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NAVAL POSTGRADUATE SCHOOL

Monterey, California

TRENDS IN MAJOR AIRCRAFT

ACCIDENT RATES

by

G.K. Poock, Ph.D.
Man-Machine Systems Design Laboratory
Naval Postgraduate School

June 1976

Approved for public release; distribution unlimited

Prepared for:
Naval Safety Center
Norfolk, Virginia 23511

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral I. W. Linder, USN
Superintendent

J. R. Borsting
Provost

The purpose of this report is to inform the sponsor of recent research efforts into possible trends and cycles in major aircraft accidents. No such trends were found although some interesting results have been found relating number of accidents and monthly hours flown in the MARTC command.

Prepared by:

G. K. Poock
Department of Operations Research
and Administrative Sciences

Approved by:

M. G. Sovereign, Chairman
Department of Operations Research

Released by:

R. R. Fossum
Dean of Research Administration

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A variety of approaches was taken to look for consistent cycles or trends in monthly major aircraft accident rates. Approaches are discussed looking at the data by years, commands and aircraft types.

251 450 LB

FOREWORD

This report is one of several being generated during a two year investigation into a variety of questions concerning major aircraft accidents. The Naval Safety Center, Norfolk, is the sponsor and data for the study has been provided by them. More recently, since January 1976, data has also been provided by the Maintenance Support Office Department, Mechanicsburg, Pennsylvania.

NOTE: All accident rates in this paper are in terms of the number of accidents per 10,000 flight hours.

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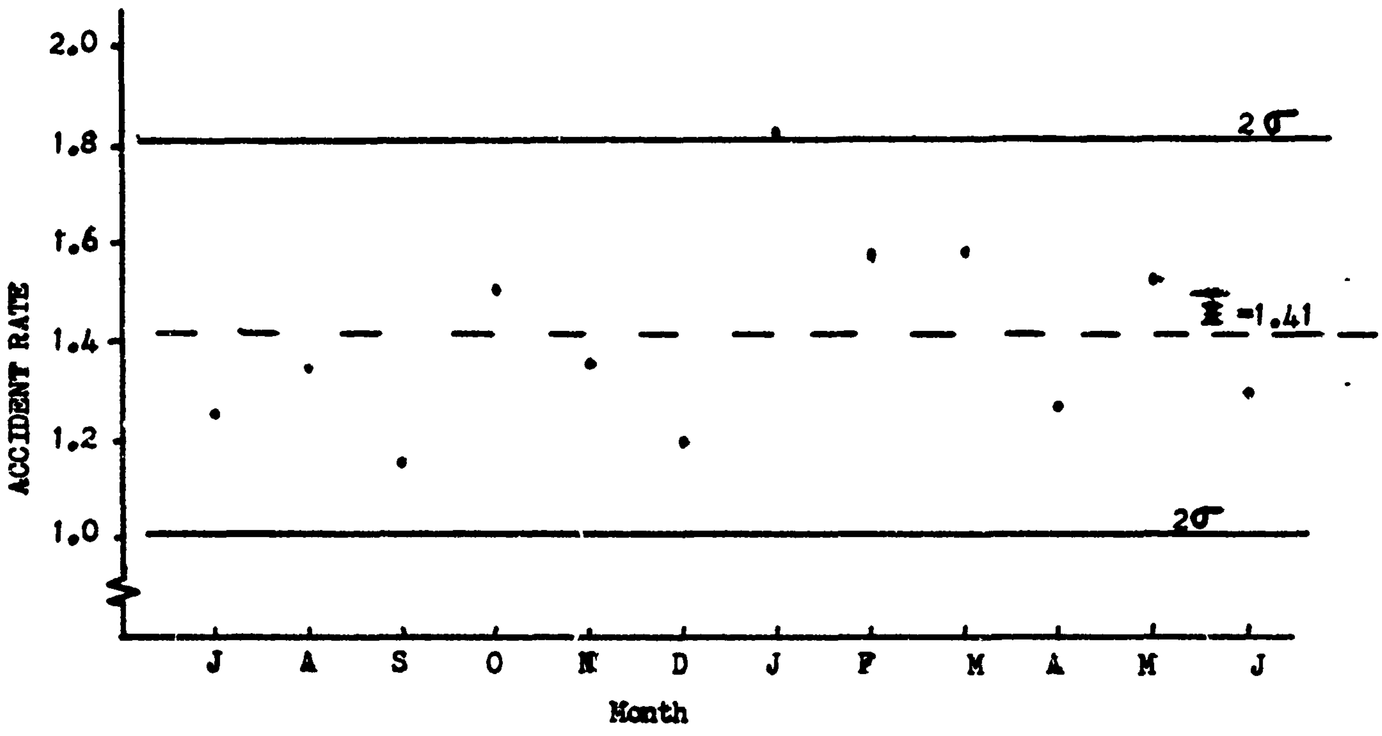
INTRODUCTION:

Previous work by this author and two of his military officer theses students was reported by Maxwell and Stucki (1975). That report described an effort in which multiple regression techniques were used to determine what types of variables appear to be able to account for the variability observed in monthly aircraft accident rates for all Navy/Marine.

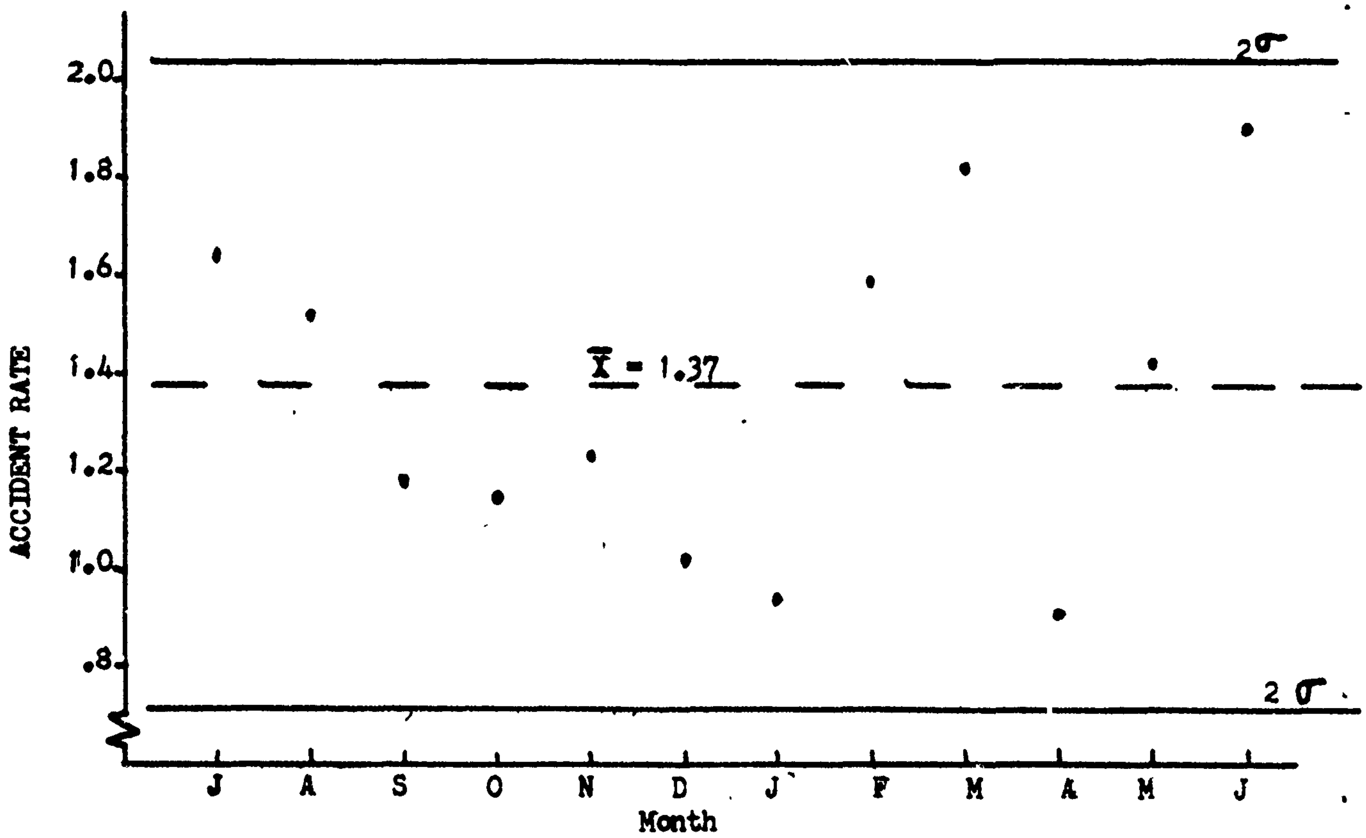
This report is also concerned with variability in monthly accident rates but examines a variety of questions with regard to the existence of a consistent monthly influence on the major accident rate, i.e. does a specific month or two consistently have high accident rates from year to year?

FISCAL YEAR ANALYSIS:

Examination of the monthly accident rates by month by year for all Navy/Marine provides the graphs shown in Figures 1, 2 and 3 for FY69-FY74. These figures show the mean and 2σ limits and are similar to control charts used in industrial quality control for purposes of checking when an on-going time process is out of control. Only 1 month falls beyond the 2σ boundaries and that is January of FY69. However, examining the following years, one sees January is second to lowest in FY70, and again second lowest in FY71, etc. In other words, January does not remain consistently high from year to year. Another example might be June, where

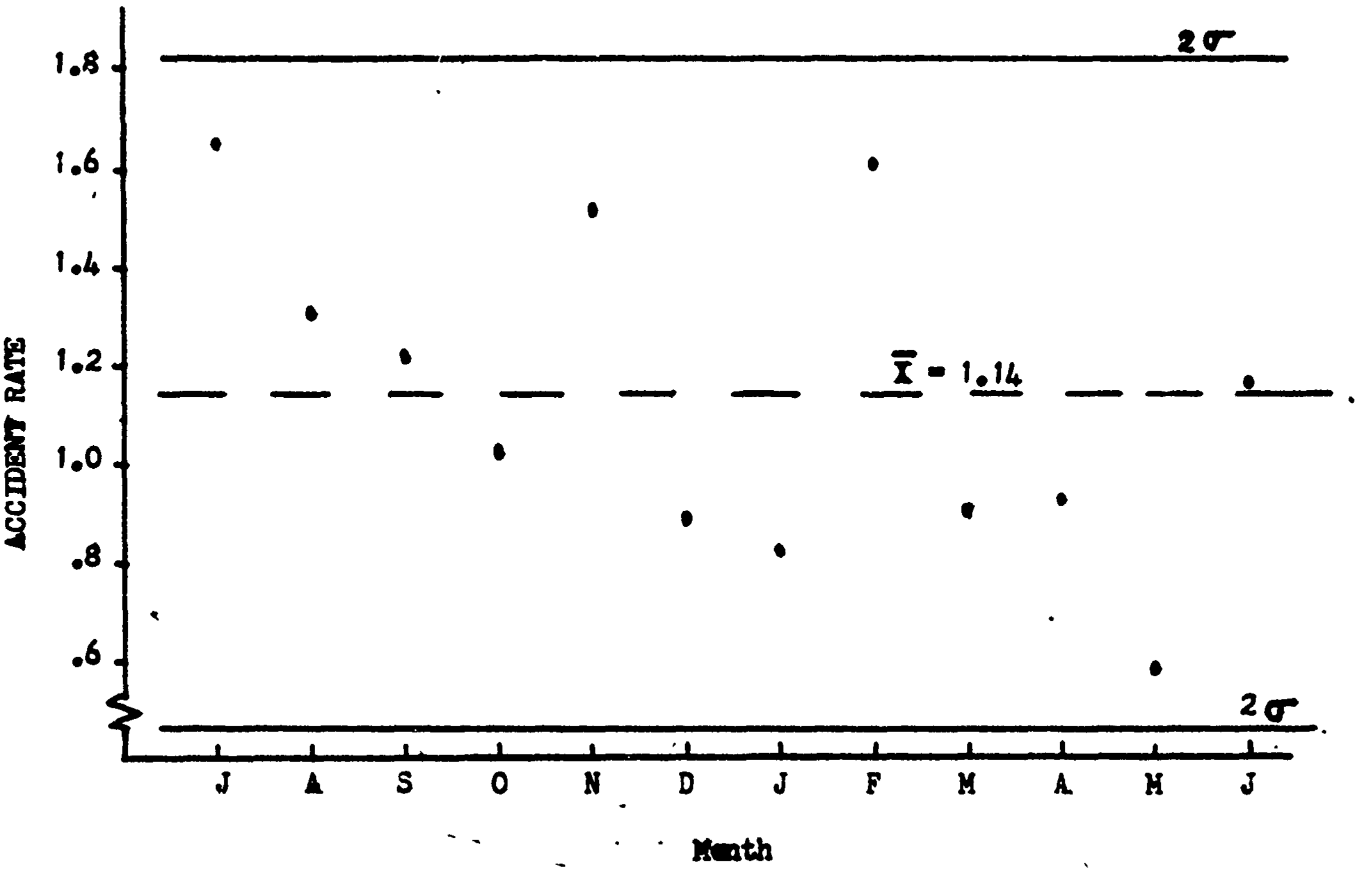


FY69

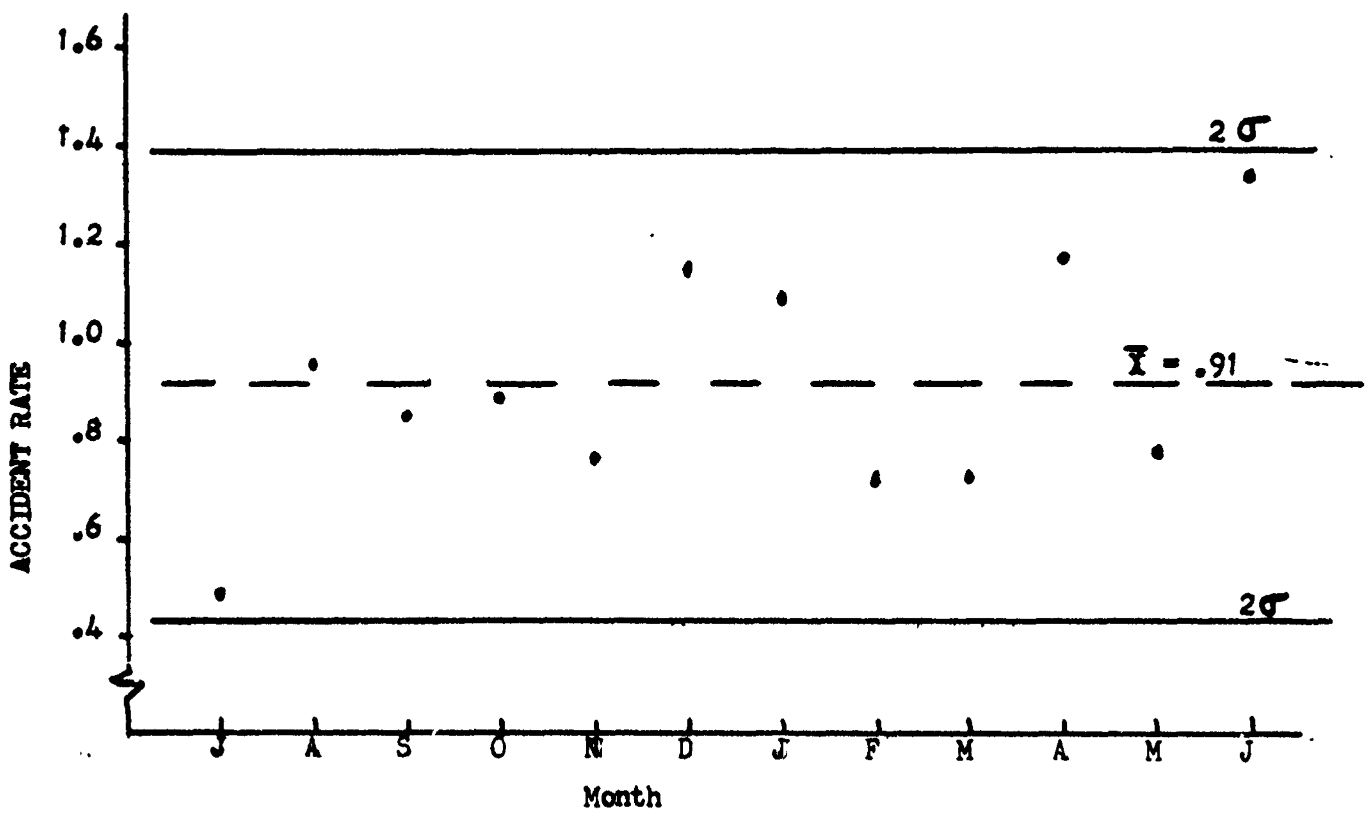


FY70

FIGURE 1. ACCIDENT RATE VS MONTH FOR FY69 AND FY70

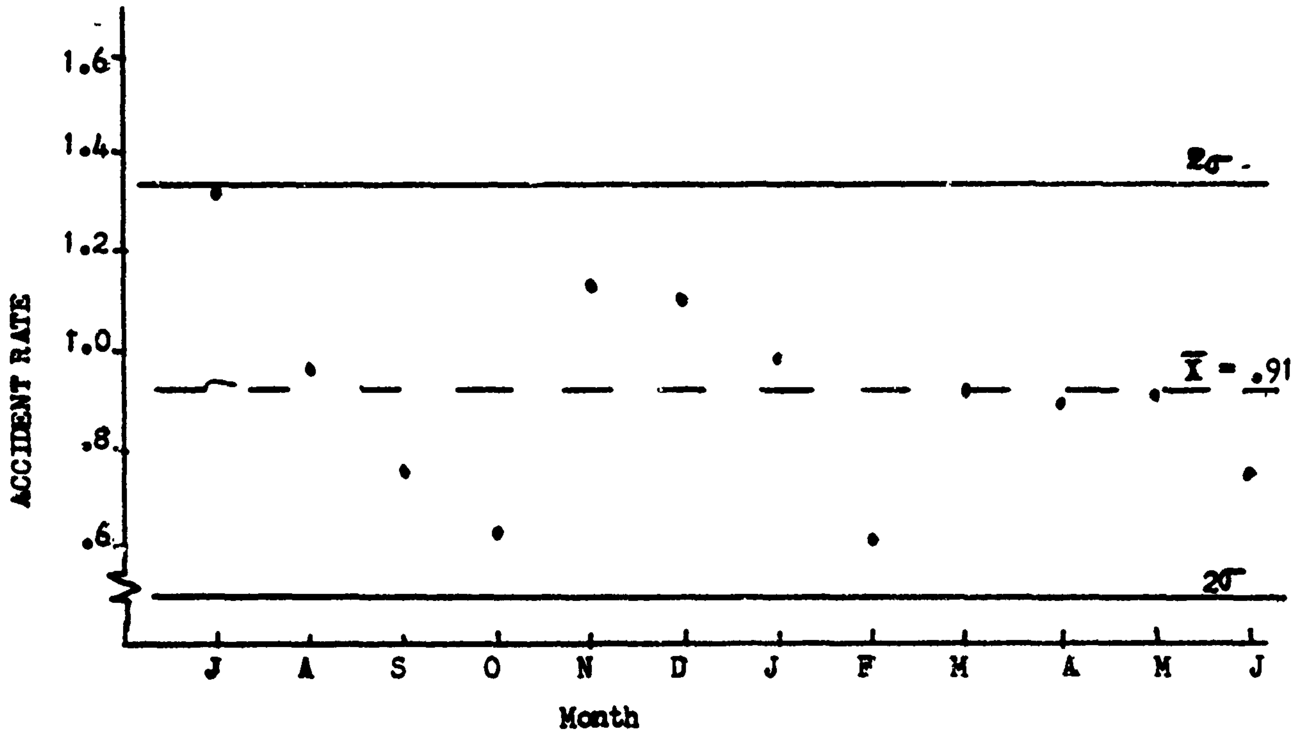


FY71

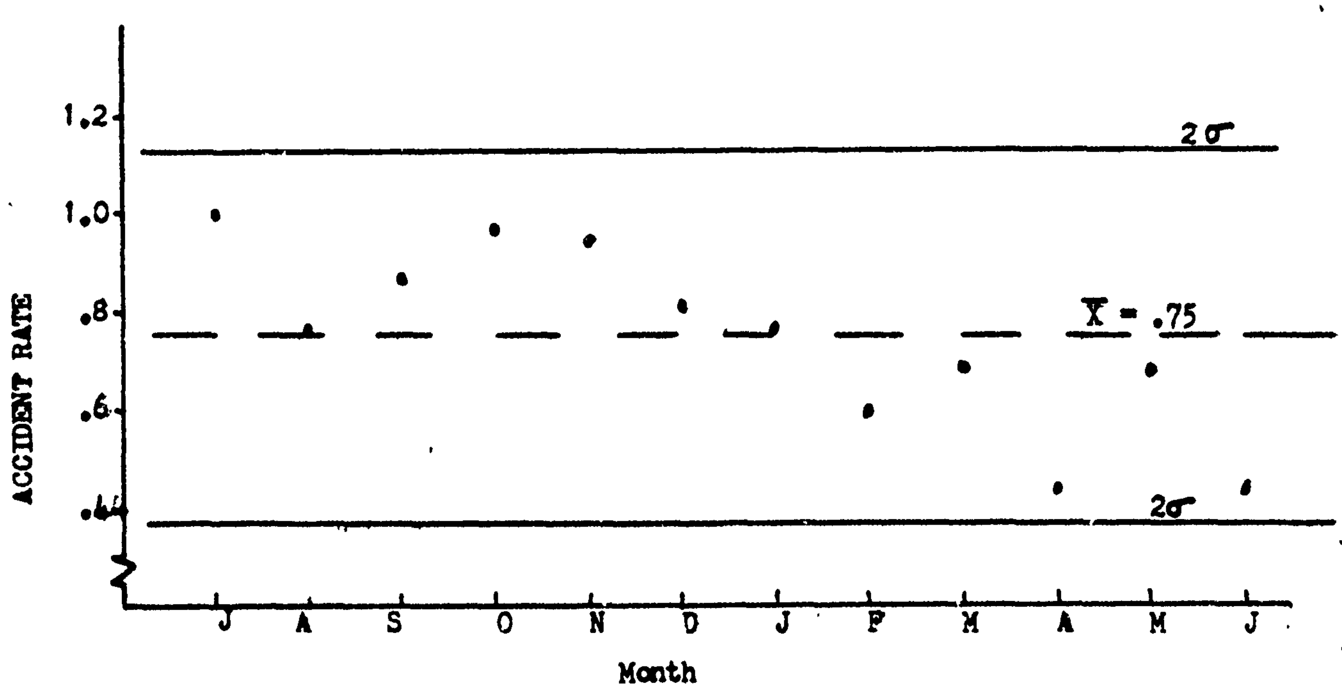


FY72

FIGURE 2. Accident rate vs Month for FY71 and FY72



FY73



FY74

FIGURE 3. ACCIDENT RATE VS MONTH FOR FY73 AND FY74

over the 6 years, it is with respect to the mean: below, above, above, above, below, below. Again no consistent trend appears nor does it appear with any month. There does not appear to be any month which is consistently high to support any belief of a consistent monthly effect. Further evidence is obtained by looking at the number of data points located within 1σ of the means shown in the 6 yearly graphs. Although the 1σ limits are not shown on the graphs, one will find that 50 of the 72 monthly data points fall within 1σ. This is 69% and very close to the theoretical 68% one would expect to fall within 1σ limits per conventional probability and statistics. As further evidence, a test for uniformity of the yearly accident rate distributions was run using a test developed by Kuiper (1960) which is an adaptation of the popular Kolmogorov-Smirnov test and is more applicable here because Kuiper's test statistic, V_N, doesn't depend on which month one uses as a starting point to test for uniformity during the fiscal year. Using Kuiper's test on each of the 6 years, the hypothesis of a uniform distribution of accident rates throughout the year would not be rejected $(p>.10)$. The accident rates over each year are uniform and there appears to be no consistent monthly effect for any month year after year.

As an informal exercise, this author also interviewed approximately 30 Navy pilots who expressed the unanimous opinion that when in a squadron, they were often made aware that the previous year had a hight accident rate for the next month coming up, and that they should be more cautious next month. Sure enough, they reported the rate would go down but then they would "relax" later on and a month that was low the year before would have a high accident rate when the squadron "relaxed" after the so called bad month had passed. This phenomena seems to act to push the rate down in one month but then the rate will rise up in another to support the uniform random distributions already illustrated statistically.

Previous work by Robino (1972) made a point of the fact that for FY67-FY72, the month of March had the highest average accident rate for the 6 years in AIRLANT. An ensuing discussion then tried to determine reasons why March was the worst month for the 6 years. That report was one of the reasons suggested by the Naval Safety Center for this writer to pursue the current research. This writer observed that Robino's argument was based purely on the fact that March had the highest mathematical average in AIRLANT over 6 years. Using Kuiper's test for uniformity on Robino's data, this writer finds that the AIRLANT rates for FY67-FY72 are statistically uniform ($p>.10$) and no strong case can be made for a March phenomena. Further, this writer assumed that FY67-FY72 was of no particular importance and thus looked at FY70-FY75, i.e. a six year period also but offset 3 years later. Looking at the pure mathematical monthly averages for the latter 6 year period, one finds July is now the worst month followed by June. If Robino's study had been done 3 years later, March wouldn't have been of interest but July would have been. The above exercise is not meant to degrade Robino's work as he did mention a statistical analysis needed to be done. The purpose of the above was to illustrate to safety researchers that simply looking at accident rates and choosing the highest one to concentrate on can be misleading. Any set of averages on monthly data will come up with one month as the highest but the question needs to be answered as to whether a uniform distribution exists among the averages. If not, then one will find one or more averages which are extremely high or low and one can then pursue this month with much more confidence that the month in question is indeed higher (lower) than one might expect beyond elements of random variability.

COMMAND ANALYSIS:

A similar investigation was conducted by major commands looking for consistent cycles and/or months which appeared to have higher than statistically reasonable accident rates. The following major commands were considered:

NAVAIRLANT

MARLANT

NAVAIRPAC

MARPAC

CNATRA

Naval Reserves

MARTC

RDTE + NASC

Data was available for FY70-FY75 for all commands and a six year average was calculated for each month for each command.

Each command was tested for uniformity of the distribution of its accident rates over the months of the year. In each command, the hypothesis of a uniform distribution of accident rates by months over the year was accepted $(p>.10)$. No evidence of non-uniformity was demonstrated statistically and further observation of the graphed data revealed no consistent trends. (The command data is presented numerically in Appendix A.)

AIRCRAFT ANALYSIS:

After examining the data by year and by command, individual types of aircraft were examined. From 56 aircraft of interest initially, only 7 had enough accident data and flight hours to permit adequate statistical examination. The individual aircraft examined were A3,A4,A5,A6,A7, F4 and F-8. All helicopters were combined to provide an eighth group of aircraft. Data for these aircraft were available for FY69-FY74. Again, a test for uniformity of the distribution of accident rates by months over the six year averages for each aircraft showed all distributions were uniform. The hypothesis of uniform accident rate distributions was accepted $(p>.10)$ for each aircraft including helicopters combined. The uniform hypothesis would have been rejected if one month (or more) had consistently stood out higher than the other months. (The data for aircraft is provided in Appendix B). No consistent trends were evident in the data, as might be expected from the uniform distributions.

YEAR VS. YEAR CORRELATIONS:

Another avenue of investigation was to examine the correlations of accident rates between years over the 12 months. If there was a consistent trend for say, six months to be high always and the other six to be low, then from year to year the correlation between the monthly averages of the two years should be high. Tables I, II and III show these parametric correlations between years by command. Based on the data set size, a correlation of .58 or higher was needed to show a significant relationship between the monthly rates of two given years at the .05 level. Any correlation less than .58 would be considered due to random chance. As can be seen in the tables, only 3 significant correlations were found and these were each in different commands and between different years. Again, no consistency of correlation trends was found between years or commands, thus reinforcing previous results that, although accident rates do move up and down, they appear to do so in a random manner resulting in uniform distributions of the accident rates.

CORRELATIONS OF FLIGHT HOURS VS. ACCIDENT RATES AND NUMBER OF ACCIDENTS:

The possibility that the number of accidents tends to go up and down with the amount of flight hours was investigated next. Since the correlation between number of accidents and flight hours, and the correlation between accident rate and

TABLE I

CORRELATIONS OF MONTHLY ACCIDENT RATES BETWEEN YEARS

AIRLANT

	FY75	74	73	72	71	70
FY75	1.00					
74	-.45	1.00				
73	-.08	.49	1.00			
72	.27	.16	.35	1.00		
71	.30	-.18	-.47	-.24	1.00	
70	.13	-.04	-.23	.28	.45	1.00

MARLANT

	FY75	74	73	72	71	70
FY75	1.00					
74	.32	1.00				
73	.01	0.00	1.00			
72	-.43	-.03	-.35	1.00		
71	.60*	-.09	.09	-.08	1.00	
70	.06	-.27	-.32	-.34	-.03	1.00

AIRPAC

	FY75	74	73	72	71	70
FY75	1.00					
74	-.41	1.00				
73	0.00	-.35	1.00			
72	-.53	.32	.12	1.00		
71	-.18	.19	-.30	.19	1.00	
70	.24	-.56	-.16	-.60*	.21	1.00

* $p < .05$

TABLE II

CORRELATIONS OF MONTHLY ACCIDENT RATES BETWEEN YEARS

MARPAC

	FY75	74	73	72	71	70
FY75	1.00					
74	.17	1.00				
73	-.40	.15	1.00			
72	-.25	.16	-.33	1.00		
71	.47	.18	-.23	-.38	1.00	
70	-.27	-.05	.18	.03	-.26	1.00

CNATRA

	FY75	74	73	72	71	70
FY75	1.00					
74	-.12	1.00				
73	.17	.17	1.00			
72	.28	-.36	-.03	1.00		
71	.39	.22	-.07	.22	1.00	
70	-.35	.22	-.07	-.37	.11	1.00

NAVAL RESERVES

	FY75	74	73	72	71	70
FY75	1.00					
74	.05	1.00				
73	.47	-.16	1.00			
72	-.28	-.37	.17	1.00		
71	-.21	.19	.10	-.41	1.00	
70	.41	-.08	-.17	-.48	.05	1.00

TABLE III

CORRELATIONS OF MONTHLY ACCIDENT RATES BETWEEN YEARS

MARTC

	FY75	74	73	72	71	70
FY75	1.00					
74	.36	1.00				
73	-.27	.25	1.00			
72	-.20	-.36	-.14	1.00		
71	-.32	-.06	.33	-.43	1.00	
70	-.15	-.02	.33	-.37	.41	1.00

RDTE + NASC

	FY75	74	73	72	71	70
FY75	1.00					
74	-.17	1.00				
73	-.05	-.01	1.00			
72	.01	.42	.45	1.00		
71	-.08	.39	.10	.49	1.00	
70	-.45	-.58*	.21	-.05	-.06	1.00

* $p < .05$

flight hours would yield different results, both correlations were run under both a parametric (Pearson Product-Moment Correlation) and nonparametric (Spearman Rank-Order Correlation) fashion. The nonparametric approach was needed since the number of accidents ranges from 0 to 15 or so in an integer fashion. Thus, nonparametric correlations were calculated first and were expected to produce the best results of the two methods.

The rank order nonparametric correlations between the number of accidents and the accident rate with the number of flight hours over twelve months of the year is shown in Table IV. Observation of the values in this table show only 5 significant correlations out of 98 shown---hardly enough to show any significant trend. For the Table IV values, the nonparametric correlation needed to exceed .50 before the correlation would be significant at $\alpha = .05$.

These results were not encouraging but parametric correlations were run on the same data anyway and are shown in Table V where a .58 parametric correlation was needed to be significant at $\alpha = .05$. Surprisingly, more significant correlations can be observed in Table V and one should specifically note the correlation between number of accidents and hours flown for MARTC. In 4 of the 6 years, MARTC shows a significant relationship between number of accidents and flight hours. This provided some evidence that two-thirds of the time, the number of accidents for MARTC appears to increase and decrease in direct proportion to the number of flight hours.

TABLE IV

NONPARAMETRIC RANK ORDER CORRELATIONS OF
MONTHLY ACCIDENT RATES WITH TOTAL HOURS
FLOWN BY THE COMMAND IN THE SAME MONTHS

	FY75	74	73	72	71	70
AIRLANT	.28	.25	.40	-.33	-.27	.25
MARLANT	-.36	0.00	.42	.06	-.44	.03
AIRPAC	-.36	.22	-.19	-.50	-.11	-.05
MARPAC	-.27	-.44	-.16	-.10	-.26	-.12
CNATRA	-.60*	-.26	.05	0.00	.34	.27
N. RESERVES	.05	.07	.26	.19	-.01	.27
MARTC	.23	.48	.51*	.29	.16	.17
RDTE + NASC	-.01	.02	-.42	.10	.12	.10

NONPARAMETRIC RANK ORDER CORRELATIONS OF
NUMBER OF MONTHLY ACCIDENTS WITH TOTAL HOURS
FLOWN BY THE COMMAND IN THE SAME MONTHS

	FY75	74	73	72	71	70
AIRLANT	.29	.46	.50	-.26	-.08	.38
MARLANT	.01	.37	.59*	.24	-.30	.24
AIRPAC	.03	.37	.09	-.28	.04	-.05
MARPAC	.15	-.22	.08	.38	.45	.25
CNATRA	-.38	-.06	.36	.33	.47	.43
N. RESERVES	.20	.31	.44	.41	.13	.42
MARTC	.37	.57*	.69*	.36	.34	.50
RDTE + NASC	.06	.25	-.23	.20	.30	.27

* $p < .05$

TABLE V

PARAMETRIC CORRELATIONS OF MONTHLY ACCIDENT RATES WITH TOTAL HOURS FLOWN BY THE COMMAND IN THE SAME MONTHS OF THE YEAR

	FY75	74	73	72	71	70
AIRLANT	.01	.16	.20	-.40	-.28	.18
MARLANT	-.24	.27	.54**	.15	-.50**	.07
AIRPAC	.05	.21	-.27	-.36	-.14	.30
MARPAC	-.01	-.40	-.07	-.03	-.14	.02
CNATRA	-.59*	-.16	-.05	-.05	.23	.45
N. RESERVES	.11	-.25	.36	.16	-.06	.09
MARTC	.25	.54**	.43	-.03	.12	.28
RDTE + NASC	-.14	.08	-.32	.18	.11	.14

PARAMETRIC CORRELATIONS OF NUMBER OF MONTHLY ACCIDENTS WITH TOTAL HOURS FLOWN BY THE COMMAND IN THE SAME MONTHS

	FY75	74	73	72	71	70
AIRLANT	.15	.38	.55**	-.26	-.03	.47
MARLANT	-.07	.39	.64*	.34	-.44	.23
AIRPAC	.21	.36	.07	-.12	.06	.41
MARPAC	.08	-.30	-.02	.14	.37	.32
CNATRA	-.48	.06	.23	.21	.38	.58*
N. RESERVES	.12	.07	.39	.30	.02	.25
MARTC	.52**	.72*	.70*	.07	.26	.62*
RDTE + NASC	-.12	.23	-.26	.20	.25	.24

$* \ p < .05$ $** \ p < .10$

To examine this relationship further, Figure 4 shows the plot of number of accidents versus flight hours for the significant 4 years shown for MARTC in Table V, i.e. FY70,FY73,FY74,FY75. Of further interest is the fact that the correlation was strong for 3 years in a row---FY73,FY74,FY75 giving evidence of a strong trend. Looking at Figure 4, one sees an interesting relationship if an imaginary vertical line is drawn at 6000 hours. For months where more than 6000 hours are flown, it can be calculated that the probability of one or more accidents is .87. This is quite a contrast to those months where less than 6000 hours were flown and the probability was .33 of an accident in a given month.

Pursuing this further, student "t" tests were run comparing the values of various parameters for those accidents in months with more than 6000 hours versus the accidents in those months with less than 6000 hours. The parameters which were examined and for which data was available were: pilot age, pilot DNA, pilot total time in model in which accident occurred, pilot hours flown during last 90 days, pilot hours flown during last 90 nights, number of aircraft tours, and aircraft hours since last major inspection. Only one of these variables, pilot hours flown during last 90 days, showed any significant difference ($p<.05$) for the accidents in the months with less than 6000 hours versus greater than 6000 hours. For the months where less than 6000 hours were flown, the average pilot hours in the last 90 days was 20.2 per pilot whereas the average was 38.9 hours in the last 90 days for

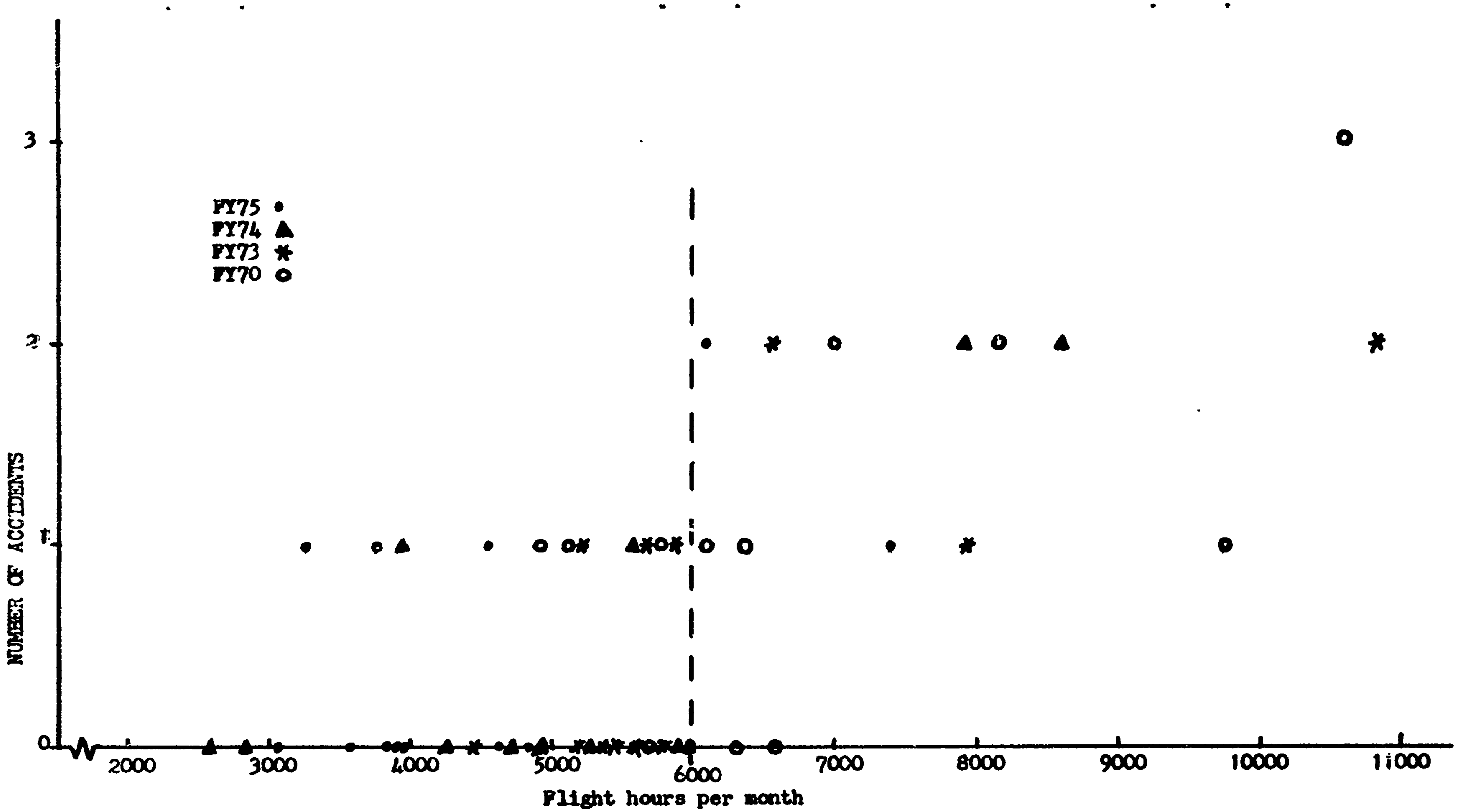


FIGURE 4. MARTC COMMAND -- TOTAL FLIGHT HOURS PER MONTH FOR THE COMMAND AND NUMBER OF ACCIDENTS IN THE MONTH FY70,73,74,75

accidents which occurred in months with more than 6000 hours. Unfortunately, data is not available to compare these data with those of pilots who didn't have accidents. However, one might hypothesize that a fatigue factor may enter here but it is difficult to know when the hours in the last 90 days were flown. If they all occurred in the last 30 of the 90 days, one might suspect fatigue much more. It is this author's understanding that hours flown in the last 30 days has begun to be collected in 1976 so could prove useful in the future. For greater or less than 6000 hour months, the distribution of the last 90 day hours is uniform in both cases with the "less than 6000 flight hour" months embedded in the left tail of the "greater than 6000 flight hour" months. In the months with less than 6000 flight hours, all accidents for which data was available, occurred with pilot hours in the last 90 days of 35 hours or less. The data are given in Appendix C.

Looking at the flight purpose codes for the MARTC accidents, no special type of operations appear to contribute more to accidents as 97.4% of them occurred in daylight visual conditions and 82.1% occurred in unit training. The others were randomly spread over a variety of reasons.

SUMMARY:

No consistent trends or monthly cyclical phenomena have appeared in this investigation so far. Many items appear to exhibit such trends but upon further analysis, none pass any statistical tests to verify their existence beyond reasonable elements of chance.

The 6000 hour break in total monthly flight hours for MARTC and the resulting probabilities of accidents below and above that mark are quite significant. However, the implications of this need to be investigated further with more data as discussed with LCDR R. Mister during his visit to the author in May 1976.

In addition to the above, the author has three more military officer students currently working on the development of regression equations to predict monthly accident rates. This is a completely different problem from the monthly or cyclical phenomena since regression equations would be very useful in predicting monthly accident rates, regardless of whether any monthly or cyclical phenomena existed.

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APPENDIX A

AVERAGE MONTHLY ACCIDENT RATES (FY70-75) BY COMMAND

	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
AIRLANT	1.57	1.02	.73	.97	.96	.75	1.04	.83	[illegible]	1.06	.87	1.24
MARLANT	1.60	.47	1.04	1.21	1.26	.74	.79	1.29	1.09	1.11	.62	1.07
AIRPAC	1.42	1.62	1.22	1.33	1.61	1.43	1.27	1.62	1.29	1.17	1.21	1.34
MARPAC	1.68	1.41	1.04	1.38	1.98	1.54	1.21	1.40	1.29	.89	1.36	1.35
CNATRA	.63	.49	.67	.34	.74	.43	.28	.54	.35	.37	.37	.36
N. RESERVES	.53	.44	.73	.51	.12	.43	.13	.60	.59	.61	.21	.80
MARTC	1.82	1.45	.31	.60	.68	1.10	1.41	1.30	1.17	1.14	1.61	1.50
RDTE + NASC	1.86	1.50	2.56	1.80	1.31	1.16	2.00	1.07	1.52	1.20	1.26	3.79

APPENDIX B

AVERAGE MONTHLY ACCIDENT RATES (FY69-74) BY AIRCRAFT TYPE

AIRCRAFT	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
A-3	1.63	3.51	1.62	2.66	.37	1.33	3.98	2.63	.79	.40	.79	2.15
A-4	2.32	2.12	1.55	1.34	1.82	1.32	1.29	2.51	1.79	1.53	1.78	1.97
A-5	4.59	2.12	4.65	2.10	2.24	1.29	7.14	3.46	6.44	3.09	1.04	2.40
A-6	1.49	1.78	1.63	1.29	1.24	1.08	4.96	1.25	4.38	1.38	.99	.20
A-7	1.85	1.40	1.97	2.34	2.29	2.07	1.49	1.52	2.57	2.40	2.52	3.35
F-4	2.73	2.68	1.85	2.90	3.46	2.12	4.35	3.16	2.84	1.58	2.36	2.50
F-8	4.30	6.15	5.23	4.46	3.24	4.89	4.70	4.58	5.78	4.73	3.40	3.34
Helos	1.43	1.33	1.23	1.41	1.53	1.67	1.70	1.76	1.33	1.43	1.35	1.46

APPENDIX C

DATA AVAILABLE FOR MARTC COMMAND SHOWING PILOT HOURS FLOWN IN LAST 90 DAYS FOR THOSE ACCIDENTS WHICH OCCURRED IN MONTHS WITH LESS THAN 6000 FLIGHT HOURS VS MONTHS WITH MORE THAN 6000 FLIGHT HOURS

PILOT HOURS FLOWN IN LAST 90 DAYS

Less than 6000 hours in the month	More than 6000 hours in the month
5	45
5	25
35	35
25	55
26	15
31	15
29	15
5	25
21	45
	45
	66
	50
	22
	17
	88
	72
	33
	32

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