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LOGISTICS IMPACT OF SORTIE ORIENTED AIR CREW TRAINING.(U)
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LOGISTICS IMPACT OF SORTIE ORIENTED AIR CREW TRAINING

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AFLC Technical Report Nr. 76-7

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PREFACE

This study was initiated at the request of HQ USAF/LG to determine the impact on logistics caused by the change to sortie oriented aircrew training initiated in July 1974. The new method for scheduling training was implemented at TAC bases by TAC Manual 51-34. It resulted in the need for more sorties than TAC had been flying and of a shorter duration, i.e., reduced flying hours per sortie. TAC representatives have expressed the belief that this change has increased logistics requirements over and above that which can be predicted by the current method of computations based on flying hours. This study reviews the above expression in light of available data and provides additional information; although it does not specifically solve the logistics problem. It is restricted to F-4D and F-4E aircraft operated at Eglin, Seymour Johnson and Holloman AFBs.

ABSTRACT

Traditionally, flying hours have been used to plan budgets and logistics actions. TAC's change to a shorter sortie for their training requirements generated the question of its impact on logistics. This study includes a short review of literature on the subject. It looks at F-4 aircraft operated by TAC and reveals that the length of time for a sortie has little affect on the number of maintenance writeups following. Therefore, an increase in sorties for a given period with no change in flying hours would generate additional maintenance writeups. It is also determined that the mission has a significant impact on the number of maintenance writeups within specific work unit codes (WUC). Some WUC's are sensitive to specific types of missions flown.

It points out that increased operating efficiencies can be expected in base maintenance if changes are made in the Maintenance Management Information Control System (MMICS). These changes would be basically the inclusion of a standardized mission code in order to relate a maintenance action to the most recent mission flown.

SUMMARY

Flying hours have traditionally been used as the basis for determining flying costs and for logistics projections. This tradition persists even though several detailed studies [1-9] during the past decade indicated that factors other than flying hours dictated costs and impacted on logistics requirements. This study was specifically initiated to determine if a change in the average sortie duration, while keeping the total flying hour program constant, has a significant impact on logistics requirements. In view of this purpose, a definition of a sortie is provided as outlined in para 18b of AFLCP 800-3 [9]. "A sortie is the flight of a single aircraft from takeoff until terminated by a landing and engine shutdown."

AFLCP 800-3 [9], paragraph 18c, describes failure rates per flying hour as follows: "A number of studies have shown that (maintenance) man-hours per flying hour (MH/FH) varies inversely with sortie length and utilization." It also references Figure 30 of the pamphlet which states: "Failure rates per flight hour increase steadily as sortie length decreases." The two reasons given are: "1. The more flying the less time for maintenance and reduced servicing activity (sortie related). 2. More equipment operational

cycles (EOCs) per flying hour." The paragraph concludes with the statement "Logistics requirements (man-hours, spares, etc.) do not increase proportionally with increases in flying hours; a specific factor such as MH/FH used as a constant and directly applied to increased flying hours will tend to over predict requirements."

This study is based on an analysis of data taken from the following sources:

1. Four years of F-4 operational and maintenance data were taken from the G098 data base. The G098 system (Analytical Interval Determination for Programmed Depot Maintenance) is a contractor operated system developed to analyze AF aircraft maintenance data and provide the means to determine a more appropriate PDM interval. This system collects data from other systems such as the reporting requirements of AFM 66-1 (Maintenance Data Collection System (MDCS)) G001/D056 and AFM 65-110 (Standard Aerospace and Equipment Inventory Status and Utilization Reporting) G033.

a. This study uses the following AFR 65-110 data stored in the G098 system:

(1) NORM/NORS hours

(2) Flying hours

(3) Sorties

b. AFM 66-1 maintenance actions were also acquired from the G098 system.

2. One year of F-4 operational and maintenance data was taken from the TAC debriefing system stored in the TAC "Maintenance Information Logically Analyzed and Presented" (MILAP) system at Eglin, Seymour Johnson and Holloman AFBs. These data were merged by a special program and processed on the AFLC CREATE computer. Maintenance actions for over 49,000 sorties were studied and related to specific mission types.

The following observations are made:

1. It was found that for the F-4 the sortie length, which varied for the majority of flights between .8 hour and 1.8 hours in duration, has little effect on the equipment failure rate per sortie. This suggests that a

series of short duration sorties could reflect a larger number of maintenance actions than a like number of flying hours for fewer sorties of longer duration.

2. The type of mission flown had a direct impact on the post mission equipment "write-ups." A "write-up" generates from the debriefing following completion of a sortie which provides the pilot's knowledge of improper operation of some part of the airplane identified to subsystem level by a three digit work unit code (WUC).

3. The above two observations bring to light possible deficiencies in the present methods employed to predict logistics requirements for F-4 type aircraft. These deficiencies could occur due to our inability to relate the type of mission flown to the failures experienced. A specific flying training program will generate one set of demand levels while a change in the training mission of the type experienced by TAC (July 1974) may generate entirely different demands. It is conceivable that a deployment for a wartime effort of a different type than that flown in a training mission could place different demands on the logistics system with resultant critical shortages.

This paper recommends further study to determine if maintenance actions can be related to logistics support requirements and if like conditions are present at other bases and on other airplanes. If so then basic changes will be recommended for both the aircrew debriefing procedures and the maintenance Management Information Control System (MMICS) to provide data to relate failures to specific missions and for consideration of further use of the mission code in logistics planning.

CONTENTS

I. INTRODUCTION

This study has been made in response to a request from HQ USAF/LG of Mar 1976. The request specified that on 1 Jul 1974, AF/XO initiated an aircrew continuation training program which was oriented toward the completion of a specified number of events/sorties. It also specified that it was felt that for an aircraft such as the B-52, KC-135 and the C-141 this posed essentially no problems in logistics support. However, for the tactical forces an increase in sorties has been required to support this program.

In addition, LG stated: "It is logical to expect that an increase in sortie generation should increase spares consumption and maintenance. If this is confirmed AFLC may need to refine its data base so they can determine/quantify the impact on these resources."

Early meetings with representatives of HQ TAC emphasized the need for this study. The TAC implementation of the 1 Jul 1974 directive is described in TAC Manual 51-34.

Each operational unit is assigned a primary (mission ready) DOC (Designed Operational Capability) and secondary (mission capable) DOCs. The implementation of this program resulted in the need for more sorties than TAC had been flying.

Further, the program resulted in an increase in aircraft utilization rates on the F-4 aircraft from about 22 hours to almost 27 hours per aircraft per month.

Another important result of TAC's program was a reduced average sortie duration from about 1.7 to 1.4 hours.

The three operational wings most seriously affected by this program were at Eglin, Seymour Johnson and Holloman AFBs. The general contention of HQ TAC was that AFLC requirements computational systems were not sufficiently responsive to changes in aircraft utilization rates and sortie lengths of the magnitude experienced in the TAC program.

II. HISTORICAL BACKGROUND

As early as 1956 LaVallee and Stoller [1] found that the length of a sortie had no influence upon the number of malfunctions discovered during or after a sortie.

In 1961 the RAND Corporation in conjunction with HQ USAF conducted tests at Oxnard AFB to improve the usefulness of AFM 66-1 data for managing the base maintenance complex [2]. Its objective was to accurately identify the maintenance generated by operational requirements. RAND and Oxnard personnel spent several months examining the AFM 66-1 information system to determine methods of augmentation for their tests. These tests resulted in recommendations for several data collection improvements among which was the capability to summarize manpower utilization, by hour, day, aircraft, etc., for personnel requirements determination and for work-shift planning for any given flying program. This early study was unique in that it allowed data to be related to specific sorties.

Messrs. Glothin and Donaldson [7] in June 1964 concluded that the probability of success on specific missions could be enhanced through careful selection of aircraft on the basis of previous maintenance records. Their findings also indicated that the selection should be based on an aircraft's mean performance during two or three preceding quarters, and especially on the reliability of particularly crucial systems during the two to five prior sorties. Their final observation was that the major obstacle to analyzing routinely and using aircraft malfunction and maintenance data as described, was the absence of a direct method of relating sortie information to maintenance records. It was suggested that the usefulness of the data would be considerably enhanced if such an association were provided formally within the AFM 66-1 system.

In 1965, Cohen, Hixon and Van Horn [4] conducted Laboratory Problem IV (LP-IV) in conjunction with ADC Project ARISE (Action Reporting for Improved System Effectiveness) field test conducted at Richards-Gebaur AFB, Missouri. Project ARISE was designed to test the feasibility of Action Reporting with a particular event record and event monitoring mechanism together with some specially designed weapon displays and scheduling rules. This test dealt with the collection of maintenance-type planning information on the AFTO 200 series forms and the operations type information generated on the AF Form 992. It pointed out the duplications of the two reports and also that they did not have the capability to combine the data in order to relate mission type to a specific failure or maintenance action. The authors of this report felt that to combine these data by a simplified reporting mechanism utilized in Project ARISE would provide the following advantages:

1. Reporting reductions:

   a. 48 percent in number of forms recorded.

   b. 43 percent in the number of digits recorded.

   c. 45 percent in the number of digits keypunched.

2. Greater accuracy:

   a. Reduced data recorded.

   b. Increased confidence due to greater utility of the data.

3. Most important of all this reporting system was augmented to provide a direct means for recognizing the sortie to which the discrepancy was associated.

Most of these factors could not be derived in any valid way from the then current Maintenance Data Collection System (MDCS), yet they constituted the primary means by which to make significant improvements in long-run resource allocations. This study was conducted on the B-52 aircraft; however, much of the above was verified in a study of the F-101 at Oxnard AFB by Donaldson and Sweetland in April 1966 [5]. Oxnard AFB was chosen for this study since it had the capability to relate aircraft mission to its failures as in the previously mentioned study at Richards-Gebaur AFB, Missouri (LP-IV).

In August of 1968, Donaldson and Sweetland [6] reported on the relationship of flightline maintenance man-hours to aircraft flying hours. They stated that the ratio of maintenance man-hours per aircraft flying hour was used throughout the Air Force and industry for estimating manpower requirements and aircraft reliability. They emphasized that in spite of this wide use, little was actually known about the relationship between unscheduled flightline maintenance man-hours in the "fix-it" category (excluding support general, etc.) and aircraft flying hours. They studied the B-52, F-100, F-102, F-4C (two samples), F-5A and C-130, using an augmented AFM 66-1 data system (as in the Oxnard AFB and Richards-Gebaur AFB studies cited above) that made it possible to assign all flightline maintenance man-hours (other than deferred maintenance) to the sorties that generated the demand for them.

The authors specified that the results of their studies (4685 sorties for the F-4C) strongly indicated that unscheduled flightline man-hours were at best only slightly related to flying hours, casting doubt on the widespread use of man-hours per flying hour for analysis and estimation. They concluded that it appeared that mission type exerted a definite influence on maintenance man-hour production.

An AFIT Thesis [7] described some of the many factors that influenced break rates. They were categorized into design related and environmental. Design related factors included hardware failures, malfunctions and other discrepancies that were attributable to the design characteristics of the airplane. Some of the environmental factors described were:

1. The urgency of the mission flown.

2. Managerial policies and decisions.

3. The human idiosnycrasies of aircrews.

4. The performance history of the aircraft.

5. The quality of maintenance performed on the aircraft.

While all of the above are recognized as important factors influencing break rate, this study will not attempt to assess their impacts upon the data presented herein.

A Boeing study of the B-52 [8] provided conclusions similar to those of Donaldson and Sweetland even though it is a different airplane with a different mission. Some of the pertinent conclusions of the Boeing study are as follows:

" 1. Unscheduled maintenance and servicing man-hour rates per flying hour decrease with increased sortie length.

2. Total maintenance man-hours per flight-hour decrease as utilization increases and sortie length is held constant.

3. After four hours of a 12 hour mission, 50% of the failures and 47% of the abort causing conditions have occurred; at eight hours, the percentages are 80% and 93%." It is implied that comparatively few failures occurred in the last four hours of a 12 hour mission.

4. "Percent of components removed to facilitate other maintenance increases with decreased sortie length."

III PROCEDURES

Discussions with TAC representatives suggested that F-4 operations at Eglin, Seymour Johnson and Holloman AFBs should be studied.

Two research hypotheses were established as follows:

H_1: The TAC increased sortie generation has increased spares consumption and maintenance.

H_2: Certain aircraft items are sensitive to one operational requirement while some are sensitive to another.

A question was established dependent upon H_1 and H_2 both being true. What items tended to be sensitive to specific operational requirements?

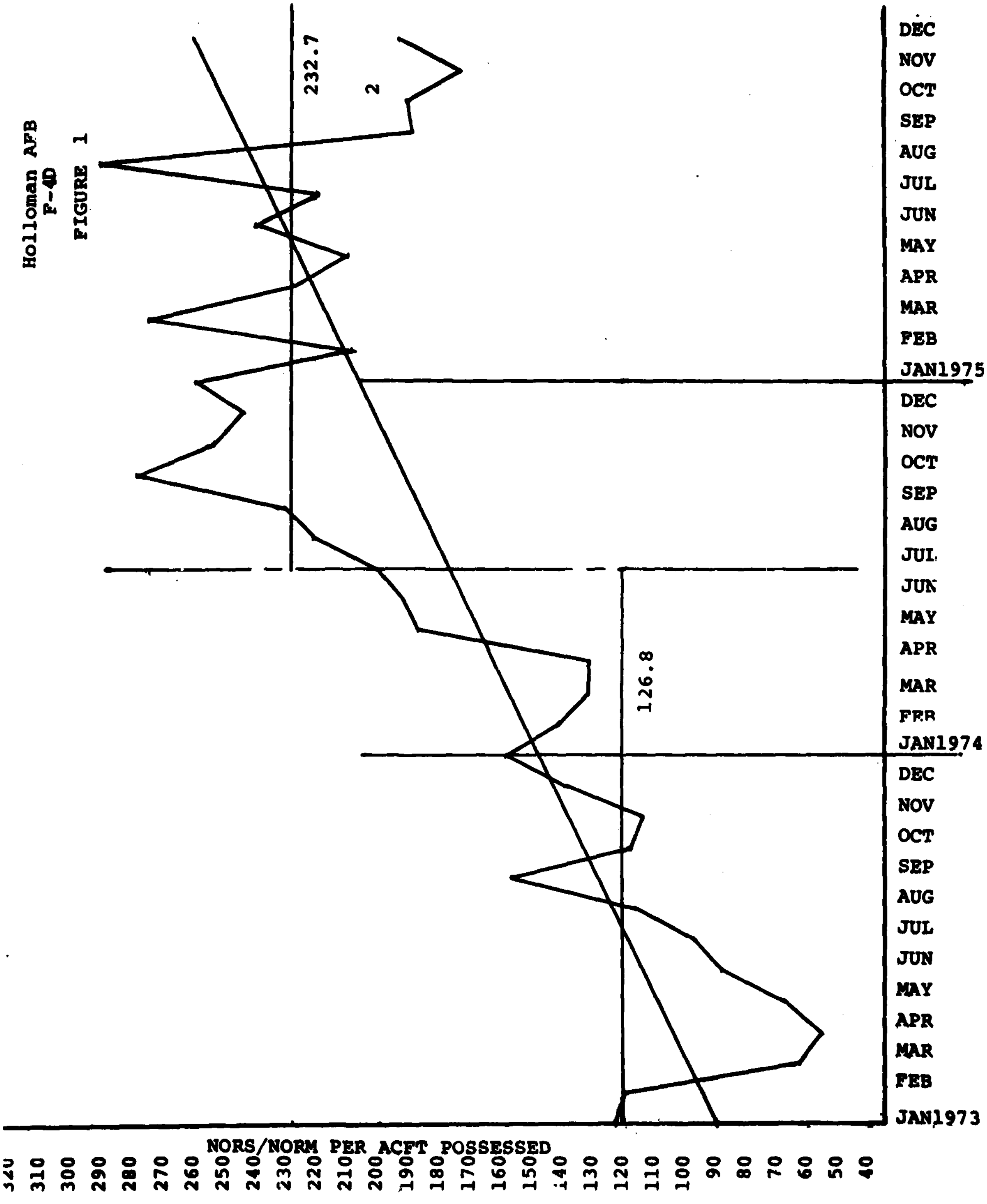
An attempt was made to test $hypothesis_1$, "that TAC increased sortie generation has increased spares consumption and maintenance." While we were unable to complete the test of this hypothesis due to the unavailability of appropriate data, we were able to obtain some information by comparing two years of AFM 66-1 and AFM 65-110 data prior to the TAC change with two years of data after the change. These data in terms of NORS/NORM generation per aircraft possessed, maintenance actions per aircraft possessed, sorties flown per aircraft possessed and flying hours per aircraft possessed for the three bases are arrayed on Figures 1 through 12. They are discussed below for the three bases.

1. Holloman AFB data for the F-4D aircraft as illustrated on Figure 1, indicates a 84% increase in the mean NORS/NORM during the period after July 1974, Figure 2 reflects a 21% increase in mean number of maintenance actions, Figure 3 has a 20% increase in sorties with Figure 4 showing only 4% increase in mean flying hours for the two periods. This significant increase in NORS/NORM with a much lesser increase in maintenance actions indicates that some factor is influencing NORS/NORM at a greater rate than maintenance actions. It is also noted that the mean sorties increase of 20% in the later period while flying hours remained nearly static indicates a reduced flying time per sortie from 1.63 hours to 1.42 hours.

2. Seymour Johnson AFB data for the F-4E aircraft indicate a 176% increase in the mean NORS/NORM (ref Figure 5) during the period after July 1974, 74% increase in mean maintenance actions (ref Figure 6), 100% increase in mean sorties (ref Figure 7), and a 78% increase in flying hours (ref Figure 8). Flying hours per sortie were reduced from 1.45 to 1.29 hours. As in the case with Holloman AFB data, the mean NORS/NORM increased 176% while the mean maintenance increased a lesser amount of 74% indicating some factor is affecting NORS/NORM to a greater extent than maintenance actions. It is also noted that these upward trends began in the January-February period and continue on up through the July 1974 period.

3. Eglin AFB data for the F-4E aircraft indicate a 71% increase in the mean NORS/NORM (ref Figure 9) during the period after July 1974, 68% increase in mean maintenance actions (ref Figure 10), 41% increase in mean sorties (ref Figure 11), and a 26% increase in flying hours (ref Figure 12). Flying hours per sortie were reduced from 1.53 to 1.42 hours.

Another test of hypothesis 1 "that TAC increased sortie generation has increased spares consumption and maintenance" was attempted using a totally different set of data for

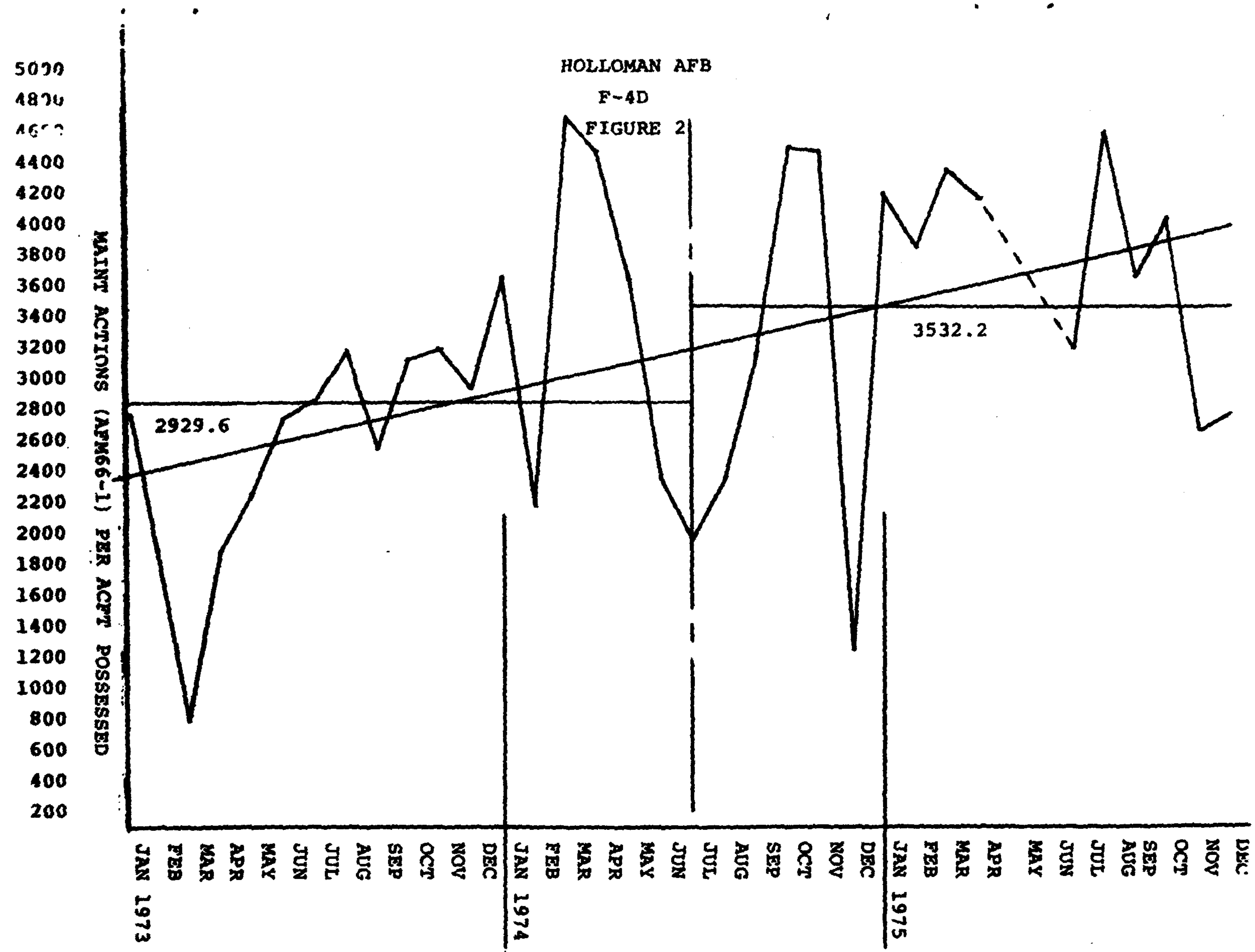


Holloman AFB
F-4D
FIGURE 1
232.7
2
126.8
NORS/NORM PER ACFT POSSESSED
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
JAN1973
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN1974
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN1975
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

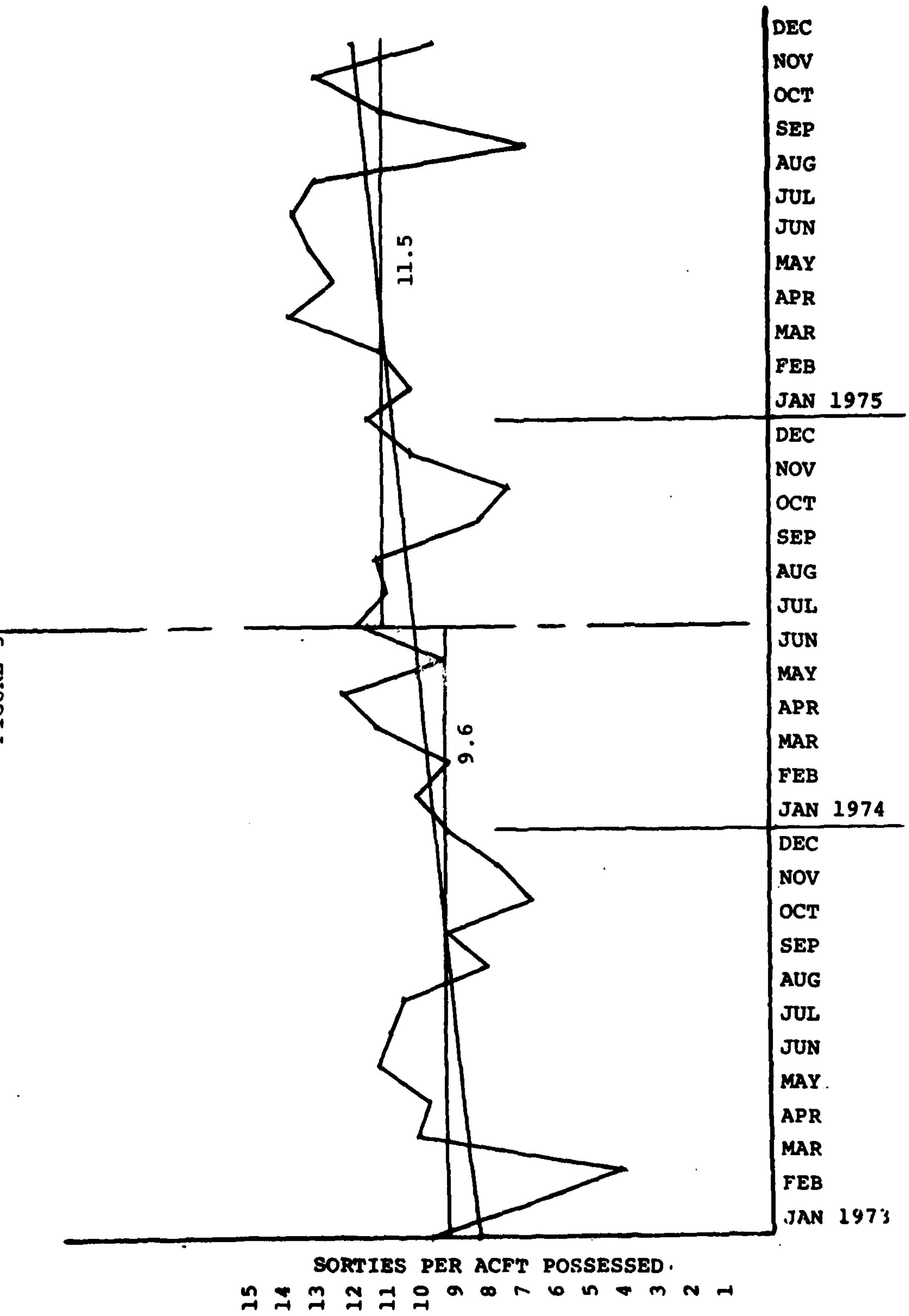
HOLLOMAN AFB

F-4D

FIGURE 2



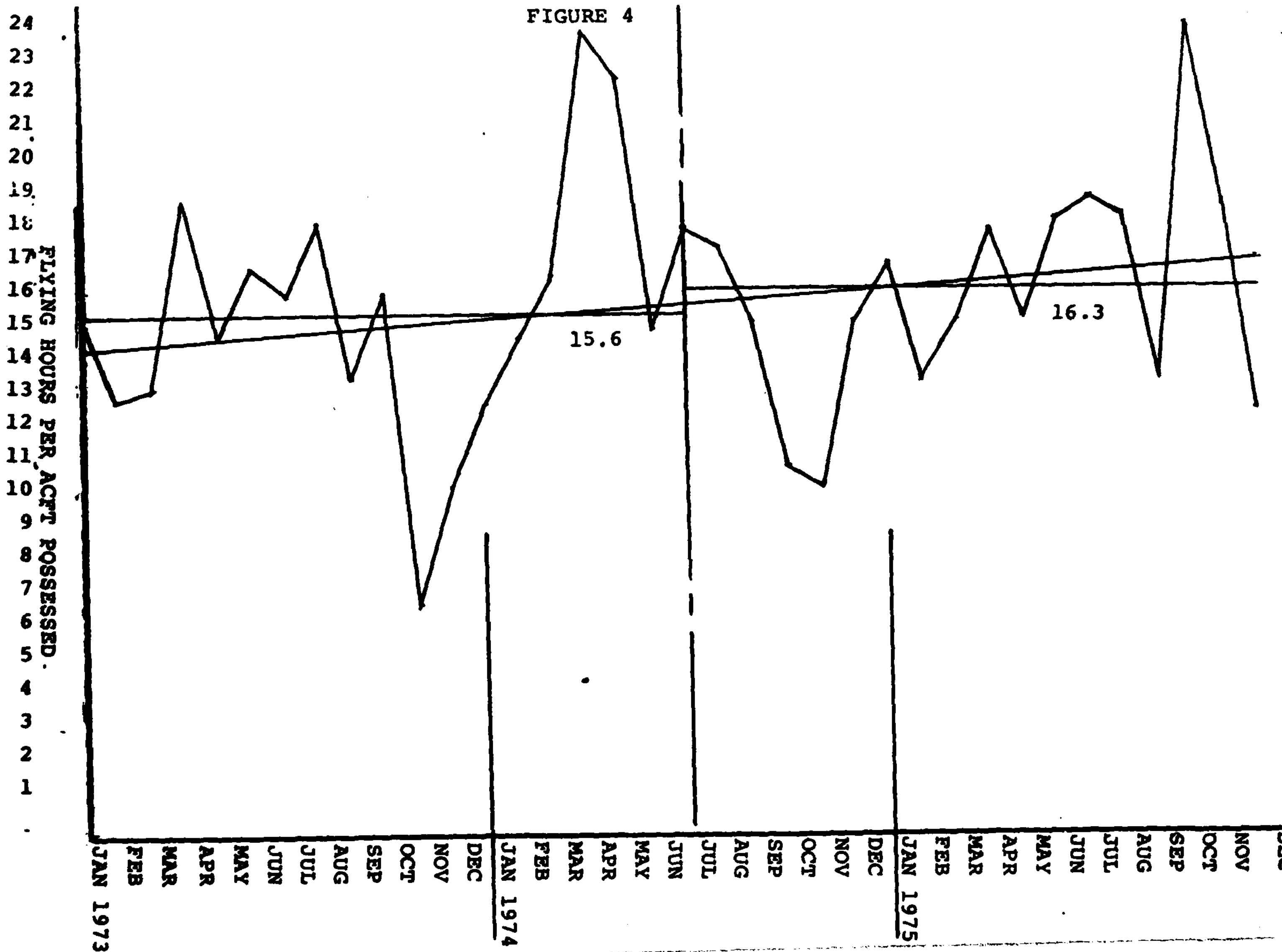
HOLLOMAN AFB
F-4D
FIGURE 3

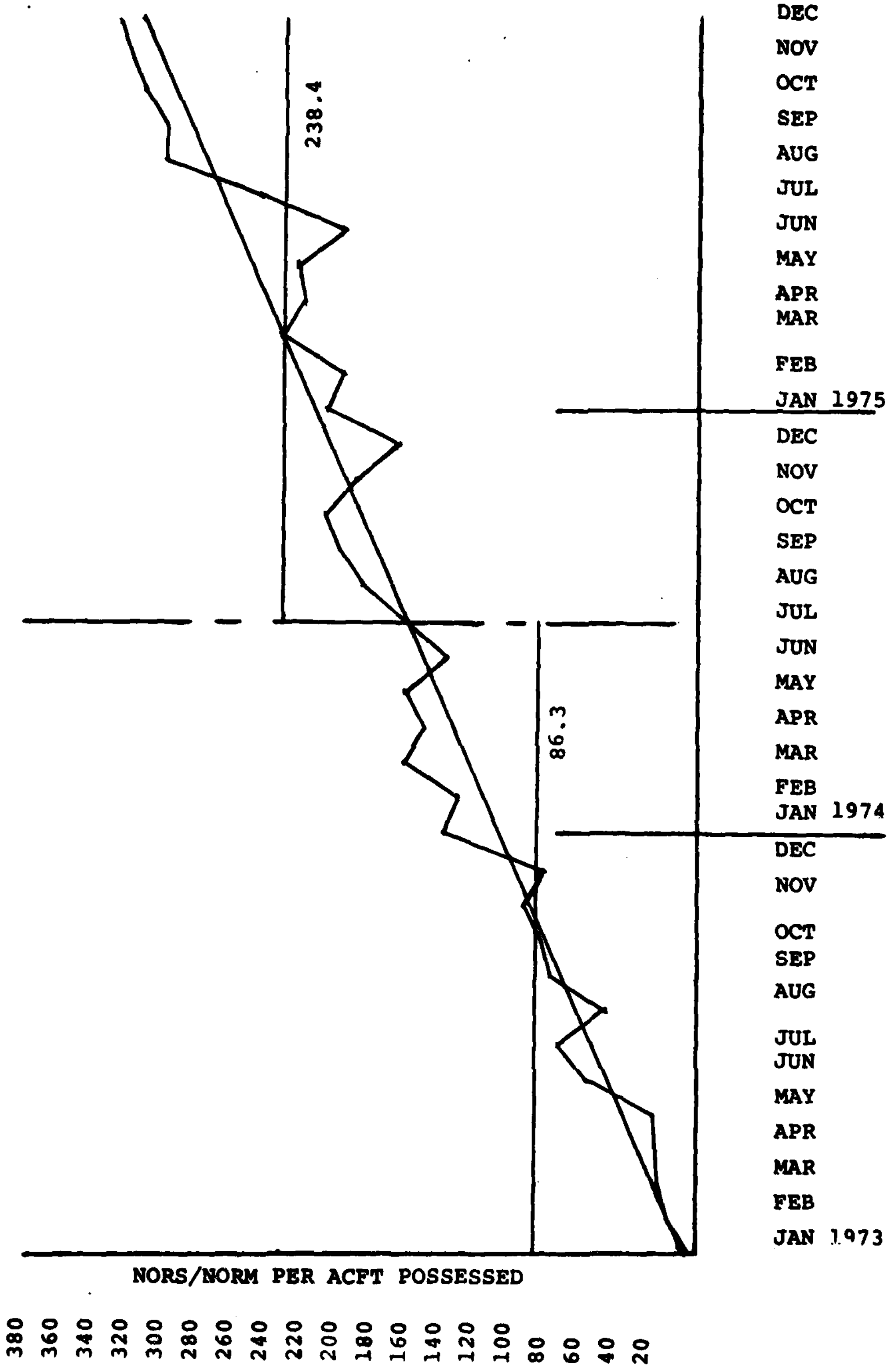


HOLLOMAN AFB

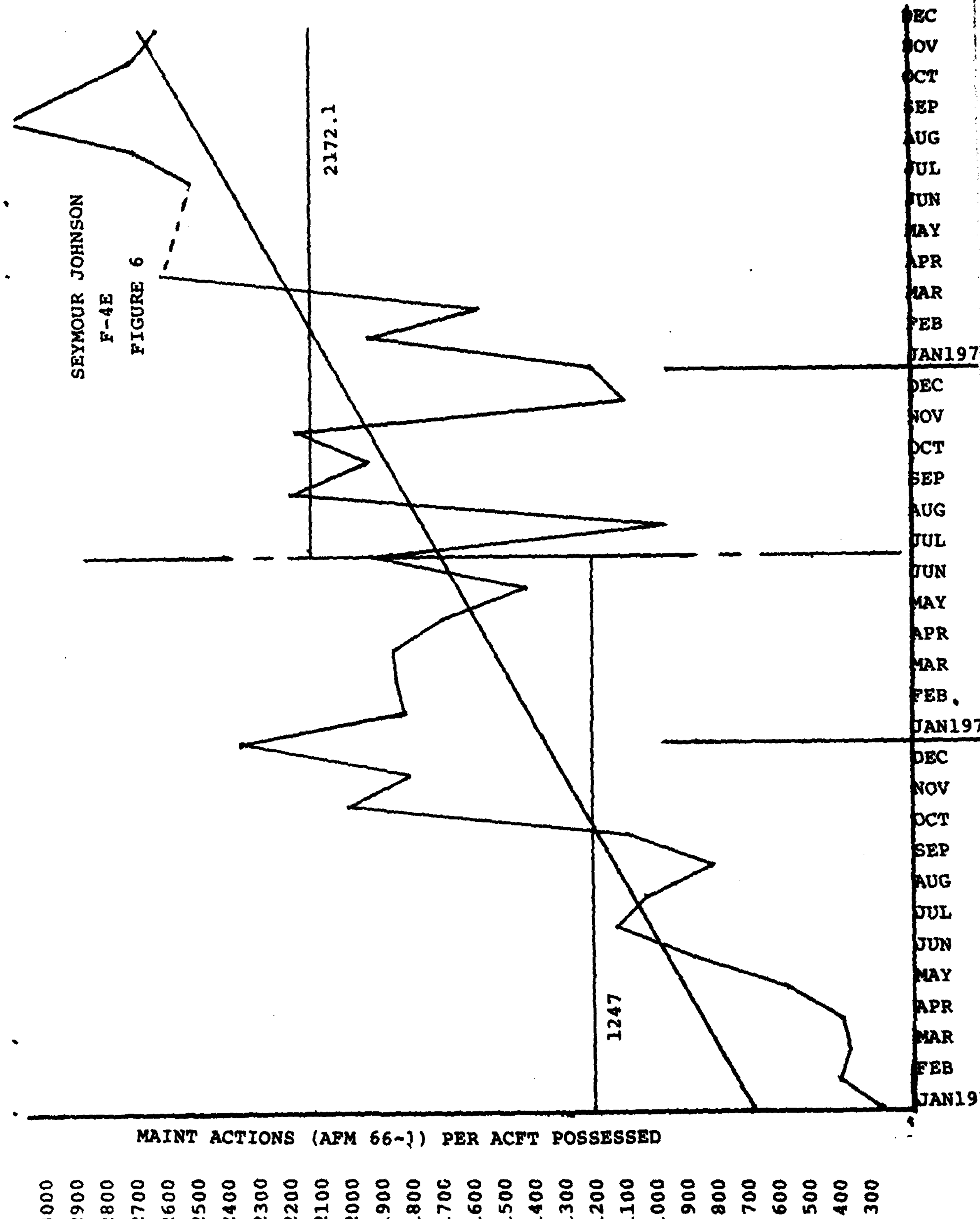
F-4D

FIGURE 4





Seymour Johnson AFB, F-4E
Figure 5

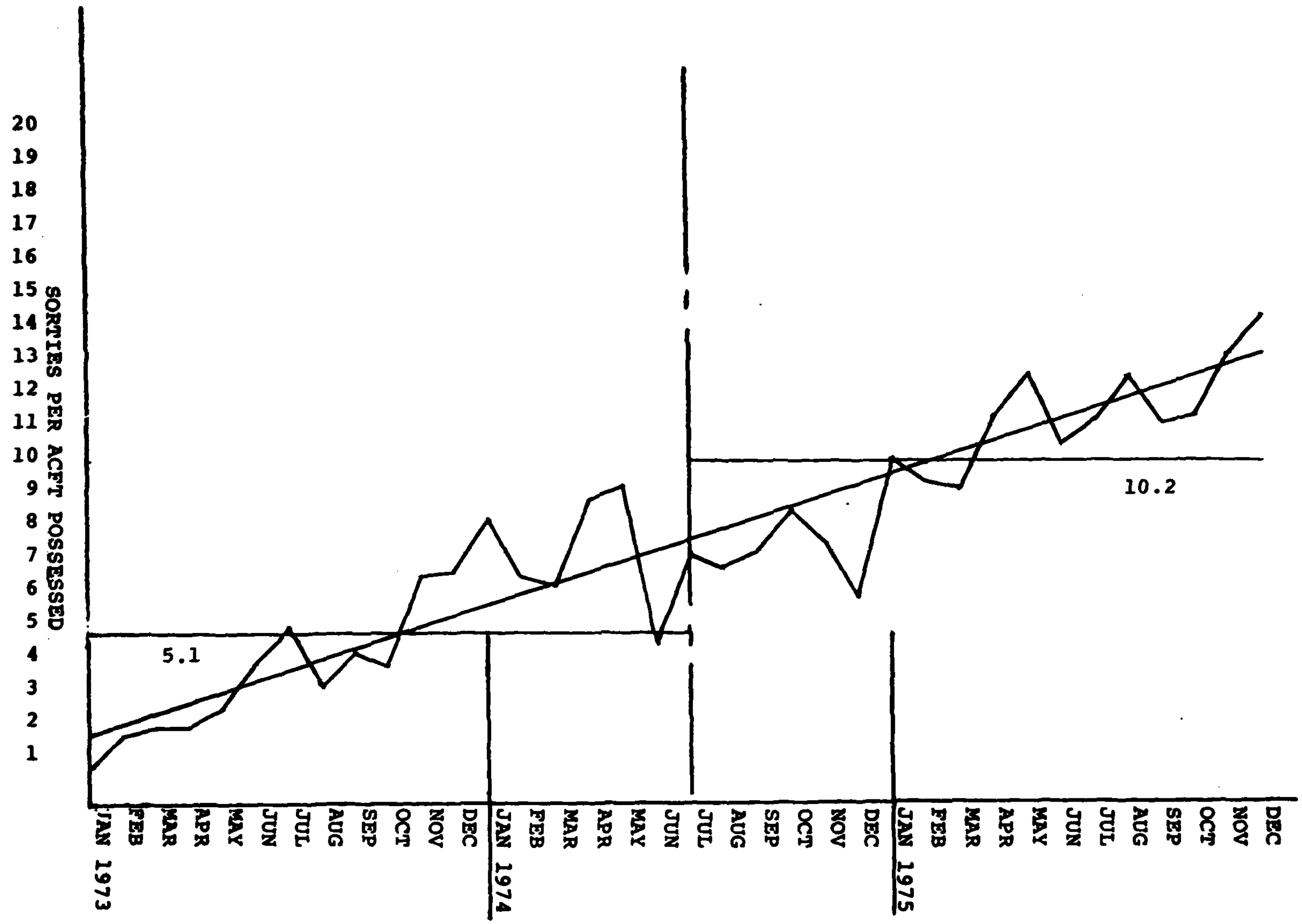


SEYMOUR JOHNSON
F-4E
FIGURE 6

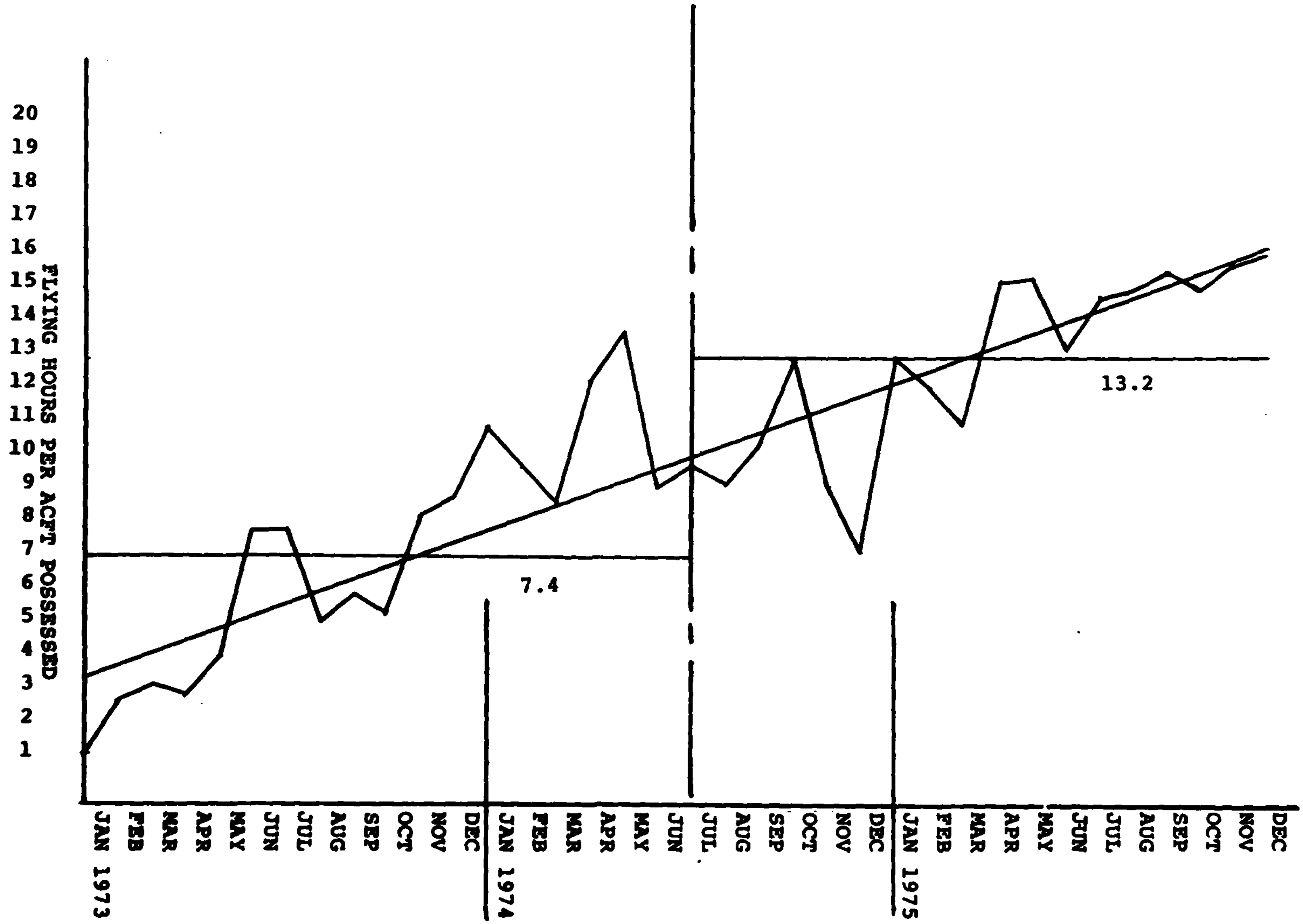
SEYMOUR-JOHNSON

F-4E

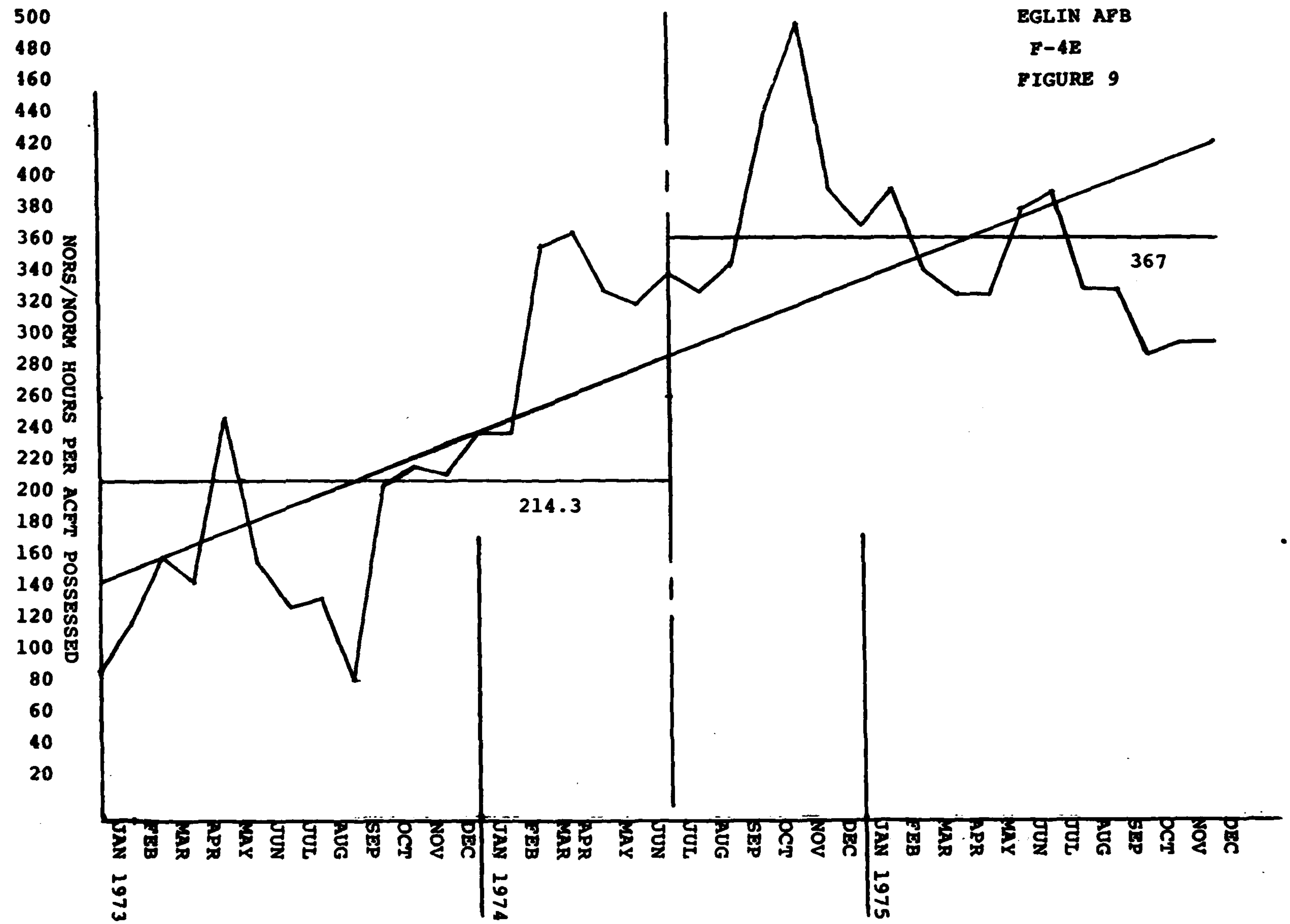
FIGURE 7

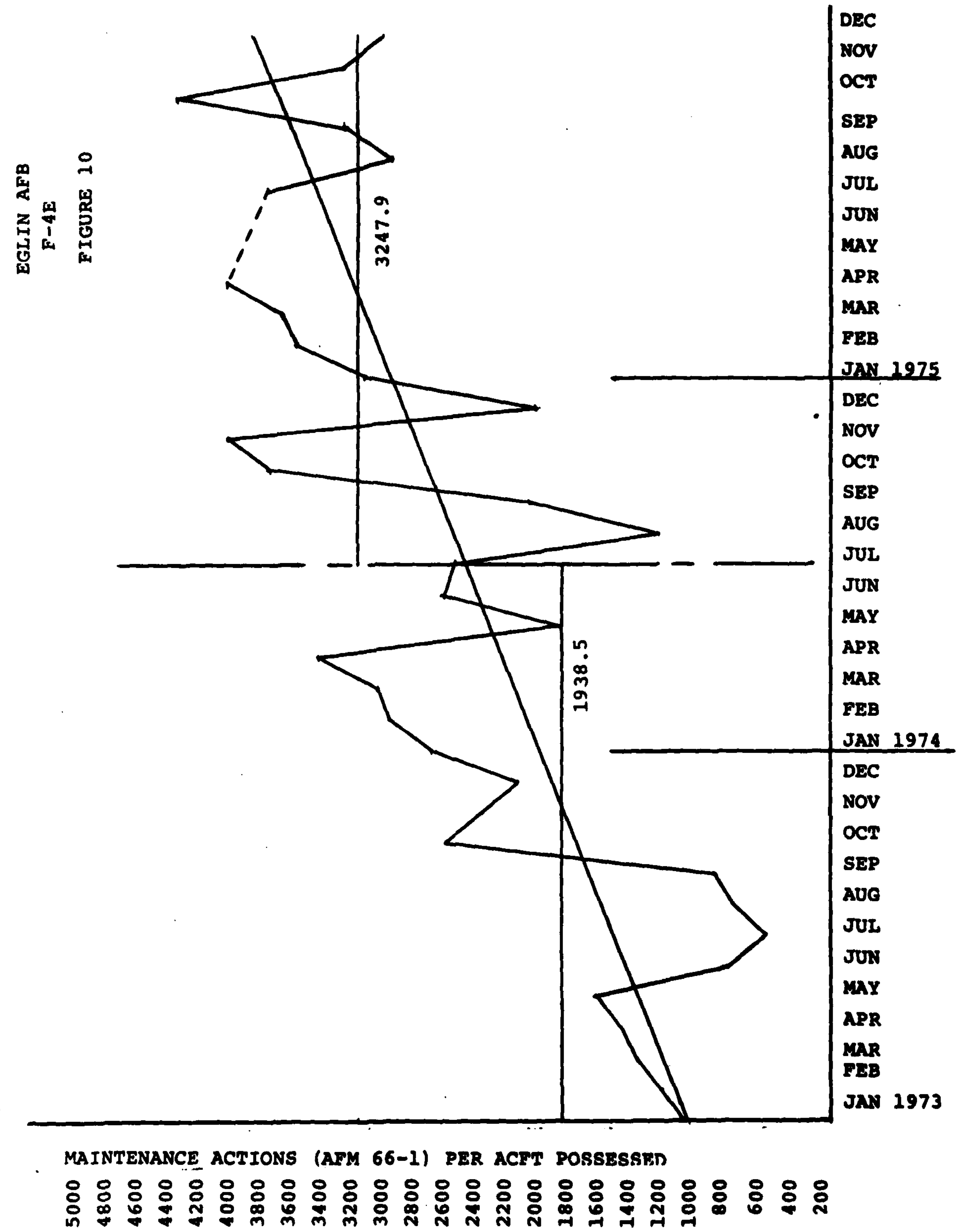


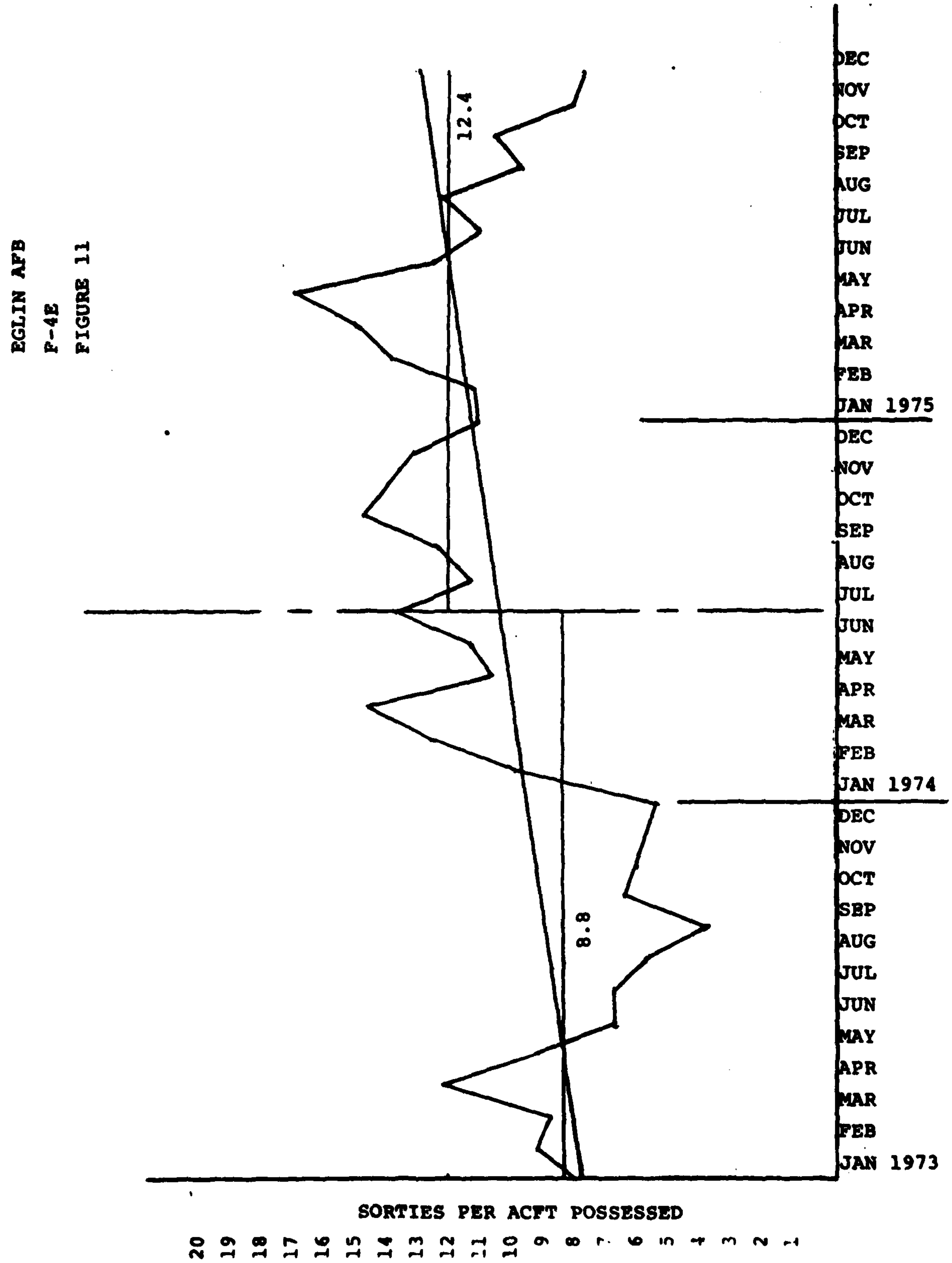
SEYMOUR-JOHNSON AFB
F-4E
Figure 8



EGLIN AFB
F-4E
FIGURE 9




EGLIN AFB
F-4E
FIGURE 10
3247.9
1938.5
JAN 1973
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN 1974
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN 1975
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MAINTENANCE ACTIONS (AFM 66-1) PER ACFT POSSESSED
5000 4800 4600 4400 4200 4000 3800 3600 3400 3200 3000 2800 2600 2400 2200 2000 1800 1600 1400 1200 1000 800 600 400 200


EGLIN AFB
F-4E
FIGURE 11
12.4
8.8
SORTIES PER ACFT POSSESSED
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
JAN 1973 FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
JAN 1974 FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
JAN 1975 FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

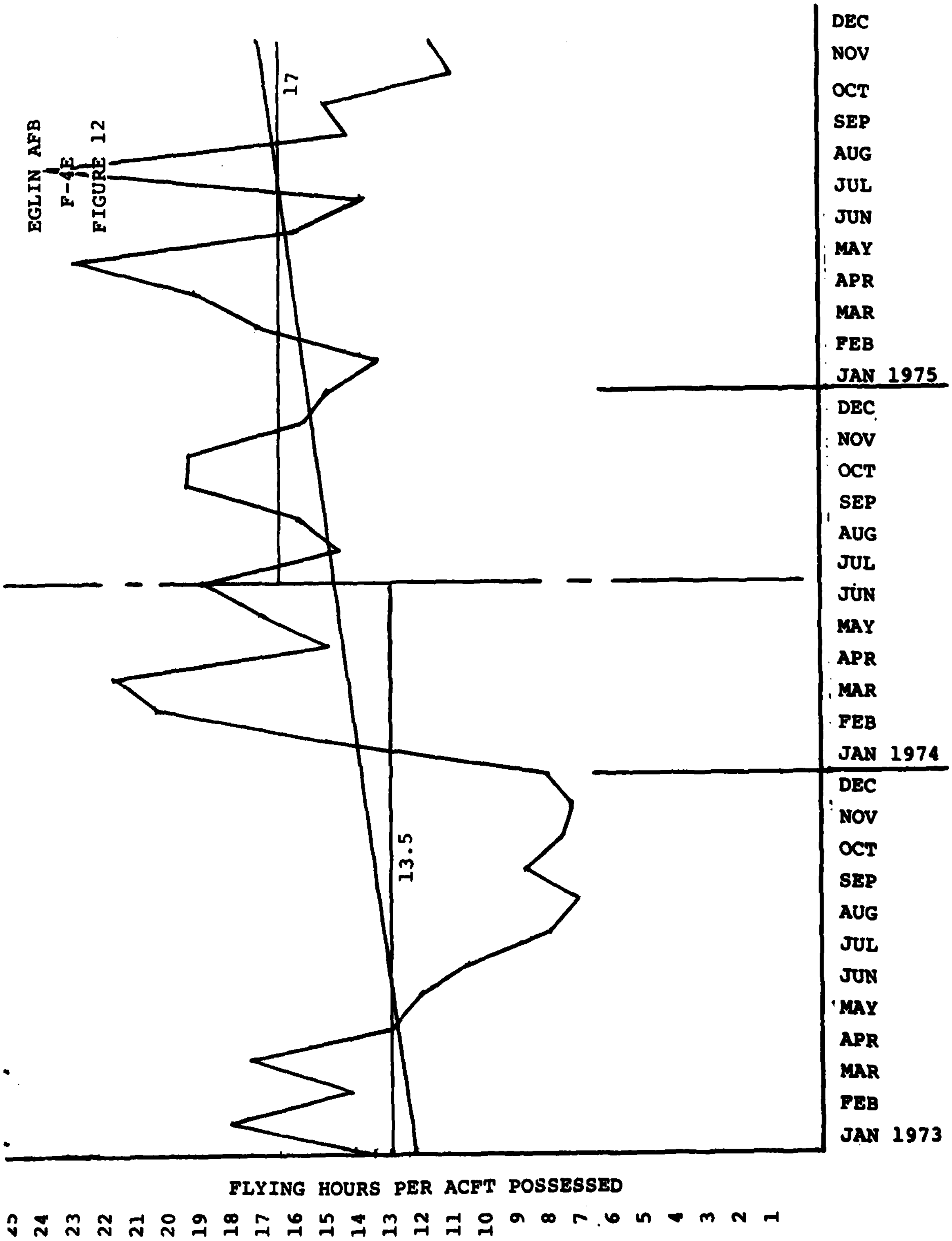


FIGURE 12
F-4E
EGLIN AFB
17
13.5
DEC
NOV
OCT
SEP
AUG
JUL
JUN
MAY
APR
MAR
FEB
JAN 1975
DEC
NOV
OCT
SEP
AUG
JUL
JUN
MAY
APR
MAR
FEB
JAN 1974
DEC
NOV
OCT
SEP
AUG
JUL
JUN
MAY
APR
MAR
FEB
JAN 1973
FLYING HOURS PER ACFT POSSESSED
24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Eglin AFB on F-4E aircraft activity. One year of TAC debriefing data were used, which had been accumulated and stored in the TAC Maintenance Information Logically Analyzed and Presented (MILAP) system which operates on the Burroughs 3500 computer system. These data were received on 9 track Burroughs tape and then converted to 7 track tape for processing on the AFLC CREATE computer system.

The Flying Record "BA" was extracted and merged with the Aircraft Discrepancy Record "HA." These records were matched on aircraft serial number, date, sortie sequence number and takeoff time. They were then sorted by type mission, work unit code (3 digit) and flight time within four increments ($\leq .8$, .9 to 1.3, 1.4 to 1.7 and ≥ 1.8). This arrangement provided maintenance actions by type of mission within the above time increments. The data are arrayed in Table 1 with the total maintenance actions per sortie listed at the bottom for each of the four time compartments. Analysis of the data in Table 1 indicated that there was practically no difference in the number of maintenance actions per sortie in those flights of shorter duration than 1.8 hours. Those sorties that had a duration longer than 1.8 hours reflected less than a 10% reduction in maintenance actions per sortie (ref Table 1). It is noted that only about 12% of the sorties had a duration in excess

TABLE 1 (page 1 of 2)

F-4E

EGLIN AFB

	≤ .8			.9 — 1.3			1.4 — 1.7			≥ 1.8			TOTAL		
MISSION CODE	MAINT ACTIONS	SORTIES	MNT ACT/SORT	MNT ACT	SORTIES	MNT ACT/SORT	MNT ACT	SORTIES	MNT ACT/SORT	MNT ACT	SORTIES	MNT ACT/SORT	MNT ACT	SORTIES	MNT ACT/SORTIES
ACTX	83	104	.8	107	126	.85	1	1	1.	0	0	0	191	231	.83
BFM	36	42	.86	37	43	.86	5	5	1.00	0	0	0	78	90	.87
DACT	203	277	.73	157	204	.77	115	152	.76	6	11	.55	481	644	.75
FCFX	197	210	.94	176	181	.97	17	17	1.00	2	2	1.00	392	410	.96
ACMX	159	205	.78	161	231	.70	21	26	.81	3	5	.6	344	467	.74
AAIX	96	134	.72	311	434	.64	306	408	.75	113	134	.84	826	1110	.74
ADXX	6	8	.75	38	42	.90	10	10	1.00	3	3	1.00	57	63	.90
AGXX	196	213	.92	3052	3539	.86	2797	3308	.85	65	88	.74	6110	7148	.85
A131	3	3	1.00	25	30	.83	34	37	.92	0	3	0	62	73	.85
DPLY	0	0	0	14	32	.44	16	18	.89	0	2	0	30	52	.58
LLLX	61	77	.79	153	205	.75	295	408	.72	104	145	.72	613	835	.73
PROF	15	20	.75	105	146	.72	193	281	.69	76	104	.73	389	551	.71
PSHE	3	3	1.00	16	16	1.00	13	15	.87	3	3	1.00	35	37	.95
HAGX	20	21	.95	155	186	.83	236	289	.82	49	59	.83	460	555	.83
PUSP	3	3	1.00	5	5	1.00	15	15	1.00	0	0	0	23	23	1.00
GNTX	0	0	0	48	54	.89	38	42	.90	12	12	1.00	98	108	.91
A119	5	5	1.00	32	49	.65	132	172	.77	27	28	.96	196	254	.77
DTOW	0	0	0	30	36	.83	59	88	.67	21	30	.70	110	154	.71
DAGX	5	5	1.00	73	81	.90	269	286	.94	10	11	.91	357	383	.93

TABLE 1 (Page 2 of 2)

F-4E

EGLIN AFB

	≤ .8			.9 1.3			1.4 1.7			≥ 1.8			TOTAL		
MISSION CODE	MAINT ACTIONS	SORTIES	MNT ACT/SORT	MNT ACT	SORTIES	MNT ACT/SORT	MNT ACT	SORTIES	MNT ACT/SORT	MNT ACT	SORTIES	MNT ACT/SORT	MNT ACT	SORTIES	MNT ACT/SORTIES
AM9L	4	4	1.00	31	34	.91	6	8	.75	17	17	1.00	58	63	.92
ARXX	0	0	0	8	9	.89	2	2	1.00	17	20	.85	27	31	.87
ASRT	0	0	0	1	3	.33	6	10	.60	8	9	.89	15	22	.68
MPXC	14	24	.58	65	106	.61	175	264	.66	120	269	.45	374	633	.56
MISC	62	97	.64	205	314	.65	247	398	.62	220	348	.63	734	1157	.63
RBFM	0	1	0	3	6	.50	3	9	.33	0	16	0	6	32	.19
RAGX	0	0	0	5	9	.56	31	35	.89	93	100	.93	129	144	.90
RMAG	0	0	0	4	4	1.00	45	48	.94	189	203	.93	238	255	.93
RGAT	0	0	0	7	8	.88	28	31	.90	179	241	.74	214	280	.76
WSEP	3	3	1.00	24	29	.83	103	130	.79	20	24	.83	150	186	.81
XCPF	5	6	.83	29	42	.69	57	86	.66	49	77	.64	140	211	.66
MAAI	1	2	.5	17	31	.55	65	89	.73	49	53	.92	132	175	.75
AL38	5	5	1.00	14	14	1.00	76	76	1.00	18	18	1.00	113	113	1.00
DCAS	0	0	0	0	1	0	12	18	.67	0	1	0	12	20	.60
TOTAL MAINT SORTIES	1185	1472	.80	5108	6250	.82	5428	6782	.80	1473	2036	.72	13194	16540	.80

of 1.8 hours. While this information is not sufficient to test the hypothesis, it does indicate that an increase in sorties for a given period with the same number of flying hours would generate additional maintenance write-ups.

TAC debriefing data described above were used to test Hypothesis No. 2 (certain aircraft items are sensitive to one operational requirement while some are sensitive to another). F-4D data from Holloman and F-4E data from Eglin AFB were used. Data from Seymour Johnson could not be used for this purpose as they had exercised a system option and had not included the mission code for about 80% of their data.

A chi-square test was applied to these data to determine if the number of maintenance write-ups within each work unit code was independent of mission type. The chi-square statistic is used to measure the discrepancy that exists between observed and expected frequencies of a set of possible events. The chi-square statistic is defined as follows:

$$\chi^2 = \frac{(o_1 - e_1)^2}{e_1} + \frac{(o_2 - e_2)^2}{e_2} + \dots + \frac{(o_k - e_k)^2}{e_k}$$

$$= \sum_{j=1}^{k} \frac{(o_j - e_j)^2}{e_j}$$

where the o_j's are the observed frequencies and the e_j's are the expected or theoretical frequencies. The larger the value of χ^2, the greater the discrepancy between observed and theoretical frequencies.

o_j represents the observed numbers of accumulated write-ups for one mission code "j" within a specific work unit code.

e_j was obtained by taking the percent of sorties a specific mission code represents of the total sorties multiplied by the total maintenance write-ups on all missions for a given work unit code.

If the computed value of χ^2 is greater than some critical value at a specific confidence level, the observed write-ups are said to differ significantly from expected write-ups (the percent of the total sorties flown in a specific mission multiplied by the total observed write-ups within a specific WUC).

As an example of the application of this statistic, consider χ^2 for WUC 74B, the Fire Control System AN/APQ-120. The value χ^2 for WUC 74B is 256.8 which is greater than the χ^2 value of 23.7 (95% confidence interval). This indicated that the observed write-ups vary significantly from the expected write-ups and the incidence of failures are not random but some missions do drive specific failures. See Table 2 for a detail description of this example.

The chi-square values are arrayed in these Tables (3 and 4) along with the number of maintenance write-ups experienced and the expected maintenance write-ups for a given mission. Infrequently used mission codes were lumped into miscellaneous and only selected work unit codes (WUCs) were used for simplicity in these illustrations. See appendicies 1 and 2 for a definition of mission and work unit codes. It is significant that these two tables represent over 49,000 sorties.

The Chi-square values of Tables 3 and 4 reveal that some missions do indeed drive maintenance write-ups on specific work unit codes; therefore, (to the extent that maintenance write-ups can be considered as item sensitivity) Hypothesis 2 is accepted, that maintenance write-ups are sensitive to mission type.

The answer to the question of "what items tend to be sensitive to specific operational requirements" is suggested by Tables 3 and 4 but only to the 3 digit work unit code level. Present system capabilities limit this to a 3 digit in lieu of 5 digit work unit code. AFM 66-1 data is reported at the 5 digit level, but cannot be related to the mission performed. The 5 digit code would afford the opportunity to identify specific item failures. Present reporting methods do not offer a means of relating AFM 66-1 data to debriefing data. This means that even though we are now collecting the necessary elements of data, they are so arrayed that they cannot be used for this important function of relating the mission flown to the specific item failure.

TABLE 2

F-4 FIRE CONTROL SYSTEM (WUC 74B)

(1) Mission Code	(2) Observed Write-Ups	(3) Expected Write-Ups	(4) (Observed Write-Ups -Expected Write-Ups)^2	(5) (4)/(3)
ADIX	244	2114X.07428= 157.03	7563.78	48.17
ACTX	87	2114X.01545= 32.66	2952.84	90.42
AGXX	976	2114X.47835=1011.23	1241.15	1.23
DACT	152	2114X.04309= 91.09	3710.03	40.73
FCFX	53	2114X.02743= 57.99	24.9	.43
LCLX	68	2114X.05587= 118.11	2511.01	21.26
NPXC	71	2114X.04436= 93.78	518.93	5.53
PROF	71	2114X.03687= 77.94	48.16	.62
MISC	78	2114X.07742= 163.67	7339.35	44.84
RNAG	41	2114X.01706= 36.06	24.40	.68
RGAT	35	2114X.01873= 39.6	21.16	.53
NAGX	77	2114X.03714= 78.51	2.28	.029
ACMX	76	2114X.03125= 66.06	98.80	1.496
A119	30	2114X.01699= 35.92	35.05	.976
DAGX	55	2114X.02563= 54.18	.67	.012
	2114			χ^2 = 256.943

CHI SQUARE VALUES, TABLE 3

[illegible] AFB (14,963 Sorties)

WORK UNIT CODE

[illegible] CODE	130 O	130 E	130 X^2	240 O	240 E	240 X^2	311 O	311 E	311 X^2	710 O	710 E	710 X^2	711 O	711 E	711 X^2	712 O	712 E	712 X^2
[illegible]	34	43.7	2.60	41	35.5	.89	51	60.6	1.52	40	33.3	.52	50	30.0	3.2	57	47.4	1.95
[illegible]	12	9.1	.92	3	7.0	2.6	10	12.6	.54	9	11.1	.39	18	8.1	12.10	9	9.8	.075
[illegible]	226	201.7	15.3	134	220.6	30.10	340	390.3	6.59	305	343.0	5.15	164	250.2	20.3	274	305.2	3.2
[illegible]	30	28.4	1.14	6	20.6	7.71	33	35.2	.62	29	30.9	.117	20	22.5	1.323	41	27.5	6.63
[illegible]	53	16.2	83.98	27	13.1	1.15	35	22.4	7.12	19	19.7	.021	21	14.3	5.21	15	17.5	.360
[illegible]	32	32.9	.025	40	26.7	6.6	76	45.6	20.28	37	40.1	.234	49	29.2	13.39	39	35.6	.315
[illegible]	19	26.1	1.95	19	21.2	.23	20	36.2	1.06	30	31.0	.103	47	23.2	24.42	21	28.3	1.88
[illegible]	36	21.7	9.4	25	17.6	3.09	30	30.1	2.00	31	26.4	.706	43	19.3	29.10	32	23.5	3.05
[illegible]	30	45.6	1.27	50	37.0	4.56	62	63.2	.02	31	55.5	10.8	35	40.5	.744	34	69.4	4.9
[illegible]	11	10.1	.080	42	8.1	140.6	17	13.9	.68	18	12.2	2.7	10	8.9	.132	20	10.9	4.64
[illegible]	13	11.0	.377	4	8.9	2.74	15	15.3	.01	10	13.4	1.55	10	9.0	.004	15	11.9	.770
[illegible]	25	21.9	.445	80	17.7	270.0	35	30.3	.73	33	36.6	1.5	10	19.4	.104	24	23.7	.004
[illegible]	30	10.4	20.0	0	14.9	14.9	29	25.5	.48	0	22.4	22.4	8	16.3	4.3	33	19.9	8.55
[illegible]	10	10.0	.00	4	8.1	2.09	25	18.9	8.95	9	12.2	.83	11	8.9	.501	11	10.8	.002
[illegible]	16	15.1	.054	9	13.2	4.3	14	20.9	2.28	20	18.4	.143	7	13.6	3.06	19	16.3	.112
	603	580.9	130.2	570	537.6	508.7	516	521.0	51.8	717	717.0	47.3	523	522.0	126.8	530	637.7	36.3

[illegible] CODE	735 O	735 E	735 X^2	740 O	740 E	740 X^2	745 O	745 E	745 X^2	750 O	750 E	750 X^2	752 O	752 E	752 X^2	762 O	762 E	762 X^2
[illegible]	24	71.7	31.7	41	22.3	11.90	244	157.0	48.17	20	41.6	11.22	9	99.1	81.9	20	23.0	.70
[illegible]	5	14.9	6.60	6	4.6	1.5	87	32.7	90.3	8	8.6	.05	0	20.6	20.6	1	5.0	3.17
[illegible]	742	461.6	170.3	207	143.5	13.10	946	1011.2	1.23	394	267.9	59.30	1115	638.1	341.6	127	154.0	4.74
[illegible]	19	41.6	12.3	19	12.9	2.05	152	91.1	40.7	21	24.1	.41	26	57.5	17.24	14	13.9	0
[illegible]	18	26.5	2.7	4	8.2	2.17	53	58.0	.43	6	15.4	5.7	2	36.6	32.7	12	8.8	1.114
[illegible]	6	53.9	42.59	11	16.0	1.90	68	118.1	21.27	3	31.3	25.6	0	74.5	59.4	12	18.0	1.99
[illegible]	12	42.0	22.10	5	13.3	5.19	71	93.8	5.5	4	24.0	17.5	4	59.2	5.45	7	14.3	3.7
[illegible]	16	35.6	10.77	10	11.1	.102	71	77.9	.62	5	20.6	11.06	4	49.2	41.5	17	11.9	2.22
[illegible]	27	74.7	30.48	12	23.2	5.4	78	163.7	44.8	29	43.4	4.76	4	103.3	95.4	34	24.9	3.3
[illegible]	11	16.5	1.8	2	5.1	1.9	41	36.1	.671	11	9.5	.22	5	13.9	5.7	3	5.3	1.13
[illegible]	13	10.1	1.4	0	5.6	5.62	35	39.6	.537	8	10.5	.59	21	15.3	2.14	9	6.0	1.46
[illegible]	31	35.8	.65	6	11.1	2.37	77	78.5	.029	26	20.0	1.3	7	30.3	17.9	15	12.0	.82
[illegible]	5	30.2	20.99	14	9.4	2.28	76	66.1	1.49	9	17.5	4.13	1	25.5	23.5	19	10.1	7.84
[illegible]	2	16.4	12.6	8	5.1	1.6	30	35.9	2.979	2	9.5	5.9	6	13.9	4.46	17	5.5	24.3
[illegible]	34	24.7	3.40	14	7.7	5.18	55	54.2	.012	14	14.3	.01	122	21.0	485.7	6	8.2	.61
	965	965	370.6	239	299.9	53.3	2004	2113.9	296.8	560	559.0	148.6	1334	1250.0	1238.2	321	322	57.2

LEGEND:
O = Observed Maintenance Write-Ups
E = Expected Maintenance Write-Ups
X^2 = Chi Square Value for WUC and Mission

[illegible] AFB - (34,074 Sorties)

CHI SQUARE VALUES, TABLE 4

WORK UNIT CODE

[illegible]	121 O	121 E	121 X²	230 O	230 E	230 X²	311 O	311 E	311 X²	712 O	712 E	712 X²	714 O	714 E	714 X²
[illegible]	4	5.7	.52	5	5.0	.12	32	21.0	5.76	23	15.0	4.23	18	10.9	4.61
[illegible]	37	19.3	16.1	18	19.7	.14	70	70.9	.01	63	50.7	2.98	42	36.8	.73
[illegible]	19	15.0	1.08	31	15.2	16.2	65	54.6	1.9	37	39.3	.13	55	28.5	24.7
[illegible]	3	35.0	29.25	20	35.7	6.9	15	128.2	99.9	10	91.0	72.9	12	66.6	44.9
[illegible]	24	9.6	21.5	16	9.8	3.80	45	35.3	2.69	27	25.2	.12	17	18.3	.10
[illegible]	13	4.5	15.98	23	4.6	73.3	33	16.5	16.36	2	11.9	1.25	7	9.6	.29
[illegible]	26	19.8	1.93	16	20.2	.88	67	72.6	.43	0	52.0	51.99	38	37.7	.002
[illegible]	15	8.1	5.90	13	8.2	2.78	88	29.5	31.44	39	21.1	15.09	35	15.3	25.2
[illegible]	3	1.3	2.06	0	1.4	1.31	9	4.9	3.38	6	3.5	1.73	2	2.6	.12
[illegible]	2	2.7	.17	2	2.7	.20	8	9.2	.33	5	7.0	.53	3	5.1	.85
[illegible]	46	74.3	10.6	90	75.9	3.76	150	272.4	48.1	161	195.0	5.96	73	141.5	33.10
[illegible]	17	5.1	27.6	3	5.3	1.99	40	18.8	24.05	12	13.4	.15	13	9.7	1.08
[illegible]	7	6.4	.05	4	6.5	.90	34	23.5	4.70	44	16.8	43.9	30	12.2	25.9
[illegible]	110	100.1	.98	112	108.3	.32	460	381.3	16.3	408	272.9	59.2	211	198.1	.84
[illegible]	0	1.7	1.67	0	1.7	1.7	15	5.1	19.22	2	4.4	3.2	7	3.2	4.63
[illegible]	1	2.3	.71	0	2.3	2.31	12	8.3	1.64	3	5.9	.71	4	4.3	.02
[illegible]	11	27.1	9.53	28	27.6	.01	130	99.1	9.63	46	70.9	8.77	84	51.5	20.51
TOTAL	342	342.0	148.9	349	349.0	116.8	1263	1252.0	285.9	897	897.0	272.7	651	650.9	187.6

[illegible]	718 O	718 E	718 X²	719 O	719 E	719 X²	723 O	723 E	723 X²	731 O	731 E	731 X²
[illegible]	27	18.0	6.15	44	15.0	58.5	9	6.1	1.35	21	18.2	.42
[illegible]	81	56.0	10.31	94	53.2	31.2	4	20.6	13.4	18	61.5	30.8
[illegible]	66	43.9	11.1	99	41.[illegible]	81.3	14	13.9	.23	12	47.5	26.6
[illegible]	11	102.7	81.9	7	96.1	82.8	1	37.2	35.3	1	111.3	109.3
[illegible]	33	28.2	.8	26	[illegible].5	.23	12	10.2	.3	18	30.6	5.18
[illegible]	11	13.2	.38	16	11.4	.47	0	4.8	2.13	4	14.3	7.46
[illegible]	78	58.2	6.74	75	[illegible]4.5	7.68	48	21.1	16.93	78	63.8	3.57
[illegible]	33	23.7	3.69	49	22.2	14.32	7	8.6	.29	6	25.6	16.6
[illegible]	3	3.9	.23	2	3.7	.78	4	1.4	4.62	6	4.3	.70
[illegible]	10	7.8	.66	10	7.3	.96	8	2.8	9.38	2	8.5	4.96
[illegible]	153	218.3	19.5	21	204.6	34.19	31	79.1	29.3	54	236.3	140.7
[illegible]	18	15.0	.59	22	14.1	4.44	12	5.4	7.87	45	16.3	50.75
[illegible]	0	18.0	18.0	33	17.6	13.4	8	6.8	.20	69	20.4	40.2
[illegible]	184	305.5	20.7	304	286.3	1.09	185	118.8	49.8	761	330.7	590.7
[illegible]	6	4.9	.25	0	4.6	4.59	0	1.8	1.77	1	5.3	3.48
[illegible]	11	6.7	2.83	15	4.2	13.3	1	2.4	.82	1	7.2	5.35
[illegible]	78	79.4	.002	41	74.4	15.01	20	28.8	2.68	11	86.6	65.38
TOTAL	1004	1003.0	184.1	941	940.8	335.2	364	363.8	176.3	1097	1086.9	1071.8

[illegible]	747 O	747 E	747 X²	748 O	748 E	748 X²	751 O	751 E	751 X²	760 O	760 E	760 X²
[illegible]	110	79.6	11.6	5	7.2	.68	3	7.5	2.71	5	10.9	3.2
[illegible]	593	260.9	390.7	67	24.3	74.9	2	25.3	21.5	42	36.0	[illegible]
[illegible]	437	207.8	252.3	10	13.8	.002	9	19.6	6.06	57	28.5	28.6
[illegible]	56	436.2	380.6	5	44.0	34.6	0	45.8	45.8	7	66.6	53.3
[illegible]	230	133.7	69.32	24	12.1	11.7	6	12.6	1.69	20	16.3	6.23
[illegible]	36	62.7	12.39	7	5.7	.31	0	5.9	5.96	11	8.4	.65
[illegible]	349	275.1	19.93	41	24.9	10.39	46	26.0	15.65	52	37.7	5.41
[illegible]	125	112.0	1.52	6	10.1	1.69	4	10.6	4.08	22	15.1	3.09
[illegible]	27	18.7	3.71	5	1.7	6.48	0	1.8	1.76	0	2.6	11.94
[illegible]	48	37.1	3.2	5	3.4	.8	0	3.5	3.49	6	9.1	.13
[illegible]	660	1023.1	134.8	20	93.5	44.9	18	97.4	64.7	102	141.5	11.04
[illegible]	89	71.1	4.48	3	6.4	1.84	7	6.7	.01	14	9.7	1.92
[illegible]	126	89.1	15.3	8	8.1	.0006	1	8.4	6.52	14	12.2	.26
[illegible]	1552	1465.9	7.78	197	130.9	33.45	342	136.3	310.3	291	198.1	14.12
[illegible]	48	23.1	26.72	0	2.1	2.09	0	2.2	2.19	2	3.2	.45
[illegible]	39	31.5	1.78	3	2.8	.01	2	3.0	.32	0	6.3	3.13
[illegible]	237	375.8	50.94	6	34.8	23.97	7	35.4	22.81	21	51.5	18.07
TOTAL	4752	4751.4	1294.5	438	429.9	246.8	448	448.0	516.2	651	650.9	161.7

LEGEND:
O - Observed Maintenance Write-Ups
E - Expected Maintenance Write-Ups
X² - Chi Square value for WUC and mission

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IV CONCLUSIONS AND DISCUSSION

This study has described a logistics problem that TAC has experienced as a result of a change in the training mission for the F-4 aircraft. During the course of the study, its authors have received inquiries from other organizations questioning the use of flying hours as the determiner for logistics and budget considerations.

This study continues nearly two decades of work accomplished by logistics researchers in attempting to revise the basic measure for logistics planning purposes. It combines a large sample of basic F-4 operations and maintenance data and emphasizes that what the airplane does while accumulating flying hours is in reality one of the determiners for maintenance actions.

Methods have been developed, tested, and utilized for several years in which mission data have been related to maintenance actions and utilized to forecast base maintenance requirements [2, 3, 5, 6]. It is concluded that consideration should be given to the standardization of these basic methods throughout the Air Force and made a part of the Maintenance Management Information Control System (MMICS) with failure data related to mission being made available for command operational and planning purposes.

V OBSERVATIONS

Base maintenance operations can be improved by a standardized mission code being carried into the MMICS and associated with maintenance actions as accomplished in project ARISE [4]. With appropriate mission definition and planning, the following improvements can be expected:

1. Maintenance resources (manning by skill and material) can be planned in advance.

2. Repair turnaround times and delays can be forecast more accurately.

3. Maintenance cost reductions due to improved resource control.

4. A wartime environment can be projected for maintenance planning purposes.

The following additional considerations outside of Base Maintenance are offered:

1. Potential constraints can be established for operator/planner use of aircraft.

2. With this new data base containing a standardized mission code and maintenance actions, additional study can be accomplished to determine the impact of mission mix upon logistics.

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APPENDIX 1, Mission Codes

Holloman AFB

Mission Code	Mission
AAR	Air Refueling
ACM	Air Combat Maneuvers
ADI	Air Defense Intercept
BFM	Basic Flight Maneuvers
DART	Shoot Air Target
FCFA	Functional Check Flight
GAT	Ground Attack
INST	Instrument Check
LLV	Low Level
MAV	Maverick Missile
MISC	Miscellaneous (all minor missions)
NRNG	Night Range
RBS	Radar Bomb Scoring
RNG	Range
DEP	Deployment
TRANS	Transition
XC	Cross Country

Eglin AFB

Mission Code	Mission
AAIX	Air to Air Intercept
ACTX	Air Combat Training
AGXX	Air to Ground
DACT	Dissimilar Air Combat Maneuvers
FCFX	Functional Check Flight
LCLX	Live Close Air Support
NPXC	Navigational Proficiency Cross Country
PROF	Instrument Proficiency
MISC	Miscellaneous (all minor missions)
RNAG	Night Refueling
RGAT	Refueling Ground Attack
NAGX	Night Air to Ground
ACMX	Aerial Combat Maneuvers
A119	ALQ 119 12/14
DAGX	Dart Air to Ground

APPENDIX 2, Work Unit Codes (F-4D & E)

Work Unit Code	Work Unit
120	Fuselage General
121	Cockpit
230	Propulsion System
440	Lighting System
511	Flight Instruments
71H	Inertial Navigation System AN/ASN-63
71L	Integrated Electronic Central AN/ASQ-19
71N	Integrated Electronic Central AN/ASQ-19B-107
71S	Interrogator Set AN/APX-76
723	Radar Altimeter: AN/APN-155
735	Computer System AN/ASQ 91
747	Radar Set AN/APQ 109 (F-4D only)
748	Lead Computing Light AN/ASG-22
74B	Fire Control System (Radar Set) AN/APQ-120 (F-4E only)
750	Weapons Delivery System (F-4E only)
751	Weapons Suspension Equipment
76D	Radar Homing and Warning Set AN/APS-107
76E	Miscellaneous Electronic Countermeasure Items

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1F-4E-06