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BASE MAINTENANCE ACTIVITY
AND REPAIR CYCLE TIMES

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PREFACE

This study analyzes data from a service test of procedures designed to reconcile supply and maintenance accounting for assets in repair and to provide information on repair cycle times. This test, described in AFLC Letter No. 65-3, was conducted at Wright-Patterson AFB between June 3 and December 31, 1963.

The Memorandum presents summary information on maintenance activity and related repair cycle times for all repair cycle items and for Federal Stock Number (FSN) groupings of these items. These data should be useful in USAF studies and policy determinations, while furnishing inputs to RAND studies of stockage policy and logistics systems performance. Both the current USAF base supply policy ("Chapter 11")* and the proposed RAND base stockage model for recoverable items use repair cycle measurements or estimates.**

The study also uses these data to analyze the stockage implications of variations in response times under current "Chapter 11" policy rules. The method for assessing these impacts may prove useful to AFLC (and other activities) for planning purposes.

These data were made available through the cooperation of several persons at Hq AFLC, particularly Charles Frey.

* Chapter 11, Part One, Vol. II, AFM 67-1.

** For a description of the RAND base stockage model, see the following three RAND Memoranda by G. J. Feeney and C. C. Sherbrooke: The (s-1,s) Inventory Policy Under Compound Poisson Demand: A Theory of Recoverable Item Stockage, RM-4176-PR (DDC No. AD 605515), September 1964; An Objective Bayes Approach for Inventory Decisions, RM-4362-PR (DDC No. AD 613470), March 1965; and A System Approach to Base Stockage of Recoverable Items, RM-4720-PR (DDC No. AD 627644), December 1965.

SUMMARY

This study examines data from a service test of a system designed to provide consistent maintenance and supply data for requirements computations. It is concerned with repair cycle data for recoverable items and suggests a method for estimating their impact on the aggregate stocks at base level.

Repair cycle data are necessary inputs to base stock-level computations, but little information about them was available until recently; to obtain such information, maintenance (AFM 66-1) data must be reconciled with supply data. The statistics in this study resulted from a service test (AFLCL 65-3 Service Test, Phase I) designed to do just that.

The data make up a 7-month demand history for recoverable items from one base; they include demand frequency, repair cycle length, and maintenance action-taken code by item. Average repair cycles were computed by item, summarized by three groups of maintenance actions: "Repaired"; "Not Repairable This Station" (NRTS) plus "Condemned"; and "Bench-checked Serviceable"; these were then translated into stock levels using the current "Chapter 11" procedures to measure their impact on base stocks.

During the 213-day period of the test, there were 10,965 maintenance actions for 3220 items, half of which had only one action (or demand). Of this total, 51 percent were Repaired, 4 percent were Bench-checked Serviceable, and 45 percent were NRTS, with average net cycle times of 10.7, 6.6, and 6.8 days, respectively.

Although demand levels for most individual items are insensitive to chance variations in repair cycle times (because of their low demand rates), the aggregate demand level for all 3220 items is responsive to even small variations in the average repair cycle for the whole group.

NRTS actions accounted for one-third of all on-base net processing time, yet they are excluded from base stock-level computations. Adding this time to the net repair cycle time, plus an 8-day pipeline time, increases the average response time by 32 percent, and the aggregate demand level by 37 percent. This suggests a need to reduce this NRTS time, or to

include on-base processing time for NRTS actions in the stock-level computations.

The use of a fixed or overall average repair cycle time for a group of items (such as the Federal Supply Group) will cause about a third of the levels to be overestimated or underestimated; almost all the errors will be within one unit of stock, however. Furthermore, these errors tend to cancel out, so that an average or fixed repair cycle can be used to estimate the aggregate demand level with reasonable accuracy.

Expressing the aggregate demand level for each FSG as a ratio of stock per item makes it possible to determine how changes in repair cycle times affect the stock ratios for different demand distributions. Then plotting the stock ratios for a given repair cycle time against the average demand rate for each FSG shows how these ratios are affected by changes in average demand. These relationships should be useful for planning purposes.

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I. INTRODUCTION

Continuing revision of base stock-level computations increases the need for better information concerning base repair cycle time. AFLC Letter No. 65-3, "Command Service Test to Provide AFM 66-1 Data for Requirements" (dated November 19, 1962, revised April 26, 1963), outlined a service test of procedures for obtaining inputs for the AFLC requirements computation by reconciling maintenance and supply data.

This Memorandum analyzes the statistics from that service test. It is concerned with repair cycle times for alternative definitions of "repair cycle" and the related supply and maintenance activity for recoverable items. Specifically, the study analyzes a 7-month sample of maintenance and supply data from one base: demands for recoverable items, length of the repair cycle, type of maintenance action, and frequency and length of maintenance and parts delays. These demand and repair cycle data are then translated into stock levels to determine the impact of changes in the repair cycles.

These data show that repair cycles are sensitive to the method of measurement (or the definition of "repair cycle"). They also show that approximately one-third of maintenance time is omitted in calculating repair cycles for the base stock-level computation, because on-base processing time for "Not Repairable This Station" (NRTS) actions is excluded. Although demand levels for individual items are somewhat insensitive to chance variations in repair cycle times, the aggregate demand level for a group of items is responsive to even small changes in the average repair cycle for that group. Therefore, if the NRTS processing time were included in the computations, the aggregate demand level for the 3220 items in this study would increase by a third.

The data are discussed in four Sections. Section II deals with the maintenance and supply activity; Sec. III presents the data relating to repair cycle measurements; Sec. IV discusses the implications of supply activity and repair cycle times in terms of observed demand levels and presents a method of estimating the impact of repair cycle changes on aggregate demand levels; Sec. V presents some conclusions.

The information on supply and maintenance activity and repair cycle times should provide useful inputs to Air Force and RAND studies concerning stockage policies. The analysis should also enable us to examine some of the management aspects concerning the measurement and use of repair cycle data. Specifically, the method of assessing variations in response times in terms of impacts on base demand levels should prove a useful planning tool for AFLC.

II. SUMMARY OF MAINTENANCE AND SUPPLY ACTIVITY

DATA DESCRIPTION

The data presented in this study were obtained from Wright-Patterson Air Force Base during the period from June 3 to December 31, 1963. They were generated as a consequence of a field test of the procedures for recording demand and measuring repair cycles, now forming Chapter 17 of Volume 2, AFM 67-1. In original form, the data consisted of AFTO Form 211s, which were matched with corresponding requests for issue of the replacement items, the document number and date of demand being entered on each 211. Therefore, each card in the sample represents a failure (or malfunction) that resulted in a demand on Base Supply.

The cards used in this study were punched (at AFLC) from the 211s. They contained the following data: stock number; quantity, date of demand for replacement item, or removal of old item -- whichever occurred later; the date the malfunctioning item entered the Reparable Processing Center; the date the maintenance action was completed (i.e., the item was made serviceable, declared NRTS, or condemned); the number of days the item awaited maintenance (AWM); the number of days the item awaited parts (AWP); and the maintenance action-taken code.

MAINTENANCE ACTIONS BY TYPE OF REPAIR

During the seven months of the service test, 10,965 usable maintenance actions (for 3220 line items) were generated (after editing to correct or eliminate actions with erroneous stock numbers, inappropriate action-taken codes, and negative segments of the repair cycle).

Table 1 shows the breakdown of the 10,965 malfunctions by maintenance action-taken code (from AFM 66-1). The percentages shown here for the total sample agree closely with the three one-week samples (chosen at random) shown in AFLC's final report of Phase I of the test.*

* Final Report, Phase I AFLCL 65-3, Command Service Test to Provide AFM 66-1 Data for Requirements, 3 June 1963 to 31 December 1963, Hq AFLC, MCMS, Service Test OPR.

The Project 65-3 Service Test required that the repair cycle times be computed only for items actually repaired at the base; it

Table 1

DISTRIBUTION OF FAILURES BY ACTION TAKEN CODES

Action Code	Type of Action	Number of Actions	%
Repair Actions			
A	Bench-checked and repaired	5,240	47.8
F	Delayed repair	392	3.6
L,N,R,X	All other repair actions (test, inspect, adjust, assemble, remove and replace)	9	0.1
		5,641	51.5
No Repair Necessary			
B	Bench-checked -- serviceable	419	3.8
NRTS and Condemned			
1	NRTS - Repair not authorized	2,766	25.2
2	NRTS - lack of equipment, tools, and facilities	1,091	10.0
3,6	NRTS - lack of technical skills and data	32	0.3
4	NRTS - lack of parts	504	4.6
5	NRTS - shop backlog	36	0.3
7	NRTS - excess to base requirements	25	0.2
9	Condemned	451	4.1
		4,905	44.7
Total		10,965	100.0

excluded time charged to items declared NRTS or condemned, or bench-checked and found serviceable. (This conforms with the rules for stock-level computation given in Chapters 11 and 17 of AFM 67-1.)

Table 1 summarizes the maintenance actions by these three groups, to be used in Sec. III to determine the amount of maintenance time charged to these excluded actions. In the following sections, these groups will be referred to as: NRTS; B/C Serviceable (or merely B/C); and Repaired.

MAINTENANCE ACTIONS BY FEDERAL SUPPLY GROUP (FSG)

This mass of data was summarized into Federal Supply Groups composed of related items that would tend to be supplied by the same depot, and would therefore be expected to show similar characteristics, problems, and repair cycle times. Appendix A lists the FSGs included in the study.

Table 2

NUMBER OF ITEMS AND MAINTENANCE ACTIONS
BY FSG AND TYPE OF ACTION^a

FSG	Items				Maintenance Actions			
	Total	NRTS	B/C	Repaired	Total	NRTS	B/C	Repaired
12	204	151	27	81	789	459	44	286
14	78	50	18	21	165	83	40	42
15	248	124	7	129	367	156	7	204
16	604	414	9	255	1,677	949	10	718
28	236	203	3	52	601	496	21	84
29	311	194	6	159	1,017	488	7	522
58	483	233	63	331	3,105	508	110	2,487
59	86	55	4	31	169	108	4	57
61	191	94	5	131	576	155	6	415
66	649	496	77	253	2,291	1,401	167	723
All other	130	77	3	55	208	102	3	103
Total	3,220	2,091	222	1,498	10,065	4,905	419	5,641

^aFor FSGs with at least 40 maintenance actions. The "All other" category includes the 20 FSGs with fewer than 40 actions, listed separately in the Appendix. (See Table 11.)

Only ten FSGs had more than 77 items and 164 maintenance actions; no one FSG of the remaining 20 had more than 30 items or 40 actions. Table 2 shows the number of items and total maintenance actions by FSG and type of action for the ten largest FSGs (the remaining 20 being lumped in one group).^{*} The maintenance actions within FSGs are additive,

^{*}Table 11, Appendix D, gives the number of items and maintenance actions by FSG and type of action for these 20.

Table 3

PERCENTAGE DISTRIBUTIONS OF LINE ITEMS
AND MAINTENANCE ACTIONS BY FSG

FSG	% of Total Line Items	% of Total Maintenance Actions				% of Total Actions Within FSG ^a		
		All Actions (10,965)	NRTS (4,905)	B/C (419)	Repaired (5,641)	NRTS	B/C	Repaired
12	6.3	7.2	9.4	10.5	5.1	58.2	5.6	36.2
14	2.4	1.5	1.7	9.5	0.7	50.3	24.2	25.5
15	7.7	3.3	3.2	1.7	3.6	42.5	1.9	55.6
16	18.8	15.3	19.3	2.4	12.7	56.6	0.6	42.8
28	7.3	5.5	10.1	5.0	1.5	82.5	3.5	14.0
29	9.7	9.3	9.9	1.7	9.3	48.0	0.7	51.3
58	15.1	28.3	10.3	26.2	44.1	16.4	3.5	80.1
59	2.7	1.5	2.2	1.0	1.0	63.9	2.4	33.7
61	5.9	5.3	3.2	1.4	7.4	26.9	1.1	72.0
66	20.1	20.9	28.6	39.9	12.8	61.2	7.3	31.5
All other	4.0	1.9	2.1	0.7	1.8	49.0	1.5	49.5
Total	100.0	100.0	100.0	100.0	100.0	44.7	3.8	51.5

^a Percentages add to 100 across the three groups of maintenance actions: NRTS + B/C Serviceable + Repaired.

but the items are not, since a single item can have more than one type of action. FSGs 16 (Aircraft Accessories and Components), 29 (Engine Accessories), 58 (Communications Equipment), and 66 (Instruments and Laboratory Equipment) account for the bulk of the items and maintenance actions.

Table 3 presents the data from Table 2 as percentages of the totals for each type of action by FSG. It also shows the percentage distribution of NRTS, B/C, and Repaired actions. Overall, half the total actions are Repaired, but this proportion varies from 14 percent Repaired for FSG 28 (Engines, Turbines, and Components) to 80 percent for FSG 58. Because of its high rate of Repaired actions, FSG 58 includes 44 percent of all Repaired actions but only 10 percent of all NRTS.

MAINTENANCE ACTIONS PER ITEM

Table 2 shows the total number of actions and total items by FSG, but now let us look at the distribution of total maintenance actions (demands) per item within FSGs, as shown by Table 4. Over half the items had only one demand during the 213-day period, and 80 percent had no more than three. Even though most items had very low demand rates, four (all in FSG 58) had over 100 demands during the period: 120, 124, 188, and 356 -- accounting for 7 percent of the 10,965 actions.

Table 5 shows the number of Repaired actions per item by FSG. The distributions in this table cannot be derived from Table 4, even though they both come from the same set of data, as summarized in Table 2. Since the distributions of Repaired actions per item as well as Total actions will be needed for computations in Sec. IV, both tables are presented. Over half the 1498 items that had Repaired actions had only one during the period. In general, the distribution of Repaired actions per item is similar to that for all actions. The same four items in FSG 58 that had the highest number of total actions also had the highest number of Repaired actions: 112, 113, 173, and 306 -- accounting for 13 percent of the 5641 Repaired actions.

This section has presented a picture of the supply and maintenance activity during the test period, necessary for evaluating the repair cycle data to be presented in the next section.

Table 4

TOTAL ACTIONS PER ITEM BY FSG

Number of Actions per Line Item	Federal Supply Group (FSG) Number											Total	Percent of Total Items
	12	14	15	16	28	29	58	59	61	66	A/O		
1	98	50	187	348	143	148	240	57	104	330	92	1797	55.8
2	33	11	37	99	35	59	82	13	28	100	25	522	16.2
3	22	7	10	46	21	22	35	8	21	58	7	257	8.0
4	7	1	5	28	8	21	21	1	5	39	1	137	4.3
5	8	2	3	22	5	12	16	3	4	18	3	96	3.0
6	7	3	3	14	7	9	13		2	12		70	2.2
7	4	2	2	6	1	8	10		6	11		50	1.6
8	1	1		7	4	5	12	1	4	10		45	1.4
9	4		1	3	2	5	3		3	11		32	1.0
10	2			5	3	3	4	1	3	12		33	1.0
11	2			4	1	4	7		1	5	1	25	0.8
12	3			2	1	3	2	1	1	9		22	0.7
13				3	1	1		1	1	8		15	0.5
14	4			1	1	2	3		1	5		17	0.5
15				3	1		5		2	3	1	15	0.5
16	2					2	3		2	2		11	0.3
17							2			2		4	0.1
18		1		1					1	3		6	0.2
19				3					1			4	0.1
20						3				1		4	0.1
21-25	4			2		2	4		1	2		15	0.5
26-30				2		1	5			2		10	0.3
31-35	1			4	1	1	1					8	0.2
36-40	1			1			2			1		5	0.1
41-50	1				1					4		6	0.2
51-100							9			1		10	0.3
Over 100							4					4	0.1
Total	204	78	248	604	236	311	483	86	191	649	130	3220	100.0

Table 5

REPAIRED ACTIONS PER ITEM BY FSG

Number of Actions per Line Item	Federal Supply Group (FSG) Number											Total	Percent of Total Items
	12	14	15	16	28	29	58	59	61	66	A/O		
1	40	14	96	148	39	73	161	22	63	143	39	838	55.9
2	13	3	18	39	8	40	53	5	23	45	9	256	17.1
3	6	1	5	23		11	22	1	13	15	1	98	6.4
4	4	1	2	11		6	19		5	13	1	62	4.1
5	2	1	3	8	2	4	11	2	5	9	3	50	3.3
6	3		3	6	2	5	8			3		30	2.0
7	4		1	2	1	3	8		7	4		30	2.0
8	1			3		2	5		1	2		14	.9
9			1			3	2		4	6		16	1.1
10	1	1				1	4		2	4		13	.9
11						1			1	1	1	4	.3
12	2			5			3	1	1	1		13	.9
13	1			2		2	1		4	1	1	12	.8
14				1		2	5					8	.5
15	2			1			1					4	.3
16	1						3					4	.3
17						1	1		2	1		5	.3
18						1	2			1		4	.3
19				2		1						3	.2
20						1						1	.1
21-25				1		1	4					6	.4
26-30	1			2		1	3			2		9	.6
31-35				1			1			2		4	.3
36-40							1					1	.1
51-100							9					9	.6
Over 100							4					4	.3
Total	81	21	129	255	52	159	331	31	131	253	55	1498	100.0

III. REPAIR CYCLE MEASUREMENTS

REPAIR CYCLE SEGMENTS

The repair cycle time specified by AFLC Letter 65-3 is the number of days between the date of removal (or demand for the replacement item) and the date the item is made serviceable, declared NRTS, or condemned (excluding the number of days the item is awaiting maintenance or parts).

For convenience, the investigator coded these dates and periods as follows:

- A - Date of demand or removal
- B - Date item entered Repairable Processing Center (RPC)
- 1 - Number of days Awaiting Maintenance (AWM)
- 2 - Number of days Awaiting Parts (AWP)
- C - Date of completion (item made serviceable, declared NRTS, or condemned)

The following portions of the repair cycle were then computed.

Total Repair Cycle (AC)

Measured from the date of demand or removal (A) to the completion date (C), including all AWM and AWP times.

Net Repair Cycle (AC₁₂)

Same as AC, but excluding all AWM and AWP times.

Repairable Processing Time (BC)

Measured from the date that the item enters the Repairable Processing Center (B) to the completion date (C), including all AWM and AWP times.

Shop Flow Time (BC₁₂)

Same as BC, but excluding all AWM and AWP times.

According to the procedures specified in the service test, a demand was recorded whenever an item was removed from an aircraft

and immediately replaced by an item drawn from supply; the reparable item was then logged into the RPC. These events could all occur on the same day, but the logging of the reparable into the RPC should not precede the date of the demand. To simplify data processing, AFLC defined date "A" as the demand date or the removal date, whichever came later. This rule was reasonable for the majority of actions, but in some cases the date of demand (A) occurred after the reparable had been logged into the RPC (B); in others, date A occurred after the completion of the maintenance action (C). Usually, however, these dates all occurred within a short period. After discussion with AFLC personnel, it was decided that discrepancies within five days were reflections of the actual maintenance operations and should be included in the sample.*

DISTRIBUTION OF REPAIR CYCLE TIMES

Although AFLC Letter 65-3 specifies that only the net repair cycle time charged to Repaired actions should be tabulated, RAND was interested in learning something about the excluded portions of the repair cycle time. Therefore, a computation was made of the elapsed times for the total repair cycle and the reparable processing time -- with and without AWM and AWP -- for the three groups of maintenance actions.

Figure 1 shows the cumulative percentage distribution of the Net Repair Cycle times (total cycle, less AWM and AWP times) for the three groups of maintenance actions. Tables 12 and 13, Appendix D, give these frequencies and percentages, respectively. Net cycle times for the Repaired actions are longest (averaging 10.7 days, as indicated by the circles on the chart); the averages for the NRTS and B/C actions are both about 4 days less (6.8 and 6.6, respectively). The average for all actions is 2 days less than that for repaired actions (8.8).

*To eliminate the problem of negative repair cycle times, the repair cycle was measured from the first date (B), with "A" changed to agree with "B." Such corrections were made on 372 actions, which were included in the total of 10,965 actions.

Fig. 1 -- Distribution of net repair cycle times

However, 75 percent of the NRTS actions were less than the average (compared to 65 percent for the other groups). About 5 percent of the cycle times were over 30 days, and 0.2 percent were over 100 days. Two had cycle times of 213 days; one was NRTS, and the other Repaired.

Figure 2 shows the distribution of Total Repair Cycle times (including all maintenance and parts delays) for the three groups of actions and the total. Tables 12 and 13 give the backup data. The average total cycle times are 3.5 days longer than the net cycle times for NRTS, Repaired, and Total actions; they are one day longer for B/C actions. Ten percent of the cycle times were longer than 30 days and 0.5 percent (60 actions) were over 100 days.

Figure 3 shows the percentage distributions of Shop Flow times (from the date the item entered the Repairable Processing Center to the Completion date, excluding any maintenance or parts delays). Figure 4 shows the distribution of Repairable Processing times (same as Shop Flow times, but including maintenance and parts delays). Tables 14 and 15, Appendix D, provide the backup data for these two figures. Of course, the differences between the Shop Flow times and the Repairable Processing times are the same as those between the Net and Total Repair Cycle times. The longest Shop Flow time is 124 days, and the longest Repairable Processing time is 155 days -- both quite a bit shorter than the longest Net or Total Cycle times. The averages and distributions of Repairable Processing and Net Cycle times are quite similar for all groups, even though all except the Repaired group had more actions with extremely short Repairable Processing times.

"AWAITING PARTS" (AWP) AND "AWAITING MAINTENANCE" (AWM) TIMES

Table 6 shows the number and percentage of the total maintenance actions that had AWM and AWP times, given separately for the Repaired actions and all others (NRTS and B/C Serviceable). It also gives the average duration of these times. Figure 5 shows the percentage distributions of the AWM and AWP times for these two groups of maintenance actions.

The average time awaiting maintenance was 5 days, regardless of whether the item was repaired or declared NRTS. But the average time

Fig. 2 -- Distribution of total repair cycle times

Fig. 3 -- Distribution of shop flow times

Fig. 4 -- Distribution of reparable processing times

Fig. 5 -- Distribution of AWM and AWP times

awaiting parts was 13 days for Repaired items and 23 days for the remainder. Presumably, the reason for the longer delay for items that are NRTS for lack of parts is they are held at the base for 15 or 30 days (depending on the cost category of the item) while required parts are requisitioned.

Table 6

AVERAGE AWM AND AWP TIMES BY TYPE OF ACTION

Type of Action	AWM	AWP	AWM + AWP
Repaired Actions			
Number of Actions	2427	743	--
Percent of Total Actions	43.0	13.2	--
Average Days	5.0	13.1	--
NRTS and B/C Serviceable			
Number of Actions	1311	499	--
Percent of Total Actions	24.6	9.4	--
Average Days	5.3	23.4	--
All Actions			
Number of Actions	3738	1242	4476
Percent of Total Actions	34.1	11.3	40.8
Average Days	5.3	17.3	9.0

Even though the average AWP time is three times as long as AWM, three times as many maintenance actions had AWM times as opposed to AWP times. Forty percent of the maintenance actions had some AWM and/or AWP delay.

EFFECT OF DELAYS ON NET REPAIR CYCLE TIMES

To determine the effect of maintenance and parts delays on net repair cycle time, actions with AWM and/or AWP delays were considered separately from those with no delays; percentage distributions were made of the net cycle times (by type of maintenance action) for each group. Only about 30 percent of the NRTS and B/C actions had delays, as opposed to 50 percent of the Repaired actions. Figure 6 shows these cumulative percentage distributions.

Fig. 6 -- Distributions of net repair cycle times for actions with and without delays

Even though the distributions are for net repair cycle times (that is, they exclude the delay time charged to them), there are substantial differences in them, especially for the NRTS and B/C Serviceable actions. The average net cycle time for NRTS actions is 5 days for those without delays and 11 for those with delays. Net cycle times for B/C Serviceable actions average 6 days without delays and 9 days with delays. The averages for the Repaired actions are about the same -- 10 days for those without delays and 12 days for those with delays.

This would seem to indicate (1) that not all of the maintenance and parts delay time is being eliminated from actions charged with delays, or (2) delays are caused by (or are a cause of) longer net cycle times. Possibly it is a combination of both.

AVERAGE REPAIR CYCLE TIMES BY FSG AND TYPE OF ACTION

The preceding section deals with the percentage distributions of all repair cycle times by type of repair action. In this section we will look at the average repair cycle times by FSG and type of repair action. Except for a few FSGs, this breakdown is too fine to make it worthwhile to compute percentage distributions.

Table 7 shows these averages by FSG, for the Total and Net Repair Cycle times, Reparable Processing time, and Shop Flow time. It also shows the averages by type of maintenance action. The averages vary a great deal by FSG; the Net Cycle time ranges from 3 to 20 days for Repaired actions, and from 3 to 10 days for NRTS actions. The Total Cycle time ranges from 7 to 23 days for Repaired actions and from 4 to 19 days for NRTS actions.

The average difference between the Total Cycle time (longest) and Shop Flow time (shortest) is about 6 days for all maintenance actions, except for the B/C actions, which show about a 3-day spread. Eliminating delay times shortens the cycle an average of 3 days.

The average cycle time for NRTS actions is only about 2 to 3 days less than that for Repaired actions; even excluding delays, the average is 7 days. Since almost half of the maintenance actions are NRTS, this amounts to 35 percent of all of the net base processing time.

Table 7

AVERAGE REPAIR CYCLE TIMES BY FSG AND TYPE OF REPAIR ACTION

FSG	Net Repair Cycle				Total Repair Cycle			
	Total	NRTS	B/C	Repaired	Total	NRTS	B/C	Repaired
12	3.8	3.0	2.5	5.4	5.7	4.5	2.8	8.0
14	3.6	2.8	5.6	3.2	5.4	4.0	6.4	7.2
15	13.8	10.2	8.0	16.8	17.3	13.0	11.4	20.7
16	8.7	7.5	7.9	10.3	12.6	11.0	9.0	14.8
28	7.5	5.6	2.7	19.8	9.2	7.2	2.7	22.6
29	9.9	7.2	7.3	12.5	14.0	10.4	7.6	17.4
58	10.1	10.2	2.8	10.4	14.1	18.8	3.8	13.6
59	5.9	2.8	10.8	11.4	7.9	3.8	11.5	15.3
61	8.8	7.0	6.3	9.5	13.7	16.8	7.3	12.7
66	8.8	6.9	10.7	12.0	11.4	9.2	12.1	15.5
All Other	7.6	6.8	3.3	8.4	11.0	9.0	5.0	13.1
All FSGs	8.8	6.8	6.6	10.7	12.2	10.2	7.6	14.3
FSG	Shop Flow Time				Reparable Processing Time			
	Total	NRTS	B/C	Repaired	Total	NRTS	B/C	Repaired
12	2.1	1.1	0.6	4.0	4.0	2.6	0.9	6.7
14	0.7	0.3	0.7	1.4	2.5	1.5	1.5	5.4
15	8.9	3.4	3.4	13.2	12.3	6.3	6.9	17.1
16	4.9	3.1	5.9	7.3	8.8	6.6	7.0	11.8
28	5.2	3.4	2.7	16.2	6.9	5.0	2.7	19.0
29	6.9	3.9	5.7	9.7	10.9	7.1	6.0	14.5
58	8.0	7.9	1.8	8.4	12.1	16.4	2.9	11.6
59	3.6	0.9	10.3	8.2	5.6	1.9	11.0	12.2
61	5.6	4.1	4.7	6.2	10.6	13.9	5.7	9.4
66	6.2	4.3	8.4	9.5	8.9	6.6	9.8	13.1
All Other	3.8	2.4	2.7	5.3	7.2	4.5	4.3	9.9
All FSGs	6.1	3.8	4.6	8.3	9.5	7.1	5.6	11.9

Therefore, we looked for any differences in the average NRTS cycle times (by action code) which might cause the long cycle times. We found that the average net processing time for Code 1 NRTS (Repair Not Authorized) is only 3.9 days, compared with 10.6 for all other NRTS action codes. Thus, even though over half of the NRTS actions are Code 1, they account for only a third of the net cycle time charged to NRTS (11 percent of the net cycle time for all actions). The average net cycle (or processing) time for the other NRTS actions (lack of skills, facilities, parts, condemnations, etc.) is as long as the average for Repaired actions; they account for a quarter of the net processing time spent on all actions.

We will discuss the impact that these cycle times have on the stock level computations in the following section.

IV. COMPUTING STOCK LEVELS

STOCK-LEVEL FORMULA

Section II presented data on the general maintenance and supply activity by FSG. Section III dealt with measuring repair cycle times and their sensitivity to the method of measurement, types of maintenance actions included, the inclusion or exclusion of maintenance and parts delays, and variations by FSG.

This section considers the impact these variations in demand rates and repair cycle times have on stock levels. Lacking the necessary item characteristics to compute the actual stock levels, (cumulative recurring demands or daily demand rates (DDR's), special levels, if any, ERRC codes, and pipeline times), it was possible, nevertheless, to compute "observed demand levels" by using the demand rates (or total maintenance actions per item) experienced during the 213-day period. While these show only the repair cycle quantity of the stock level, one can add an assumed average pipeline time for NRTS actions to approximate the total demand level.*

These levels were computed by using the current stock-level formula given in Chapter 11, Part One, Volume II, AFM 67-1. The RAND base stockage model could not be used for this, because cost data were not available. The "Chapter 11" stock-level formula can be summarized as follows:

Let $S = x + y + z$, where:

S = stock level (or demand level)

x = (daily demand rate) times (% base repair)
times (repair cycle time)

y = (daily demand rate) times (% NRTS) times (pipeline
time, or order and shipping time (OST))

$z = \sqrt{3(x + y)}$, which is the safety level quantity

*"Demand level" refers to the portion of the total stock level that is based upon demands; it excludes any special levels that may be imposed.

These three segments can be expressed as:

$$S = \frac{RC + NP}{D} + \sqrt{\frac{3(RC + NP)}{D}}, \text{ where:}$$

D = number of days in the reporting period (213 days in this case)

R = number of repaired items (demands) during period D

C = average repair cycle time for repaired items

N = number of NRTS actions (plus condemnations) during period D

P = average pipeline (or OST) time for NRTS items

(See Appendix B for the derivation of this formula.)

For this study, RC is given as the sum of all repair times for any one line item (the sum of "AC," "AC₁₂," "BC," and "BC₁₂"). NP can be estimated by assuming a standard pipeline time, P, and applying this to the number of NRTS actions. The standard times given in AFM 67-1 are 8 and 30 days for cost category I and II items, respectively. Lacking ERRC codes, it was possible, nevertheless, to compute two stock levels for all NRTS items: one with P = 8 days, and one with P = 30 days. Knowing the time items spent in maintenance before they were declared NRTS, one can, of course, add this time to the computation.

To make the formula more useful for this study, the investigator turned it around and solved for the values of RC + NP that would give stock levels of 0, 1, 2, 3, etc. Then, by ordering the items by the value of RC + NP, stock levels for whole groups of items could be determined without any computation.

If we let A = RC + NP, then:

$$S = \frac{A}{D} + \sqrt{3 \frac{A}{D}}$$

And solving for A,

$$A = .5D \left[(2S + 3) - \sqrt{12S + 9} \right]$$

(See Appendix B for the derivation of this equation and the table of values of RC + NP for stock levels from 0 to 100.)

This formula provides a simple method for computing large numbers of stock levels, since it gives the "break points" in $RC + NP$ at which the level changes. It is a simple procedure to rank items by this $RC + NP$ value and obtain the corresponding levels directly.

DEMAND LEVELS FOR OBSERVED RESUPPLY TIMES

With the above procedures, it was relatively simple to compute the aggregate demand levels for all items in the study, using the observed distributions of repair cycle times and demand rates. We will refer to any combination of repair cycle and pipeline (or order and shipping) time, weighted by the respective number of Repaired and NRTS actions ($RC + NP$), as "Resupply Time."

Some may argue that the on-base processing time (net of delays) consumed by NRTS actions is not properly part of either the base repair cycle or the order and shipping time, since it is part of the depot repair cycle and is reflected in depot stocks. However, it represents an interval or delay during which support must be provided out of base stocks, and in this sense its impact resembles that of cycle or pipeline time. We will call this time C' (to distinguish it from the average repair cycle time C for repaired actions). Then our Resupply Time (or A) becomes: $RC + NC' + NP$. Subsequent portions of this section will be concerned with the impact on the aggregate demand level of alternate definitions of cycle times, the sensitivity to variations in values of C , C' , and P , and the effects of using standard, rather than actual, times.

Aggregate demand levels were computed for four different combinations of repair-cycle and on-base processing time. Three assumed pipeline times for NRTS actions were added to each of the cases, making twelve variations of resupply time in all. The four basic cases are:

1. Net repair cycle time for repaired actions
2. Total repair cycle time for repaired actions
3. Net repair cycle time for repaired actions plus net on-base processing time for NRTS actions
4. Total repair cycle time for repaired actions plus total on-base processing time for NRTS actions

The three assumed pipeline times for NRTS actions that were added to each of the four cases are: a) 0 days; b) 8 days; and c) 30 days.

These twelve combinations of repair cycle times, NRTS on-base processing times, and pipeline times are shown in Fig. 7, plotted against the average resupply time per maintenance action, which we will refer to as "Average Response Time."^{*} This is, then, a weighted average repair cycle plus pipeline time per demand. Table 16 (Appendix D) gives the backup data for Fig. 7. These average times will differ from those in Table 7 where the averages were expressed in terms of the average for Repaired actions only, the average for NRTS actions only, etc.

As the average response time increases from 6 to 25 days, the observed aggregate demand level increases from 1100 to 4200 units (an average of 160 units for each additional day). In other words, the stock levels of 5 percent of the 3220 items (160/3220) are increased by one unit for each day that is added to the response time.

Tables 17 and 18 (Appendix D) show the distribution of observed demand levels for net cycle times for all items (Case 3a), and net cycle times for all items, plus 8 days pipeline for NRTS (Case 3b); they illustrate how the demand levels shift when an 8-day pipeline time is added.

Cases 1a and 3a in Fig. 7 show the effect of adding the net NRTS on-base processing time (NC') to the net repair cycle time for Repaired actions (RC). This increases the average response time by 52 percent (from 5.8 to 8.8 days), and increases the demand level by 58 percent (from 1108 to 1753 units). These percentages are inflated, however, since they do not include NRTS pipeline time. Cases 1b and 3b show the results of adding NRTS processing time (NC') to the net repair cycle time for Repaired actions when an 8-day pipeline time for NRTS actions is included. Average response time increases by 32 percent (9.4 to 12.4 days), and the demand level increases by 37 percent (1896 to 2591 units); thus, the increase is still substantial. If the administrative NRTS actions are excluded from the computations

^{*} Average response time = $\frac{RC + NC' + NP}{R + N}$.

Fig. 7 -- Observed demand levels versus average response time

(their processing time is much shorter than that for the other NRTS actions, which require the same amount of time as the Repaired actions), then the average response time increases 21 percent (from 9.4 to 11.4 days), and the aggregate demand level increases about 17 percent (from 1896 to 2216, at 160 units per additional day).

FIXED VERSUS ACTUAL REPAIR CYCLE TIME

We have seen from the simplification of the stock-level formula at the beginning of this section that it is not necessary to compute repair cycle times if, during a specified period, we know the total number of repaired actions for a given item and the total repair time charged to that item, plus the number of NRTS actions and the total on-base processing and pipeline time charged to the item. Management should be able to monitor cycle times, however, because: 1) supply effectiveness may be downgraded if they become too long, and 2) it may be important to determine stock-level impacts for given cycle times (or changes in cycle times).

One might argue that using observed repair cycle times instead of a fixed standard tends to have an adverse effect on the computed stock levels. For example, the observed cycle time for an item in short supply might be shorter than normal, because the repairs would probably be expedited. Using this abnormally short cycle time in the stock-level computation would reduce the stock level and worsen the condition. Conversely, an item in long supply might have abnormally long observed cycle times, because items in short supply would be repaired first. Using the longer observed repair cycle time in the computation would increase the stock level for that item. Eliminating AWP and AWM time from the observed repair cycle, however, should adjust for this difficulty.

For low-demand items, there can be substantial variations in the repair cycle time before the stock level is affected. The range gets smaller, of course, as the demand rate increases. For example, the following table shows the ranges of repair cycle times for given

demand rates to generate stock levels of 0, 1, 2, 3, and 4. These ranges come from the data in Table 10, Appendix B.

Stock Level	Demands (in 213 Days)			
	1	2	10	100
0	0.0- 13.4	0.0- 6.7	0.0- 1.3	0.0-0.1
1	13.5- 86.4	6.8- 42.7	1.4- 8.5	0.2-0.8
2	86.5-186.4	42.8- 93.2	8.6-18.6	0.9-1.8
3	186.5-303.4	93.3-151.7	18.7-30.3	1.9-3.0
4	303.5-432.4	151.8-216.2	30.4-43.2	3.1-4.3

Although we are not prepared to answer the question of whether a standard should be used rather than the actual repair time, we can show the effect of doing so on the number of units stocked for our data. For each of the twelve cases shown in Fig. 7, a computation was made of aggregate demand levels that would have resulted had the observed average response time been applied to the observed pattern of demand rates. There are actually two demand patterns, because the first two cases include only the repair cycle time charged to the 1498 items with Repaired actions; the others include some time (repair cycle or pipeline) charged to all items. Therefore, these two distributions are discussed separately. Tables 4 and 5 in Sec. II show these two demand distributions.

The solid dots in Fig. 8 show the aggregate demand levels that would result from applying average repair cycles of 10, 10.7, 12, 13, 14.3, 15, 16, and 20 days to the demand patterns for items with repaired actions only (no depot resupply actions were required for these items). The cycle times of 10.7 and 14.3 days are the average net and total repair cycle times, respectively, observed in our data for repaired actions only. These correspond to Cases 1a and 2a of Fig. 7. The others are included to give sufficient spread to show how the aggregate demand levels respond to changes in the repair cycle time. The big jump between repair cycle times of 13 and 14 days is caused by the large number of items with one demand during the period that shift from a stock level of 0 to 1. A similar jump would occur at a repair cycle time of 86 days; at this point, these items would shift from a stock level of 1 to 2.

Fig. 8 -- Aggregate demand levels using fixed repair cycle times versus actuals for all FSGs -- Repaired actions only

This is an artificial situation that would not occur (or at least the effect would be much less) if we had actual daily demand rates (DDRs) for these items. For instance, the range of DDRs for fractional demands of 0.1 to 1.4 (rounded to one demand in 213 days) is from < 0.001 to 0.006 . The DDRs range from 0.007 to 0.012 for a demand of two in 213 days. The open dots in Fig. 8 show how the aggregate demand levels increase with increases in the average repair cycle time if the items with demands of 1 and 2 are distributed over this range of DDRs.

The "X's" show the two "actual" aggregate demand levels for repaired actions, where actual refers to the levels computed from the observed distributions of demand rates and cycle times by item. These are described in the section titled "Demand Levels for Observed Resupply Times" on p. 25. Applying an average repair cycle time to the demand distribution adjusted for DDRs seems to approximate the "actual" overall demand level. For an average repair cycle time of 10.7 days, the estimated level is 1091 and the "actual" figure is 1108. For an average of 14.3 days, the estimated level is 1468 and the "actual" is 1410.

Figure 9 shows the results of the same sort of analysis for all actions. Here we have ten cases of "actual" levels with which to compare the estimates. The results are similar to those for Repaired actions. Over the whole range of response times, the absolute errors (signs ignored) in the estimates tend to be about one-third less for those based on the adjusted demand distribution (260 versus 410 units on the average). The errors are largest for those assumed pipeline times of 30 days for NRTS actions. These so-called "actual" demand levels are still somewhat biased as a result of applying a fixed pipeline time of 8 or 30 days to the demands during the 213-day period.

TOTAL DEVIATIONS OF ESTIMATED LEVELS FROM ACTUAL LEVELS

Figures 8 and 9 show the net differences in aggregate demand levels only; they tell nothing about the total number of items with levels that are incorrectly estimated as a result of using a fixed cycle (or response) time rather than the observed time. Table 8 shows

Fig. 9 -- Aggregate demand levels using fixed response times
versus actuals for all FSGs -- all actions

Table 8

DEVIATION OF ESTIMATED DEMAND LEVELS FROM ACTUAL FOR
AVERAGE REPAIR CYCLE OF 8.8 DAYS

Estimated Demand Level ^a	Estimated > Actual					0	Estimated < Actual				
	+5	+4	+3	+2	+1		-1	-2	-3	-5	-14
0						1342	348				
1					521	685	97	12	1		
2				9	82	45	20	4	1		
3				8	6	6	4	1		1	
4			2	3	3	1	3	1			
5			1					1			
6	1		1					1		1	
7	1			1				1	1		
9					1					1	
13		1									
21											1
Total Items	2	1	4	21	613	2079	472	21	3	3	1
Percent of Items	.06	.03	.13	.65	19.04	64.57	14.66	.65	.09	.09	.03
Total Units	<div> <div>10</div> <div>4</div> <div>12</div> <div>42</div> <div>613</div> </div>					--	<div> <div>472</div> <div>42</div> <div>9</div> <div>15</div> <div>14</div> </div>				
	+681						-552				

NOTE: Actual Demand Level = 1753.

Estimated Demand Level for Average R/C (= 8.8) = 1753 + 681 - 552 = 1882.

^aEstimated by applying an average repair cycle time of 8.8 days to the demand distribution.

Table 9

EFFECTS OF ERRORS IN ESTIMATED REPAIR CYCLE TIMES
FOR INDIVIDUAL ITEMS^a

Error in Demand Levels (Units)	Error in Estimating Repair Cycle (Days)					
	+3	+2	+1	-1	-2	-3
+5	1					
+4	1	1				
+3	2	1				
+2	8	3	2			
+1	478	321	158			
0	(2724)	(2894)	(3060)	(3018)	(2863)	(2739)
-1				201	352	469
-2				1	4	9
-3						2
-4					1	
-6						1
Total items affected	490	326	160	202	357	481
Percent of items (3220)	(15.2)	(10.1)	(5.0)	(6.3)	(11.1)	(14.9)
Total units affected	510	334	162	203	364	499
Percent of units (1830)	(27.9)	(18.3)	(8.9)	(11.1)	(19.9)	(27.3)

^aDeviations from distributions of net repair cycles (average of 9.3 days). The actual demand level = 1830; number of items = 3220. This average repair cycle time differs from the 8.8 days shown in Table 7 because each fraction of a repair cycle was rounded to the next whole day.

the total deviations in demand levels that result from using an average net cycle time of 8.8 days for all items, rather than the actual net cycle time for each item (with an overall average of 8.8 days). Although the net difference in aggregate levels is only 129 units, 641 items were overestimated by a total of 681 units, and 500 items were underestimated by 552 units. As these figures indicate, most of the errors were only one unit per item. In fact, 35 percent of the items had incorrectly estimated levels, but less than 2 percent were more than one unit off. Except for one underestimate of 14 units, the rest of the errors were within ± 5 units.

Now suppose, for purposes of stock-leveling, that each item had a different fixed repair cycle time (such as an engineering standard or an average that was only revised periodically), but each was overestimated or underestimated by a day or so. For example, as mentioned above, the average repair cycle for a given item may have been measured during a series of expedited repairs, and was thus underestimated. Table 9 shows the total discrepancies that would result if the repair cycles for all items were consistently overestimated or underestimated by one, two, or three days. The items for which levels were incorrectly estimated range from about 5 to 15 percent of the total items over the 3-day spread. The errors in units range from 9 to 28 percent of the aggregate demand level; these are almost proportional to the percentage error in the repair cycle time.

Any conclusions drawn from this analysis must be tentative because they relate to this particular data collection. It seems, however, that although individual items with only one or two demands (the bulk of the items) can have a substantial error in the repair cycle time before the stock level for that item is affected, the total number of units stocked for a given range of items seems to be rather sensitive to the average repair cycle times used. For our data, the aggregate stock level increases about 160 units for each day that is added to the average repair cycle, or response, time (about 5 percent of the 3220 items).

It would seem that a fixed repair time might safely be used on the low-demand items, if there are periodic checks to see what the

actual times are. If fixed times are used on higher-demand items, such checks would be particularly important, because the stock levels for these items are more sensitive to discrepancies in the repair cycle time.

DEMAND LEVELS BY FSG

Although errors for individual items occurred when a fixed cycle time was used in computing demand levels, estimated levels were usually within one unit of the actual. Furthermore, errors tended to cancel out over a group of items (such as an FSG); the total estimated level, therefore, should be close to the actual.

We computed aggregate demand levels for each FSG by this method, applying the average repair cycle times to the demand distributions for total actions and repaired actions (see Tables 4 and 5). There are five average repair cycle times for each FSG. The first four are the net and total repair cycle times, shop flow time, and the reparable processing time given in Table 7. The fifth is an assumed standard time of 10 days used as a comparison across FSGs.

Figures 10 and 11 show these computed aggregate demand levels for repaired actions and total actions, respectively, plotted against the average repair cycle times by FSG. (See Table 19, Appendix D, for backup data.) From these figures, one can readily see how changes in repair cycle times affect aggregate demand levels. It is apparent from FSGs 28 and 58 in Fig. 10 (repaired actions) that long cycle times, per se, do not necessarily cause large increases in demand levels.

Figures 10 and 11 do not permit ready comparisons between FSGs, because the numbers of items, the range of repair cycle times, and the average demand rates are all different for each group. Expressing the aggregate units stocked as a ratio of stock per item for each FSG eliminated the problem of differing numbers of items in each group. Assumed average repair cycle times of 5, 10, 15, 20, 25, 30, 35, 40, and 45 days were then applied to each FSG, to make the range of cycle times comparable. Figures 12 and 13 show these stock level ratios for

Fig. 10 -- Aggregate demand levels versus average repair cycle times
by FSG -- Repaired actions only

Fig. 11 -- Aggregate demand levels versus average repair cycle times by FSG -- all actions

Fig. 12 -- Average stock per item versus average repair cycle time by FSG -- Repaired actions only

Fig. 13 -- Average stock per item versus average repair cycle time
by FSG -- All actions

repaired actions and total actions, respectively, for each FSG. (Table 20 in Appendix D gives the backup data.)

Figures 12 and 13 show how the ratios of stock per item respond to changes in repair cycle times for different distributions of demands (each FSG). The FSGs with the highest average demand have the greatest increase in stock per item for a given increase in repair cycle time. Figure 12 (repaired actions) shows, for example, that increasing the average repair cycle from 10 to 15 days increases the average stock per item by 0.17 units for FSG 15, by 0.22 units for FSG 66, and by 0.40 units for FSG 58; these FSGs had average demand rates of 1.58, 2.86, and 7.51, respectively. With only a couple of exceptions, the FSGs were ranked by their average demand rates for all average repair cycle times. For the reader's convenience the average demands for each FSG are noted on Figs. 12 and 13.

Plotting the stock-per-item ratios for a given repair cycle time against the average demand for each of the FSGs shows how sensitive the average stock levels are to different demand rates when cycle time is held constant. Figure 14 shows these data for both Repaired and total actions for repair cycle times of 5, 10, 20, 30, and 40 days. One might argue that it is not appropriate to combine the two sets of data, because repaired actions are included in the total actions, and would be counted twice. However, the two sets of actions have different demand distributions (and average demand rates) for each FSG, and the purpose here is to see how stock-per-item ratios respond to these different distributions of demands.

There are definite curvilinear clusters of points for each cycle time, but those for cycle times of 5 and 10 days tend to be semilogarithmic and those for cycle times of 20, 30, and 40 days are logarithmic. Rather than fit two different types of curves to the data, freehand curves were drawn through the clusters for each repair cycle time. From Fig. 14, in combination with Figs. 12 and 13, one can estimate the effects on the stock-per-item ratios of varying both demand rates and repair cycle times.

Although in many cases changing the repair cycle of the average demand by a given factor results in about the same change in stock per

Fig. 14 -- Average stock per item versus average demand for selected repair cycle times

item, it does not always do so. Increasing the repair cycle from 20 to 30 days with an average demand of 2.0 results in the same stock per item as does increasing the demand from 2.0 to 3.0 with a repair cycle of 20 days. However, increasing the repair cycle from 10 to 20 days with an average demand of 3.0 gives a larger increase in stock per item than does increasing the demand from 3.0 to 6.0 with a repair cycle of 10 days.

V. CONCLUSIONS

These data confirm our general view of the volume and distribution of supply activity. There were 10,965 demands for the 3220 items during the 7-month period. Demand rates varied considerably; half the items had only one demand, but one item had 356 during the period. Three others had over 100 demands.

Net cycle times averaged 10.7 days for Repaired actions, 6.8 days for NRTS, and 6.6 days for B/C-Serviceable. About 5 percent of the cycle times were over 30 days, and 0.2 percent were over 100 days. Total cycle times (including parts and maintenance delays) were 3.5 days longer than net cycle times for the Repaired and NRTS actions, and 1 day longer for B/C. Ten percent were over 30 days, and 0.5 percent were over 100 days.

The on-base processing time charged to NRTS actions represents an interval or delay during which support must be provided out of base stocks. In this sense, it has an impact similar to that of repair-cycle or pipeline time, yet it is excluded from the base stock-level computations. If the processing time per NRTS action is short, the impact on base stocks is probably negligible; however, 45 percent of all actions were NRTS, accounting for one-third of all on-base net maintenance processing time. If this NRTS time were included in the stock-level computations (using the net repair cycle times, plus an 8-day pipeline time for NRTS), the aggregate demand level would be increased by 37 percent. This suggests a need to measure NRTS time so that management can at least be aware of its magnitude, and possibly take steps to reduce it.

Over half the NRTS actions were administrative (Code 1) and had shorter average net processing times than the other NRTS actions (3.9 days compared with 10.6). Perhaps only these Code 1 NRTS actions should be excluded from the stock-level computations, with the remainder (whose processing times are as long as those for Repaired actions) included in the formula. This would increase the aggregate demand level by about 15 percent (assuming an 8-day pipeline time for NRTS).

Although it is not necessary to know the average repair cycle times for stock-level computations, management should be able to monitor

them; supply effectiveness may be downgraded if they get too long, and it may be important to determine stock level impacts for given cycle times.

Two things tend to reduce the effects of short-term or chance variations in cycle times on stock levels for individual items:

- 1) there can be substantial errors in repair cycle times for items with low demand rates before the stock level for that item is affected;
- 2) although stock levels for items with high demand rates are quite sensitive to changes in repair cycle times, the large volume of transactions tends to minimize the effect of short-term changes in the repair cycle. However, aggregate stock levels for a group of items are sensitive to changes in repair cycle times; for this demand distribution (it might be different for other distributions), each day added to the average repair cycle time increases the levels for about 5 percent of the items.

Using a fixed or an overall average repair cycle to estimate stock levels will underestimate or overestimate the levels for about one-third of the items, but 98 percent of the errors will be within one unit, and virtually all will be within five units.

Using fixed standard repair cycle times that vary from item to item, but are consistently underestimated or overestimated by one, two, or three days, results in an error in stock levels for 5 percent of the items for each day of error. In terms of units, the error is proportional to the percentage error in the repair cycle time -- e.g., a 10-percent error in repair cycle time will cause a 10-percent error in the aggregate stock level.

The errors in estimated levels for individual items that result from applying an average repair cycle time to a group of items tend to cancel out; thus, the estimated aggregate level is quite close to the actual. These aggregate demand levels were expressed as ratios of stock per item so that FSGs of varying sizes could be compared. This made it possible to determine how responsive average demand levels were to varying repair cycle times and average demand rates for a group of items, which should be a useful tool for planning purposes.

Appendix A

FEDERAL SUPPLY GROUPS*

- 10 Weapons
- 12 Fire Control Equipment
- 14 Guided Missiles
- 15 Aircraft; and Airframe Structural Components
- 16 Aircraft Components and Accessories

- 17 Aircraft Launching, Landing, and Ground Handling Equipment
- 22 Railway Equipment
- 28 Engines, Turbines, and Components
- 29 Engine Accessories
- 31 Bearings

- 41 Refrigeration and Air Conditioning Equipment
- 42 Fire Fighting, Rescue, and Safety Equipment
- 43 Pumps and Compressors
- 45 Plumbing, Heating, and Sanitation Equipment
- 46 Water Purification and Sewage Treatment Equipment

- 47 Pipe, Tubing, Hose, and Fittings
- 48 Valves
- 49 Maintenance and Repair Shop Equipment
- 53 Hardware and Abrasives
- 58 Communication Equipment

- 59 Electrical and Electronic Equipment Components
- 61 Electrical Wire, and Power and Distribution Equipment
- 62 Lighting Fixtures and Lamps
- 63 Alarm and Signal Systems
- 65 Medical, Dental, and Veterinary Equipment and Supplies

- 66 Instruments and Laboratory Equipment
- 67 Photographic Equipment
- 71 Furniture
- 73 Food Preparation and Serving Equipment
- 85 Toiletries

* Includes only those FSGs used in the study.

Appendix B

STOCK-LEVEL FORMULA

The stock level at the base is composed of three segments:

x = base repair cycle quantity

y = depot cycle (OST) quantity

z = safety level quantity

Let:

D = number of days in the reporting period (or days of experience;
in our case, it is 213 days)

T = total number of demands during the period, D. ($T = R + N$), where:

R = number of repaired items during period D (including those that
were bench-checked and found serviceable)

N = number of NRTS (plus condemnations) during period D

C = average repair cycle time for repaired items

P = pipeline (OST) time for NRTS items

DDR = daily demand rate = $\frac{T}{D}$

1) $x = \text{DDR} \times (\% \text{ base repair} \times \text{repair cycle time})$

$$x = \frac{T}{D} \times \frac{R}{T} \times C + \frac{RC}{D}$$

2) $y = \text{DDR} \times (\% \text{ NRTS} \times \text{OST})$

$$y = \frac{T}{D} \times \frac{N}{T} \times P = \frac{NP}{D}$$

3) $z = c \sqrt{3(x + y)}$, where c is a constant that is set = 1 (for these items). (Note: "c" should not be confused with C, which is the average repair cycle time.)

$$z = \sqrt{3 \left(\frac{RC + NP}{D} \right)}$$

$$4) \quad S = \frac{RC + NP}{D} + \sqrt{3 \left(\frac{RC + NP}{D} \right)}$$

SOLVING FOR RC + NP IN THE STOCK-LEVEL FORMULA

Using the stock-level formula given above to solve for the values of RC + NP that would give stock levels for 0, 1, 2, etc.:

Let A = RC + NP

$$1) \quad \text{Then } S = \frac{A}{D} + \sqrt{\frac{3A}{D}}$$

$$2) \quad S - \frac{A}{D} = \sqrt{\frac{3A}{D}}$$

Squaring both sides:

$$3) \quad \left(S - \frac{A}{D} \right)^2 = \frac{3A}{D}$$

$$4) \quad S^2 - \frac{2AS}{D} + \frac{A^2}{D^2} = \frac{3A}{D}$$

$$5) \quad \frac{A^2}{D^2} - \frac{A}{D} (2S + 3) + S^2 = 0$$

$$6) \quad \text{Solving the quadratic equation by the formula: } x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} :$$

$$\frac{A}{D} = \frac{(2S + 3) \pm \sqrt{(2S + 3)^2 - 4S^2}}{2}$$

$$7) \quad A = 0.5D \left[(2S + 3) - \sqrt{12S + 9} \right] \quad \text{(The negative root is the relevant one; the other is a spurious root introduced by the squaring operation of Step 3.)}$$

8) Since D = 213,

$$A = 106.5 \left[(2S + 3) - \sqrt{12S + 9} \right]$$

Since the stock-level figures are half-adjusted in the original formula, we set $S = s + 0.5$ and substitute s for S in the equation. The

resulting values are the limits of A (or $RC + NP$) for given values of S. Solving for A, we find that a value of A of < 14 gives an observed demand level of 0; 14 to 85 = 1; 86 to 186 = 2; etc.

The length of the reporting period, D, appears only as a multiplier of the equation, so it is very easy to use any value of D. It was convenient in this study to use $D = 213$; this eliminated the problem of computing daily demand rates for each item and converting these to some more convenient period, such as a year.

Table 10 shows the lower limits of A for given values of S, for $D = 1$; $D = 213$; and $D = 365$. The first column expresses the A values in terms of daily demand rates; these can be converted to any reporting period merely by multiplying by the number of days in the reporting period. The second column shows the limits of A used for the 213-day period. The third column shows the values of A in terms of yearly demand rates, a convenient and frequently used reporting period.

Table 10

MINIMUM VALUES OF A (= RC + NP) REQUIRED TO GENERATE STOCK LEVEL "S"

S	s	A(D = 1)	A(D = 213)	A(D = 365)
1	0.5	0.06	14	23
2	1.5	0.40	86	147
3	2.5	0.88	187	320
4	3.5	1.43	304	522
5	4.5	2.03	433	741
6	5.5	2.67	569	975
7	6.5	3.34	711	1218
8	7.5	4.03	857	1469
9	8.5	4.73	1008	1727
10	9.5	5.45	1162	1991
11	10.5	6.19	1319	2260
12	11.5	6.94	1478	2532
13	12.5	7.70	1639	2809
14	13.5	8.46	1802	3089
15	14.5	9.24	1967	3371
16	15.5	10.02	2134	3657
17	16.5	10.81	2302	3944
18	17.5	11.60	2471	4234
19	18.5	12.40	2641	4526
20	19.5	13.21	2813	4820
21	20.5	14.02	2985	5116
22	21.5	14.83	3159	5413
23	22.5	15.65	3333	5712
24	23.5	16.47	3508	6012
25	24.5	17.30	3684	6313
26	25.5	18.13	3861	6616
27	26.5	18.96	4038	6920
28	27.5	19.79	4216	7225
29	28.5	20.63	4395	7531
30	29.5	21.47	4574	7838
31	30.5	22.32	4754	8146
32	31.5	23.16	4934	8455
33	32.5	24.01	5115	8765
34	33.5	24.86	5296	9075
35	34.5	25.72	5478	9387
36	35.5	26.57	5660	9699
37	36.5	27.43	5842	10012
38	37.5	28.29	6025	10325
39	38.5	29.15	6209	10639
40	39.5	30.01	6392	10954
41	40.5	30.88	6577	11270
42	41.5	31.74	6761	11586
43	42.5	32.61	6946	11902
44	43.5	33.48	7131	12220
45	44.5	34.35	7316	12537

Table 10 -- continued

S	s	A(D = 1)	A(D = 213)	A(D = 365)
46	45.5	35.22	7502	12856
47	46.5	36.09	7688	13174
48	47.5	36.97	7874	13494
49	48.5	37.84	8061	13813
50	49.5	38.72	8248	14134
51	50.5	39.60	8435	14454
52	51.5	40.48	8622	14775
53	52.5	41.36	8810	15097
54	53.5	42.24	8998	15419
55	54.5	43.13	9186	15741
56	55.5	44.01	9374	16064
57	56.5	44.89	9563	16387
58	57.5	45.78	9751	16710
59	58.5	46.67	9940	17034
60	59.5	47.56	10129	17358
61	60.5	48.44	10319	17682
62	61.5	49.33	10508	18007
63	62.5	50.23	10698	18332
64	63.5	51.12	10888	18658
65	64.5	52.01	11078	18983
66	65.5	52.90	11268	19309
67	66.5	53.80	11459	19636
68	67.5	54.69	11649	19962
69	68.5	55.59	11840	20289
70	69.5	56.48	12031	20616
71	70.5	57.38	12222	20944
72	71.5	58.28	12413	21271
73	72.5	59.18	12604	21599
74	73.5	60.08	12796	21927
75	74.5	60.98	12988	22256
76	75.5	61.88	13179	22585
77	76.5	62.78	13371	22913
78	77.5	63.68	13564	23243
79	78.5	64.58	13756	23572
80	79.5	65.48	13948	23902
81	80.5	66.39	14141	24231
82	81.5	67.29	14333	24561
83	82.5	68.20	14526	24892
84	83.5	69.10	14719	25222
85	84.5	70.01	14912	25553
86	85.5	70.91	15105	25884
87	86.5	71.82	15298	26215
88	87.5	72.73	15491	26546
89	88.5	73.64	15685	26877
90	89.5	74.55	15878	27209
91	90.5	75.45	16072	27541
92	91.5	76.36	16266	27873
93	92.5	77.27	16459	28205
94	93.5	78.18	16653	28537
95	94.5	79.10	16847	28870
96	95.5	80.01	17042	29203

Table 10 -- continued

S	s	A(D = 1)	A(D = 213)	A(D = 365)
97	96.5	80.92	17236	29536
98	97.5	81.83	17430	29869
99	98.5	82.74	17625	30202
100	99.5	83.66	17819	30535
101	100.5	84.57	18014	30869
102	101.5	85.49	18208	31202

Appendix C

COMPUTING AGGREGATE STOCK LEVELS FROM CUMULATIVE
PERCENTAGE DISTRIBUTIONS OF DEMANDS

Example: FSG 12 (All Actions) -- assumed repair cycle of 10 days.*

Stock Level	Limits of Demands x RC	Number of Demands (RC = 10)	Number of Items	% of Items	Cumulative Percent	Units Stocked #L/I(SL)	Units Stocked Per L/I %L/I(SL) /100
0	0-13	1	98	48.0	48.0	0	0
1	14-85	2-8	82	40.2	88.2	82	.402
2	86-186	9-18	17	8.3	96.5	34	.166
3	187-303	19-30	4	2.0	98.5	12	.060
4	304-432	31-43	2	1.0	99.5	8	.040
5	433-568	44-56	1	.5	100.0	5	.025
			204			141	.693

The average number of units stocked per item equals 141/204, or 0.69 units per item. This ratio can be obtained directly by multiplying the percentage distribution of items by the appropriate stock level (see the last column).

The same thing can be done from the cumulative distribution, as follows:
 Stock-level/line item (or S/L) = $0(.480 - 0) + 1(.882 - .480) + 2(.965 - .882)$
 $+ 3(.985 - .965) + 4(.995 - .985)$
 $+ 5(1.000 - .995)$

Rearranging and simplifying this equation:

$$S/L = 5(1.000) + (4 - 5).995 + (3 - 4).985 + (2 - 3).965 + (1 - 2).882 - .480$$

Or:

$$S/L = 5.000 - .995 - .985 - .965 - .882 - .480 = .693$$

This short method has several interesting advantages over computing stock levels the long method. By using cumulative percentage distributions of demands (or rates), different repair cycle times can be applied rapidly by determining the new demand limits for each stock level for various assumed repair cycle times. For instance, the number of demands during a 213-day period required for stock levels of 0, 1, 2, 3, 4, and 5 with repair cycles

* Assumed to be a weighted average of repair cycle days and pipeline resupply days.

of 10, 15, and 20 days are:

Stock Level	Repair Cycle (Days)		
	10	15	20
0	1	--	--
1	2-8	1-5	1-4
2	9-18	6-12	5-9
3	19-30	13-20	10-15
4	31-43	21-28	16-21
5	44-56	29-37	22-28

Using cumulative percentage distributions of demands, one merely has to read off the appropriate percentage for demands of 5, 12, 20, 28, and 37 for a repair cycle of 15 days, for instance. There is no need to add up the line items in each group (stock level), and the computation is done by successive subtractions rather than cumulative multiplications.

If the stock-level figures skip one (say, from 2 to 4), then the cumulative percentage distribution at SL = 2 should be subtracted twice (once for a stock level of 3 and once for 2). For example, if the cumulative percentage distribution were:

Stock Level	Percent
0	48.0
1	88.2
2	96.5
3	--
4	98.5
5	99.5
6	100.0

$$S/L = 6.000 - .995 - .985 - .965 - .965 - .882 - .480 = .73$$

Checking this with numbers:

Stock Level	Line Items	Units Stocked	
0	98	--	
1	82	82	
2	17	34	
3	--	--	
4	4	16	
5	2	10	
6	1	6	
Total	204	148	148/204 = .73

If the gaps in the stock-level figures are large (and numerous), it may be easier to add in the percentage of items in each stock level group (not cumulative). This can be done as follows:

Stock Level	Cumulative Percent	Percent
0	70	70
1	83	13
2	85	2
3	95	10
4	98	3
--	--	--
16	99	1
--	--	--
22	100	1

$$S/L = .01(22) + .01(16) + .98(4) - .95 - .85 - .83 - .70 = .97$$

Check:

$$S/L = .13 + 2(.02) + 3(.10) + 4(.03) + 16(.01) + 22(.01) = .97$$

This same method can be used to compute the mean demand rates.

Appendix D
Tables 11-20

Table 11

NUMBER OF ITEMS AND MAINTENANCE ACTIONS FOR FSGs
WITH FEWER THAN 40 ACTIONS

FSG	Items				Maintenance Actions			
	Total	NRTS	B/C	Repaired	Total	NRTS	B/C	Repaired
10	5	4	-	1	7	6	-	1
17	3	1	-	2	4	2	-	2
22	1	-	-	1	1	-	-	1
31	11	11	-	-	14	14	-	-
41	3	3	-	-	5	5	-	-
42	3	-	-	3	17	-	-	17
43	6	5	-	1	7	6	-	1
45	2	1	-	1	2	1	-	1
46	1	-	-	1	1	-	-	1
47	3	2	1	-	3	2	1	-
48	1	1	-	-	1	1	-	-
49	20	17	-	4	29	21	-	8
53	1	-	-	1	1	-	-	1
62	23	3	1	21	39	3	1	35
63	10	6	-	4	13	7	-	6
65	1	-	-	1	1	-	-	1
67	6	5	-	2	23	9	-	14
71	27	17	1	9	34	23	1	10
73	2	1	-	2	5	2	-	3
85	1	-	-	1	1	-	-	1
Total	120	77	3	55	208	102	3	103

Table 12

DISTRIBUTION OF NET CYCLE AND TOTAL CYCLE TIMES BY TYPE OF REPAIR ACTION

Days	Net Repair Cycle (Excluding AWM + AWP)				Total Repair Cycle (Including AWM + AWP)			
	All Actions	NRTS	B/C Serv.	Repaired	All Actions	NRTS	B/C Serv.	Repaired
0	1,576	1,090	54	432	1,377	1,023	44	310
1	1,779	875	115	789	1,435	747	102	586
2	998	480	47	471	707	349	37	321
3	672	376	23	273	614	331	32	251
4	578	285	23	270	491	254	24	213
5	419	196	7	216	408	193	9	206
6	396	159	6	231	406	162	8	236
7	394	164	10	220	438	180	16	242
8	337	114	6	217	322	131	11	180
9	328	107	15	206	253	84	7	162
10	312	98	13	201	253	91	12	150
11	269	86	13	170	249	80	14	155
12	241	70	6	165	253	83	5	165
13	233	82	12	139	310	96	13	201
14	228	71	13	144	301	83	17	201
15	196	61	4	131	233	81	6	146
16	160	45	3	112	176	54	3	119
17	176	47	6	123	162	42	5	115
18	142	40	4	98	156	44	6	106
19	116	38	3	75	160	51	2	107
20	110	26	3	81	177	41	3	133
21-25	444	120	15	309	550	155	16	379
26-30	269	76	7	186	438	128	12	298
31-35	248	68	7	173	362	112	10	240
36-40	91	38	-	53	189	71	1	117
41-45	67	18	1	48	118	32	-	86
46-50	41	11	1	29	79	26	1	52
51-55	25	6	-	19	51	21	1	29
56-60	28	13	1	14	57	24	1	32
61-70	27	7	-	20	59	28	-	31
71-80	17	9	-	8	51	29	-	22
81-90	13	6	1	6	41	25	1	15
91-100	8	2	-	6	29	13	-	16
101-125	22	17	-	5	38	28	-	10
Over 125	5	4	-	1	22	13	-	9
Total	10,965	4,905	419	5,641	10,965	4,905	419	5,641

Table 13

PERCENTAGE DISTRIBUTION OF NET CYCLE AND TOTAL CYCLE TIMES
BY TYPE OF REPAIR ACTION

Days	Net Repair Cycle (Excluding AWM + AWP)				Total Repair Cycle (Including AWM + AWP)			
	All Actions	NRTS	B/C Serv.	Repaired	All Actions	NRTS	B/C Serv.	Repaired
0	14.4	22.2	12.9	7.7	12.6	20.9	10.5	5.5
1	30.6	40.1	40.3	21.6	25.6	36.1	34.8	15.9
2	39.7	49.8	51.6	30.0	32.1	43.2	43.7	21.6
3	45.8	57.5	57.0	34.8	37.7	49.9	51.3	26.0
4	51.1	63.3	62.5	39.6	42.2	55.1	57.0	29.8
5	54.9	67.3	64.2	43.4	45.9	59.1	59.2	33.5
6	58.5	70.6	65.5	47.5	49.6	62.4	61.1	37.6
7	62.1	73.9	68.0	51.4	53.6	66.0	64.9	41.9
8	65.2	76.2	69.5	55.3	56.6	68.7	67.5	45.1
9	68.2	78.4	73.0	58.9	58.8	70.4	69.2	48.0
10	71.0	80.4	76.1	62.5	61.1	72.3	72.1	50.6
11	73.5	82.2	79.2	65.5	63.4	73.9	75.4	53.4
12	75.7	83.6	80.7	68.4	65.7	75.6	76.6	56.3
13	77.8	85.3	83.5	70.9	68.5	77.6	79.7	59.9
14	79.9	86.7	86.6	73.5	71.3	79.2	83.8	63.4
15	81.7	88.0	87.6	75.8	73.4	80.9	85.2	66.0
16	83.1	88.9	88.3	77.8	75.0	82.0	85.9	68.1
17	84.7	89.8	89.7	80.0	76.5	82.9	87.1	70.2
18	86.0	90.6	90.7	81.7	77.9	83.8	88.5	72.1
19	87.1	91.4	91.4	83.0	79.4	84.8	89.0	74.0
20	88.1	91.9	92.1	84.5	81.0	85.6	89.7	76.3
21-25	92.1	94.4	95.7	89.9	86.0	88.8	93.6	83.0
26-30	94.6	95.9	97.4	93.2	90.0	91.4	96.4	88.3
31-35	96.9	97.3	99.0	96.3	93.3	93.7	98.8	92.6
36-40	97.7	98.1	-	97.2	95.0	95.1	99.0	94.6
41-45	98.3	98.5	99.3	98.1	96.1	95.8	-	96.2
46-50	98.7	98.7	99.5	98.6	96.8	96.3	99.3	97.1
51-55	98.9	98.8	-	98.9	97.3	96.7	99.5	97.6
56-60	99.2	99.1	99.8	99.2	97.8	97.2	99.8	98.2
61-70	99.4	99.2	-	99.5	98.3	97.8	-	98.7
71-80	99.6	99.4	-	99.7	98.8	98.4	-	99.1
81-90	99.7	99.5	100.0	99.8	99.2	98.9	100.0	99.4
91-100	99.8	99.6	-	99.9-	99.5	99.2	-	99.7
101-125	99.9+	99.9	-	99.9+	99.8	99.7	-	99.8
Over 125	100.0	100.0	-	100.0	100.0	100.0	-	100.0

Table 14

DISTRIBUTION SHOP FLOW AND REPARABLE PROCESSING TIMES
BY TYPE OF REPAIR ACTION

Days	Shop Flow Time (Excluding AWM + AWP)				Reparable Processing Time (Including AWM + AWP)			
	All Actions	NRTS	B/C Serv.	Repaired	All Actions	NRTS	B/C Serv.	Repaired
0	3,711	2,518	165	1,028	3,256	2,343	144	769
1	1,696	783	65	848	1,115	518	49	548
2	627	232	26	369	479	180	25	274
3	420	159	19	242	447	173	32	242
4	344	109	15	220	390	139	14	237
5	324	99	3	222	320	105	6	209
6	309	96	8	205	341	111	14	216
7	392	87	17	288	463	138	21	304
8	398	97	12	289	285	73	13	199
9	299	90	13	196	241	60	6	175
10	200	56	10	134	198	52	10	136
11	177	49	4	124	238	70	9	159
12	165	45	9	111	212	49	10	153
13	174	40	9	125	255	79	10	166
14	210	49	7	154	289	76	9	204
15	168	52	2	114	193	60	2	131
16	131	37	2	92	149	44	2	103
17	94	18	4	72	115	28	4	83
18	96	29	3	64	130	33	4	93
19	75	24	1	50	110	33	-	77
20	79	15	4	60	134	28	5	101
21-25	344	70	12	262	468	103	14	351
26-30	222	61	7	154	366	111	10	245
31-35	114	34	1	79	254	82	5	167
36-40	66	18	1	47	129	43	-	86
41-45	37	9	-	28	72	19	1	52
46-50	20	3	-	17	62	22	-	40
51-55	18	6	-	12	39	15	-	24
56-60	19	7	-	12	40	16	-	24
61-70	17	6	-	11	51	32	-	19
71-80	10	3	-	7	39	22	-	17
81-90	3	2	-	1	29	16	-	13
91-100	3	1	-	2	26	16	-	10
101-125	3	1	-	2	17	9	-	8
Over 125	-	-	-	-	13	7	-	6
Total	10,965	4,905	419	5,641	10,965	4,905	419	5,641

Table 15

PERCENTAGE DISTRIBUTION OF SHOP FLOW AND REPARABLE PROCESSING TIMES
BY TYPE OF REPAIR ACTION

Days	Shop Flow Time (Excluding AWM + AWP)				Reparable Processing Time (Including AWM + AWP)			
	All Actions	NRTS	B/C Serv.	Repaired	All Actions	NRTS	B/C Serv.	Repaired
0	33.8	51.3	39.4	18.2	29.7	47.8	34.4	13.6
1	49.3	67.3	54.9	33.3	39.9	58.3	46.1	23.3
2	55.0	72.0	61.1	39.8	44.2	62.0	52.0	28.2
3	58.9	75.3	65.6	44.1	48.3	65.5	59.7	32.5
4	62.0	77.5	69.2	48.0	51.9	68.4	63.0	36.7
5	65.0	79.5	69.9	51.9	54.8	70.5	64.4	40.4
6	67.8	81.5	71.8	55.6	57.9	72.8	67.8	44.2
7	71.3	83.2	75.9	60.7	62.1	75.6	72.8	49.6
8	75.0	85.2	78.8	65.8	64.7	77.1	75.9	53.1
9	77.7	87.1	81.9	69.3	66.9	78.3	77.3	56.2
10	79.5	88.2	84.2	71.6	68.7	79.3	79.7	58.7
11	81.1	89.2	85.2	73.8	70.9	80.8	81.9	61.5
12	82.6	90.1	87.4	75.8	72.8	81.8	84.2	64.2
13	84.2	90.9	89.5	78.0	75.1	83.4	86.6	67.1
14	86.1	91.9	91.2	80.7	77.8	84.9	88.8	70.7
15	87.7	93.0	91.6	82.8	79.5	86.2	89.3	73.1
16	88.9	93.7	92.1	84.4	80.9	87.1	89.7	74.9
17	89.7	94.1	93.1	85.7	82.0	87.6	90.7	76.4
18	90.6	94.7	93.8	86.8	83.1	88.3	91.6	78.1
19	91.3	95.2	94.0	87.7	84.1	89.0	-	79.4
20	92.0	95.5	95.0	88.8	85.4	89.5	92.8	81.2
21-25	95.1	96.9	97.9	93.4	89.6	91.6	96.2	87.4
26-30	97.2	98.2	99.5	96.1	93.0	93.9	98.6	91.7
31-35	98.2	98.9	99.8	97.5	95.3	95.6	99.8	94.7
36-40	98.8	99.2	100.0	98.4	96.5	96.5	-	96.2
41-45	99.2	99.4	-	98.9	97.1	96.8	100.0	97.1
46-50	99.3	99.5	-	99.2	97.7	97.3	-	97.9
51-55	99.5	99.6	-	99.4	98.0	97.6	-	98.3
56-60	99.7	99.7	-	99.6	98.4	97.9	-	98.7
61-70	99.8	99.9	-	99.8	98.9	98.6	-	99.0
71-80	99.9	99.9	-	99.9	99.2	99.0	-	99.3
81-90	99.9	99.9+	-	99.9	99.5	99.3	-	99.6
91-100	99.9+	99.9+	-	99.9+	99.7	99.7	-	99.8
101-125	100.0	100.0	-	100.0	99.9	99.9	-	99.9
Over 125	-	-	-	-	100.0	100.0	-	100.0

Table 16

OBSERVED AGGREGATE DEMAND LEVELS

Case	On-Base Cycle Time		Pipeline (Days) Applied to NRTS Actions	Average Repair Cycle (Days)	Demand Level (Units)
	Cycle	Applied to: (Actions)			
1a	Net	Repaired		5.8	1108
2a	Total	Repaired		7.7	1410
3a	Net	All		8.8	1753
1b	Net	Repaired	8	9.4	1896
2b	Total	Repaired	8	11.3	2170
4a	Total	All		12.2	2272
3b	Net	All	8	12.4	2591
4b	Total	All	8	15.8	3024
1c	Net	Repaired	30	19.2	3708
2c	Total	Repaired	30	21.1	3964
3c	Net	All	30	22.3	3942
4c	Total	All	30	25.7	4325

Table 17

OBSERVED DEMAND LEVELS, USING NET CYCLE TIMES FOR ALL ITEMS^a

Number of Actions per Line Item	Observed Demand Levels													Total
	0	1	2	3	4	5	6	7	8	9	11	14	35	
1	1342	449	6	-	-	-	-	-	-	-	-	-	-	1797
2	304	207	10	1	-	-	-	-	-	-	-	-	-	522
3	108	135	14	-	-	-	-	-	-	-	-	-	-	257
4	45	75	15	2	-	-	-	-	-	-	-	-	-	137
5	23	54	16	3	-	-	-	-	-	-	-	-	-	96
6	18	39	12	1	-	-	-	-	-	-	-	-	-	70
7	13	24	11	2	-	-	-	-	-	-	-	-	-	50
8	8	26	8	2	1	-	-	-	-	-	-	-	-	45
9	2	24	5	1	-	-	-	-	-	-	-	-	-	32
10	1	21	7	3	-	1	-	-	-	-	-	-	-	33
11	3	14	6	2	-	-	-	-	-	-	-	-	-	25
12	-	12	9	1	-	-	-	-	-	-	-	-	-	22
13	3	4	7	1	-	-	-	-	-	-	-	-	-	15
14	1	9	5	2	-	-	-	-	-	-	-	-	-	17
15	1	5	5	2	2	-	-	-	-	-	-	-	-	15
16	-	6	1	3	1	-	-	-	-	-	-	-	-	11
17	-	3	-	1	-	-	-	-	-	-	-	-	-	4
18	-	4	2	-	-	-	-	-	-	-	-	-	-	6
19	-	1	2	1	-	-	-	-	-	-	-	-	-	4
20	-	1	1	2	-	-	-	-	-	-	-	-	-	4
21-25	-	6	2	4	2	-	-	1	-	-	-	-	-	15
26-30	-	1	4	3	2	-	-	-	-	-	-	-	-	10
31-35	-	4	1	1	1	1	-	-	-	-	-	-	-	8
36-40	-	1	-	2	-	1	1	-	-	-	-	-	-	5
41-50	-	-	2	1	1	2	-	-	-	-	-	-	-	6
51-100	-	1	2	1	-	1	-	1	1	1	2	-	-	10
101-150	-	-	-	-	-	-	-	-	1	-	-	1	-	2
151-200	-	-	-	-	-	-	-	-	-	1	-	-	-	1
(356)	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Total	1872	1126	153	42	10	6	1	2	2	2	2	1	1	3220
Units Stocked	-	1126	306	126	40	30	6	14	16	18	22	14	35	1753

^aIncludes the on-base processing time for NRTS items, but does not include any depot pipeline time.

Table 18

OBSERVED DEMAND LEVELS, USING NET CYCLE TIMES FOR ALL ITEMS
PLUS PIPELINE TIME (8 DAYS) FOR NRTS ITEMS

Number of Actions per Line Item	Observed Demand Levels														Total
	0	1	2	3	4	5	6	7	8	9	10	11	15	37	
1	1078	710	9	-	-	-	-	-	-	-	-	-	-	-	1797
2	105	404	12	1	-	-	-	-	-	-	-	-	-	-	522
3	21	219	17	-	-	-	-	-	-	-	-	-	-	-	257
4	6	109	20	2	-	-	-	-	-	-	-	-	-	-	137
5	4	63	26	3	-	-	-	-	-	-	-	-	-	-	96
6	4	44	18	4	-	-	-	-	-	-	-	-	-	-	70
7	4	25	18	2	1	-	-	-	-	-	-	-	-	-	50
8	1	24	16	3	1	-	-	-	-	-	-	-	-	-	45
9	-	13	18	1	-	-	-	-	-	-	-	-	-	-	32
10	-	5	22	5	-	1	-	-	-	-	-	-	-	-	33
11	1	5	17	2	-	-	-	-	-	-	-	-	-	-	25
12	-	6	10	6	-	-	-	-	-	-	-	-	-	-	22
13	-	1	10	4	-	-	-	-	-	-	-	-	-	-	15
14	-	5	7	5	-	-	-	-	-	-	-	-	-	-	17
15	-	4	4	4	3	-	-	-	-	-	-	-	-	-	15
16	-	4	3	-	4	-	-	-	-	-	-	-	-	-	11
17	-	2	1	1	-	-	-	-	-	-	-	-	-	-	4
18	-	1	3	2	-	-	-	-	-	-	-	-	-	-	6
19	-	-	3	-	1	-	-	-	-	-	-	-	-	-	4
20	-	-	1	2	1	-	-	-	-	-	-	-	-	-	4
21-25	-	1	5	6	2	-	-	1	-	-	-	-	-	-	15
26-30	-	1	2	2	5	-	-	-	-	-	-	-	-	-	10
31-35	-	1	2	1	3	-	1	-	-	-	-	-	-	-	8
36-40	-	-	-	1	1	1	2	-	-	-	-	-	-	-	5
41-50	-	-	-	-	2	3	-	-	1	-	-	-	-	-	6
51-100	-	1	2	1	-	1	-	-	1	2	-	2	-	-	10
101-150	-	-	-	-	-	-	-	-	1	-	-	-	1	-	2
151-200	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
(356)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Total	1224	1648	246	58	24	6	3	1	3	2	1	2	1	1	3220
Units Stocked	-	1648	492	174	96	30	18	7	24	18	10	22	15	37	2591

Table 19

DEMAND LEVELS VERSUS REPAIR CYCLE TIME BY FSG

FSG	Items	Actions	Demands Per Item	Net Cycle		Total Cycle		Shop Flow		Reparable Processing		Standard (10 Days) Units
				Days	Units	Days	Units	Days	Units	Days	Units	
Repaired Actions												
12	81	286	3.53	5.4	36	8.0	52	4.0	23	6.7	44	58
14	21	42	2.00	3.2	2	7.2	7	1.4	1	5.4	5	9
15	129	204	1.58	16.8	87	20.7	110	13.2	72	17.1	91	60
16	255	718	2.82	10.3	158	14.8	214	7.3	125	11.8	176	156
28	52	84	1.62	19.8	37	22.6	37	16.2	30	19.0	37	19
29	159	522	3.28	12.5	134	17.4	164	9.7	118	14.5	154	119
58	331	2487	7.51	10.4	341	13.6	417	8.4	301	11.6	381	338
59	31	57	1.84	11.4	17	15.3	19	8.2	13	12.2	17	15
61	131	415	3.17	9.5	97	12.7	111	6.2	64	9.4	93	97
66	253	723	2.86	12.0	180	15.5	213	9.5	157	13.1	185	157
All Other	55	103	1.87	8.4	21	13.1	28	5.3	11	9.9	24	24
Total Actions												
12	204	789	3.87	3.8	57	5.7	110	2.1	31	4.0	59	157
14	78	165	2.12	3.6	10	5.4	21	0.7	0	2.5	7	37
15	248	367	1.48	13.8	109	17.3	129	8.9	74	12.3	109	87
16	604	1677	2.78	8.7	332	12.6	447	4.9	199	8.8	332	381
28	236	601	2.55	7.5	101	9.2	127	5.2	76	6.9	99	132
29	311	1017	3.27	9.9	221	14.0	274	6.9	177	10.9	227	221
58	483	3105	6.43	10.1	454	14.1	560	8.0	406	12.1	517	454
59	86	169	1.96	5.9	23	7.9	34	3.6	8	5.6	23	40
61	191	576	3.02	8.8	109	13.7	153	5.6	80	10.6	126	124
66	649	2291	3.53	8.8	422	11.4	526	6.2	337	8.9	422	467
All Other	130	208	1.60	7.6	39	11.0	62	3.8	7	7.6	39	55

Table 20

AVERAGE STOCK PER ITEM VERSUS REPAIR CYCLE TIME BY FSG

Ranked by Demands per Item

FSG	Demands per Item	Repair Cycle Time (Days)								
		5	10	15	20	25	30	35	40	45
Repaired Actions										
15	1.58	.17	.38	.55	.68	.71	.88	.95	1.02	1.05
28	1.62	.16	.37	.57	.72	.72	.87	.95	1.03	1.08
59	1.84	.20	.48	.63	.83	.83	1.03	1.07	1.24	1.28
A/O ^a	1.87	.20	.44	.60	.78	.81	.98	1.04	1.16	1.21
14	2.00	.25	.45	.65	.84	.89	1.08	1.16	1.26	1.33
16	2.82	.35	.61	.84	.99	1.08	1.32	1.43	1.56	1.62
66	2.86	.35	.62	.84	1.00	1.10	1.31	1.45	1.56	1.64
61	3.17	.42	.74	.96	1.11	1.22	1.49	1.60	1.75	1.89
29	3.28	.43	.75	.87	1.15	1.27	1.45	1.63	1.78	1.90
12	3.53	.43	.71	1.00	1.17	1.28	1.58	1.70	1.85	1.98
58	7.51	.61	1.02	1.40	1.70	1.95	2.32	2.58	2.83	3.06
Total Actions										
15	1.48	.16	.35	.55	.68	.70	.91	.97	1.03	1.07
A/O ^a	1.60	.17	.42	.62	.70	.72	.93	.98	1.08	1.11
59	1.96	.25	.47	.63	.79	.83	1.06	1.12	1.22	1.28
14	2.12	.30	.47	.70	.84	.88	1.10	1.19	1.29	1.34
28	2.55	.32	.56	.76	.90	.98	1.19	1.30	1.41	1.47
16	2.78	.35	.62	.81	.97	1.06	1.28	1.38	1.51	1.60
61	3.02	.41	.65	.87	1.03	1.15	1.39	1.53	1.65	1.73
29	3.27	.43	.71	.91	1.07	1.20	1.44	1.56	1.72	1.84
66	3.53	.45	.72	.93	1.10	1.25	1.48	1.62	1.78	1.89
12	3.87	.47	.77	.99	1.18	1.30	1.58	1.73	1.91	2.04
58	6.43	.55	.94	1.26	1.51	1.71	2.04	2.26	2.46	2.70

^aAll other FSGs.