.7%		55	38
BOEING WICHITA	C	N	11705	17023.5	45.4%		20	29
MARTIN MARIETTA, CO	C	K	10658	18323.2	71.9%		18	32
MCDON/DOUGLAS, MO	C	S	31928	23699.1	25.8%		55	41
MCDON DOUGLAS, MESA	W	8	11811	23365.6	97.8%		20	40
MCDON/DOUGLAS, HUNT	W	M	17928	26944.9	50.3%		31	46
TRW, REDONDO	W	T	12070	15064.5	24.8%		21	26
BOEING, SEATTLE	W	5	22507	20893.9	7.2%		39	36
HUGHES, LA	W	Z	21906	16740.4	23.6%		38	29
HUGHES, FULLERTON	W	H	13136	14847.2	13.0%		23	26
GD POMONA	W	G	11165	9561.2	14.4%		19	16
AEROJET	W	4	8243	12256.0	48.7%		14	21
GD, SAN DIEGO	W	C	28990	14577.6	49.7%		50	25
DOUGLAS, LONG BEACH	W	D	15841	13307.6	16.0%		27	23
FMC, SAN JOSE	W	F	15428	11932.2	22.7%		27	21
WESTINGHOUSE, OH	M	4	8632	9999.3	15.8%		15	17
GE AERO, NJ	M	M	41262	20059.4	51.4%		71	35
LORAL	M	8	12860	11159.7	13.2%		22	19
BOEING, PA	M	E	12081	13184.4	9.1%		21	23
GE EVENDALE,OH	M	J	11357	20020.5	76.3%		20	35
WESTINGHOUSE, MD	M	W	13424	20941.1	56.0%		23	36
GD, LIMA, OH	M	Y	10624	11170.6	5.1%		18	19
KEARFOTT PLESSEY	M	7	11952	11570.0	3.2%	**	21	20

* ORIGINALLY CLASSIFIED AS SMALL DPRO IN DEVELOPMENT DATA
** ORIGINALLY CLASSIFIED AS MEDIUM DPRO IN DEVELOPMENT DATA

MEDIUM DPROS

FISCAL YEAR TO DATE DATA

SLFA	DIST/ QAORG		APCAPS HOURS	EARNED HOURS	ABSOLUTE PERCENT ERROR	ACTUAL PERSONNEL	EARNED PERSONNEL
ROCKWELL INT'L	S	R	6344	6591.2	3.9%	11	11
PRATT-WHITNEY, FL	S	7	6790	6577.0	3.1%	12	11
LOCKHEED,GA	S	5	7477	7430.6	0.6%	13	13
HARRIS, MELBOURNE	S	2	6959	7540.4	8.4%	12	13
BELL HELICOPTER, TX	S	V	6442	7090.8	10.1%	11	12
SANDERS LYCOMING	N	K	6948	7229.0	4.0%	12	12
UNISYS, NY	N	6	5953	6931.7	16.4%	10	12
IBM, NY	N	T	6323	7224.5	14.3%	11	12
FMC TWIN CITIES	C	P	6340	6711.5	5.9%	11	12
MAGNAVOX	C	F	6860	6690.9	2.5%	12	12
HUGHES, TUCSON	W	P	5808	6722.8	15.7%	10	12
WESTINGHOUSE, CA	W	K	7444	6786.5	8.8%	13	12
ROCKWELL, ANAHEIM	W	J	5856	6865.6	17.2%	10	12
IBM, MANASSAS	M	I	6574	6814.2	3.7%	11	12
ALLIED SIGNAL	M	3	8622	7079.4	17.9%	15	12
GRUMMAN, ST.AUG	S	J	3178	7707.1	142.5%	* 5	13

* NOT INCLUDED IN SUMMARY STATISTICS; DISESTABLISHED

SMALL DPROS

FISCAL YEAR TO DATE DATA

DPRO	DIST/ QAORG		APCAPS HOURS	EARNED HOURS	ABSOLUTE PERCENT ERROR	ACTUAL PERSONNEL	EARNED PERSONNEL
ROCKWELL,RICHARDSON	S	P	4158	4607.9	10.8%	7	8
GRUMMAN, STUART	S	G	4111	4412.9	7.3%	7	8
AT&T	S	W	1489	4816.9	223.5%	3	8
LINK FLIGHT	N	O	2084	4444.0	113.2%	4	8
EATON AIL	N	I	4778	7367.3	54.2%	8	13
SUNDSTRAND, IL	C	B	5175	5898.3	14.0%	9	10
NORTHROP, IL	C	H	4316	4553.0	5.5%	7	8
FORD, NEWPORT	W	B	4518	4776.8	5.7%	8	8
IT&T, OH	M	5	6310	4301.7	31.8%	11	7
WILLIAMS INT'L, MI	M	L	3434	4278.6	24.6%	6	7
HARRIS, SYOSSET,NY	N	H	5823	4591.0	21.2%	* 10	8
DETROIT DIESEL	C	C	7846	7148.4	8.9%	* 14	12
GD WARREN, MI	M	T	5755	4742.1	17.6%	* 10	8
BMY, OH	M	9	5451	4759.2	12.7%	* 9	8

* ORIGINALLY CLASSIFIED AS LARGE DPROS IN DEVELOPMENT DATA

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13. ABSTRACT *(Maximum 200 words)*

This set of models uses workload indicators to equitably estimate the Quality Assurance Operations personnel resources needed at each DCMAO and DPRO. Regression Analysis is used to identify, and quantify, those logical workload indicators that have statistically valid correlations with the corresponding workhours from the Automated Payroll Cost and Accounting System (APCAPS). These APCAPS workhours include all QA Operations time less supervisory, clerical and leave hours. The DCMAO model is statistically more significant than the results for the DPRO models. The average error between the actual and estimated hours for DCMAOs is 12%. The three DPRO models average error is 9.2%. However, when applied to recent QA data as a test, the DCMAO model performed well and better than the DPRO models. The QUARM models set a uniform, analytical approach for the DLA Directorate of Quality Assurance, DLA Office of the Comptroller, District Commanders and District QA Directors to compare workloads and balance resources. Judicious use of the models, coupled with other analyses or field reviews can result in important cost savings.

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