NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

AVAILABILITY OF AIRCRAFT SUBJECT TO
IMPERFECT PREVENTIVE MAINTENANCE

by

Michael J. Bond

September, 1990

Thesis Advisor: Michael P. Bailey

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b. OFFICE SYMBOL OR	7a. NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c. ADDRESS (City, State, and ZIP Code) Monterey, CA 93943-5000	7b. ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Including Security Classification)
Availability of Aircraft Subject to Imperfect Preventive Maintenance

12 PERSONAL AUTHOR(S)
BOND, Michael J.

13 TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. Page Count
Master's Thesis	FROM TO	1990, September	90

16. SUPPLEMENTAL NOTATION
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Availability, Imperfect Preventive Maintenance

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

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20 DISTRIBUTION/AVAILABILTIY OF ABSTRACT [X] UNCLASSIFIED/UNLIMITED [ ] SAME AS RPT. [ ] DTIC	1a. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Michael P. Bailey	22b. TELEPHONE (Include Area Code) (408)646-2085 22c. OFFICE SYMBOL OR/Ba

DD Form 1473, JUN 86
Previous editions are obselete.
S/N 0102-LF-014-6603
SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

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Availability of Aircraft
Subject to
Imperfect Preventive Maintenance

by

Michael J. Bond
Lieutenant Commander, United States Navy
B.E., University of Mississippi, 1979

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1990

Author: Michael J. Bond

Approved by: M. P. Bailey, Thesis Advisor

P. Bloch, Second Reader

Peter Purdue, Chairman
Department of Operations Research

ABSTRACT

This thesis studies the impact that imperfect preventive maintenance has on the availability of aircraft and, as a result, the decrease in effectiveness. We further consider the practicality of using an imperfect preventive maintenance model for determining preventive maintenance schedules. Simulation was used to recreate the operational environment in order to study the effects that levels of imperfect preventive maintenance have on the aircraft effectiveness during execution of an actual fleet tactic.

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The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I. INTRODUCTION

This thesis will study the impact that imperfect preventive maintenance has on the availability of carrier based aircraft, the potential of using an imperfect preventive maintenance model for determining an improved preventive maintenance policy, and the strength of simulating the operating environment when determining scheduled preventive maintenance policy. The aircraft used in this thesis is the E-2C airborne radar surveillance platform.

The E-2C is the primary platform for providing advanced, long range early warning radar coverage for a carrier battle group (CVBG). Its ability to provide this support increases the readiness state of the CVBG and the reaction time to a hostile or unknown surface or airborne threat. To provide this support the aircraft must be maintained in a mission capable state. This is accomplished in two ways. One, by increasing the reliability of the systems which comprise the E-2C aircraft. Or, by maintaining the present systems thereby increasing the availability of the aircraft and subsequently expanding the amount of radar coverage provided over time.

The E-2C aircraft, as a functioning unit, exists in one of three states; fully mission capable (FMC), partially mission capable (PMC), or non-mission capable (NMC). The aircraft is made up of several surveillance, communication and flight systems, all or part of which are necessary to perform the assigned mission. If all required systems are operating normally the aircraft is FMC. If one or more systems fail or malfunction yet the crew is capable of completing the mission in this degraded state then aircraft is said to PMC. If one or more systems fail or malfunction and crews' ability to perform the mission is impacted to such a degree that they can no longer continue and must abort the flight and return to base, the aircraft is then declared to be NMC. The systems and what status an aircraft in the simulation will assume is defined in Table 1.

TABLE 1. SYSTEM DATA

WUC	System Description	MTTF	MTTR	Phase	Failure Status
11	Airframe	91.0	11.12	A,B	NMC
12	Fuselage	2257.0	7.79	A,B	NMC
13	Landing Gear	58.0	5.65	A,B	NMC
14	Flight Control	104.0	11.01	B	NMC
22	Turbo Shaft Engines	61.0	5.44	A,B	NMC
29	Power Plant	61.0	6.97	A,B	NMC
32	Hydraulic Propellor	105.0	6.72	A,B	NMC
41	Air Cond/Pressurization	164.0	7.72	A,B	NMC
42	Electrical System	46.0	3.09		NMC
44	Lighting	393.0	2.99		PMC
45	Hyd. Pnu. Power	196.0	7.66	A,B	NMC
46	Fuel	120.0	9.29	A	NMC
47	Oxygen System	291.0	4.81		PMC
49	Misc. Utility	645.0	5.02		PMC
51	Instrument System	80.0	2.42		NMC
56	Flight Reference	50.0	2.6		NMC
57	Int. Guidance/Flt	311.0	3.86		PMC
58	Internal Flt. Test	1806.0	2.44		PMC
61	HF Communications	322.0	2.14		PMC
62	VHF Communications	1290.0	3.32		FMC
63	UHF Communications	119.0	1.37		PMC
64	ICS	1806.0	1.37		PMC
65	IFF System	4514.0	1.66		NMC
71	Radio Navigation	903.0	2.4		PMC
72	Radar Navigation	2257.0	2.24		NMC
73	Inertial Navigation	127.0	2.14		NMC
91	Emergency Equipment	3009.0	4.33		NMC

Time of completing Phase "A"/"B" preventive maintenance - 6.5/9.5 hours

Since all systems of the E-2C are subject to failure and repair consequently they all must undergo maintenance. There are two types of maintenance that the systems are subject to during their operational lifetime, unscheduled and scheduled. Unscheduled maintenance, or repair, is performed when a system has failed placing the aircraft in an NMC or PMC status. Maintenance action is then undertaken to return the aircraft to a fully mission capable status. Scheduled maintenance, or preventive maintenance, is performed at specified intervals of time for particular systems. In the case of the E-2C, this will occur after T hours of engine run time. At the present time, 200 hours is the designated interval, T. The aircraft then enters what is called a "phased" maintenance period during which selected components and/or systems are inspected, serviced, or overhauled. By performing this preventive maintenance the system is kept in a "like new" condition and prevents failures. The interval between phased maintenance actions is determined by the failure rate of the system and the reliability standards. The time allotted for the performance of this preventive maintenance task may also be predetermined by taking into account the complexity of the system, the difficulty of inspecting, servicing, or overhauling the system and the average skill level of the maintenance technician. [Ref. 1:pp 165-167]

Perfect preventive maintenance is accomplished when the aircraft enters a preventive maintenance period and all prefailure conditions are discovered and corrected. Imperfect preventive maintenance occurs when an aircraft enters the preventive maintenance period and, due to one or more of the causes listed below, prefailure conditions are not discovered and the system maintains the same prefailure state as before preventive maintenance. There are several reasons why preventive maintenance might be performed imperfectly:

1. Poor maintenance techniques are used by the maintenance technician performing the preventive maintenance.

2 Lack of training or skill on the part of the technician.

3. External conditions are less than ideal for the performance of the preventive maintenance (eg., inclement weather, poor lighting, etc.).

4. Failed systems are repaired with faulty components.

5. Additional damage is done during the accomplishment of preventive maintenance. [Ref. 1:pp. 165-167]

Thus, assuming that preventive maintenance is, to some degree, imperfect, how strong an effect will this have on the availability and effectiveness of the aircraft and what would be a better interval between preventive maintenance periods?

II. METHODOLOGY

A. FLIGHT OPERATIONS

In order to fully appreciate the impact that imperfect preventive maintenance would have on the aircraft it was necessary to place the E-2C in an operationally stressful environment. Carrier operations conducted in support of a sustained long range anti-aircraft warfare (LRAAW) scenario was proposed to provide those conditions. The scenario chosen is the current long range anti-aircraft warfare tactic and calls for continuous radar coverage at an extended distance from the aircraft carrier. For maximum coverage a single station had to be maintained with on station relief, as one E-2C reached the end of its cycle time and departed, another E-2C entered the station. The time spent on station plus the time spent in transit to and from the ship to the station required the E-2C to be airborne for a total of four and a half hours for this mission. The maximum airborne time of the E-2C is five and a half hours since it is not capable of refueling while airborne. The on station relief requirement coupled with the inability to refuel dictate that a minimum of two E-2C's be in FMC or PMC status at all times. This will allow for a third E-2C to undergo preventive and/or unscheduled maintenance. E-2C squadrons have four aircraft attached but the fourth E-2C is usually rotated to the hangar deck and undergoes an extensive (four to six weeks) corrosion inspection and restoration due to the corrosive effects of the at sea environment.

B. IMPERFECT PREVENTIVE MAINTENANCE MODEL

1. Description

The model used to describe the state of each aircraft in the simulation is represented in Figure 1 below:

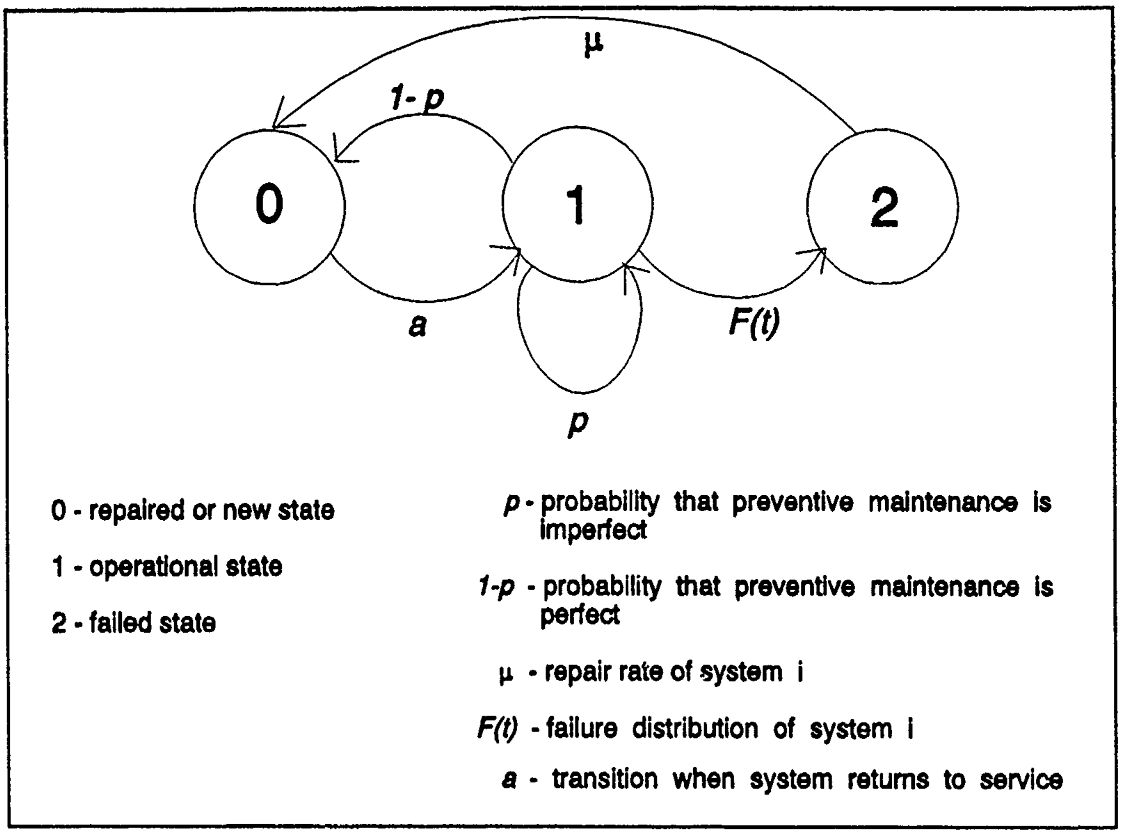


Figure 1. Imperfect PM Model

The model represents the three states that a system of the E-2C will transit during its operation. State 0, the initial state, represents the system in a new condition or after it has undergone repair or perfect preventive maintenance. It remains in this state until the system is placed back in operation. State 1 is the normal operating state, here system i fails at a rate determined by its distribution $F(t)$

or is preventively maintained at time T and returns to state 0. If it fails prior to performance of preventive maintenance it enters state 2, otherwise it undergoes preventive maintenance and either remains in state 1 with probability p or returns to state 0 with probability $1-p$. State 2 is the failure state. In this state the system has failed and is subject only to repair and is returned to state 0. This simple model was embedded in a system simulation which reflected the dynamics of the LRAAW tactic, preventive maintenance, and contingencies upon return of an NMC or PMC aircraft.

2. Model Assumptions

The following assumptions pertain to the imperfect preventive maintenance model used in the simulation. [Ref. 2:p 331]

1. The system undergoes repair at failure or is maintained preventively at intervals of length T, whichever occurs first.
2. After repair the system is as good as new.
3. The unit after preventive maintenance has the same time of failure as it had before preventive maintenance with probability p ($0 \leq p < 1$), and is as good as new with probability $1-p$.

C. THE SIMULATION

As was stated above in Section A, simulation was used to gather the necessary data for analysis. The LRAAW stationing of the E-2C would provide the basis for determining if flight operations would have an impact on the preventive maintenance policy and, combined with the probability of imperfect preventive maintenance, p, ascertain an improved method of preventive maintenance scheduling. A primary motivation for simulating flight operations and studying its impact on preventive maintenance is due to the goal of maintaining 100 percent radar coverage. During carrier operations an aircraft might suffer failures which place the aircraft in a PMC status rather than a NMC status but it could continue its mission. In addition, preventive maintenance may be delayed until a more advantageous time, ie, until more than one aircraft is in a FMC or PMC status, and then be taken "off line" and enter phased maintenance.

The simulation puts the aircraft through the maintenance and flight cycles repeatively in order that an aircraft may enter the preventive maintenance period several times. The phases of the operating and maintenance cycles are represented by five subroutines in the simulation (see Appendix G).

1. Prelaunch

During the pre-launch portion of the flight an available aircraft is readied for launch. This entails a walk-around inspection of the aircraft by the flight crew, engine startup and system performance checks. The purpose of the inspection and performance checks is to identify failures which would preclude performing the mission. If failures are found, the launch is aborted and an alert launch must be scheduled to fill the station with little lapse in radar coverage. An alert aircraft is the first aircraft which becomes available for launch. This will include aircraft which land in an FMC or PMC status and aircraft coming out of a repair or preventive maintenance.

2. Launch

The launch portion encompasses the portion of the flight profile from launch until the end of on station time when the aircraft departs the station. A failure during the launch segment has a more degrading effect on radar coverage than during the warmup portion. During the transit to the station the aircraft presently on station is preparing to depart leaving the station empty for its relief. If the relieving aircraft fails, a lapse in coverage exists until a third aircraft is launched. If this third aircraft is NMC and requires repair or is undergoing preventive maintenance then the returning aircraft must be "hot spun" back to station. During a "hot spin", the aircrafts engines are left running, it is refueled and a fresh crew replaces the crew onboard. The elapsed time for this evolution, from leaving station until launch and return to station, takes from three and a half to four and a half hours during which there is no radar coverage.

3. RTB

RTB, or *R*eturn *To* *B*ase, is the final airborne portion of the flight profile. During this segment of the flight the aircraft has left the station and is handing over the coverage duties to its relief. While still able to provide a radar picture to the CVBG until it lands, it provides less long range coverage as it closes the carrier to land. A failure rendering the departing aircraft NMC during the RTB segment does not affect the current radar coverage to as great a degree as a failure during the launch segment since a relieving aircraft is transiting to station. However, if the relieving aircraft fails during the warmup portion or while in transit to station in the launch portion, a critical gap in coverage will occur until a third aircraft is made available or either of the failed aircraft are repaired.

4. Recovery

This portion considers landing and maintenance of the aircraft. A recovering aircraft is either FMC, PMC or NMC. If NMC it undergoes repair. If the aircraft returns in an FMC or PMC status one of three actions will occur:

1. If the station is empty (no relieving aircraft in transit) then the returning aircraft is hot spun and launched back to station.
2. If an aircraft is not available as a scheduled relief for the aircraft in transit to station then the returning aircraft undergoes turnaround maintenance.
3. If all relief requirements are met then the returning aircraft undergoes repair if PMC and/or phase maintenance if T hours of engine run time have lapsed since last preventive maintenance cycle. It is during this phase maintenance period that the imperfect preventive maintenance model described in Section B is used.

During turnaround maintenance the aircraft is refueled and the aircrafts' systems are inspected for any visible damage or failure.

5. RTS

RTS, or *R*eturn *To* *S*ervice, is the final portion in the maintenance cycle. Aircraft leaving preventive maintenance and/or repair must undergo turnaround maintenance after which they are made available for immediate (alert) launch or else await a scheduled launch time as a relief.

D. MAINTENANCE DATA

The current preventive maintenance schedule calls for the E-2C to enter phased maintenance every 200 hours of engine run time. At this time all systems subject to preventive maintenance undergo either phase A or phase B preventive maintenance. The two phased maintenance cycles, A and B, are independent preventive maintenance periods. Both are accomplished after 200 hours of accumulated engine time and it requires 6.5 hours and 9.5 hours, respectively, to accomplish the preventive maintenance. Therefore, the preventive maintenance cycles are staggered so that they do not overlap and interfere with the accomplishment of the other phase. Table 1 lists the systems inspected and serviced during phase A and B preventive maintenance, respectively .

In order to make the simulation as realistic as possible, it was decided to use actual failure and repair times as reported by E-2C squadrons operating off carriers during a deployment period. The data was provided by records maintained at the Naval Air Development Center, Warminster, Pennsylvania. From the collected data, five E-2C squadrons where selected. For each squadron a cruise period was selected and from this period the Maintenance Action Forms (MAF's) were inspected for the failure and repair times. The MAF documents record the aircraft bureau number, repair and maintenance activity, the system affected, the type of failure or phase maintenance action, total engine run time, when the failure was discovered,i.e., during flight, before flight (the simulation also allows for a failure to be discovered inflight, after flight, etc.), what repair action was undertaken and the time that the aircraft spent in maintenance. From the five E-2C squadrons chosen 27,344 maintenance level one (squadron level maintenance) MAF's were investigated which represented 9,028 total flight hours. Of these 27,344 MAF's, 16,043 were submitted for performance of unscheduled maintenance and had a "when discovered" code indicating the failure was found during either the warmup, launch, or RTB portion of the flight. From analyses of these maintenance action forms a time to failure and time of repair were derived for each system. Limitations on the data provided constrained failure statistics to a system as a unit as listed in Table 1 and not as individual components which comprise the system. Due to this restriction distributions were not available. Therefore is was decided to approximate the failure distributions to fit the system. For those systems which where not subjected to preventive maintenance (electrical and avionic systems) an exponential distribution was used and the failure rate computed from the data was input to the random number generator LLRANDOM II [Ref. 3] for a time to failure. For those systems which underwent preventive maintenance (flight control surfaces, engines, etc.) a Gamma distribution was used with the computed failure rate and a shape parameter to produce a time to failure with increasing failure rate (IFR). The author felt that his fleet experience supported these choices.

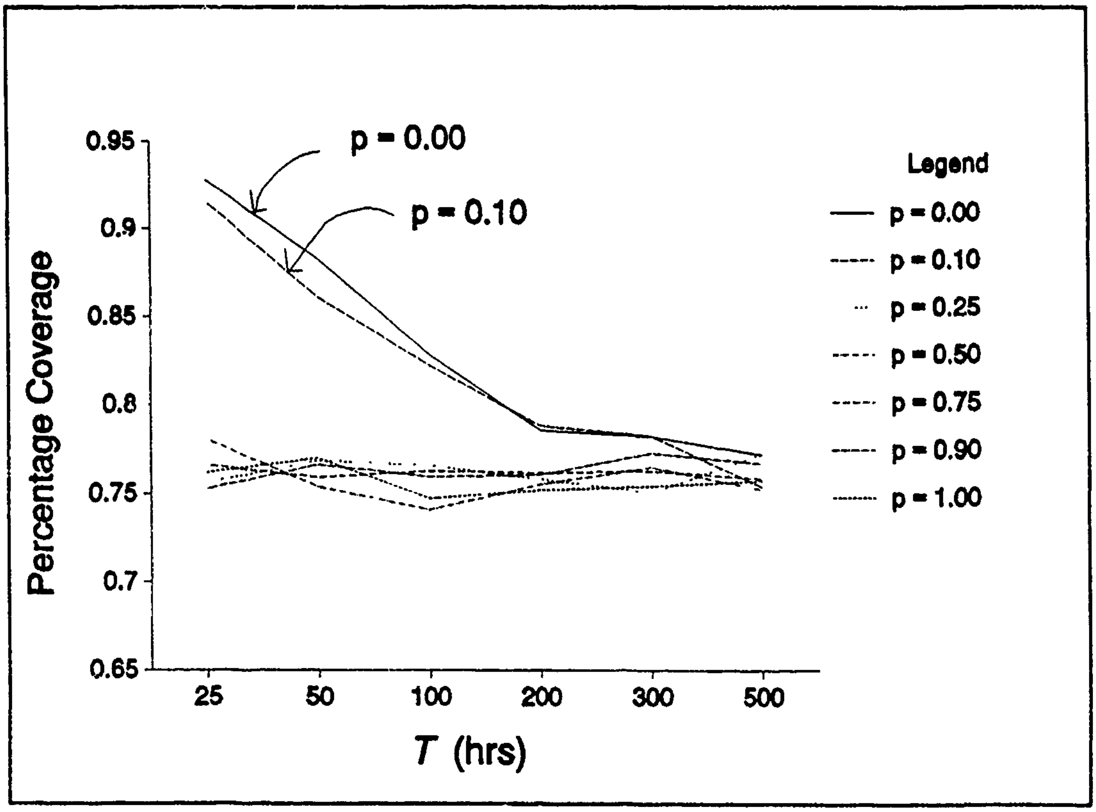
III. ANALYSIS

The simulation reached steady state at 60 hours and then was run for an additional time of 6000 hours for each preventive maintenance interval. Selected phased maintenance intervals varied from 25 to 500 hours. To assess the overall effects of the imperfect preventive maintenance program the amount of radar coverage provided during the 6000 hours was divided into 1000 periods of six hours each. The amount of coverage provided during this period was then calculated as a percentage and then averaged over the maximum time period to find the mean coverage. These values were computed for several levels of p (the probability of imperfect preventive maintenance), 0.00, 0.10, 0.25, 0.50, 0.75, 0.90 and 1.00. This would cover maintenance accomplishment from perfect (p = 0.00) to imperfect (p = 1.00). The results of each run are reported in Table 2.

TABLE 2. COVERAGE PRECENTAGE

			Interval Between Preventive Maintenance Checks (Hrs)					
			25	50	100	200	300	500
p	0.00	%	.9277	.8829	.8284	.7858	.7822	.7720
		std dev	.1553	.1750	.1707	.1707	.1662	.1594
	0.10	%	.9150	.8609	.8222	.7883	.7827	.7540
		std dev	.1623	.1623	.1608	.1631	.1658	.1643
	0.25	%	.7564	.7687	.7662	.7583	.7505	.7724
		std dev	.1631	.1642	.1614	.1647	.1632	.1588
	0.50	%	.7804	.7537	.7409	.7552	.7650	.7524
		std dev	.1698	.1610	.1593	.1590	.1626	.1637
	0.75	%	.7660	.7591	.7629	.7616	.7629	.7568
		std dev	.1604	.1598	.1620	.1629	.1572	.1580
	0.90	%	.7529	.7665	.7595	.7607	.7729	.7672
		std dev	.1580	.1594	.1569	.1620	.1618	.1624
	1.00	%	.7621	.7699	.7474	.7521	.7541	.7576
		std dev	.1610	.1616	.1612	.1537	.1528	.1500

Since periods of coverage were not independent, batch means of the coverage were computed for each run and the variance computed from these means. Coverage provided was then plotted against all intervals between preventive maintenance periods and p values and is presented in Graph 1. For each preventive maintenance interval individual values of coverage for 100 time periods were plotted to study the variance in coverage and length of periods of little or no coverage. For these graphs, the values of $p = 0.10$, 0.50 and 0.90 were plotted against $p = 0.00$ to better visualize the coverage picture.



Graph 1. T .vs. Percentage Coverage

Analysis was first concentrated on the impact that imperfect preventive maintenance would have on the mean radar coverage. From Table 2 and Graph 1 it may be seen that for short preventive maintenance cycles, 25, 50 and 100 hours, the coverage decreases as p increases until the probability of imperfect preventive maintenance reaches 0.25. After this value of p is reached coverage does not differ appreciably and greater values have no noticeable effect. As the interval between preventive maintenance increases to 200, 300 and 500 hours, it may be seen that p has no appreciable affect at any value. Next, investigation of Graphs 2 thru 37 in Appendices A thru F was conducted to evaluate the variance in coverage provided from time period to time period.

At an interval of 25 hours between preventive maintenance actions, Graph 2 of Appendix A shows little variance in coverage at $p = 0.00$. Coverage is maintained at a consistent level and intermittently drops below 80 percent coverage during any one time period. At values of p larger than 0.00, Graphs 3, 4, 5, 6 and 7 there is a greater variability in levels of coverage obtained in a time period and as p increases above 0.50 gaps in coverage become apparent as aircraft fail and replacements are not available.

At a 50 hour interval between preventive maintenance actions,as seen in Appendix B, the effect of a less than optimum preventive maintenance interval becomes apparent. At $p = 0.00$ (perfect preventive maintenance) there are time periods of less than 50 percent coverage at approximately evenly spaced intervals. At less than perfect preventive maintenance, $p = 0.10$ and greater, this same effect is observed until p exceeds 0.50. At this value and greater the failure rate overcomes any positive effects of preventive maintenance and coverage fluctuates drastically from periods of high coverage to periods of little or no coverage.

At a 100 hour interval (Appendix C) it is again apparent that there is an effect induced by the amount of time between preventive maintenance actions. It is also apparent, even at $p = 0.00$ and 0.10, that there is a greater variability of coverage provided from period to period and fewer periods of 100 percent coverage and increased number of periods with less than 80 percent coverage. As p increases to 0.25 and beyond the coverage becomes more erratic and vacillates between periods of low (less than 60 percent) coverage to periods of moderate coverage (70 to 80 percent).

At intervals of 200 hours or greater (Appendices D, E, and F) between preventive maintenance actions consistent high or moderate coverage is no longer attainable and though coverage in some periods reaches 100 percent this level is not continued and drops during subsequent periods to little or no coverage. At intervals of 300 and 500 hours it is seen that there is virtually no difference in coverage over all values of p.

Periods of highly variable or moderate (70 percent or less) coverage are unsatisfactory when conducting long range surveillance operations. With the E-2C platform providing the primary means of detecting, tracking and reporting of unknown air contacts these gaps in coverage that resulted from the simulation "blind" the CVBG commander and allow for undetected aircraft to close the formation.

IV. CONCLUSIONS

This thesis studies the impact that imperfect preventive maintenance has on the availability of aircraft and as a result the decrease in effectiveness. It further looks at the feasibility of using an imperfect preventive maintenance model for determining an improved preventive maintenance schedule and the use of simulation as a driver for the model. For those systems that are subject to preventive maintenance, the model assumes that maintenance is performed imperfectly with some probability *p* and perfectly with probability *1-p*. Various levels of *p* were studied at several intervals *T* between successive preventive maintenance actions.

The following conclusions are drawn from the results of the study:

1. There is a level of *p* such that above this value preventive maintenance is ineffective and the failure rate of the system overwhelms any advantage of preventive maintenance.

2. As used in the model, there is a time interval *T*, the time between preventive maintenance checks, above which preventive maintenance is not advantageous. Availability of the aircraft and radar coverage does not change for any value of *p*.

3. The use of simulation for estimating the impact of imperfect preventive maintenance on aircraft systems in an operating environment is practical and should be investigated for use in determining optimal preventive maintenance schedules.

V. RECOMMENDATIONS

As new aircraft enter the fleet to replace the present systems, these aircraft will have increased capabilities and longer lifetimes. Along with these better capabilities will be more complex systems that will entail greater and possibly different maintenance requirements. As the system changes, the maintenance technicians' knowledge must grow to the level of the system. Therefore the following recommendations are made:

1. Based upon the output of the simulation and the possible causes of imperfect preventive maintenance listed in Chapter I, a model of imperfect preventive maintenance should be investigated for use in determining optimal preventive maintenance schedules for present and future carrier based aircraft.

2. That the training of the maintenance technician concentrate as much on proper preventive maintenance techniques as it does on repair. That such training include what a prefailure condition looks like and other indicators necessitating repair or replacement of the system prior to failure.

3. That the intensity of carrier operations and environmental conditions under which preventive maintenance is performed be considered as factors in models used to determine optimal preventive maintenance schedules.

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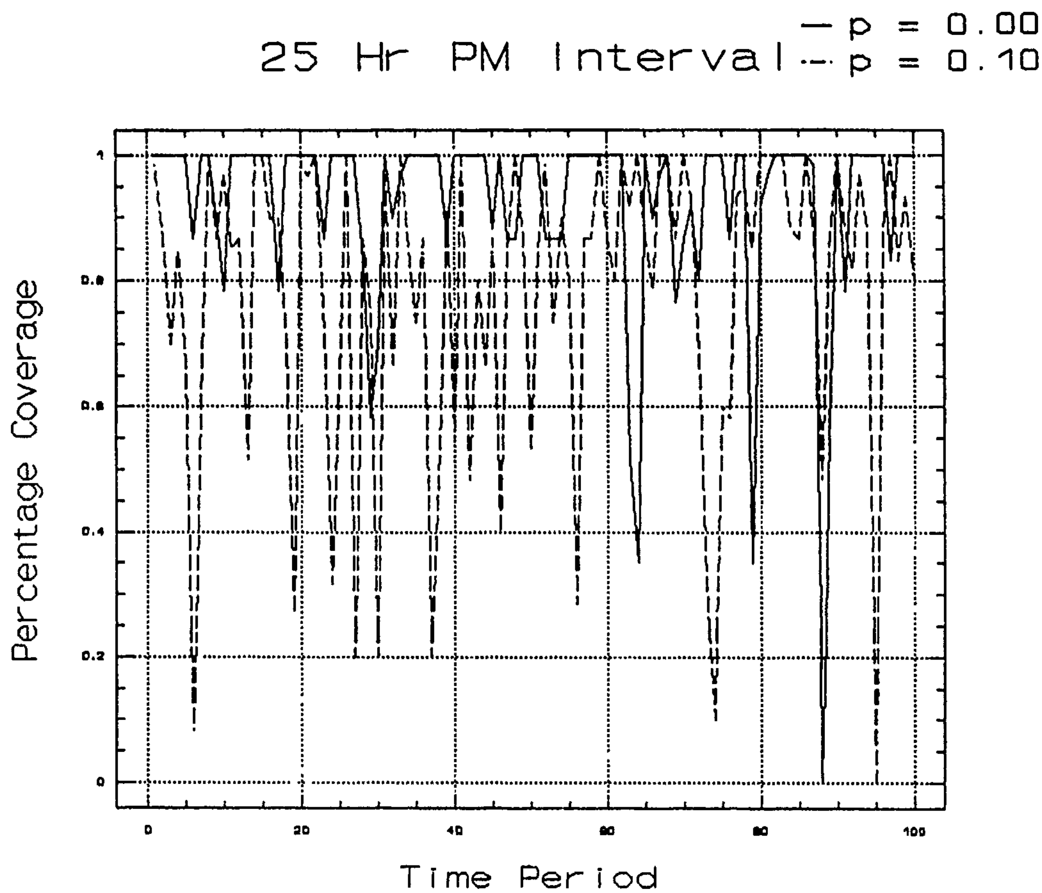
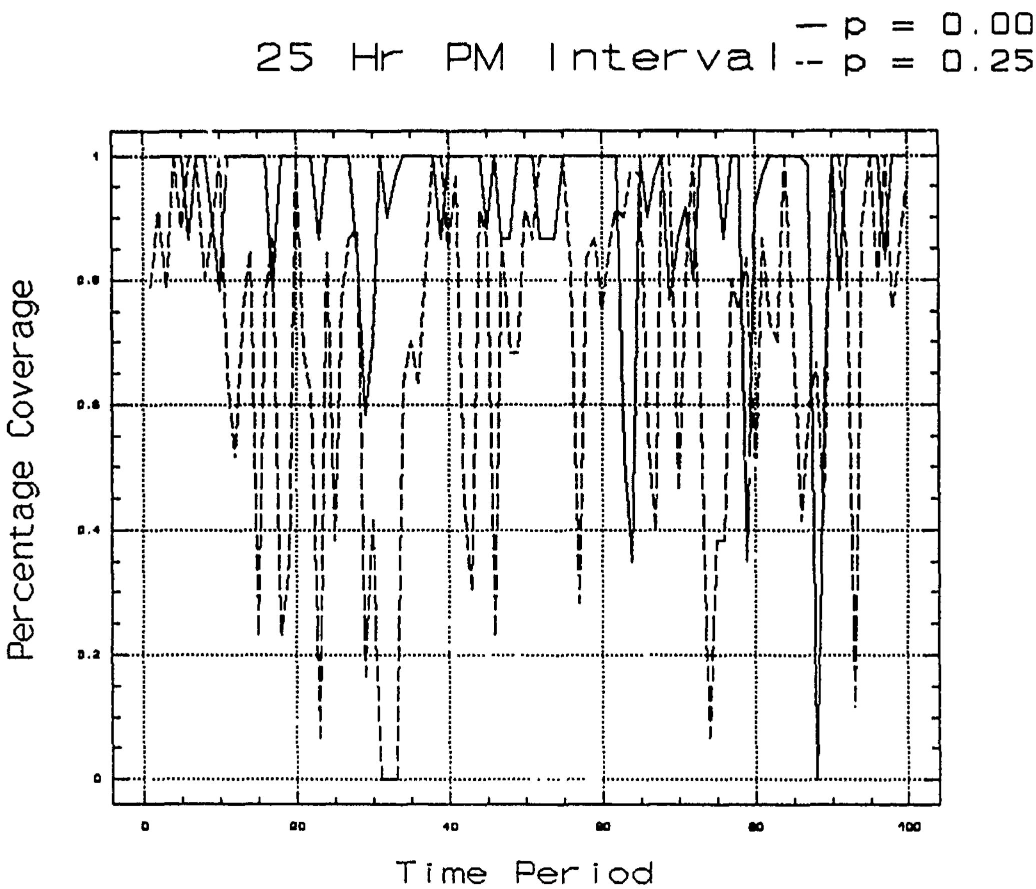
4. Bailey, M. P., Naval Postgraduate School, Department of Operations Research, 1990.

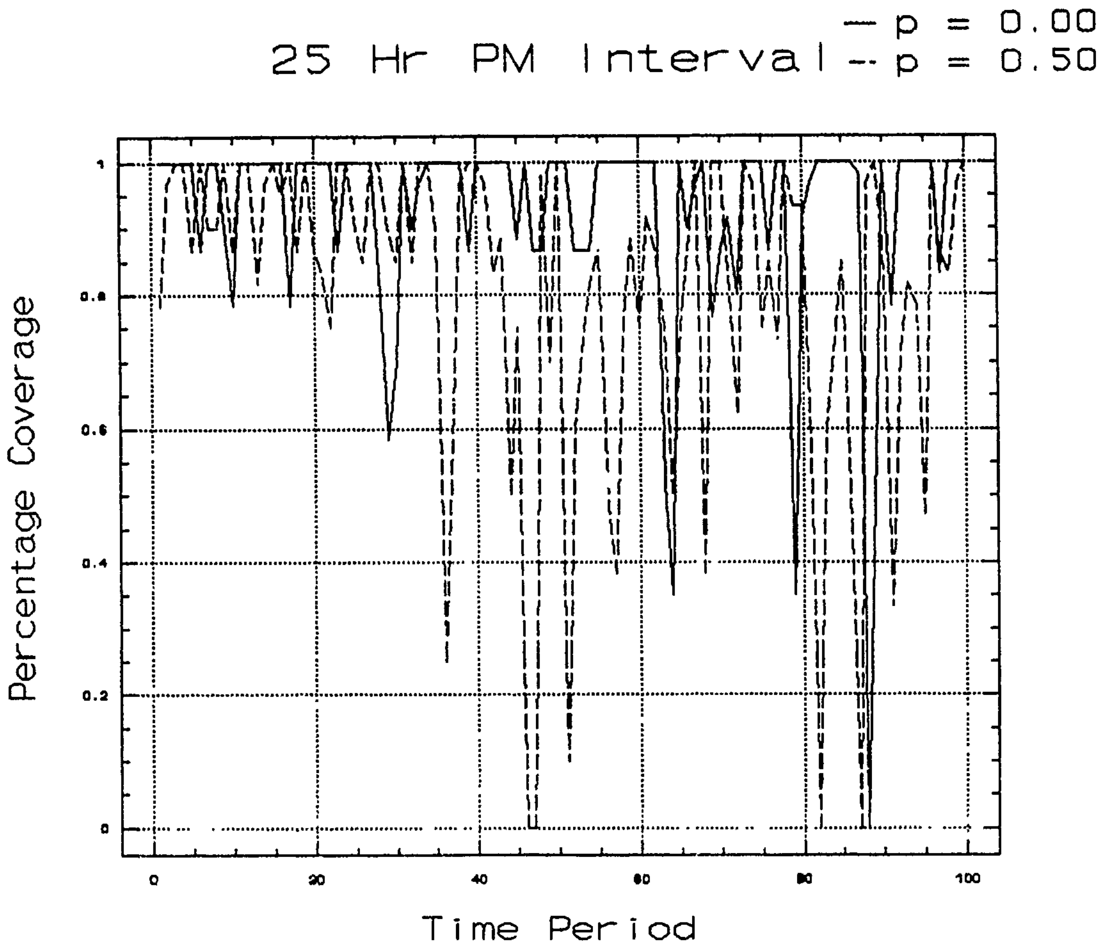
APPENDIX A. T = 25 HOURS



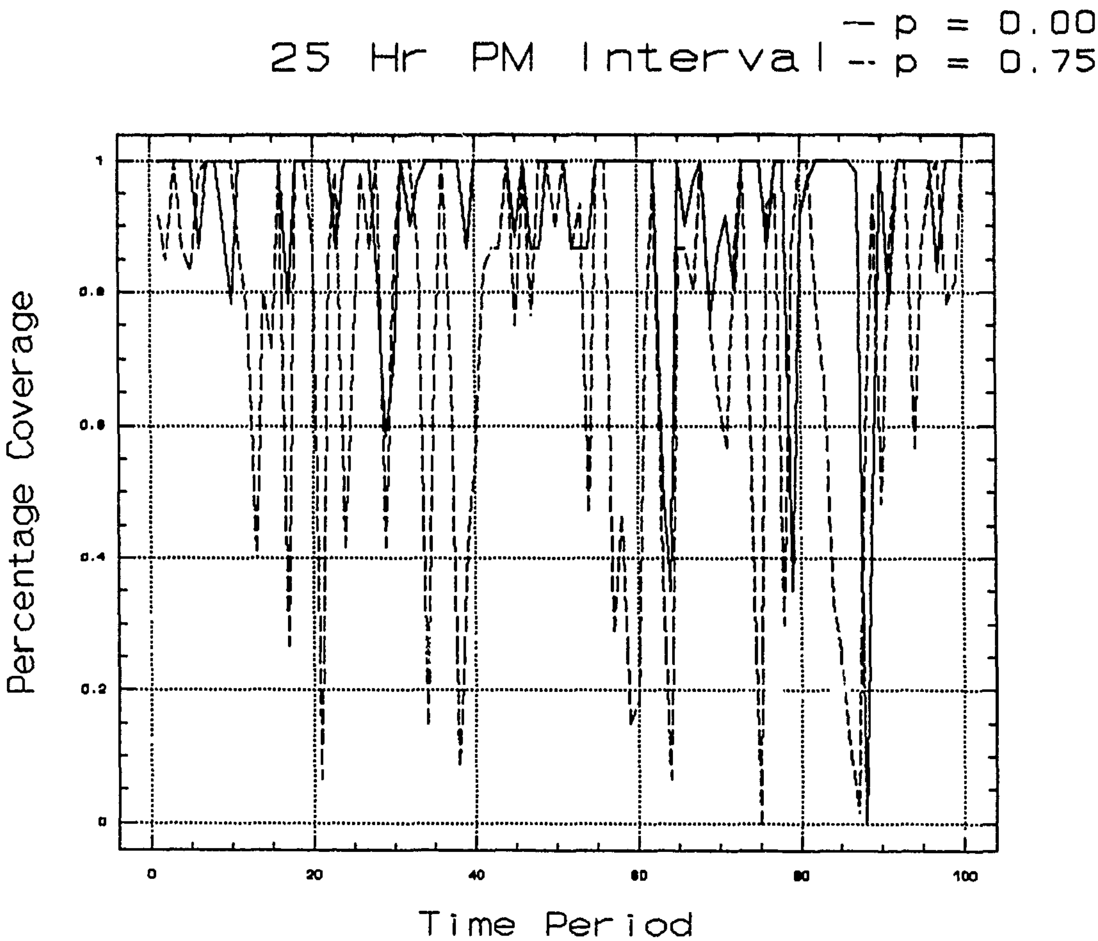
Graph 2. (P=0.00 .vs. P=0.10) : 25 Hr



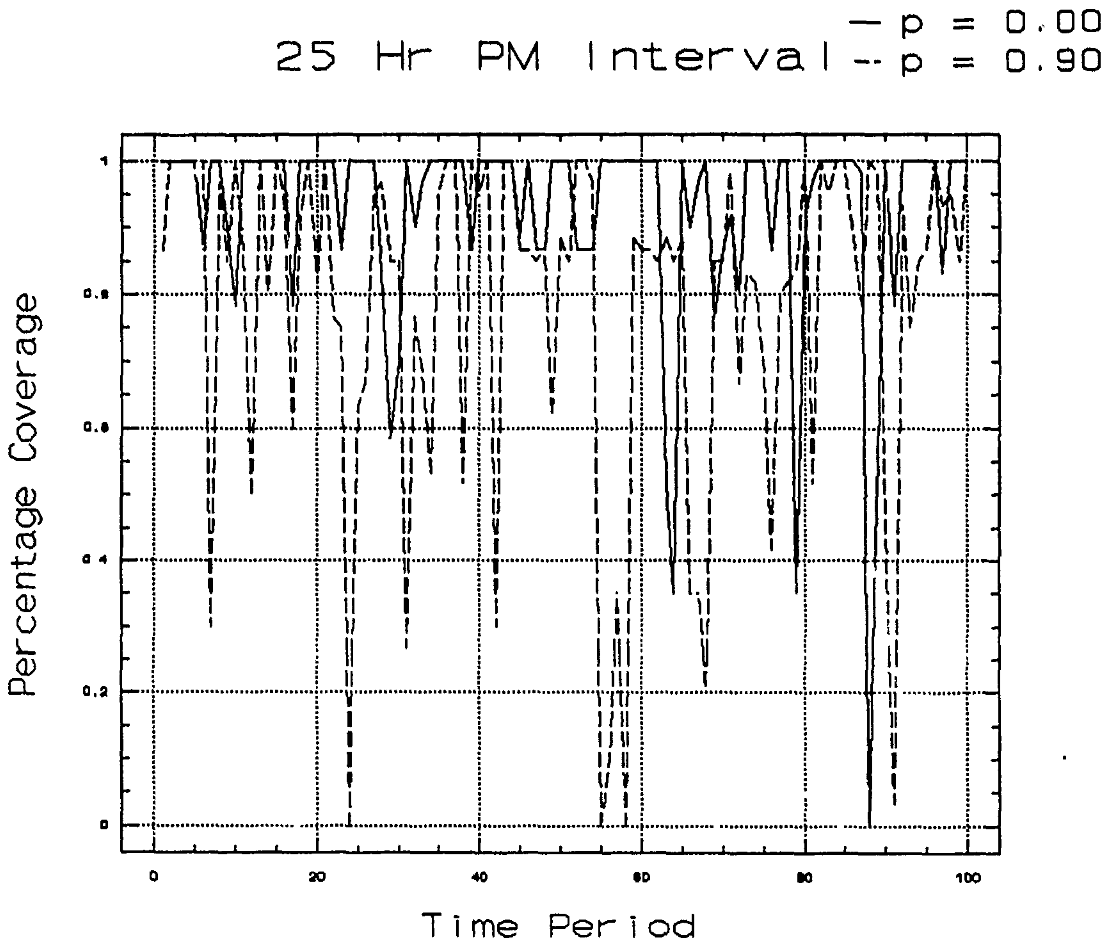
Graph 3. (P=0.00 .vs. P=0.25) : 25 Hr



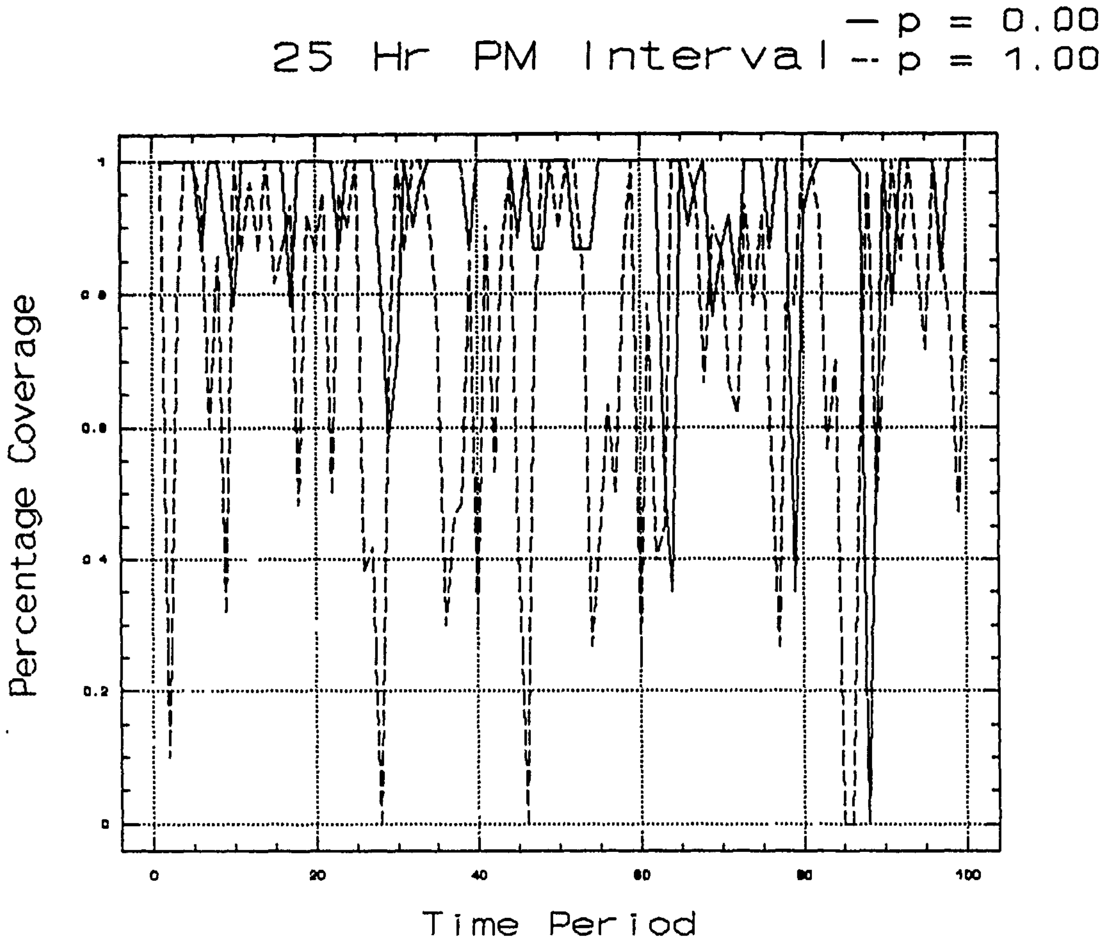
Graph 4. (P=0.00 .vs. P=0.50) : 25 Hr



Graph 5. (P=0.00 .vs. P=0.75) : 25 Hr

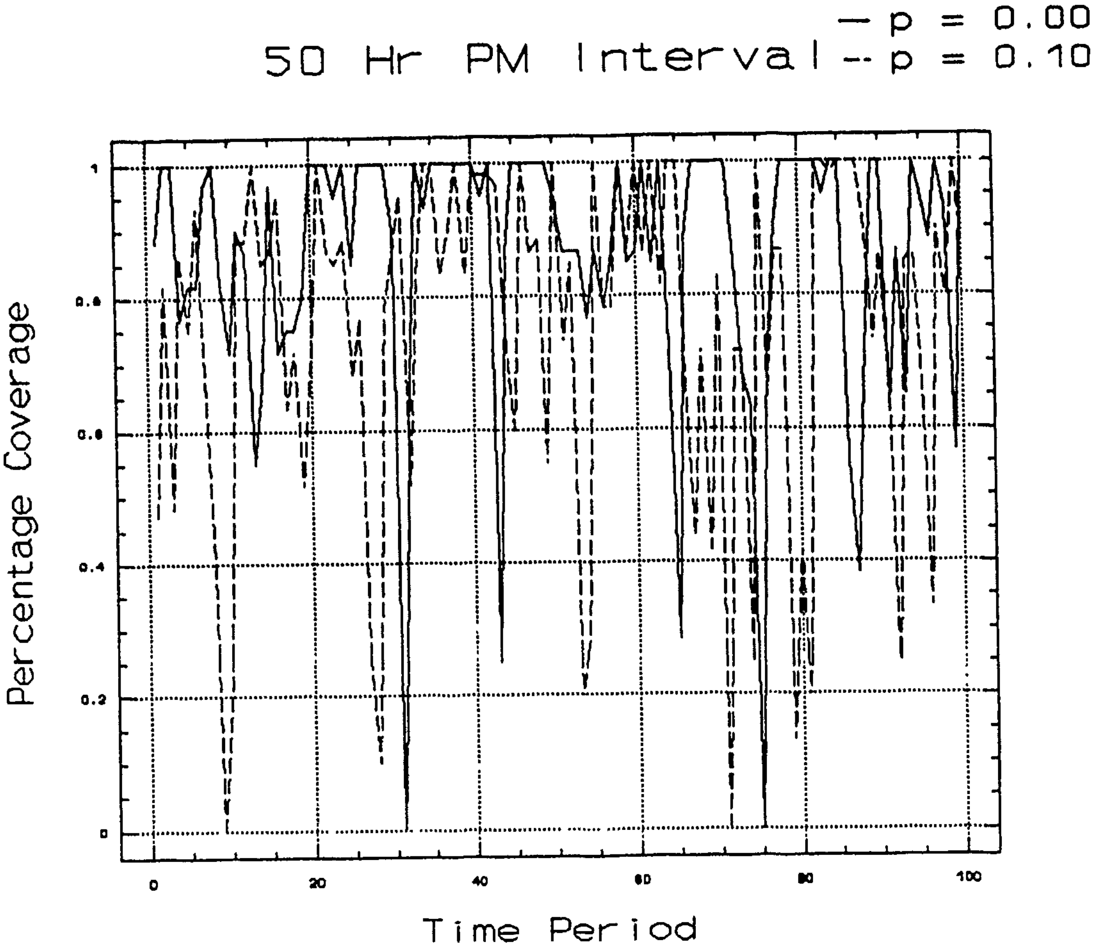


Graph 6. (P=0.00 .vs. P=0.90) : 25 Hr

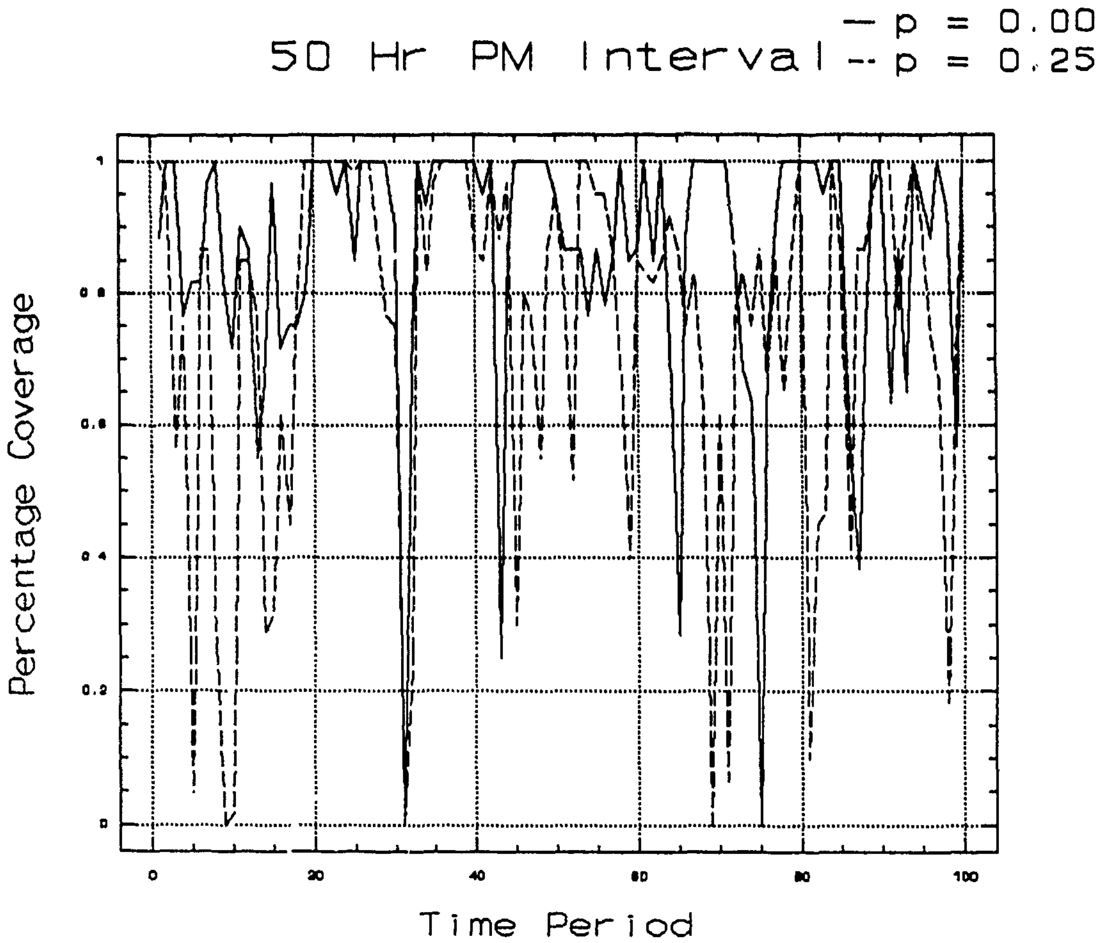


Graph 7. (P=0.00 .vs. P=1.00) : 25 Hr

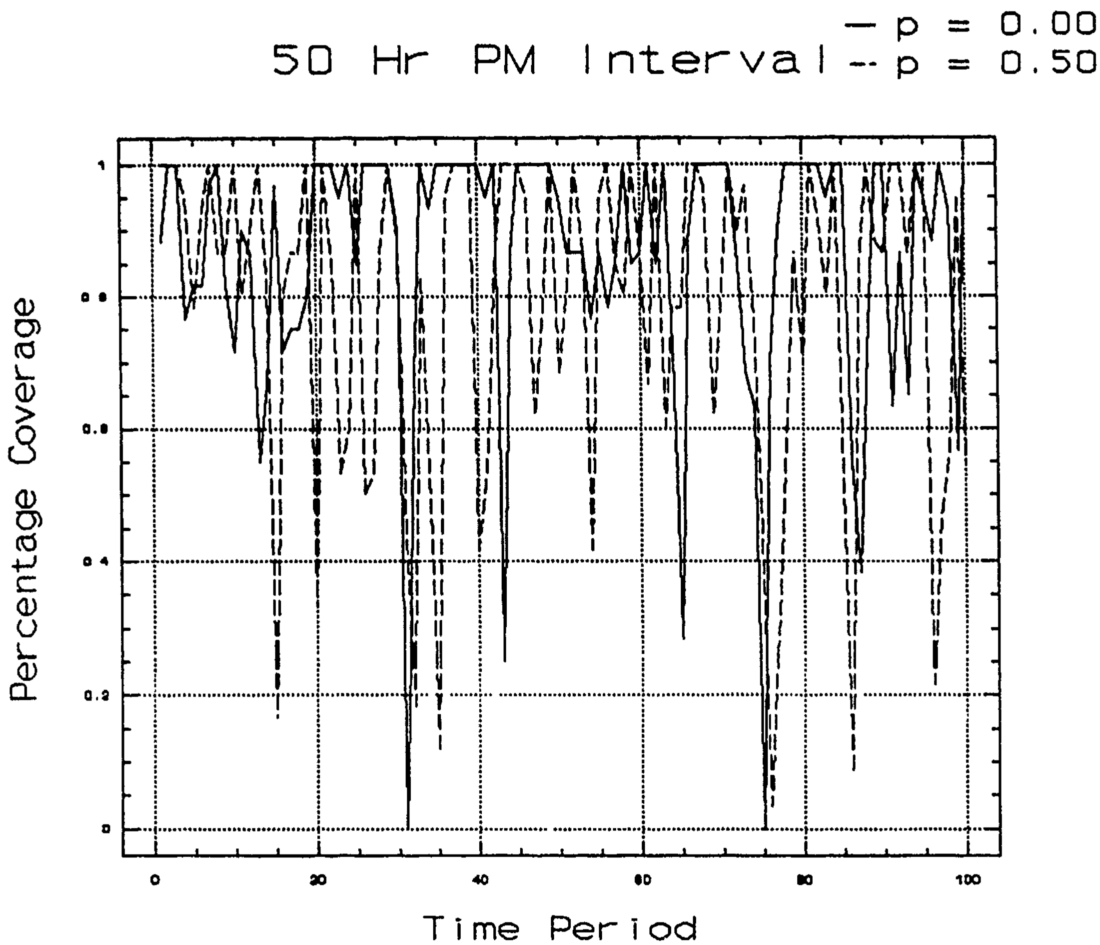
APPENDIX B. T = 50 HOURS



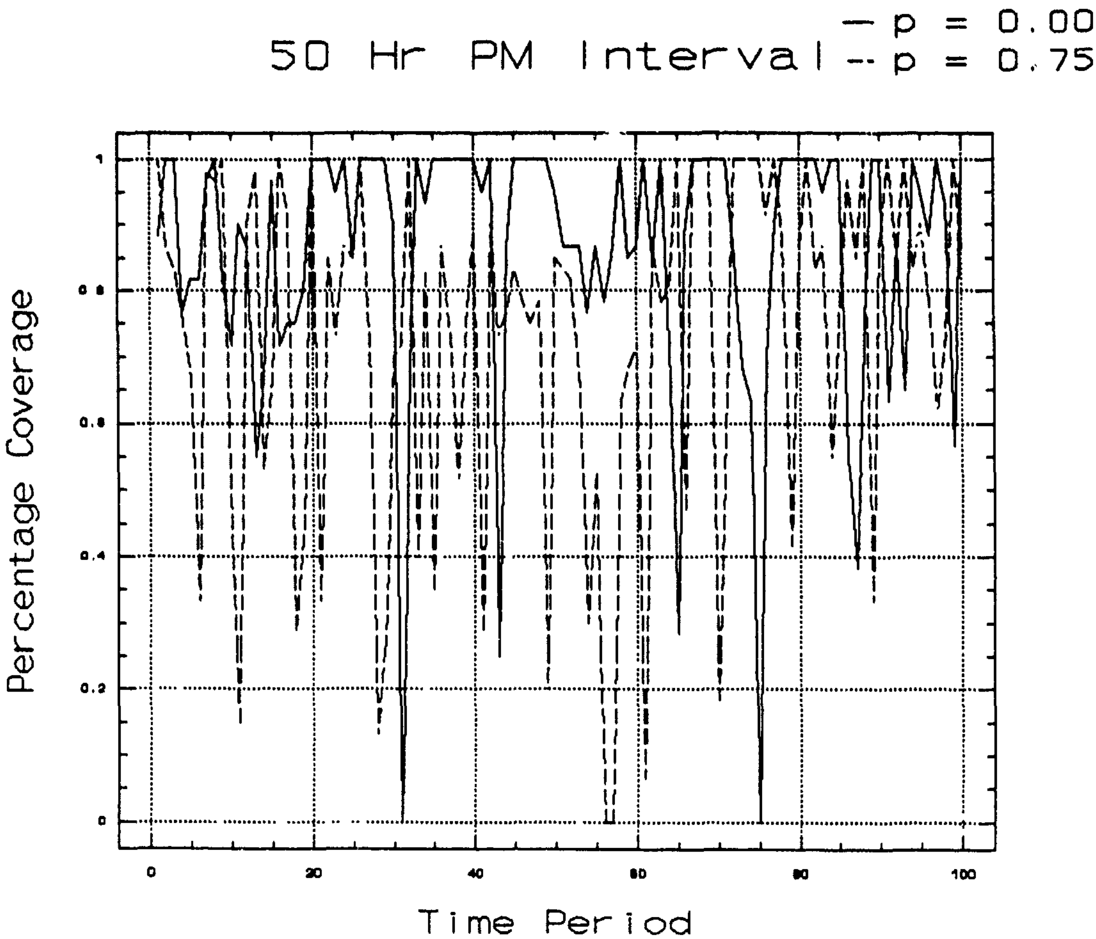
Graph 8. (P=0.00 .vs. P=0.10) : 50 Hr



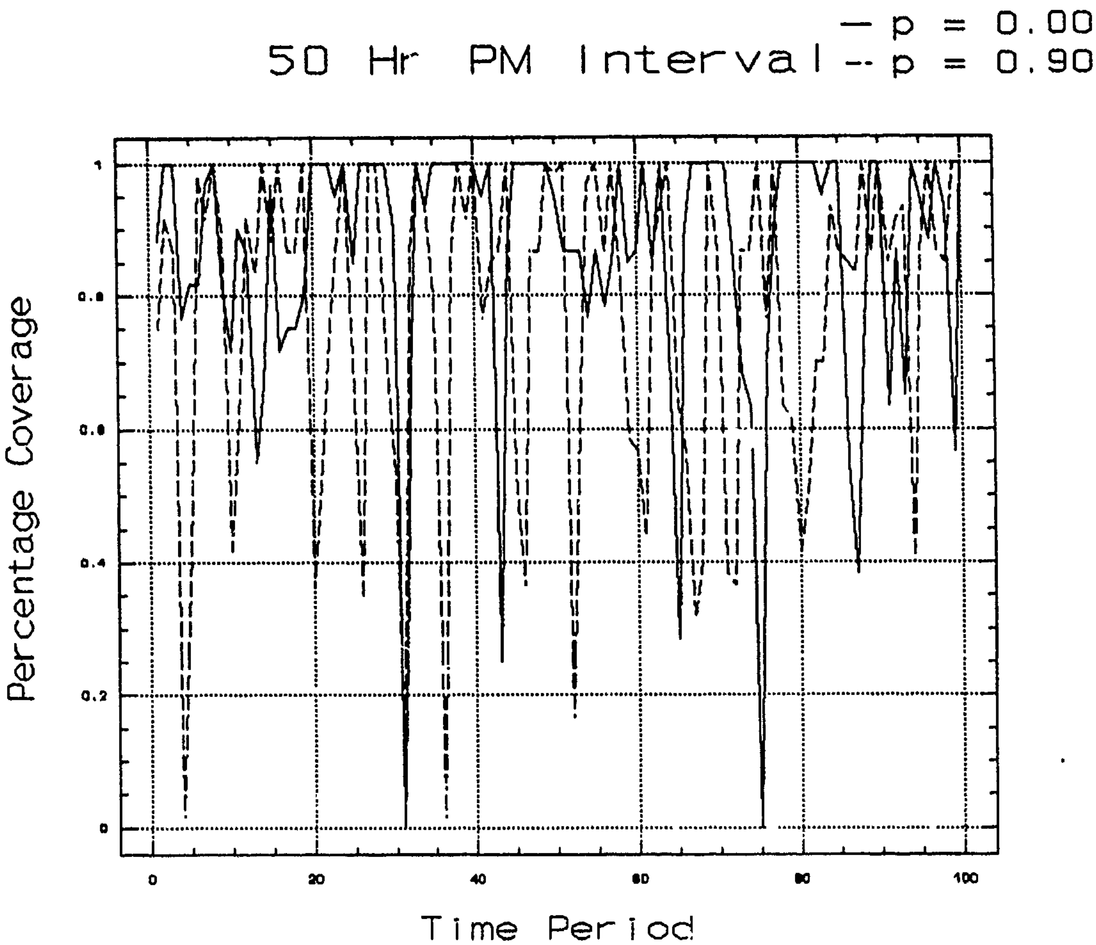
Graph 9. (P=0.00 .vs. P=0.25) : 50 Hr



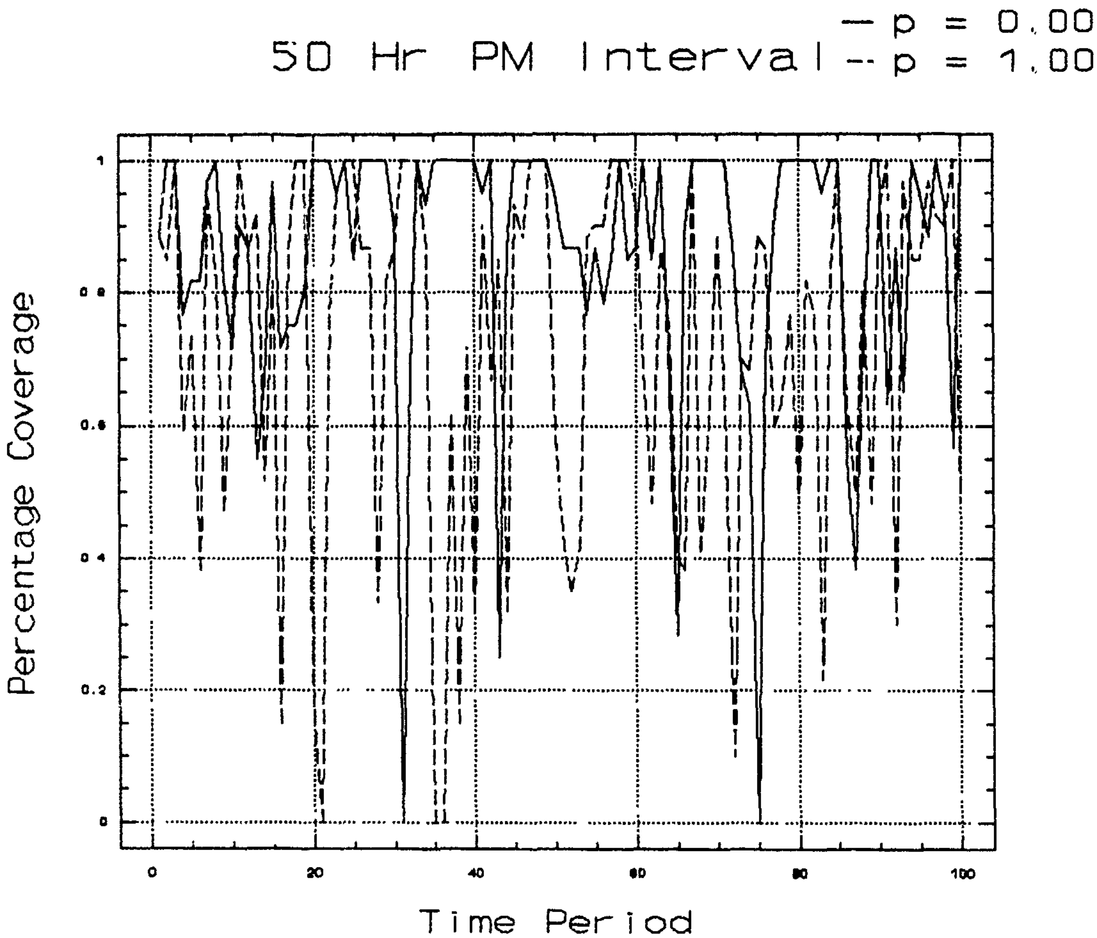
Graph 10. (P=0.00 .vs. P=0.50) : 50 Hr



Graph 11. (P=0.00 .vs. P=0.75) : 50 Hr

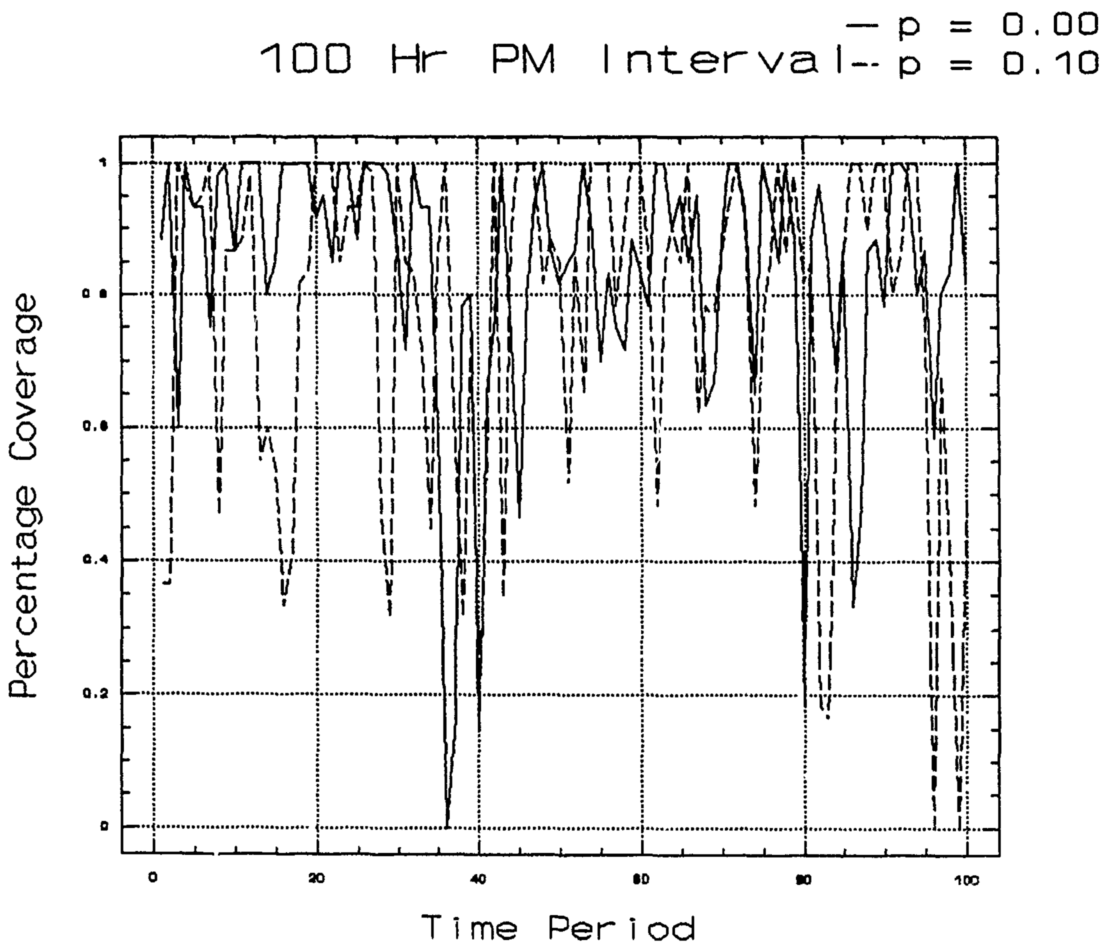


Graph 12. (P=0.00 .vs. P=0.90) : 50 Hr

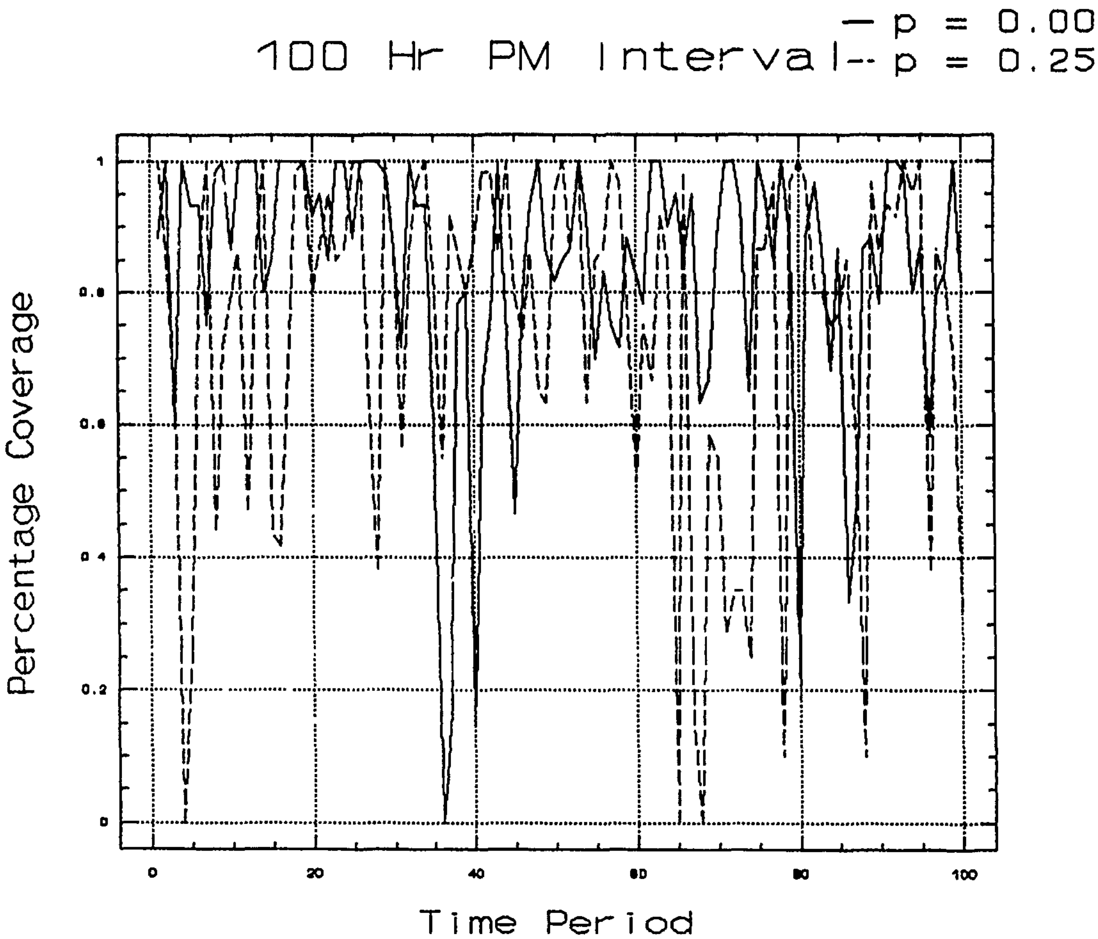


Graph 13. (P=0.00 .vs. P=1.00) : 50 Hr

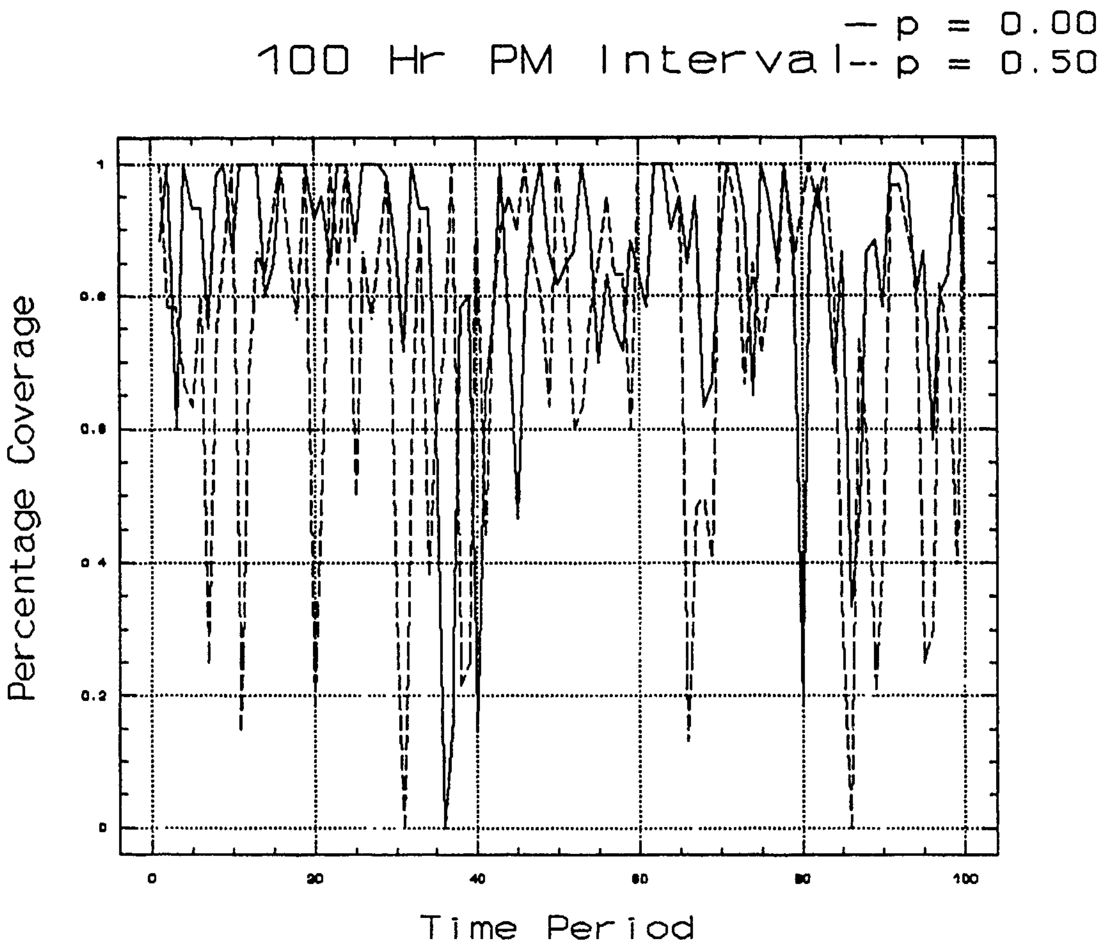
APPENDIX C. T = 100 HOURS



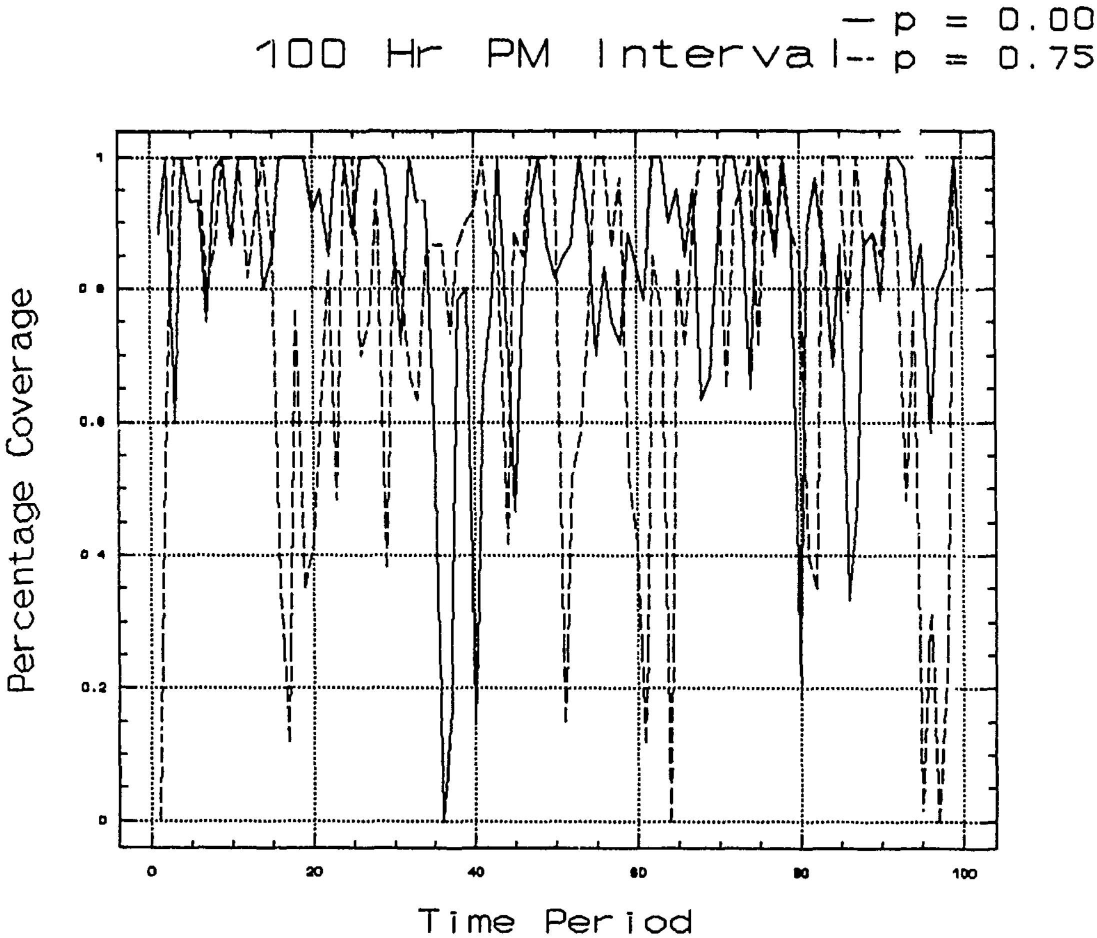
Graph 14. (P=0.00 .vs. P=0.10) : 100 Hr



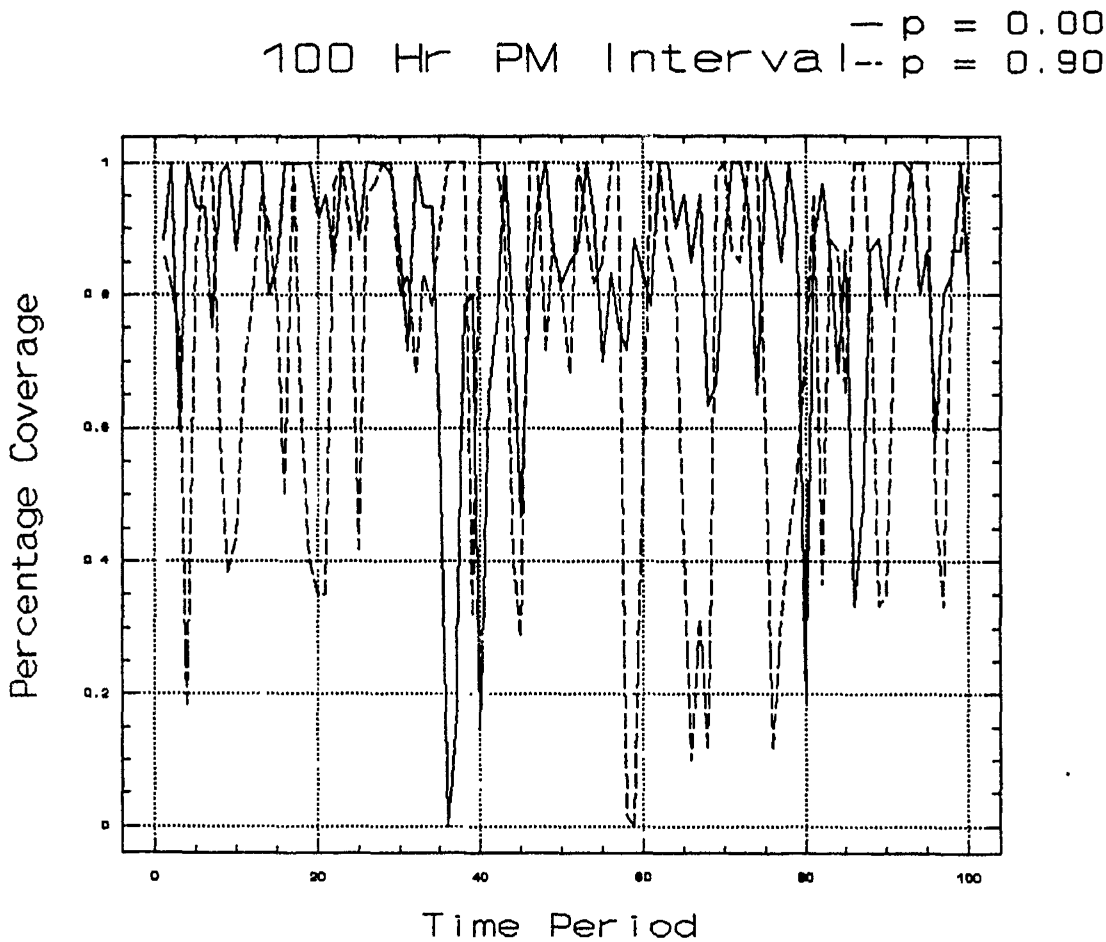
Graph 15. (P=0.00 .vs. P=0.25) : 100 Hr



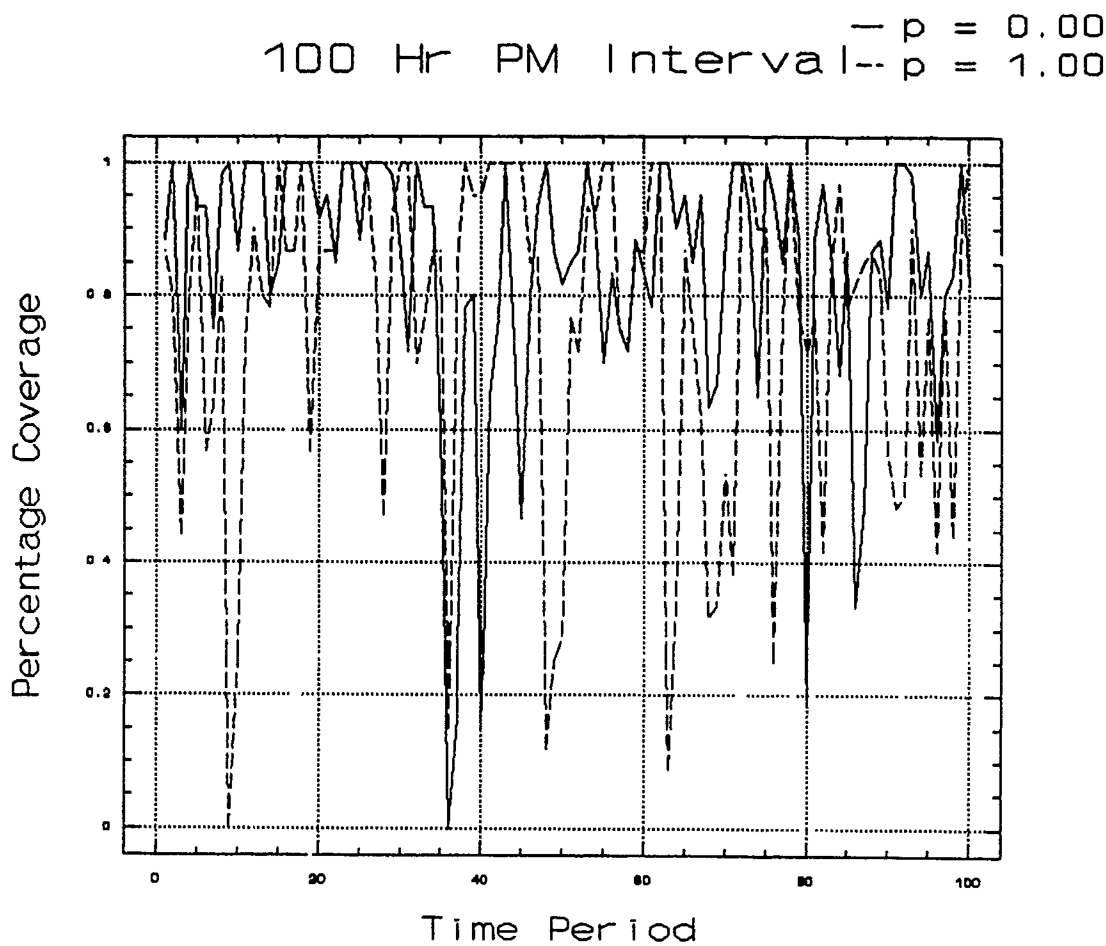
Graph 16. (P=0.00 .vs. P=0.50) : 100 Hr



Graph 17. (P=0.00 .vs. P=0.75) : 100 Hr

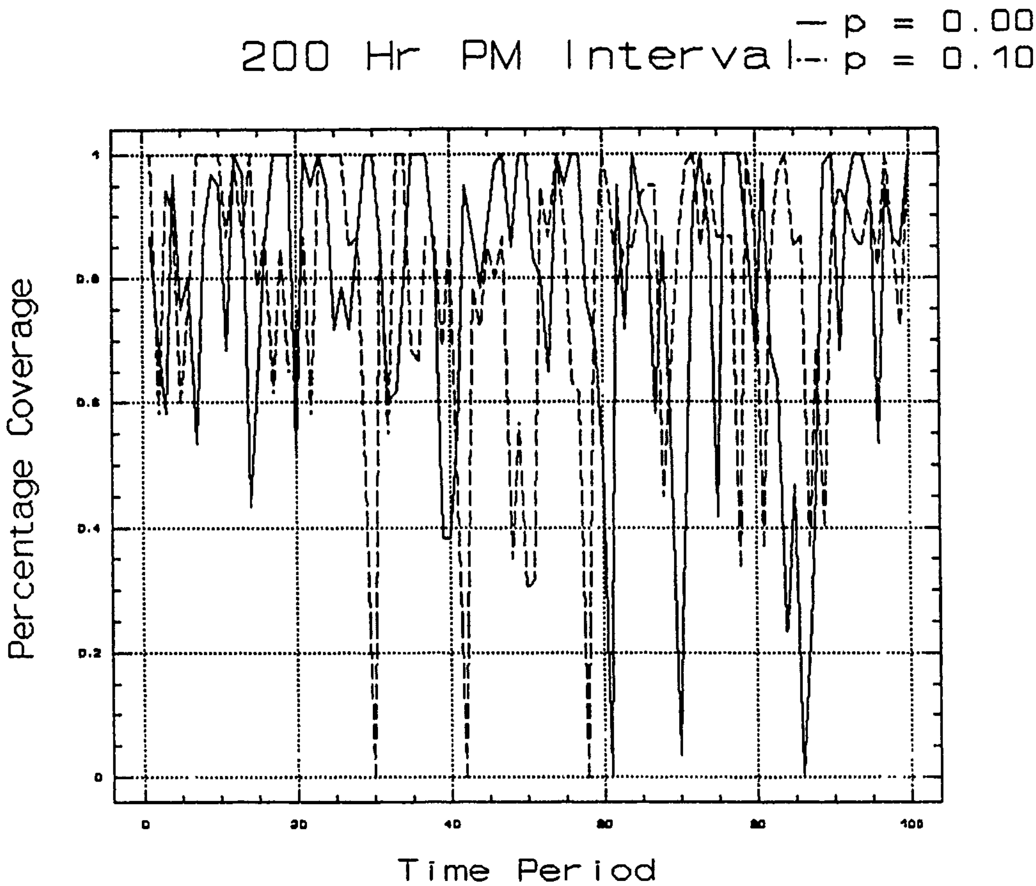


Graph 18. (P=0.00 .vs. P=0.90) : 100 Hr

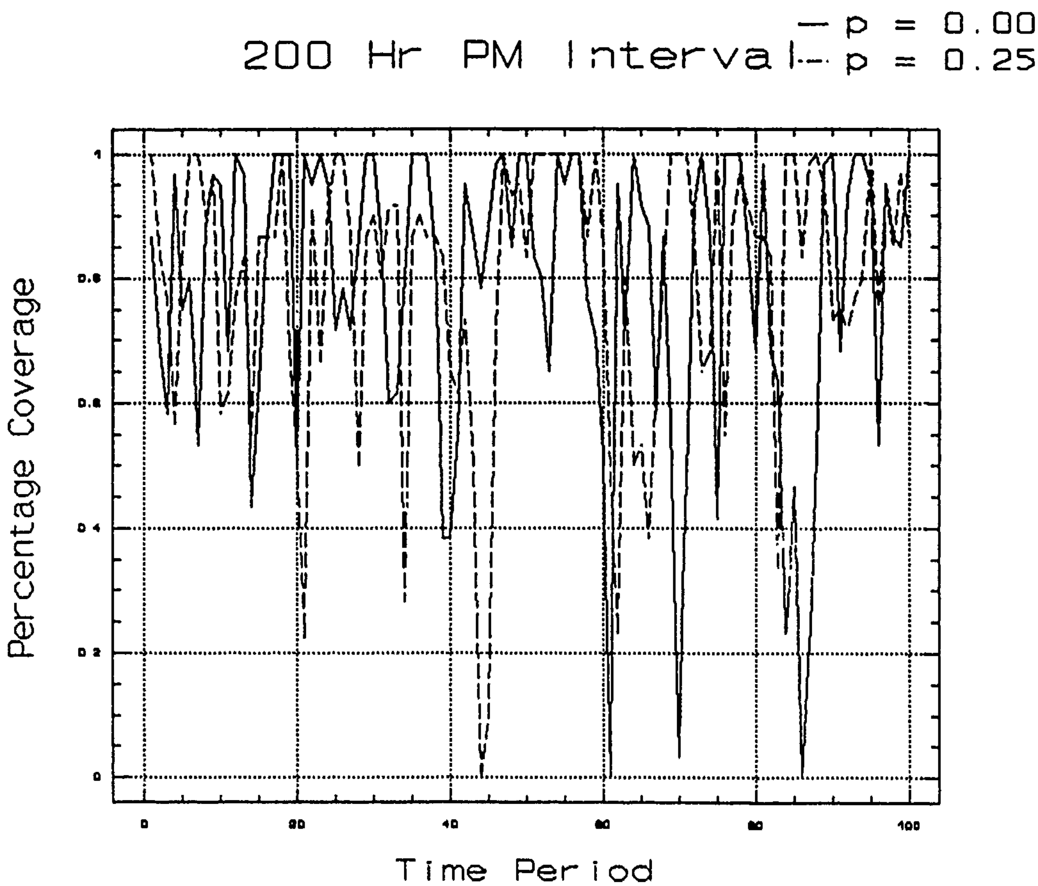


Graph 19. (P=0.00 .vs. P=1.00) : 100 Hr

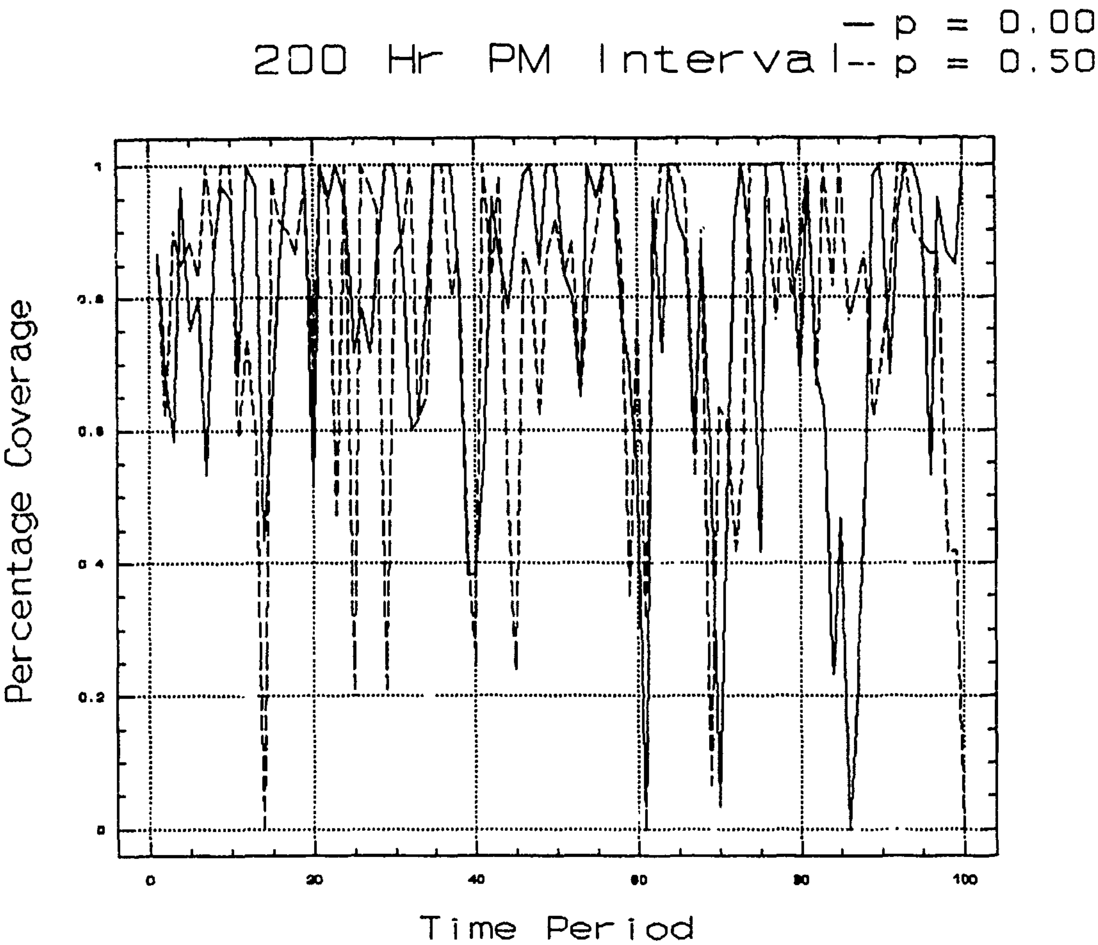
APPENDIX D. T = 200 HOURS



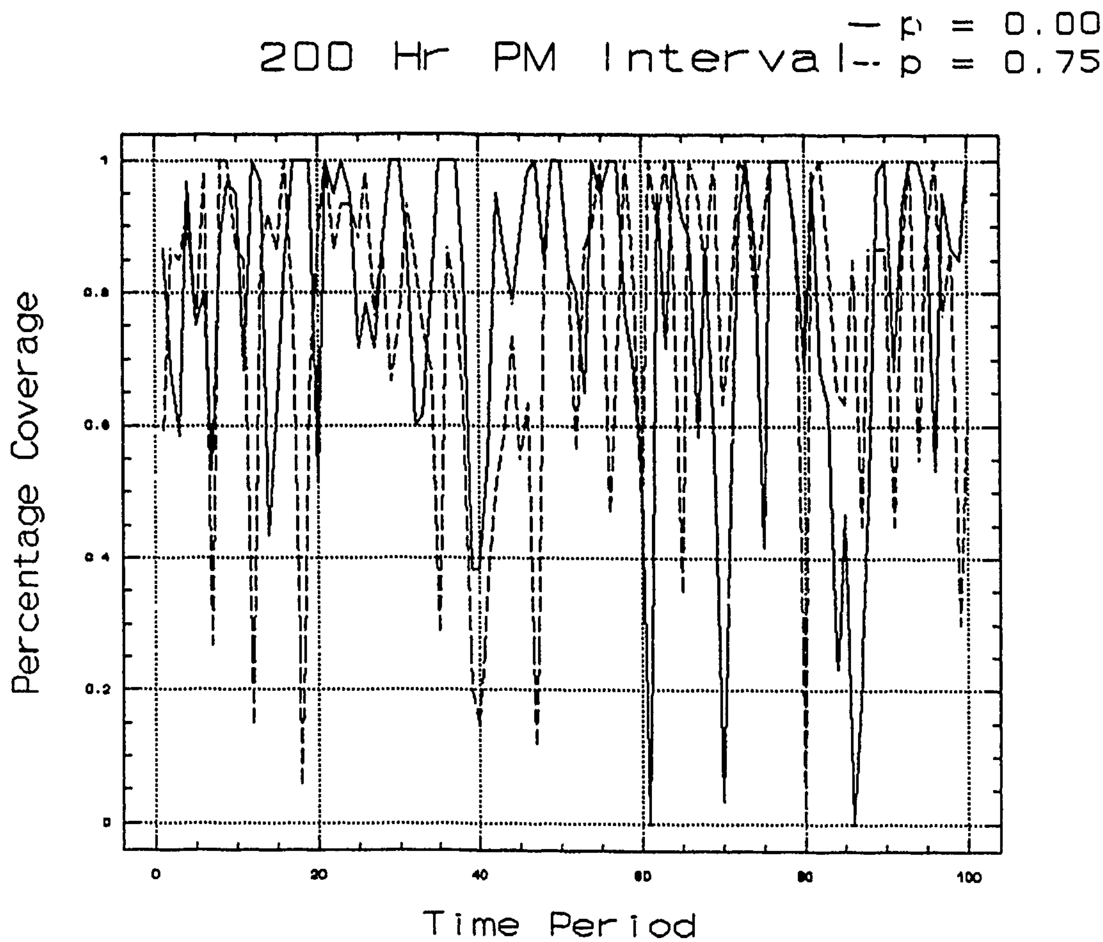
Graph 20. (P=0.00 .vs. P=0.10) : 200 Hr



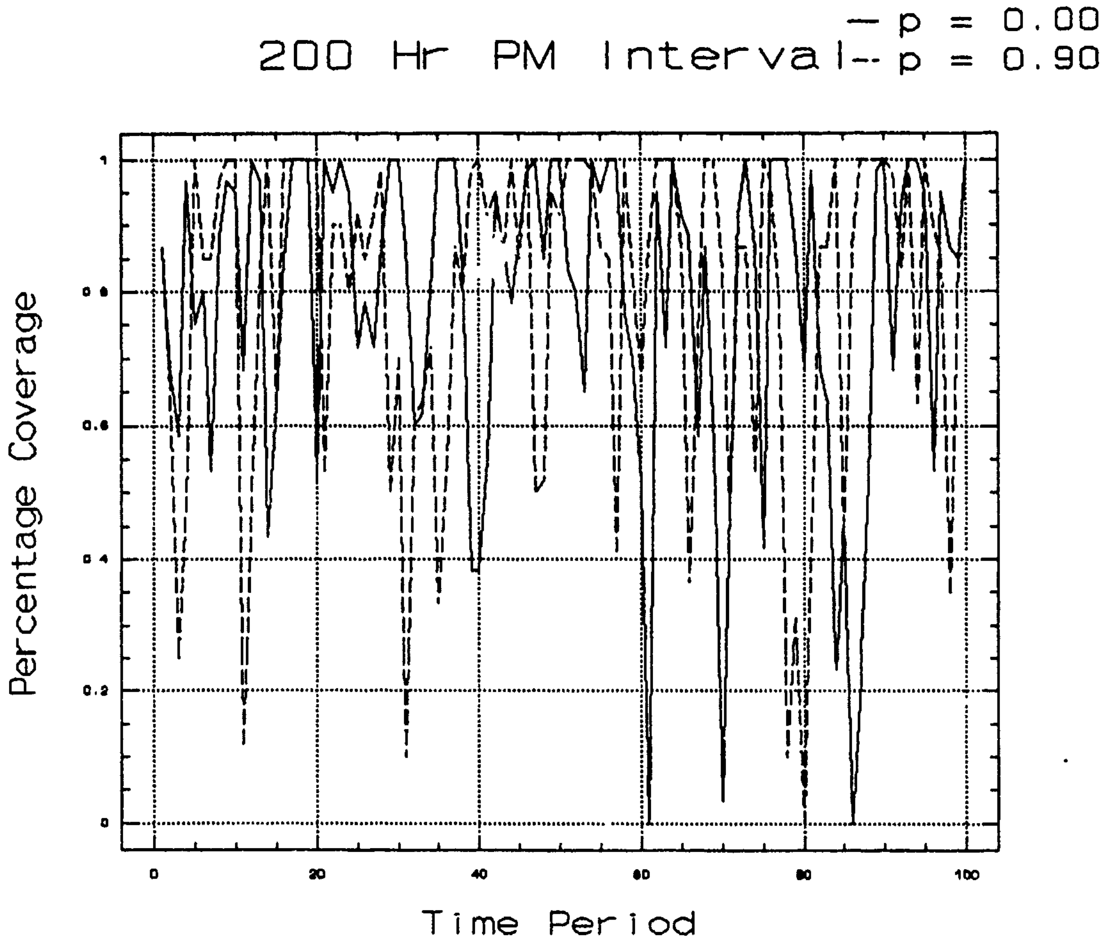
Graph 21. (P=0.00 .vs. P=0.25) : 200 Hr



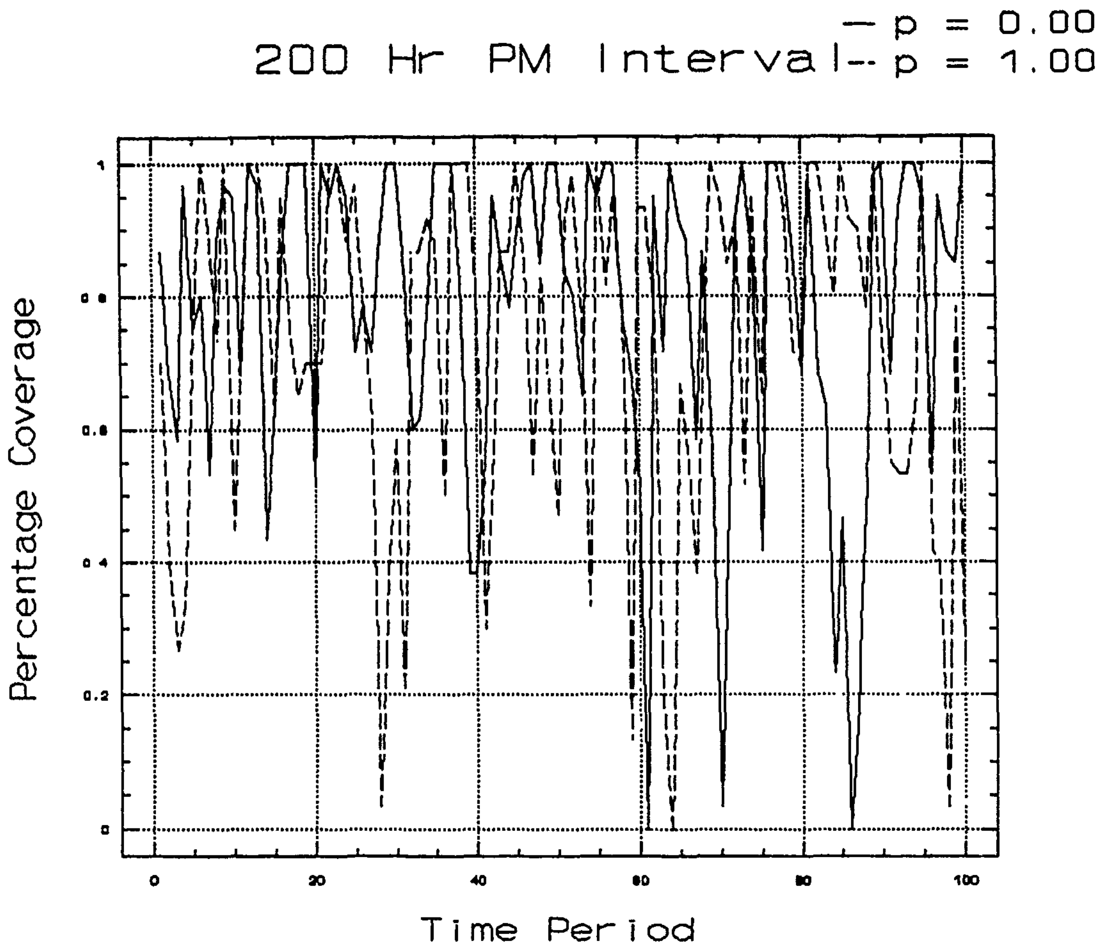
Graph 22. (P=0.00 .vs. P=0.50) : 200 Hr



Graph 23. (P=0.00 .vs. P=0.75) : 200 Hr

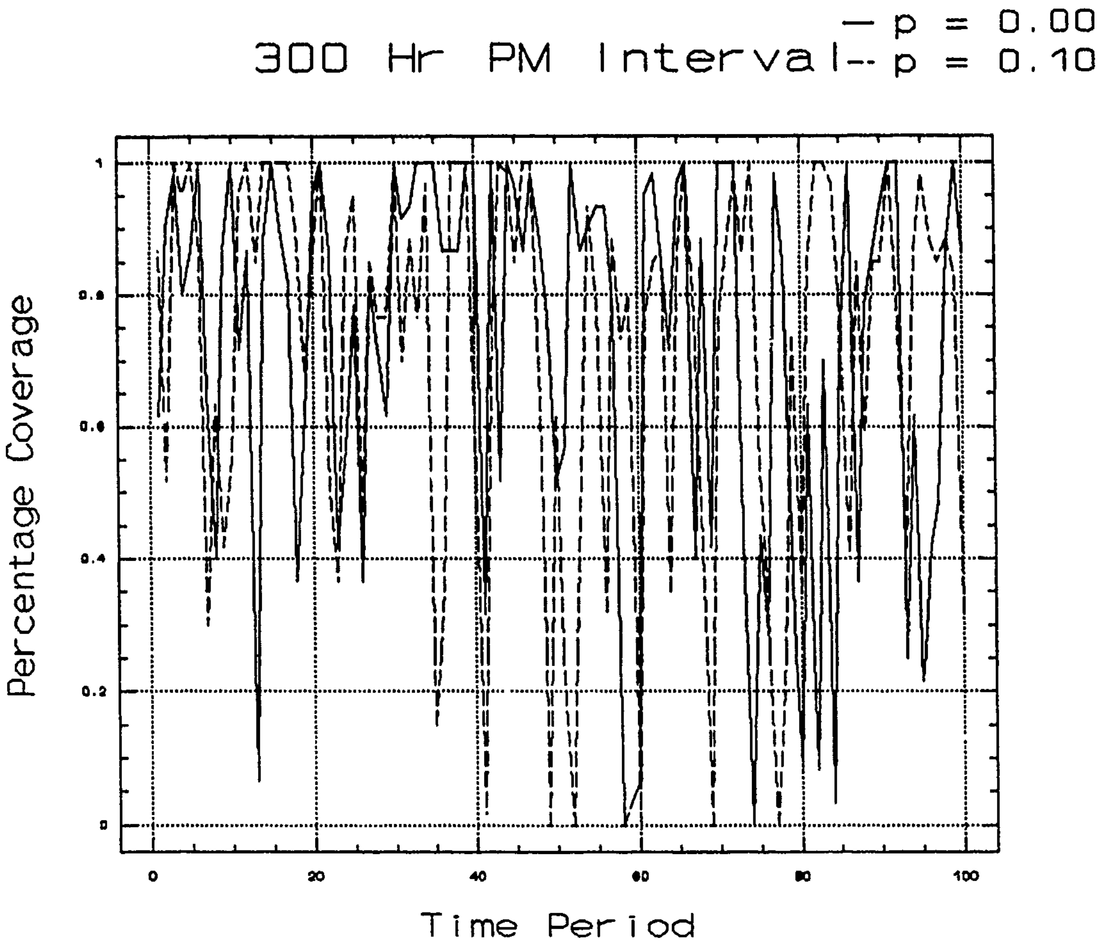


Graph 24. (P=0.00 .vs. P=0.90) : 200 Hr

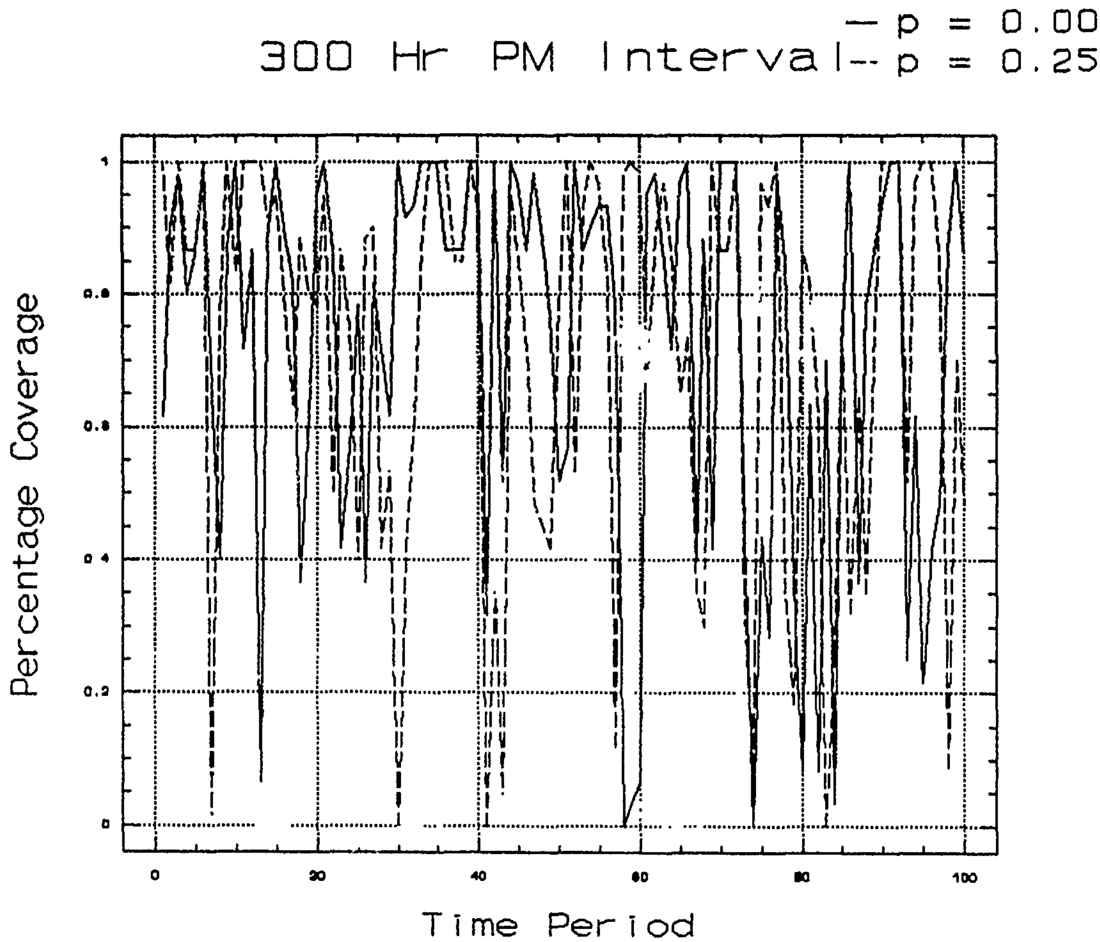


Graph 25. (P=0.00 .vs. P=1.00) : 200 Hr

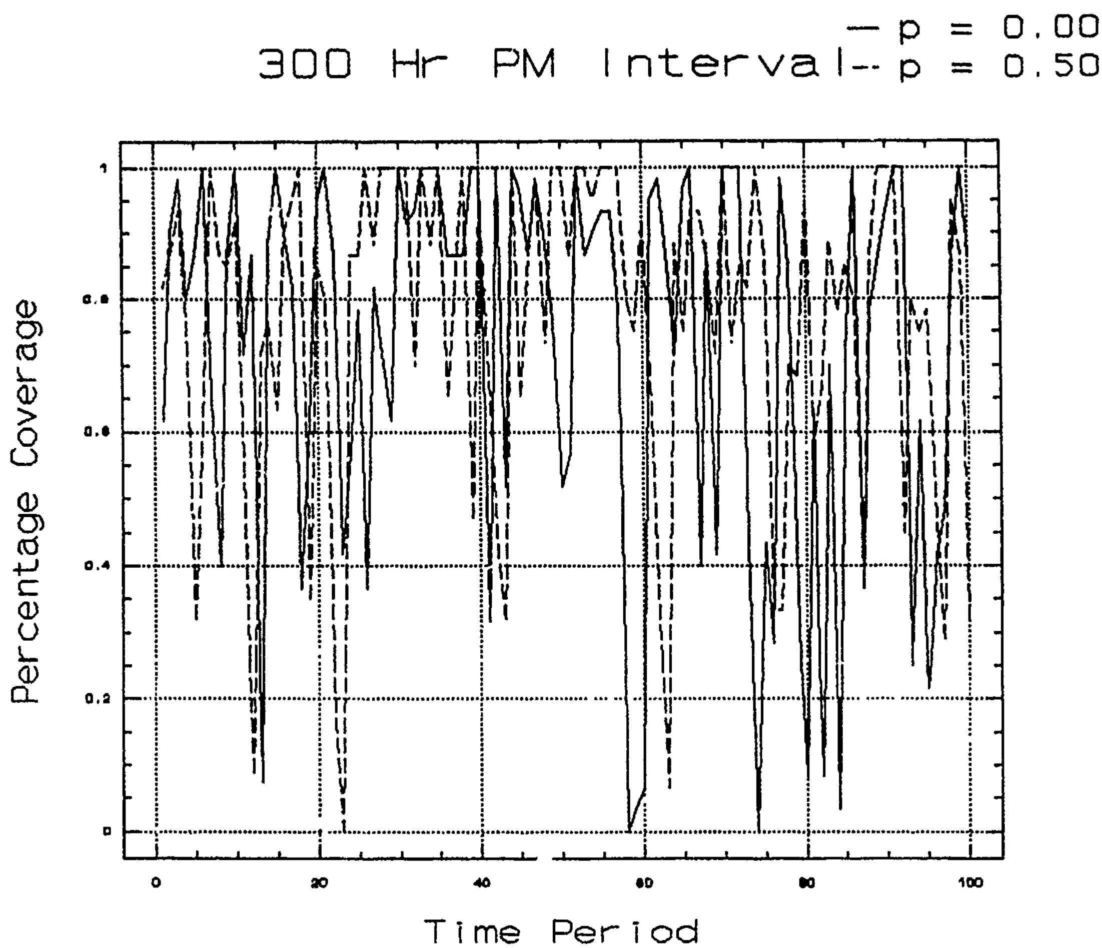
APPENDIX E. T = 300 HOURS



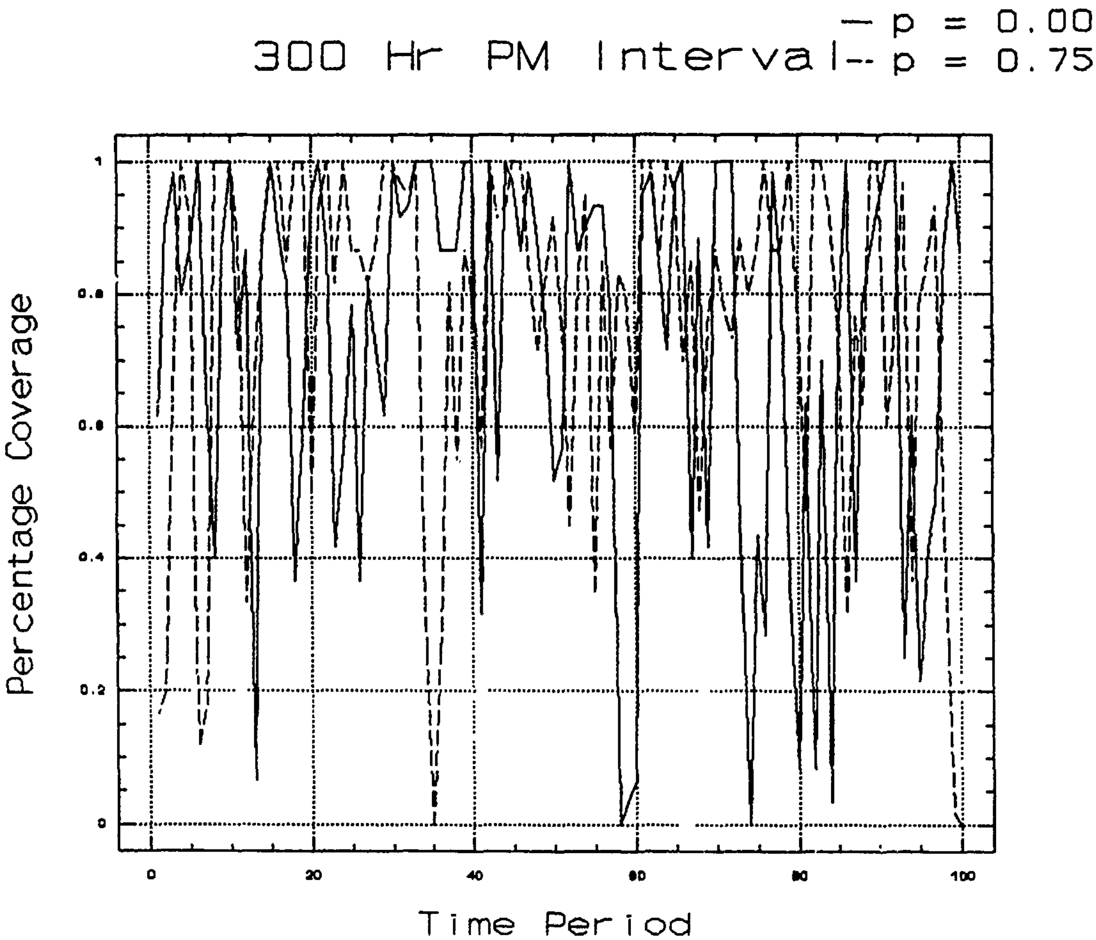
Graph 26. (P=0.00 .vs. P=0.10) : 300 Hr



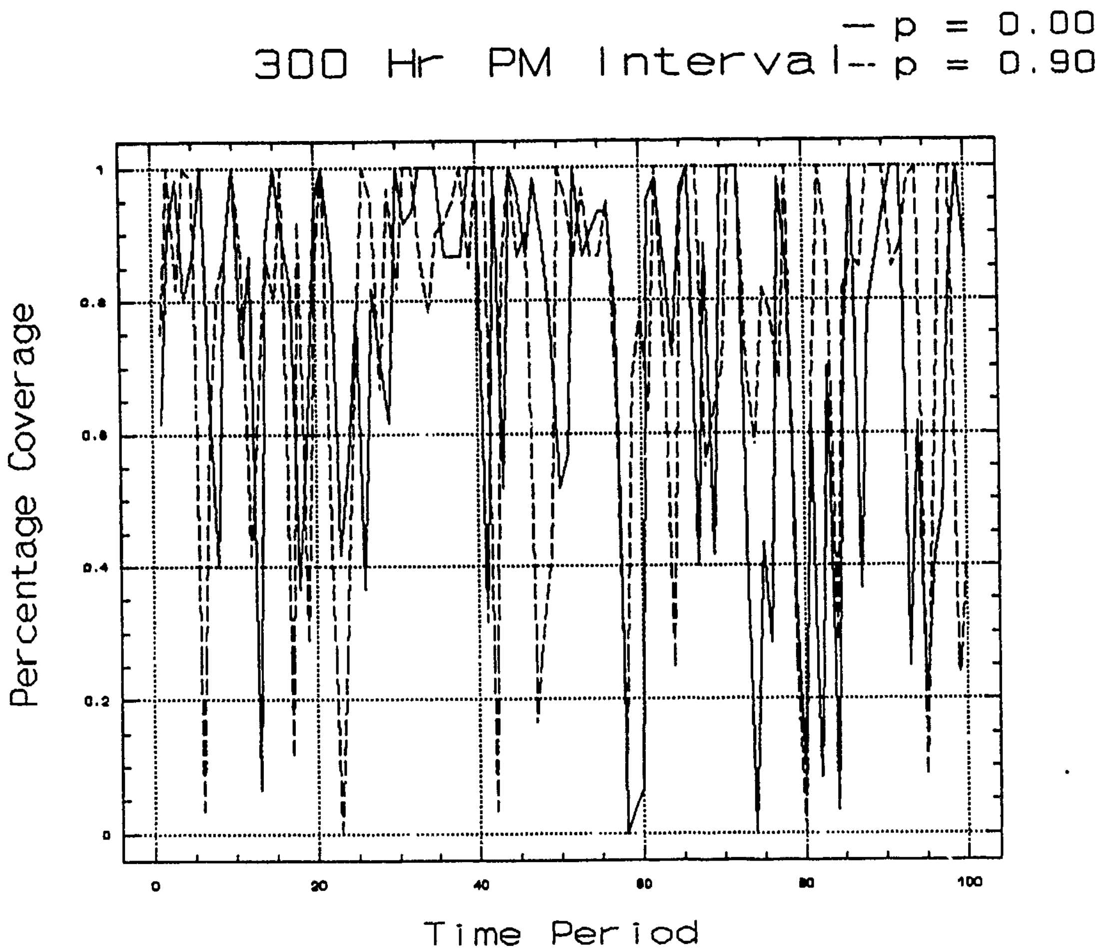
Graph 27. (P=0.00 .vs. P=0.25) : 300 Hr



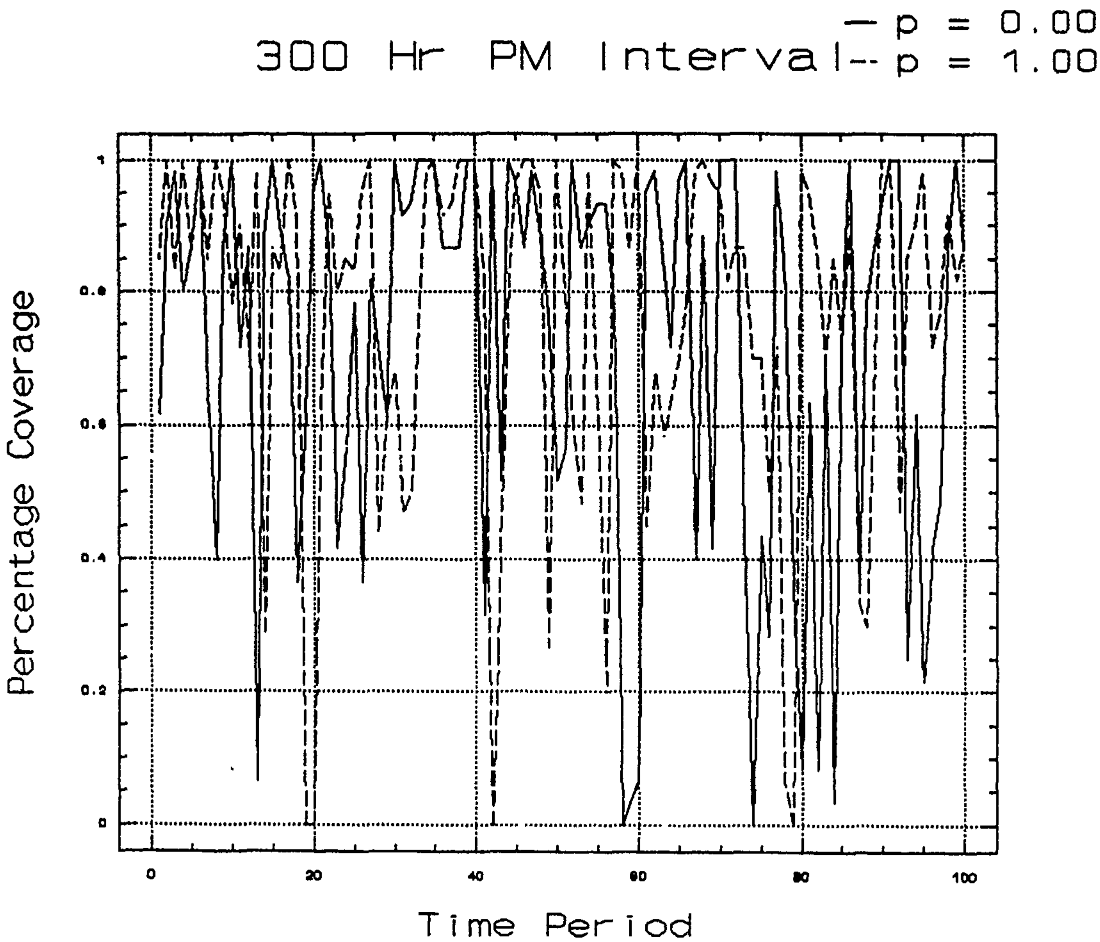
Graph 28. (P=0.00 .vs. P=0.50) : 300 Hr



Graph 29. (P=0.00 .vs. P=0.75) : 300 Hr

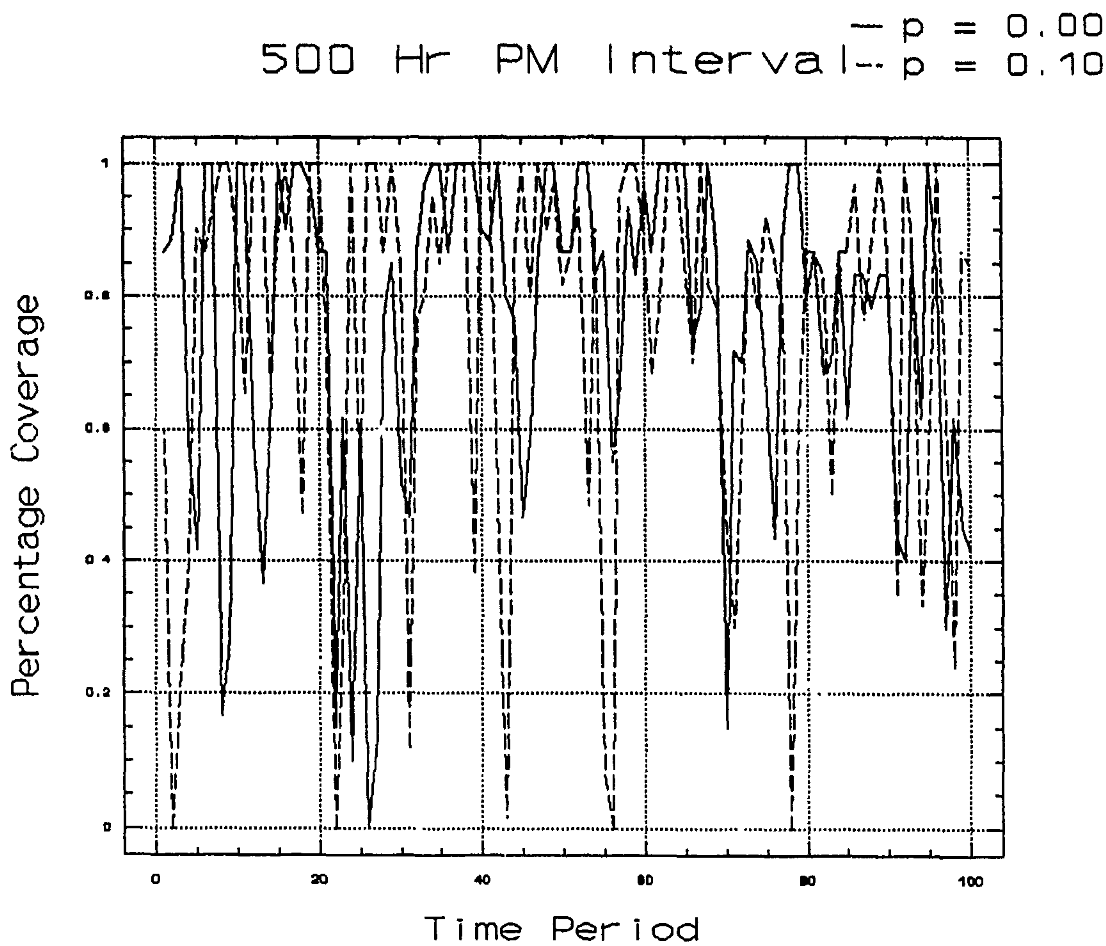


Graph 30. (P=0.00 .vs. P=0.90) : 300 Hr

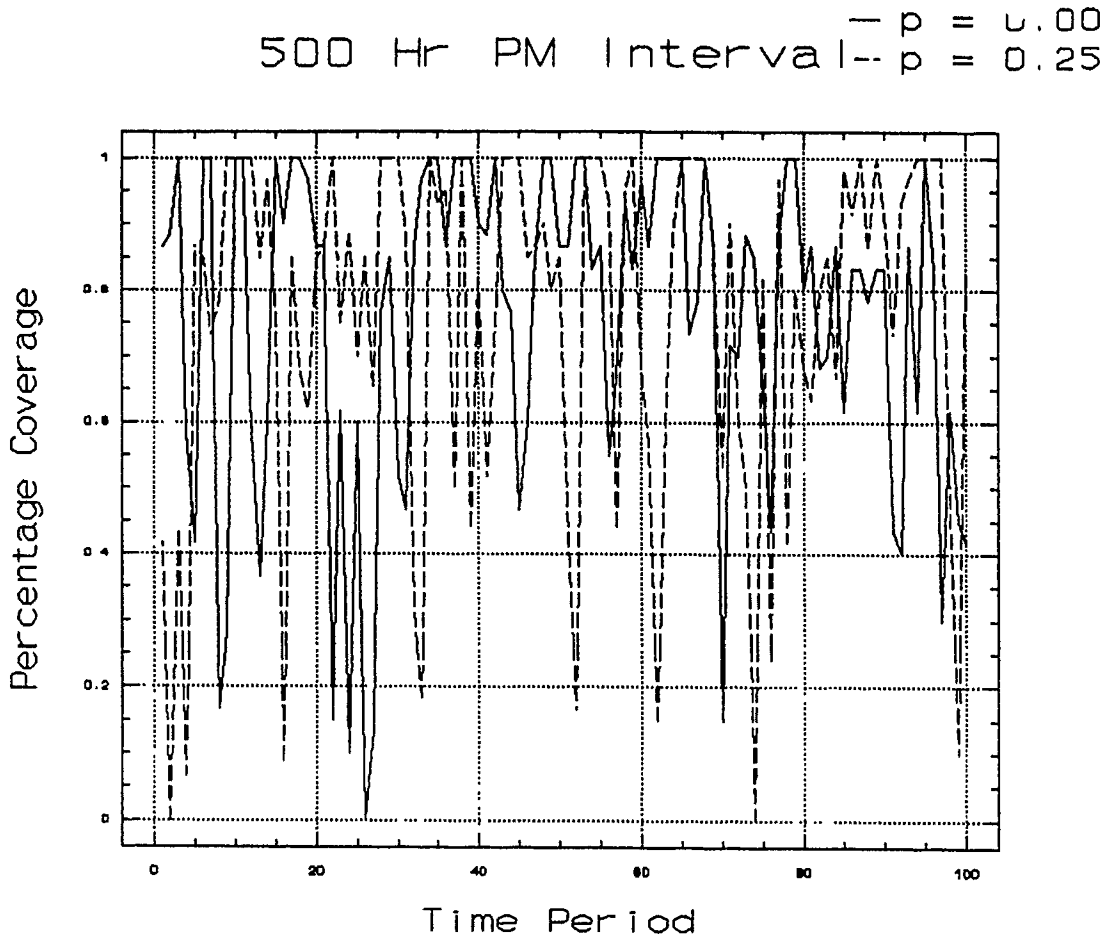


Graph 31. (P=0.00 .vs. P=1.00) : 300 Hr

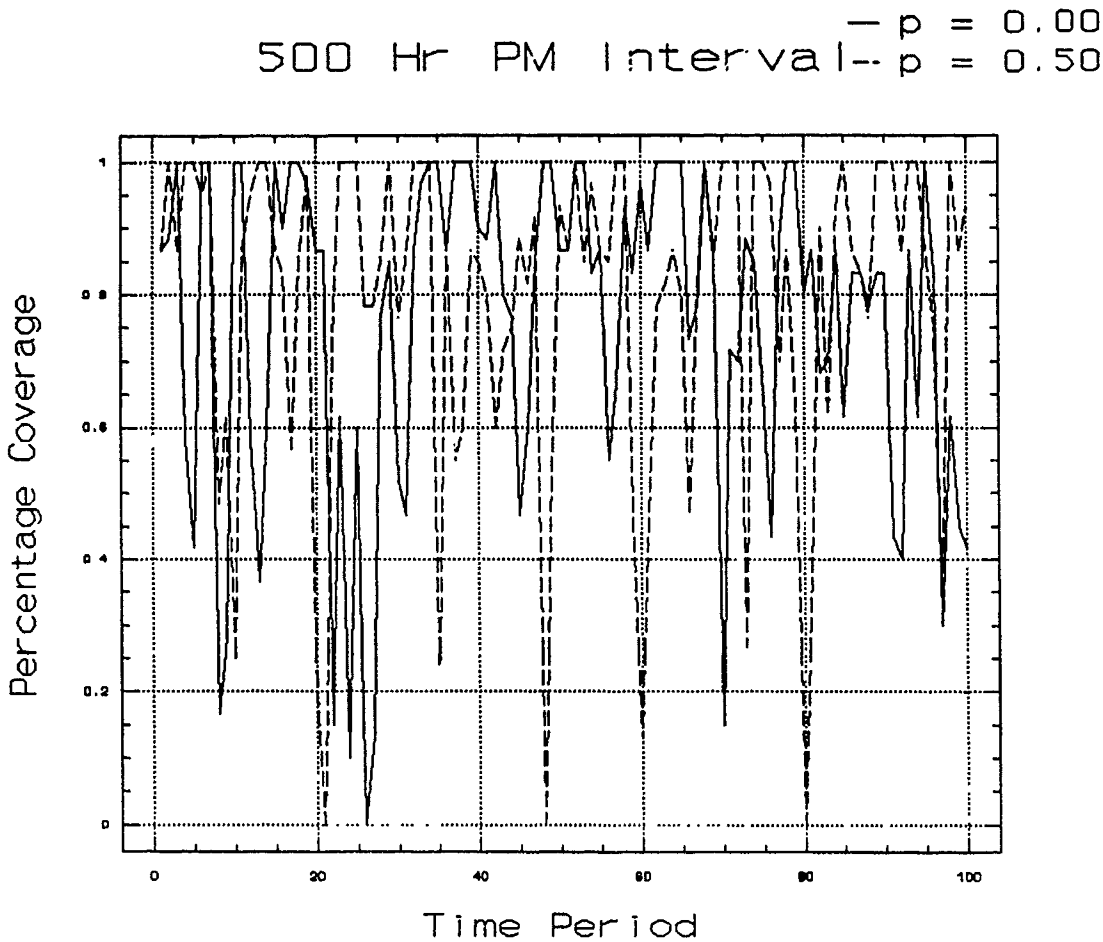
APPENDIX F. T = 500 HOURS



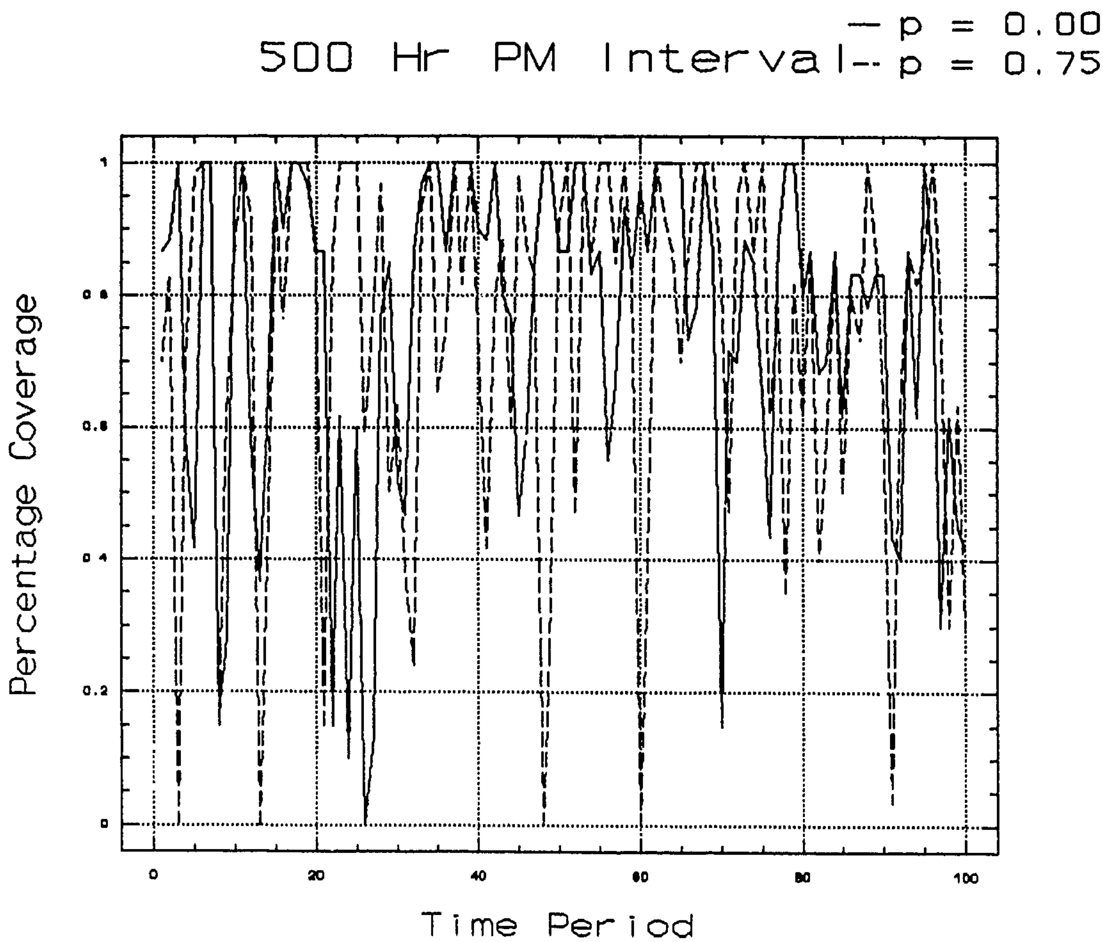
Graph 32. (P=0.00 .vs. P=0.10) : 500 Hr



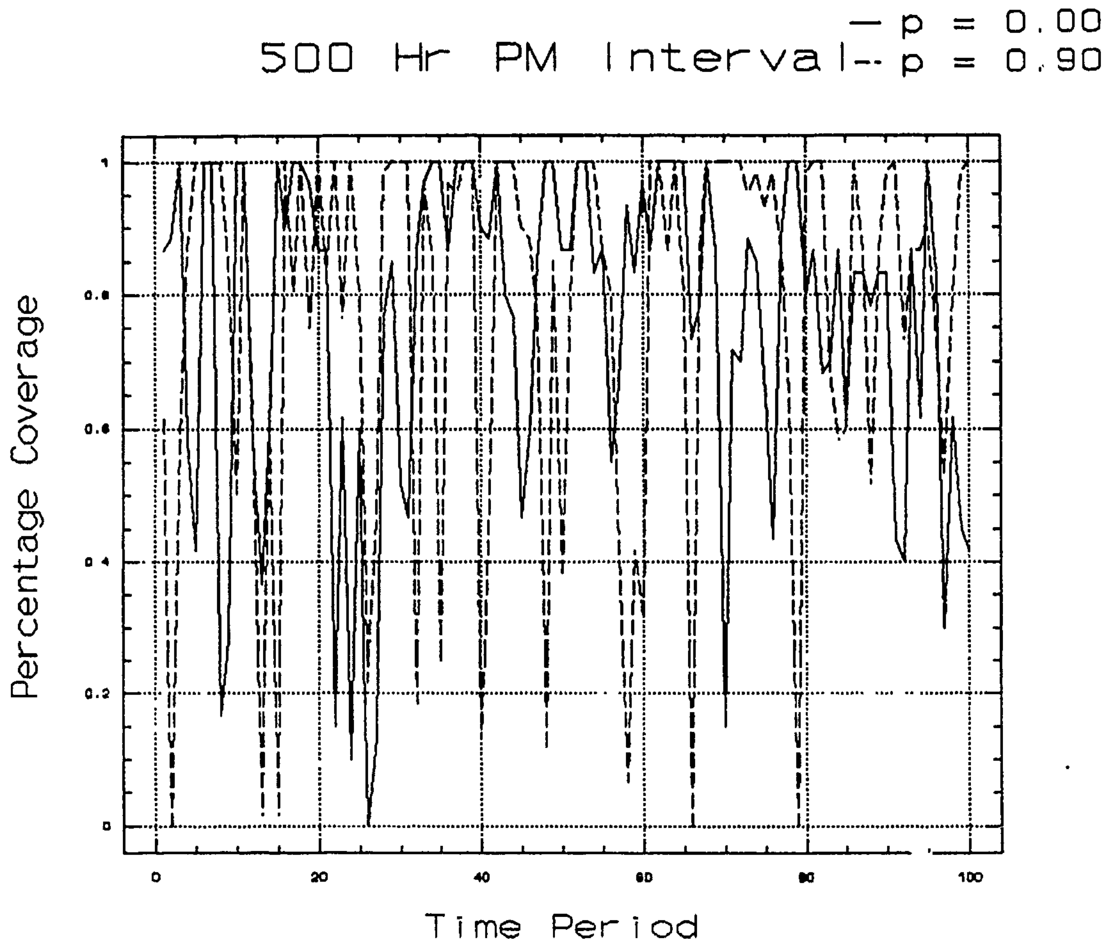
Graph 33. (P=0.00 .vs. P=0.25) : 500 Hr



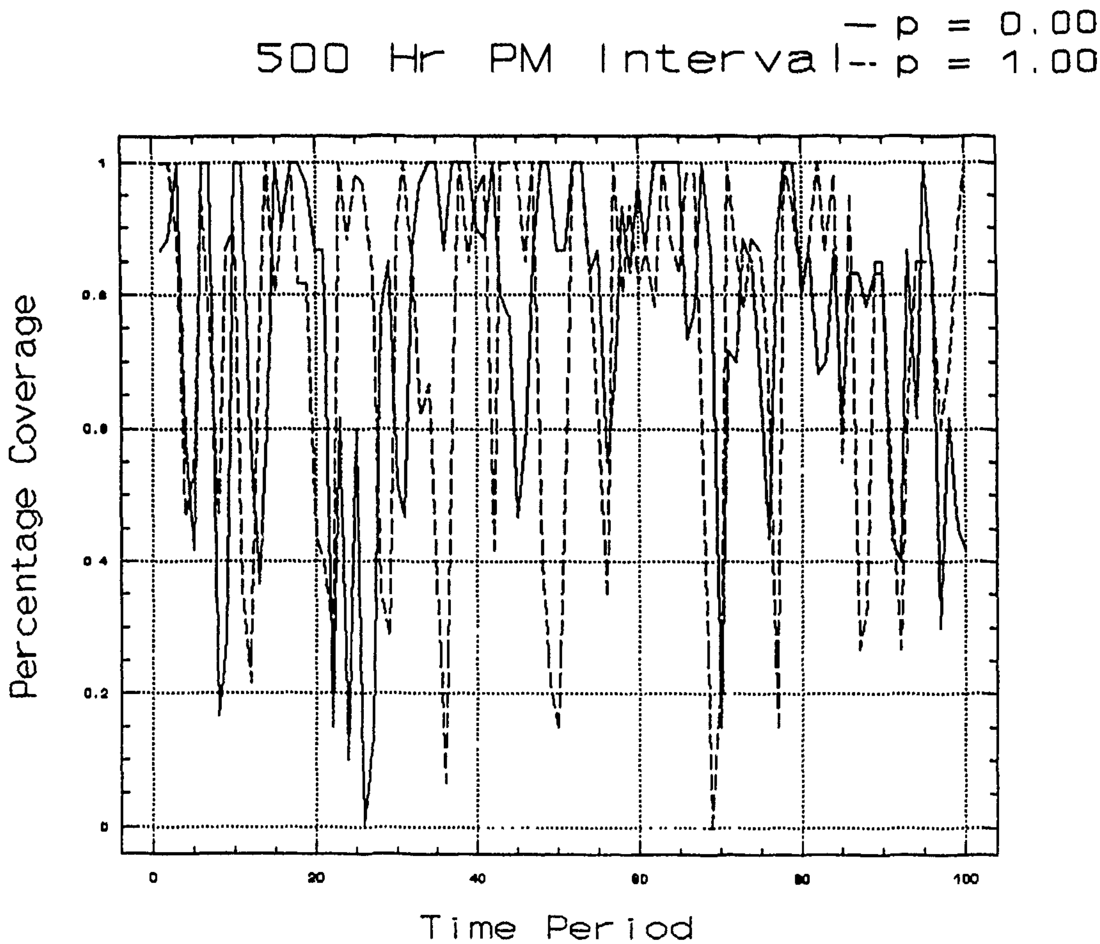
Graph 34. (P=0.00 .vs. P=0.50) : 500 Hr



Graph 35. (P=0.00 .vs. P=0.75) : 500 Hr



Graph 36. (P=0.00 .vs. P=0.90) : 500 Hr



Graph 37. (P=0.00 .vs. P=1.00) : 500 Hr

APPENDIX G. AEWSIM

A. MAIN PROGRAM

```
C*******************************************************************
C
C
C  AIRBORNE EARLY WARNING PLATFORM STATIONING SIMULATION
C                        BY
C                LCDR MICHAEL J. BOND
C
C THIS PROGRAM SIMULATES THE STATIONING AND RECOVERY OF
  AEW PLATFORMS IN A DEFENSIVE AAW POSTURE AROUND THE
          CARRIER BATTLE GROUP.
C IT FURTHER SIMULATES THE REPAIR AND MAINTENANCE
  PERFORMED ON  THE PLATFORM  DURING  THE  TURNAROUND
  PHASE  AND PERIODIC MAINTENANCE
  SCHEDULE.  ASSUMPTIONS MADE IN THE MODELING  OF  THE
  MAINTENANCE
  PORTION ARE:
    A)  REPAIR IS PERFECT AND RETURNS  THE  SYSTEM TO A GOOD AS
        NEW STATE.
    B)  PREVENTIVE MAINTENANCE IS IMPERFECT WITH PROBABILITY
        P AND PERFECT WITH PROBABILITY 1-P.  IF THE PM IS  IMPER-
        FECT THEN IT MAINTAINS ITS ORIGINAL FAILURE TIME. IF IT
        IS PERFECT THEN THE SYSTEM IS RETURNED TO  AS  GOOD  AS
        NEW STATE.
    C)  THE PLATFORM UNDERGOES PREVENTIVE MAINTENANCE
        ACCORDING TO A PLANNED PREVENTIVE MAINTENANCE CYCLE.
C
C          PARAM(1) = A/C NUMBER
C              (2) = ENGINE START TIME
C              (3) = STATION ASSIGNED
C              (4) = STATE (FMC, PMC, NMC)
C              (5) = TOTAL TIME ON ENGINE
C              (6) = TIME TO FAILURE
C              (.) =  "   "   "
C
C          STANUM     Station number a/c is assigned to
           ABORT      Aircraft fails on deck or on station
           QUEUE      Aircraft in FMC or PMC status for assignment
```

```
EMPTY      Flags station as empty, no replacement
FLAG       Flags program to fill empty station
MAXAC      Maximum aircraft on flight deck
HANGAR     Storage space for PARAM()
MINFAL     Minimum failure time
FALTIM     MTTF for system i
RFAIL      Random time to fail for system i
MAXPRM     Maximum number of parameters in PARAM()
ENDURE     Mission flight time
TTS        Time to station
TOS        Time on station
NOW        Current program time
STATUS     Aircraft status (up or down, for stats)
COVER      Station is filled (for stats)
DTIME      Maximum down time
FLYTIM     Total time on engine from startup to recovery
HSTIM      Hotspin time
TATIM      Turnaround time
REPTIM     MTTR for system i
RTIME      Random assigned time for repair of system
HTPM(1)    Hours till next pm phase A for aircraft #
HTPM(2)    "                   " B "          "
INWORK(#)  Denotes whether system i undergoes phase A/B pm
PERFPM     Random probability of perfect pm
IMPERF     Probability of imperfect pm
MAXTIM     Maximum running time of program

C*********************************************************************
C    THIS MODULE CONTAINS:
C       -MAIN PROGRAM
C       -DOIT
C
C*********************************************************************
      PROGRAM AEWSIM
C*********************************************************************
C    MAIN PROGRAM
C*********************************************************************
      CALL READIT
      CALL CONFRM
      N = 1
 10   CONTINUE
      IF(N .EQ. 1)IMPERF = 0.0
      IF(N .EQ. 2)IMPERF = .10
```

```
      IF(N .EQ. 3)IMPERF = .25
      IF(N .EQ. 4)IMPERF = .50
      IF(N .EQ. 5)IMPERF = .75
      IF(N .EQ. 6)IMPERF = .90
      IF(N .EQ. 7)IMPERF = 1.0
      WRITE(12,*)'RUN NUMBER ',N
      CALL INITZE
      CALL DOIT
      N = N + 1
      IF(N .LE. 7)GOTO 10
      STOP
      END
C************************************************************************
      SUBROUTINE DOIT [Ref 6]
C************************************************************************
C     THIS SUBROUTINE
C         - HANDLES THE PASSAGE OF TIME AND THE EXECUTION OF
C           EVENTS
C         - STOPS AS SOON AS MAXTIM TIME UNITS HAVE TRANSPIRED
C
C     EVENT 1 IS THE PRELAUNCH/WARMUP PHASE OF THE LAUNCH
C           CYCLE
C     EVENT 2 IS THE LAUNCH OF THE AIRCRAFT TO STATION
C     EVENT 3 IS RETURN TO BASE COMMAND FOR EACH AIRCRAFT
C     EVENT 4 IS THE RECOVERY OF THE AIRBORNE AIRCRAFT
C     EVENT 5 IS THE RETURN TO SERVICE OF THE AIRCRAFT AFTER
C           MAINT.
C     EVENT 6 IS A STATISTICAL EVENT
C************************************************************************
C
 1000 CONTINUE
C
C ..............PULL AN EVENT OFF THE CALANDAR
C
      CALL POP(TIMEVT,NUMBER,PARAM)
C
C ..............STOPPING CONDITIONS CHECKED
C
      IF((NUMBER .NE. 0) .AND. (NOW .LE. REAL(MAXTIM)))THEN
        IF(TIMEVT .LT. NOW)THEN
          WRITE(*,*)'TIME IS GOING BACKWARD, TIME=',NOW
          CALL DMPCAL
          STOP
```

```
      ENDIF
      IF(NUMBER .NE. 7)THEN
        NOW = TIMEVT
      ENDIF
      GOTO (10,20,30,40,50,60,70), NUMBER
C
 10    CONTINUE
      CALL WARMUP(PARAM)
      GOTO 99

C                 ...............LAUNCH EVENT
C
 20    CONTINUE
      CALL LAUNCH(PARAM)
      GOTO 99
C
C                 ...............RETURN TO BASE (RTB) EVENT
C
 30    CONTINUE
      CALL RTB(PARAM)
       GOTO 99
C
C                 ...............RECOVERY EVENT
C
 40    CONTINUE
      CALL RECOV(PARAM)
      GOTO 99
C
C
C                 ...............RETURN TO SERVICE (RTS) EVENT
C
 50    CONTINUE
      CALL RTS(PARAM)
      GOTO 99
C
C
C                 ...............A STATISTICAL ROUTINE
C
 60    CONTINUE
      CALL STAT2(PARAM)
      GOTO 99
C
C                 ..............ANOTHER STATISTICAL ROUTINE
```

```
 70     CONTINUE
       CALL STAT3(PARAM)
       GOTO 99
C
 99 CONTINUE
C
       GOTO 1000
     ELSE
C       WRITE(*,*)'SIMULATION COMPLETED AT TIME',NOW
C       CALL DMPCAL
       IF(NOW .LT. REAL(MAXTIM))THEN
         WRITE(*,*)'SIMULATION ENDED DUE TO EMPTY CALANDAR'
       ENDIF
     ENDIF
     RETURN
     END
C*********************************************************************
     SUBROUTINE INITZE
C*********************************************************************
C    THIS SUBROUTINE WILL
C       - INITIALIZE ALL STATE VALUES
C       - SCHEDULE INITIAL SORTIES FOR LAUNCH
C       - INTIALIZE THE EVENT CALANDER
C*********************************************************************
C
     EPS = 1.0E-6
     L = 1.0
     DO 5 I = 1,MAXAC
       STATUS(I) = 1.0
       COVER(I)  = 0.0
  5 CONTINUE
     QUEUE = MAXAC
     DO 20 I = 1,LISTL-1
       TIME(I) = 0.0
       EVTNUM(I) = 0
         DO 10 J = 1,MAXPRM
           PASSED(I,J) = 0.0
 10        CONTINUE
         NXTEVT(I) = I + 1
 20  CONTINUE
     NXTEVT(LISTL) = 0
     FSTEVT = 0
     AVAIL = 1
```

```
      NOW = 0.0
      DO 100 I = 1,MAXAC
        HANGAR(I,1) = REAL(I)
        DO 90 J = 2,MAXPRM
          HANGAR(I,J) = EPS
 90     CONTINUE
100   CONTINUE
      DO 110 I = 1,MAXAC
        EMPTY(I) = .FALSE.
        FLAG(I) = .FALSE.
110   CONTINUE
      STAGAR = 0.0
      STANUM = STATNS
      DO 130 I = 1,STATNS
        DO 120 J = 1,MAXPRM
          PARAM(J) = EPS
120     CONTINUE
        PARAM(3) = REAL(STANUM)
        STANUM = STANUM - 1
        CALL SCHDLE(NOW+STAGAR,1,PARAM)
        STAGAR = STAGAR + STAG
130   CONTINUE
      CALL SCHDLE(6.0,7,PARAM)
      CALL SCHDLE(0.1,6,PARAM)
C     CALL DMPCAL
      RETURN
      END
```

B. WARMUP

```
C**********************************************************************
      SUBROUTINE WARMUP(PARAM)
C**********************************************************************
C     THIS SUBROUTINE WILL
C        -FLAG A STATION EMPTY IF NO AIRCRAFT AVAILABLE
C        -SAMPLES EACH SYSTEM FOR FAILURE DURING WARMUP
         PERIOD
C        -SCHEDULES
C          :A LAUNCH EVENT
C**********************************************************************
C
      STANUM = INT(PARAM(3))
      ABORT = .FALSE.
      IF(QUEUE .EQ. 0)THEN
        EMPTY(STANUM) = .TRUE.
        FLAG(STANUM) = .TRUE.
C        WRITE(11,5)STANUM,NOW
 5      FORMAT(1X,'STATION ',I2,' IS EMPTY AT TIME ',F7.1)
        RETURN
      ELSE
        DO 20 I = 1,MAXAC
          IF(HANGAR(I,1) .GE. 0.5) THEN
            DO 10 J = 1,MAXPRM
              PARAM(J) = HANGAR(I,J)
              HANGAR(I,J) = EPS
 10         CONTINUE
            QUEUE = QUEUE - 1
            PARAM(2) = NOW
            PARAM(3) = REAL(STANUM)
            GOTO 40
          ENDIF
 20     CONTINUE
      ENDIF
 40   CONTINUE
      MINFAL = 100000.0
      DO 50 K = 6,MAXPRM
        IF(PARAM(K) .EQ. EPS)THEN
          CALL RANNUM(5,SEED(K-5),FALTIM(K-5),4.0,0,RFAIL)
          PARAM(K) = RFAIL
        ENDIF
 50   CONTINUE
```

```
      DO 60 K = 6,MAXPRM
        IF(PARAM(K) .LT. 0.5)THEN
          ABORT = .TRUE.
          MINFAL = MIN(MINFAL,PARAM(K))
          IF(MINFAL .LT. 0.1)MINFAL = 0.1
          IF(K .GE. NUM)THEN
            PARAM(4) = 1.0
          ELSE
            PARAM(4) = 2.0
          ENDIF
        ENDIF
 60   CONTINUE
      IF(ABORT)THEN
C       WRITE(11,70)PARAM(1),NOW+MINFAL
 70     FORMAT(1X,F4.1,'FAILED ON DECK AT TIME',F7.1)
        CALL SCHDLE(NOW+MINFAL,4,PARAM)
        CALL SCHDLE(NOW+MINFAL,1,PARAM)
      ELSE
        CALL SCHDLE(NOW+0.5,2,PARAM)
      ENDIF
      STATUS(INT(PARAM(1))) = 1.0
      COVER(INT(PARAM(1))) = 0.0
      RETURN
      END
```

C. LAUNCH

```
C***********************************************************************
      SUBROUTINE LAUNCH(PARAM)
C***********************************************************************
C     THIS SUBROUTINE WILL
C         -LAUNCH AN AIRCRAFT TO STATION
C         -SAMPLES EACH SYSTEM FOR AN INFLIGHT FAILURE
C         -SCHEDULES
C           :A RELIEF AIRCRAFT
C           :A RETURN TO BASE TIME BASED UPON FAILURE STATUS
C***********************************************************************
      ABORT = .FALSE.
      DO 10 K = 6,MAXPRM
        PARAM(K) = PARAM(K) - 0.5
 10   CONTINUE
      COVER(INT(PARAM(1))) = 1.0
      MINFAL = 100000.0
      DO 20 K = 6,MAXPRM
        IF(PARAM(K) .LT. ENDURE)THEN
          IF(PARAM(K) .GE. NUM)THEN
            PARAM(4) = 1.0
          ELSE
            ABORT = .TRUE.
            MINFAL = MIN(MINFAL,PARAM(K))
            PARAM(4) = 2.0
          ENDIF
        ENDIF
 20   CONTINUE
      IF((ABORT) .AND. (MINFAL .LT. TTS+TOS))THEN
        CALL SCHDLE(NOW+MINFAL,3,PARAM)
      ELSE
        CALL SCHDLE(NOW+TTS+TOS,3,PARAM)
      ENDIF
      IF((ABORT) .AND. (MINFAL .LT. TTS))THEN
        CALL SCHDLE(NOW,1,PARAM)
      ELSE
        CALL SCHDLE(NOW+TTS+TOS-0.5,1,PARAM)
      ENDIF
      IF(MINFAL .LT. ENDURE)THEN
C       WRITE(11,50)PARAM(1),MINFAL+NOW
 50     FORMAT(1X,F4.1,' WILL FAIL AT TIME ',F7.1)
      ENDIF
```

```
STATUS(INT(PARAM(1))) = 1.0
COVER(INT(PARAM(1))) = 1.0
RETURN
END
```

D. RTB

```
C***********************************************************************
     SUBROUTINE RTB(PARAM)
C***********************************************************************
C    THIS SUBROUTINE WILL
C        -SCHEDULE A RECOVERY TIME ON THE CALENDAR BASED
         UPON
C          A) IF IT IS STILL IN TRANSIT TO STATION OR
C          B) ON STATION
C***********************************************************************
     IF((NOW - PARAM(2)+0.5) .LT. TTS)THEN
       CALL SCHDLE(NOW+(NOW-(PARAM(2)+0.5)),4,PARAM)
     ELSE
       CALL SCHDLE((NOW+TTS),4,PARAM)
     ENDIF
     IF(PARAM(4) .GT. 1.5)STATUS(INT(PARAM(1))) = 0.0
     IF(PARAM(4) .GT. 1.5)COVER(INT(PARAM(1))) = 0.0
     RETURN
     END
```

E. RECOVERY

```
C***********************************************************************
      SUBROUTINE RECOV(PARAM)
C***********************************************************************
C     THIS SUBROUTINE WILL
C       -HOT SPIN AN AIRCRAFT TO AN EMPTY STATION IF NO OTHER
        AIRCRAFT
C        ARE AVAILABLE AND WILL NOT UNDERGO PREVENTIVE
        MAINTENANCE
C       -REPAIR RECOVERING AIRCRAFT IF REQUIRED AND PERFORM
        PREVENTIVE
C        MAINTENANCE OF SYSTEMS NOT SUBJECT TO REPAIR
C***********************************************************************
C
      DTIME = 0.0
      COVER(INT(PARAM(1))) = 0.0
      IF(PARAM(4) .GT. 1.5)STATUS(INT(PARAM(1))) = 0.0
      FLYTIM(INT(PARAM(1))) = NOW - PARAM(2)
      PARAM(5) = PARAM(5) + FLYTIM(INT(PARAM(1)))
      DO 5 I = 6,MAXPRM
        PARAM(I) = PARAM(I) - FLYTIM(INT(PARAM(1)))
    5 CONTINUE
      DO 10 I = 1,STATNS
        IF(EMPTY(I) .AND. (PARAM(4) .LT. 1.5))THEN
          EMPTY(I) = .FALSE.
          PARAM(3) = REAL(I)
          CALL SCHDLE((NOW+HSTIM),5,PARAM)
C          WRITE(11,6)PARAM(1),I
    6     FORMAT(1X,'HOTSPIN ',F4.1,' TO STATION ',I2)
          RETURN
        ENDIF
   10 CONTINUE
      IF((QUEUE .LT. 1) .AND. (PARAM(4) .LT. 1.5))THEN
        CALL SCHDLE(NOW+TATIM,5,PARAM)
        RETURN
      ENDIF
      DO 20 I = 6,MAXPRM
        IF(PARAM(I) .LT. 0.0)THEN
          PARAM(I) = EPS
          PARAM(4) = 0.0
          CALL RANNUM(3,SEED(I-5),REPTIM(I-5),0.0,0,RTIME)
          DTIME = MAX(RTIME,DTIME)
```

```
      ENDIF
 20 CONTINUE
    IF(HTPM(INT(PARAM(1)))/PARAM(5) .LT. 1.0)THEN
      DO 30 K = 6,MAXPRM
        IF(INWORK(K-5) .GT. 0.5)THEN
          CALL RANNUM(1,SEED(K-5),0.0,1.0,0,PERFPM)
          IF(PERFPM .GT. IMPERF)PARAM(K) = EPS
          DTIME = DTIME + HTPM(6)
        ENDIF
 30   CONTINUE
      HTPM(INT(PARAM(1))) = HTPM(INT(PARAM(1))) + HTPM(7)
    ENDIF
    CALL SCHDLE((NOW+DTIME+TATIM),5,PARAM)
C    WRITE(11,60)PARAM(1),NOW+DTIME+TATIM
 60 FORMAT(1X,F4.1,' IS IN FOR MAINTENANCE UNTIL TIME ',F7.1)
    RETURN
    END
```

F. RTS

```
C*********************************************************************
      SUBROUTINE RTS(PARAM)
C*********************************************************************
C     THIS SUBROUTINE WILL
C        -RETURN AIRCRAFT TO THE QUEUE
C        -SCHEDULE AN AIRCRAFT FOR IMMEDIATE LAUNCH IF A
         STATION IS
C         EMPTY
C*********************************************************************
      DO 10 I = 1,MAXPRM
        HANGAR(INT(PARAM(1)),I) = PARAM(I)
   10 CONTINUE
      STATUS(INT(PARAM(1))) = 1.0
      QUEUE = QUEUE + 1
      DO 20 J = 1,STATNS
        IF(FLAG(J))THEN
          PARAM(3) = REAL(J)
          CALL SCHDLE(NOW,1,PARAM)
          FLAG(J) = .FALSE.
C          WRITE(11,15)J,PARAM(1)
   15      FORMAT(1X,'STATION ',I2,' WAS EMPTY ',F4.1,' TO FILL')
          RETURN
        ENDIF
   20 CONTINUE
      RETURN
      END
```

G. READIT

```
C*********************************************************************
      SUBROUTINE READIT
C*********************************************************************
C     THIS SUBROUTINE
C        -READS PARAMETERS AND VARIABLE FROM THE DATA FILE
C*********************************************************************
      READ(9,*)HSTIM
      READ(9,*)MANTIM
      READ(9,*)TATIM
      READ(9,*)ALTIM
      READ(9,*)ENDURE
      READ(9,*)STAG
      READ(9,*)SECTOR
```

```
      READ(9,*)SENSOR
      READ(9,*)DETECT
      READ(9,*)SPEED
      READ(9,*)TTS
      READ(9,*)TOS
      READ(9,*)STATNS
      DO 100 I = 1,MAXRV
        READ(9,*)FALTIM(I),REPTIM(I)
100   CONTINUE
      DO 101 I = 1,MAXRV
        FALTIM(I) = (1/FALTIM(I))*4.0
        REPTIM(I) = (1/REPTIM(I))
101   CONTINUE
      DO 105 I = 1,MAXRV
        READ(9,*)INWORK(I)
105   CONTINUE
      READ(9,*)HTPM(1),HTPM(2),HTPM(3),HTPM(4),HTPM(5)
     &,HTPM(6),HTPM(7)
107   CONTINUE
      DO 110 I = 1,MAXRV
        READ(9,*)SEED(I)
110   CONTINUE
      RETURN
      END
```

H. CONFIRM

```
C**********************************************************************
      SUBROUTINE CONFRM
C**********************************************************************
C     THIS SUBROUTINE
C          -READS PARAMETERS AND VARIABLES TO AN OUTPUT DATA
           FILE
C**********************************************************************
C              .........READ THE DATA INTO THE FILE
      WRITE(10,*)'     **************** INPUT DATA **************'
      WRITE(10,*)' '
      WRITE(10,5)MAXTIM
 5    FORMAT(1X,'SIMULATION RUN TIME (MIN)              ',I7)
      WRITE(10,10)HSTIM
 10   FORMAT(1X,'HOTSPIN TIME (MIN)                     ',F4.1)
      WRITE(10,15)MANTIM
 15   FORMAT(1X,'MAN UP TIME (MIN)                      ',F4.1)
      WRITE(10,20)TATIM
 20   FORMAT(1X,'TURNAROUND TIME (MIN)                  ',F4.1)
      WRITE(10,25)ALTIM
 25   FORMAT(1X,'ALERT LAUNCH TIME (MIN)                ',F4.1)
      WRITE(10,35)ENDURE
 35   FORMAT(1X,'CREW FATIGUE TIME (HRS)                ',F4.1)
      WRITE(10,40)STAG
 40   FORMAT(1X,'STAGAR INITIAL SORTIES TO STATION (MIN) ',F4.1)
      WRITE(10,45)SECTOR
 45   FORMAT(1X,'SECTOR OF AEW COVERAGE (DEG)           ',F5.1)
      WRITE(10,50)SENSOR
 50   FORMAT(1X,'SENSOR COVERAGE (NM)                   ',F5.1)
      WRITE(10,55)DETECT
 55   FORMAT(1X,'REQUIRED RAID DETECTION RANGE (NM)     ',F5.1)
      WRITE(10,60)SPEED
 60   FORMAT(1X,'PLATFORM SPEED TO STATION (KTS)        ',F5.1)
      WRITE(10,65)TTS
 65   FORMAT(1X,'TIME TO STATION (HR)                   ',F5.1)
      WRITE(10,70)TOS
 70   FORMAT(1X,'TIME ON STATION   (HR)                 ',F5.1)
      WRITE(10,75)STATNS
 75   FORMAT(1X,'NUMBER OF STATIONS                     ',I1)
      WRITE(10,*)' '
      WRITE(10,*)'     ********************************************'
      WRITE(10,*)' '
```

```
      WRITE(10,*)'  MTTF   MTTR '
      WRITE(10,*)' '
      DO 105 I = 1,MAXRV
        WRITE(10,100)FALTIM(I),REPTIM(I)
100     FORMAT(1X,F5.2,3X,F5.2)
105   CONTINUE
      WRITE(10,*)' '
      WRITE(10,*)'    *******************************************'
      DO 111 I = 1,MAXRV
        WRITE(10,110)INWORK(I)
110     FORMAT(1X,F3.1)
111   CONTINUE
      WRITE(10,*)' '
      WRITE(10,*)'    *******************************************'
      WRITE(10,*)'         HOURS TO PREVENTIVE MAINTENANCE      '
      WRITE(10,*)' '
      WRITE(10,*)'         A/C NUMBER        TIME TO    TIME  '
      WRITE(10,*)'    1  2  3  4   5    PERFORM    BETWEEN '
      WRITE(10,112)HTPM(1),HTPM(2),HTPM(3),HTPM(4),HTPM(5),
     &HTPM(6),HTPM(7)
112   FORMAT(1X,F5.1,3X,F5.1,3X,F5.1,3X,F5.1,3X,F5.1,3X,F3.1,3X,F5.1)
      WRITE(10,*)'    ***************** SEEDS *****************'
      DO 120 I = 1,MAXRV
        WRITE(10,*)SEED(I)
120   CONTINUE
      RETURN
      END
```

I. SCHEDULE

```
C*********************************************************************
      SUBROUTINE SCHDLE(EVTTIM,NEWNUM,PARAM) [Ref. 6]
C*********************************************************************
C     THIS SUBROUTINE SCHEDULES AN EVENT
C        -AT THE TIME EVENTTIME
C        -WITH THE PROPER EVENT NUMBER EVTNUM
C        -WITH THE PASSED PARAMETERS PARAM GIVEN
C
C     EVTTIM BE REAL
C     NEWNUM MUST BE INTEGER
C     PARAM MUNST BE AN ARRAY OF MAXPRM REALS
C*********************************************************************
      IF(AVAIL .LE. 0.5) THEN
        WRITE(*,*) 'CALANDAR FULL'
        WRITE(10,*) 'CALANDAR FULL'
        STOP
      ENDIF
      IF(FSTEVT .EQ. 0)THEN
        EVENT = AVAIL
        AVAIL = NXTEVT(AVAIL)
        NXTEVT(EVENT) = 0
        FSTEVT = EVENT
      ELSE
        IF(TIME(FSTEVT) .GT. EVTTIM)THEN
C            ........INSERT THE EVENT ON THE TOP OF THE CALANDAR
          EVENT = AVAIL
          AVAIL = NXTEVT(AVAIL)
          NXTEVT(EVENT) = FSTEVT
          FSTEVT = EVENT
      ELSE
C          ........THE EVENT IS NOT THE FIRST EVENT IN THE CALANDAR
        LSTEVT = FSTEVT
        CUREVT = NXTEVT(FSTEVT)
        COUNT = 0
200      CONTINUE
        IF(CUREVT .EQ. 0)THEN
C            ........WE HAVE RUN OUT OF CALANDAR, THE EVENT IS LAST
          EVENT = AVAIL
          AVAIL = NXTEVT(AVAIL)
          NXTEVT(EVENT) = 0
          NXTEVT(LSTEVT) = EVENT
```

```
        ELSE
          IF(TIME(CUREVT) .GT. EVTTIM)THEN
C           ........INSERT THE EVENT BETWEEN LSTEVT AND CUREVT
            EVENT = AVAIL
            AVAIL = NXTEVT(AVAIL)
            NXTEVT(EVENT) = CUREVT
            NXTEVT(LSTEVT) = EVENT
          ELSE
C           ........MOVE DOWN THE CALANDAR
            LSTEVT = CUREVT
            CUREVT = NXTEVT(CUREVT)
            COUNT = COUNT + 1
            IF(COUNT .GT. LISTL)THEN
              WRITE(*,*)'INFINITE LOOP IN THE EVENT LIST'
              STOP
            ENDIF
            GOTO 200
          ENDIF
        ENDIF
      ENDIF
      ENDIF
C     ........ASSIGN THE OTHER VALUES AT THE ARRAY LOCATION EVENT
      TIME(EVENT) = EVTTIM
      EVTNUM(EVENT) = NEWNUM
      DO 201 I = 1,MAXPRM
        PASSED(EVENT,I) = PARAM(I)
 201  CONTINUE
      RETURN
      END
```

J. POP

```
C*********************************************************************
     SUBROUTINE POP(EVTTIM,NUMEVT,PARAM) [Ref. 6]
C*********************************************************************
C    THIS SUBROUTINE TAKES THE FIRTS EVENT OFF THE CALANDAR
     AND
C     RETURNS THE PERTINENT DATA
C
C     EVTTIM IS THE TIME OF THE EVENT
C     NUMEVT IS THE EVENT NUMBER OF THE EVENT
C     PARAM IS AN ARRAY OF FIVE REAL PASSED PARAMETERS
C
C    EVTTIM AND NUMEVT ARE RETURNED AS 0 IF THE CALANDER IS
     EMPTY
C*********************************************************************
C
     IF(FSTEVT .EQ. 0)THEN
       NUMEVT = 0
       EVTTIM = 0.0
       RETURN
     ELSE
       EVENT = FSTEVT
       NUMEVT = EVTNUM(EVENT)
       EVTTIM = TIME(EVENT)
       DO 501 I = 1,MAXPRM
         PARAM(I) = PASSED(EVENT,I)
501    CONTINUE
       FSTEVT = NXTEVT(EVENT)
       NXTEVT(EVENT) = AVAIL
       AVAIL = EVENT
       RETURN
     ENDIF
     END
```

K. DUMP CALENDAR

```
C*************************************************************************
  SUBROUTINE DMPCAL [Ref. 6]
C*************************************************************************
C
C   DUMPS THE CURRENT CALANDAR TO THE OUTPUT FILE UNIT 10
C
C*************************************************************************
C                                                        SIM06250
    WRITE(10, *) '________________________________________'
    WRITE(10, 405)                                       SIM06270
    WRITE(10, 401) FSTEVT, AVAIL                         SIM06280
    WRITE(10, 406)                                       SIM06290
    EVENT = FSTEVT                                       SIM06300
    COUNT = 0                                            SIM06310
404  CONTINUE                                            SIM06320
    IF (EVENT.NE.0.AND.COUNT.LT.LISTL + 1) THEN
 WRITE(10, 402) EVENT, TIME(EVENT), EVTNUM(EVENT),
   &     NXTEVT(EVENT),(PASSED(EVENT, J),J = 1, 5)
EVENT = NXTEVT(EVENT)
      COUNT = COUNT + 1                                  SIM06370
      GOTO 404                                           SIM06380
    ENDIF                                                SIM06390
C                                                        SIM06400
405 FORMAT(' OUTPUT FROM THE ROUTINE DMPCAL, THE CALANDAR
DUMPER',/)
401  FORMAT(' FIRST EVENT (FSTEVT)        = ', I10,/,    SIM06420
   & ' FIRST AVAILABLE SLOT (AVAIL) = ', I10, /)         SIM06430
406  FORMAT(' EVENT     TIME     NUMBER   NEXT EVNT ')
SIM06440
402  FORMAT(I4, 4X, F8.3, 4X, I4, 4X, I4, /15X, 5(2X, F8.3))   SIM06450
    RETURN                                               SIM06460
    END
```

L. STATISTICS 2

```
C***********************************************************************
      SUBROUTINE STAT2(PARAM)
C***********************************************************************
C
      CALL SCHDLE(NOW+0.1,6,PARAM)
      IF(NOW .LE. 0.15)THEN
        AEW = 0.0
        DO 10 I = 1,MAXAC
          RVAIL(I) = 0.0
          DTIME(I) = 0.0
          UTIME(I) = 0.0
          PDOWN(I) = 0.0
 10     CONTINUE
      ENDIF
      PAEW = 0.0
      DO 20 I = 1,MAXAC
        IF(STATUS(I) .GT. 0.5)THEN
          UTIME(I) = UTIME(I) + 0.1
        ELSE
          DTIME(I) = DTIME(I) + 0.1
        ENDIF
        RVAIL(I) = UTIME(I)/(UTIME(I) + DTIME(I))
        IF(COVER(I) .GT. 0.5)PAEW = 0.1
 20   CONTINUE
      AEW = AEW + PAEW
      RETURN
      END
```

M. STATISTICS 3

```
C***********************************************************************
      SUBROUTINE STAT3(PARAM)
C***********************************************************************
C
      IF(K .LE. 999)CALL SCHDLE(NOW+6.0,7,PARAM)
      TAEW = AEW/6.0
      IF((K .GT. 199.5) .AND. (K .LT. 300.0))THEN
        WRITE(11,20)TAEW
 20     FORMAT(1X,F7.4)
      ENDIF
C
      TTAEW = TTAEW + TAEW
      AEW = 0.0
      RETURN
      END
```

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