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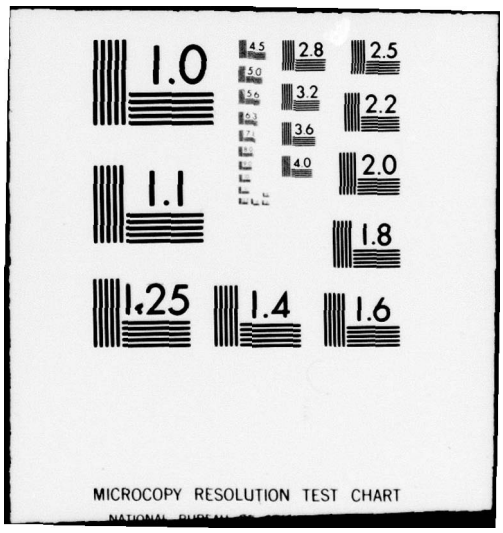
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October 1979

ESTIMATING THE TIME REQUIRED TO TRANSITION AIRCRAFT FLEETS TO NEW SCHEDULED MAINTENANCE INTERVALS

I. K. Cohen, Eugene Poggio

A Rand Note
prepared for the
United States Air Force

Rand
SANTA MONICA, CA. 90406

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Typically, decisionmakers are called upon to make decisions on aircraft inspection intervals on the basis of very limited analytic information. Under such circumstances, decisionmakers are understandably concerned about the risks incurred in extending inspection intervals. This Note presents in some detail a discussion of the phenomenon that although an immediate change is made in inspection intervals, it takes a considerable period of time for the fleet to transition to the changed interval. The slow fleet maturation may provide considerable opportunity to monitor and control the condition of the fleet during the transition period. Thus, in the case of extending inspection intervals, risk is reduced and spread over time while the payoff for the change is immediate. (Author)

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PREFACE

This Rand Note was first issued in working paper form in October 1970. It is being published at this time in a form that will make it more readily available to potential users.

The issue discussed here is as relevant today as it was when originally addressed. The Note should be of interest to Air Force managers faced with the problem of determining and extending aircraft scheduled maintenance intervals at depot and base levels.

The Note appears as originally written; only some minor editing has taken place. It is published under the Project AIR FORCE project "Concept Development and Project Formulation" in the Operations and Readiness Improvements Program.

SUMMARY

Typically, decisionmakers are called upon to make decisions on aircraft inspection intervals on the basis of very limited analytic information. Under such circumstances, decisionmakers are understandably concerned about the risks incurred in extending inspection intervals.

This Note presents in some detail a discussion of the phenomenon that, although an immediate change in inspection intervals may be made, it takes a considerable time for the fleet to transition to the changed interval. The slow fleet maturation may provide considerable opportunity to monitor and control the condition of the fleet during the transition period. Thus, in the case of extending inspection intervals, risk is reduced and spread over time while the payoff for the change is immediate.

Illustration of fleet maturation is provided. Tables and the algebra included in the Note permit extension of the illustration to other real or hypothetical scenarios.

There is some discussion about the difficulties in accelerating the slow maturation when this is desired. Some alternatives are introduced. Finally, the need for evaluating a number of alternative interval extension strategies is discussed.

ACKNOWLEDGMENTS

In early 1970, Rand was working closely with elements of the Air Force Logistics Command on many issues associated with aircraft scheduled maintenance. One such study concerned the establishment of depot inspection intervals based on the observed variability in IRAN* intervals for C-141. The C-141 study was undertaken jointly with Mr. J. W. Lewis, Jr., of the Warner-Robins Air Logistics Center. The phenomenon discussed in this Note was observed during the course of that joint study.

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*Inspect and Repair As Necessary. Programmed Depot Maintenance (PDM) is the successor program to IRAN.

CONTENTS

I. INTRODUCTION

It is likely that if we were to perform a historical analysis of the conditions that lead to explicit policy change in inspection intervals, at either base or depot level, we would find that a prevalent reason for the change would be related to the issue of resource availability. In the course of conducting a study in scheduled maintenance, we have observed what appears to be considerable deviation from scheduled maintenance interval policy. These deviations also seem to have been dominated by resource considerations.

Perhaps we should not be surprised that interval setting has been driven largely by issues of resource availability. After all, our ability for analytically determining a cost-effective interval is very limited. Interval setting is largely a matter of expert judgment. Under such conditions, perhaps it is to be expected that the position is sometimes taken that as much maintenance needs to be performed as there are resources. Furthermore, when it is diffiuclt to estimate requirements for a function such as maintenance, which is so tied to issues of safety and mission, prudence would argue for a conservative stance.

In a previous report* we suggested that there are indeed quantitative methods that can be used to complement expert judgment for establishing inspection requirements. These methods, though they do not ordinarily lead to "optimal" intervals, can be useful in improving current intervals. We urged that variability in interval size could provide significant information to the decisionmaker. Essentially, this approach argues that if long and short intervals (planned or not) have been experienced between inspections without apparent degradation in the performance of the aircraft which have been subjected to the longer interval, it is unnecessary to inspect aircraft with the shorter interval. One concern we have for our proposed method is that the

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*I. K. Cohen, *Aircraft Planned Inspection Policies: A Briefing*, R-1025-PR, June 1972.

available data systems for testing aircraft degradation have their limitations. When we find no differences in aircraft performance among aircraft with long and short intervals between inspections, we are not as certain as we would like to be that differences do not, in fact, exist. The decisionmaker is therefore faced with degrees of evidence for making an interval change. Under these circumstances, it is likely that the decisionmaker will often feel ambivalent in considering an interval extension.

In reviewing some C-141 depot maintenance data, we were exposed to a phenomenon that affected our views about the risks involved in changing inspection intervals. We had assumed (naively) that, as soon as a policy change in intervals is made, the entire fleet immediately experiences the new interval. Actually, the new interval is not realized for a considerable period of time.

This Note explores the rapidity with which the transition to a new interval occurs. As will be seen, the transition is such that decisionmakers are likely to find such information useful in reaching decisions about intervals in the face of inconclusive evidence regarding the appropriateness of a proposed new interval.

II. THE TRANSITION BETWEEN INSPECTION POLICIES

It turns out that transitioning a fleet of aircraft from one inspection interval to another is a very slow process--precisely how slow is illustrated in the following example.

Suppose we have a fleet of 200 aircraft. This hypothetical fleet is on a 24-month PDM, which means in our illustration that the inspection interval or the time between successive PDM completion dates for an aircraft is 24 months. In this case, assume that we have sufficient resources to PDM 100 aircraft a year, and that each aircraft has been through the PDM once during the 24-month period and that their *completion dates are deterministic and uniformly spaced over time*.

A decision is made to extend the PDM interval from 24 to 36 months. Let us now assume that the resources available to accomplish the PDM are cut back from 100 inspections per year to 66, and aircraft continue to be inspected at the lower rate.*

Under this scenario, it turns out that six months after introducing the new policy, the mean number of months between PDMs for that portion of the fleet that has been PDM'd (33 aircraft) has shifted upward only one month, from 24 to 25. The mean for the entire fleet of 200 aircraft is only slightly above 24 months and the longest PDM interval that exists at this time is 26 months.

To continue, the 66 aircraft that will flow through PDM during the first year of transition to the 36-month policy will have intervals ranging from 24 to 28 months; the next 66 aircraft in the second year will have intervals ranging from 28 to 32 months; and in the third year the interval range for the last third of the fleet will be from 32 to 36 (with the 200th aircraft being the only one to reach the 36-month interval). The fleet will require another three years for *all* aircraft to reach the 36-month interval.

Appendix A presents the algebra that permitted us to make the foregoing calculations. Appendix B provides the procedure for calculating

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*See Sec. III for the basis of this policy, which limits the rate at which the fleet's mean time between PDMs reaches the newly chosen interval.

the mean for the fleet during the transition between inspection intervals. Appendix C is provided for those readers who wish to examine in detail the transition of our hypothetical fleet from the 24-month to the 36-month interval. In that Appendix it is possible to note, for each inspection, the time of that inspection, the PDM interval length for that aircraft, and the mean interval for those aircraft that have been PDM'd under the new policy as well as the mean interval for the entire fleet.

Some readers may wish to quickly estimate the increase in the mean number of months between PDM for those aircraft that have been transitioned to a new interval, for a number of old and new intervals. Table 1 is provided for that purpose. Note that it provides the marginal increase of mean months between PDMs for every six months during the transition between the old and new intervals. For our foregoing

Table 1

SIX-MONTH MARGINAL INCREASE OF MEAN MONTHS BETWEEN PDM
FOR THOSE INSPECTIONS PERFORMED DURING
THE PERIOD OF TRANSITON

		New Policy--Months Between PDM						
		28	32	36	40	44	48	52
Old Policy--Months Between PDM	24	.429	.750	1.000	1.200	1.364	1.500	1.615
	28		.375	.667	.900	1.091	1.250	1.385
	32	-.429		.333	.600	.818	1.000	1.154
	36	-.857	-.375		.300	.545	.750	.923
	40	-1.286	-.750	-.333		.273	.500	.692
	44	-1.714	-1.125	-.667	-.300		.250	.462
	48	-2.143	-1.500	-1.000	-.600	-.273		.231

hypothetical fleet, for example, we find the value in the table that intersects the old policy of 24 months, as shown on the vertical axis, with the new policy of 36 months on the horizontal axis. The circled number (1.000) indicates that as we transition from a 24-month to a 36-month policy, the mean interval length for the transitioned aircraft will increase by one (1.000) month every six months. Thus, with this marginal increase of one, the mean number of months under the old policy--24--will increase to 25 after the first six months, to 26 after the second six months, to 27 after the third six months, and so forth.

Another illustration: In Table 1, the number .667 within the triangle indicates that during the transition from an interval of 28 months between PDM to a new policy of 36 months between PDM, the mean of the transitioned aircraft will increase by three-quarters (.667) of a month every six months. Thus, six months after the new interval of 36 has been introduced, the mean number of months between PDM for those aircraft inspected will be 28.667; in 12 months the mean will be 29.334; in 18 months the mean for all those aircraft inspected in that period will be 30.001; and so forth.

Table 1 has also been set up to give the indicated information for policy changes wherein the size of the interval is being shortened rather than lengthened. For example, if the old policy provides for a 48-month interval between PDM, and this policy is being changed to a new policy of 36 months between PDM, the mean interval length for the transitioned aircraft will *decrease* by one (1.000) month every six months (see the number within the dashed rectangle in Table 1). In this illustration the resources required to support the 48-month interval (50 inspections per year) are increased at the time of the policy change to support the 36-month interval (66 inspections per year).

Table 2 is entered and read similarly to Table 1. However, the values in Table 2 indicate the marginal increase in interval size *(months) every six months* for that aircraft which is experiencing the longest inspection interval during the transition period. For example, the table indicates that as we transition from a 24-month to 36-month policy, the marginal increase of inspection interval size at six months is two months (see circled value of 2.000 in table) and increases by

Table 2

SIX-MONTH MARGINAL INCREASE OF MONTHS TO PDM FOR THE LONGEST INTERVAL EXPERIENCED DURING THE PERIOD OF TRANSITION

Old Policy--Months Between PDM	New Policy--Months Between PDM						
	28	32	36	40	44	48	52
24	.857	1.500	(2.000)	2.400	2.727	3.000	3.231
28		.750	1.333	1.800	2.182	2.500	2.769
32	-.857		.667	1.200	1.636	2.000	2.308
36	-1.714	-.750		.600	1.091	1.500	1.846
40	-2.571	-1.500	-.667		.545	1.000	1.385
44	-3.429	-2.250	-1.333	-.600		.500	.923
48	-4.286	-3.000	-2.000	-1.200	-.545		.462

two months for each successive six-month period. Thus, in our example, the longest inspection interval after six months is 26, after 12 months the interval is 28, after 18 months it is 30, and so forth.

III. DISCUSSION

Section II provides important information for the decisionmaker who is about to decide on a proposed new interval in the face of inconclusive evidence regarding its appropriateness. The risk being assumed by the decisionmaker obviously changes when it is recognized that, even though the policy change occurs suddenly, nothing is going to happen *suddenly* to his aircraft.

If the decisionmaker concludes that the evidence made available to him to change the interval is less than adequate, he can set up mechanisms to track the behavior of the fleet while it slowly transitions to the changed policy. His control mechanisms might include measurements of the fleet's operational and maintenance performance while in the hands of the operator; this would entail routine analysis of available data systems. The decisionmaker might even send his engineers on visits to the field to examine (and discuss) the condition of aircraft, especially as observed in base docks. Such routine or extra-routine evaluation action might also be taken with the aircraft flowing through the PDM facility. Thus, the slow fleet maturation and the apparent opportunity to check the effects give the decisionmaker what seems like reasonable opportunity to modify his decision while he is transitioning from one policy to another. It may be that problems will arise that will cause a need to levy base-level special inspections. It may even be that it will be necessary to send a depot team to the field to fix the problem. However, such actions are not extraordinary; they occur now without interval extensions. In the extreme, it may become necessary to shorten the interval somewhat.

The slow maturation of a weapon system to a new interval is likely to be comforting to those decisionmakers who respond in conservative ways to the evidence for an interval change. Another factor makes the situation even more attractive to the conservative decisionmaker: Not only is he provided with reasonable protection by the slow maturation, but also he is rewarded by obtaining a dollar savings as soon as he cuts back resources, such as manpower required to support the old interval,

to the level required to support the new interval. The payoff occurs immediately and the effect of the decision is spread over time in such a way as to minimize the risk.

Strangely enough, however comforting the slow maturation and the immediate payoff may be to decisionmakers who need to behave conservatively, slow maturation may be frustrating to the decisionmaker who becomes convinced by the evidence that he should not behave conservatively. He has a challenging problem if he wishes to hasten the maturation process so that he can move on to intervals beyond the new one. For example, given strong evidence for a 36-month interval, there is no reasonable way of moving all aircraft into that interval immediately without shutting down maintenance for a year. However, were this option to be chosen, recurring shutdowns every third year would be required. This is so because, with 100 aircraft on a 24-month PDM and with their PDM completion dates uniformly spaced over time from 0 to 24 months, accelerating the PDM ages of these aircraft by deferring PDM for one year will provide aircraft at that time with PDM completion dates uniformly spaced over time from 12 to 36 months. Within two years after entering aircraft into PDM, their age since the last PDM will be spaced from 0 to 24 months. To continue the PDM of these aircraft will not place them on the 36-month interval. To do so will require that PDM be deferred again for one year in order that the PDM ages be from 12 to 36 months. This deferral of PDM every third year seems impossible from a resource management point of view.

One means for accelerating fleet maturation time somewhat without recurring maintenance shutdowns is to use an interval somewhat greater than 36 months. Following a review of Tables 1 and 2 above, one might decide to transition to a 40-month interval. Such a decision will lead to 2.5 aircraft entering PDM every month. From Table 2 it can be seen that as the transition from the 24-month interval to the 40-month interval takes place, the marginal increase of the inspection interval size at six months is 2.4 months and increases by 2.4 months for each successive six-month period. Thus, at 30 months 75 aircraft will have been PDM'd (30×2.5), and the largest PDM interval will be 36 months [$2.4(5) + 24$]. The use of the 40-month PDM interval strategy means

that the first aircraft reaches a 36-month interval at 30 months rather than at 36 months, and 25 aircraft will exceed the 36 month interval. In the transition from the 30th month to the 40th month, aircraft will continue to be PDM'd at the rate of 2.5 aircraft per month. At the 36th month, for example, the longest PDM interval will be 38.4 months, with 10 aircraft remaining to the PDM before the first aircraft is on the 40-month interval.

Another strategy that needs to be considered in the context of slow maturation is a strategy that does not cling to one interval very long if all goes well with that interval. However, instead of changing the interval for the entire fleet, one might take a sample of aircraft to be extended beyond their normal new interval. Under this strategy, problems of when to initiate this extension, the sample size to be extended, and the length of the extension, are all issues that need to be addressed.*

The observation of slow maturation also dramatizes that it is important to deal with the question of interval size and its iteration during early stages in the life of a weapon system. Is it wise to start conservatively and be "slow to obtain a policy change," and then make a sizeable interval change which is then "slow to transition to the changed policy?" An alternative is the one pursued by United Air lines over the ten-year history of the "Basic" or "E-Check" for its DC-8 fleet.† This check is the most comprehensive one for the aircraft, consuming nearly one week in the dock and nearly 12,000 man-hours. The original interval of 2500 hours was known to be quite conservative. After only 24 aircraft had been examined under this schedule (about once each for the fleet then in service), the interval was raised to 3000 hours. In the years since, the interval has been increased, on the average, 500 hours for each 17 aircraft overhauled, or approximately each eight months of calendar time.

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*One form of this option has been used by AFLC in its Controlled Interval Extension (CIE) programs.

†The information for this alternative was provided by M. Kamins at the time of the 1970 publication of this document.

A range of interesting strategies are therefore available. It is likely that the choice of a particular policy will need to be based on the aircraft type, its current interval, the nature of the data available to support an interval extension, and the risk-aversion tendencies of the decisionmaker.

IV. RECAP

Although decisions regarding interval change immediately affect resources required and the input rate to inspections, an aircraft fleet requires considerable time to transition to the new policy. During this transition, reasonable opportunity is likely to exist for monitoring and controlling the condition of the fleet. System performance and maintenance actions may be observed over a variety of operational scenarios. These observations are important for all persons concerned with interval extensions. It is especially important for the many likely occasions when the evidence argues for interval extension, but not with desired degrees of engineering certainty.

Appendix A

CALCULATING SELECTED STATISTICS WHEN TRANSITIONING BETWEEN INSPECTION INTERVALS

Let N denote the fleet size. Consider a policy of n years as signifying that the time between successive completion dates for an aircraft, henceforth called the inspection interval, should be n years. Let the current inspection policy be n_1 years. Assume that the current staff is such that (N/n_1) planes are inspected each year, that all aircraft in the fleet have been inspected precisely once within the last period of time $[(N-1)/N]n_1$ and that the completion dates for these aircraft are uniformly spaced over this period of time. Number the aircraft from 1 to N chronologically according to these completion dates. Label 0 the time at which the last of these inspections was completed. Given, then, that the N completion dates are spaced uniformly over the interval $[-(N-1)/N]n_1, 0]$, and given that N/n_1 aircraft are inspected each year, the time between successive dates is n_1/N. Hence, aircraft #1 was completed at time $-(N-1)(n_1/N)$, #2 at time $-(N-2)(n_1/N)$, and #i at time $-(N-i)(n_1/N)$.

Suppose we are considering a new policy of n_2 years. Let us schedule the aircraft in the same sequence as before, with the completion dates again uniformly spaced. Suppose we alter the staff in inverse proportion, that is by a factor of (n_1/n_2). Then (N/n_2) planes will be inspected each year and the time between successive completion dates will be n_2/N. Thus, the i^{th} aircraft will be inspected next at time $i(n_2/N)$. Since it was last inspected at time $-(N-i)(n_1/N)$, the inspection interval for the i^{th} aircraft, for its first inspection after time 0, is given by

$$i\left(\frac{n_2}{N}\right) - \left[-\left(N-i\right)\left(\frac{n_1}{N}\right)\right]$$

$$= \frac{in_2}{N} + \frac{Nn_1}{N} - \frac{in_1}{N}$$

$$= n_1 + \frac{i}{N}(n_2 - n_1).$$

In particular, for aircraft N, we have

$$n_1 + \frac{N}{N}(n_2 - n_1) = n_2,$$

so that in fact the N^{th} aircraft will be the first to have an inspection interval of the full n_2 years and this occurs only after a transition period of n_2 years.

Now suppose we are interested in calculating the mean inspection interval for the inspections performed in some initial segment of this transition period, $[0, n_2]$. Since during this period the i^{th} aircraft will have an inspection interval of length $n_1 + i/N\,(n_2 - n_1)$, first j aircraft, $1 \leq j \leq N$, the desired mean is given by

$$\frac{1}{j} \sum_{i=1}^{j} [n_1 + \frac{i}{N}(n_2 - n_1)]$$

$$= \frac{j}{j} n_1 + \left(\frac{n_2 - n_1}{N}\right) \left(\frac{1}{j}\right) \sum_{i=1}^{j} i$$

$$= n_1 + \left(\frac{n_2 - n_1}{N}\right) \left(\frac{j+1}{2}\right)$$

$$= n_1 + \frac{j+1}{2N} \left(n_2 - n_1\right).$$

(More generally and more simply, since $n_1 + i\,(n_2 - n_1)/N$ is a linear function of i, its mean over any range of i is simply equal to the value of this function evaluated at the mean of this range, which in this case is simply $(j + 1)/2$).

Suppose we are interested in calculating the mean inspection interval over the inspections performed during and immediately subsequent to the transition period. Now, the k^{th} inspection of the i^{th} aircraft after time 0 occurs at time $[(k - 1)N + i]\, n_2/N$. Hence, for $k \geq 2$,

the time between the k^{th} and the $(k-1)^{st}$ inspection is given by

$$\left[\left(k-1\right)N+i\right]\left[\frac{n_2}{N}\right]-\left[\left(k-2\right)N+i\right]\left[\frac{n_2}{N}\right]$$

$$=\left[\left(k-1\right)-\left(k-2\right)\right]\frac{Nn_2}{N}$$

$$=\frac{Nn_2}{N}$$

$$=n_2\ .$$

Thus, after the transition period, all intervals are of length n_2. For the N inspections during the transition period the mean is given from the previously derived formula by $n_1 + (N+1)/2N\ (n_2 - n_1)$. Hence, for the first j inspection after time 0, $j > N$, the mean inspection interval is given by

$$\frac{N[n_1+\frac{N+1}{2N}(n_2-n_1)]+(j-N)n_2}{j}$$

$$=\frac{Nn_1+\frac{N+1}{2}(n_2-n_1)+jn_2-Nn_2}{j}$$

$$=\frac{N(n_1-n_2)+\frac{N}{2}(n_2-n_1)+\frac{1}{2}(n_2-n_1)+jn_2}{j}$$

$$=\frac{jn_2+\frac{N}{2}(n_2-n_1)-N(n_2-n_1)+\frac{1}{2}(n_2-n_1)}{j}$$

$$=n_2+\frac{(n_2-n_1)(\frac{N}{2}-N+\frac{1}{2})}{j}$$

$$=n_2+\frac{(n_2-n_1)(\frac{1}{2}-\frac{N}{2})}{j}$$

$$=n_2+\frac{1-N}{2j}(n_2-n_1)$$

Letting $\ell(j)$ be the inspection interval length for the i^{th} inspection after time 0 and $\mu_\ell(j)$, the mean of these interval lengths over all inspections performed after time 0 up to and including the j^{th} inspection, we have in summary

$$\ell(j) = \begin{cases} n_1 + \frac{j}{N}(n_2 - n_1) & \text{for } j = 1, \ldots, N \\ n_2 & \text{for } j = N+1, N+2, \ldots \end{cases}$$

and

$$\mu_\ell(j) = \begin{cases} n_1 + \frac{j+1}{2N}(n_2 - n_1) & \text{for } j = 1, \ldots, N \\ n_2 + \frac{1-N}{2j}(n_2 - n_1) & \text{for } j = N+1, N+2, \ldots \end{cases}$$

By employing the fact that the j^{th} inspection was performed at time $T = j(n_2/N)$, we can obtain formulas analogous to the above expressed in terms of time. Let $\ell(T)$ be the inspection interval length at time T and $\mu_\ell(T)$ the mean over all inspections performed in the interval (0, T). We have then

$$\ell(T) = \begin{cases} n_1 + \frac{T}{n_2}(n_2 - n_1) & \text{for } T = \frac{n_2}{N}, \frac{2n_2}{N}, \ldots, n_2 \\ n_2 & \text{for } T > n_2 \end{cases}$$

and

$$\mu_{\ell}(T) = \begin{cases} n_1 + \dfrac{\frac{TN}{n_2} + 1}{2N}(n_2 - n_1) & \text{for } T = \dfrac{n_2}{N}, \dfrac{2n_2}{N}, \ldots, n_2 \\ n_2 + \dfrac{1 - N}{\frac{2TN}{n_2}}(n_2 - n_1) & \text{for } T > n_2 \end{cases}$$

$$= \begin{cases} n_1 + (\dfrac{T}{2n_2} + \dfrac{1}{2N})(n_2 - n_1) & \text{for } T = \dfrac{n_2}{N}, \dfrac{2n_2}{N}, \ldots, n_2 \\ n_2 + (\dfrac{n_2}{2TN} - \dfrac{n_2}{2T})(n_2 - n_1) & \text{for } T > n_2 \end{cases}$$

Appendix B

CALCULATING THE FLEET MEAN WHEN TRANSITIONING BETWEEN INSPECTION INTERVALS

Suppose we wish to calculate the mean inspection interval for the fleet, that is, the mean time between the last two PDMs for each aircraft serial number. We employ the notation and make the assumptions of App. A, "Calculating Selected Statistics When Transitioning Between Inspection Intervals." We make the additional assumption that the inspection interval for each tail number is that of the old policy n_1.

At the j^{th} inspection after initiation of the new policy $1 \leq j \leq N$, the fleet mean is given by

$$\frac{\left(N - j\right) n_1 + j \left[n_1 + \frac{j + 1}{2N} \left(n_2 - n_1\right)\right]}{N}$$

Since $N - j$ aircraft have not yet had an inspection since implementation and for the j which have, the mean is given by $n_1 + (j + 1)/2N(n_2 - n_1)$. At the j^{th} inspection, where $N < j < 2N$, the mean is given by

$$\frac{\left(2N - j\right)\left[n_1 + \frac{N + N - (2N - j) + 1}{2N} \left(n_2 - n_1\right)\right] + \left(j - N\right) n_2}{N}$$

$$= \frac{\left(2N - j\right)\left[n_1 + \frac{j + 1}{2N} \left(n_2 - n_1\right)\right] + \left(j - N\right) n_2}{N}$$

since $2N - j$ aircraft in the fleet had their last inspection during the end of the transition period with a mean interval for these of $n_1 + (j + 1)/2N\ (n_2 - n_1)$, and the remaining $j - N$ had their last

inspection after the transition period so that each of these had an interval of the new policy n_2.

At the j^{th} inspection for $2N \leq j$, all aircraft have reached the new policy, so that the mean is simply given by n_2.

Thus, letting $\mu_F(j)$ denote the fleet mean, we have

$$\mu_F(j) = \begin{cases} \dfrac{(N - j)\, n_1 + j\left[n_1 + \dfrac{j+1}{2N}(n_2 - n_1)\right]}{N} & \text{for } 1 \leq j \leq N \\ \dfrac{(2N - j)\left[n_1 + \dfrac{j+1}{2N}(n_2 - n_1)\right] + (j - N)\, n_2}{N} & \text{for } N < j < 2N \\ n_2 & \text{for } 2N \leq j \end{cases}$$

And by employing the fact that the j^{th} inspection was performed at time $T = j(n_2/N)$, we obtain comparable formulas expressed in terms of time as follows:

$$\mu_F(T) = \begin{cases} \dfrac{(N - \frac{TN}{n_2})\, n_1 + \frac{TN}{n_2}\left[n_1 + \dfrac{\frac{TN}{n_2} + 1}{2N}(n_2 - n_1)\right]}{N} & \text{for } \dfrac{n_2}{N} \leq T \leq n_2 \\ \dfrac{(2N - \frac{TN}{n_2})\left[n_1 + \dfrac{\frac{TN}{n_2} + 1}{2N}(n_2 - n_1)\right] + (\frac{TN}{n_2} - N)\, n_2}{N} & \text{for } n_2 < T < 2n_2 \\ n_2 & \text{for } T > 2n_2 \end{cases}$$

$$\mu_P(T) = \begin{cases} (1 - \frac{T}{n_2})\, n_1 + \frac{T}{n_2}\left[n_1 + (\frac{T}{2n_2} + 1/2)(n_2 - n_1)\right] & \text{for } \frac{n_2}{N} - \leq T \leq n_2 \\ (2 - \frac{T}{n_2})\left[n_1 + (\frac{T}{2n_2} + \frac{1}{2N})(n_2 - n_1)\right] + (\frac{T}{n_2} - 1)\, n_2 & \\ & \text{for } n_2 < T < 2n_2 \\ n_2 & \text{for } T > 2n_2 \end{cases}$$

Appendix C

THE TRANSITION BETWEEN INSPECTION POLICIES: AN ILLUSTRATION

In the following detailed illustration of the transition between inspection intervals, the old policy is 24 months, the new policy is 36 months, and the fleet size is 200. The assumptions in the preparation of this illustration are specified in Apps. A and B.

In the illustration, the Inspection Number column provides the chronological numbers of the aircraft by completion dates. These completion dates (uniformly spaced over time) are shown in the column headed "Time." The Interval Length column provides the length of the inspection interval for the indicated aircraft (inspection number). The mean number of months between PDMs for the entire fleet at the indicated time is shown in the fourth column. Finally, the Initiation Mean column provides the mean inspection interval (months) for the inspections performed in the transition period up to the time indicated in the "Time" column.

THE TRANSITION BETWEEN INSPECTION POLICIES

(Old Policy = 24 months, New Policy = 36 months, Fleet Size = 200)

Inspection Number	Time	Interval Length	Fleet Mean	Initiation Mean
1	.180	24.060	24.000	24.060
2	.360	24.120	24.001	24.090
3	.540	24.180	24.002	24.120
4	.720	24.240	24.003	24.150
5	.900	24.300	24.005	24.180
6	1.080	24.360	24.006	24.210
7	1.260	24.420	24.008	24.240
8	1.440	24.480	24.011	24.270
9	1.620	24.540	24.014	24.300
10	1.800	24.600	24.017	24.330
11	1.980	24.660	24.020	24.360
12	2.160	24.720	24.023	24.390
13	2.340	24.780	24.027	24.420
14	2.520	24.840	24.032	24.450
15	2.700	24.900	24.036	24.480
16	2.880	24.960	24.041	24.510
17	3.060	25.020	24.046	24.540
18	3.240	25.080	24.051	24.570
19	3.420	25.140	24.057	24.600
20	3.600	25.200	24.063	24.630
21	3.780	25.260	24.069	24.660
22	3.960	25.320	24.076	24.690
23	4.140	25.380	24.083	24.720
24	4.320	25.440	24.090	24.750
25	4.500	25.500	24.098	24.780
26	4.680	25.560	24.105	24.810
27	4.860	25.620	24.113	24.840
28	5.040	25.680	24.122	24.870
29	5.220	25.740	24.131	24.900
30	5.400	25.800	24.140	24.930
31	5.580	25.860	24.149	24.960
32	5.760	25.920	24.158	24.990
33	5.940	25.980	24.168	25.020
34	6.120	26.040	24.179	25.050
35	6.300	26.100	24.189	25.080
36	6.480	26.160	24.200	25.110
37	6.660	26.220	24.211	25.140
38	6.840	26.280	24.222	25.170
39	7.020	26.340	24.234	25.200
40	7.200	26.400	24.246	25.230
41	7.380	26.460	24.258	25.260
42	7.560	26.520	24.271	25.290
43	7.740	26.580	24.284	25.320
44	7.920	26.640	24.297	25.350
45	8.100	26.700	24.311	25.380

THE TRANSITION BETWEEN INSPECTION POLICIES

(Old Policy = 24 months, New Policy = 36 months Fleet Size = 200) (con't.)

46	8.280	26.760	24.324	25.410
47	8.460	26.820	24.338	25.440
48	8.640	26.880	24.353	25.470
49	8.820	26.940	24.368	25.500
50	9.000	27.000	24.383	25.530
51	9.180	27.060	24.398	25.560
52	9.360	27.120	24.413	25.590
53	9.540	27.180	24.429	25.620
54	9.720	27.240	24.446	25.650
55	9.900	27.300	24.462	25.680
56	10.080	27.360	24.479	25.710
57	10.260	27.420	24.496	25.740
58	10.440	27.480	24.513	25.770
59	10.620	27.540	24.531	25.800
60	10.800	27.600	24.549	25.830
61	10.980	27.660	24.567	25.860
62	11.160	27.720	24.586	25.890
63	11.340	27.780	24.605	25.920
64	11.520	27.840	24.624	25.950
65	11.700	27.900	24.644	25.980
66	11.880	27.960	24.663	26.010
67	12.060	28.020	24.683	26.040
68	12.240	28.080	24.704	26.070
69	12.420	28.140	24.725	26.100
70	12.600	28.200	24.746	26.130
71	12.780	28.260	24.767	26.160
72	12.960	28.320	24.788	26.190
73	13.140	28.380	24.810	26.220
74	13.320	28.440	24.833	26.250
75	13.500	28.500	24.855	26.280
76	13.680	28.560	24.878	26.310
77	13.860	28.620	24.901	26.340
78	14.040	28.680	24.924	26.370
79	14.220	28.740	24.948	26.400
80	14.400	28.800	24.972	26.430
81	14.580	28.860	24.996	26.460
82	14.760	28.920	25.021	26.490
83	14.940	28.980	25.046	26.520
84	15.120	29.040	25.071	26.550
85	15.300	29.100	25.097	26.580
86	15.480	29.160	25.122	26.610
87	15.660	29.220	25.148	26.640
88	15.840	29.280	25.175	26.670
89	16.020	29.340	25.202	26.700
90	16.200	29.400	25.229	26.730
91	16.380	29.460	25.256	26.760
92	16.560	29.520	25.283	26.790
93	16.740	29.580	25.311	26.820
94	16.920	29.640	25.340	26.850
95	17.100	29.700	25.368	26.880
96	17.280	29.760	25.397	26.910
97	17.460	29.820	25.426	26.940
98	17.640	29.880	25.455	26.970
99	17.820	29.940	25.485	27.000

THE TRANSITION BETWEEN INSPECTION POLICIES

(Old Policy = 24 months, New Policy = 36 months, Fleet Size = 200)
(continued)

100	18.000	30.000	25.515	27.030
101	18.180	30.060	25.545	27.060
102	18.360	30.120	25.576	27.090
103	18.540	30.180	25.607	27.120
104	18.720	30.240	25.638	27.150
105	18.900	30.300	25.670	27.180
106	19.080	30.360	25.701	27.210
107	19.260	30.420	25.733	27.240
108	19.440	30.480	25.766	27.270
109	19.620	30.540	25.799	27.300
110	19.800	30.600	25.832	27.330
111	19.980	30.660	25.865	27.360
112	20.160	30.720	25.898	27.390
113	20.340	30.780	25.932	27.420
114	20.520	30.840	25.967	27.450
115	20.700	30.900	26.001	27.480
116	20.880	30.960	26.036	27.510
117	21.060	31.020	26.071	27.540
118	21.240	31.080	26.106	27.570
119	21.420	31.140	26.142	27.600
120	21.600	31.200	26.178	27.630
121	21.780	31.260	26.214	27.660
122	21.960	31.320	26.251	27.690
123	22.140	31.380	26.288	27.720
124	22.320	31.440	26.325	27.750
125	22.500	31.500	26.363	27.780
126	22.680	31.560	26.400	27.810
127	22.860	31.620	26.438	27.840
128	23.040	31.680	26.477	27.870
129	23.220	31.740	26.516	27.900
130	23.400	31.800	26.555	27.930
131	23.580	31.860	26.594	27.960
132	23.760	31.920	26.633	27.990
133	23.940	31.980	26.673	28.020
134	24.120	32.040	26.714	28.050
135	24.300	32.100	26.754	28.080
136	24.480	32.160	26.795	28.110
137	24.660	32.220	26.836	28.140
138	24.840	32.280	26.877	28.170
139	25.020	32.340	26.919	28.200
140	25.200	32.400	26.961	28.230
141	25.380	32.460	27.003	28.260
142	25.560	32.520	27.046	28.290
143	25.740	32.580	27.089	28.320
144	25.920	32.640	27.132	28.350
145	26.100	32.700	27.176	28.380
146	26.280	32.760	27.219	28.410
147	26.460	32.820	27.263	28.440
148	26.640	32.880	27.308	28.470
149	26.820	32.940	27.353	28.500
150	27.000	33.000	27.398	28.530
151	27.180	33.060	27.443	28.560
152	27.360	33.120	27.488	28.590
153	27.540	33.180	27.534	28.620

THE TRANSITION BETWEEN INSPECTION POLICIES

(Old Policy = 24 months, New Policy = 36 months, Fleet Size = 200)
(Continued)

154	27.720	33.240	27.581	28.650
155	27.900	33.300	27.627	28.680
156	28.080	33.360	27.674	28.710
157	28.260	33.420	27.721	28.740
158	28.440	33.480	27.768	28.770
159	28.620	33.540	27.816	28.800
160	28.800	33.600	27.864	28.830
161	28.980	33.660	27.912	28.860
162	29.160	33.720	27.961	28.890
163	29.340	33.780	28.010	28.920
164	29.520	33.840	28.059	28.950
165	29.700	33.900	28.109	28.980
166	29.880	33.960	28.158	29.010
167	30.060	34.020	28.208	29.040
168	30.240	34.080	28.259	29.070
169	30.420	34.140	28.310	29.100
170	30.600	34.200	28.361	29.130
171	30.780	34.260	28.412	29.160
172	30.960	34.320	28.463	29.190
173	31.140	34.380	28.515	29.220
174	31.320	34.440	28.568	29.250
175	31.500	34.500	28.620	29.280
176	31.680	34.560	28.673	29.310
177	31.860	34.620	28.726	29.340
178	32.040	34.680	28.779	29.370
179	32.220	34.740	28.833	29.400
180	32.400	34.800	28.887	29.430
181	32.580	34.860	28.941	29.460
182	32.760	34.920	28.996	29.490
183	32.940	34.980	29.051	29.520
184	33.120	35.040	29.106	29.550
185	33.300	35.100	29.162	29.580
186	33.480	35.160	29.217	29.610
187	33.660	35.220	29.273	29.640
188	33.840	35.280	29.330	29.670
189	34.020	35.340	29.387	29.700
190	34.200	35.400	29.444	29.730
191	34.380	35.460	29.501	29.760
192	34.560	35.520	29.558	29.790
193	34.740	35.580	29.616	29.820
194	34.920	35.640	29.675	29.850
195	35.100	35.700	29.733	29.880
196	35.280	35.760	29.792	29.910
197	35.460	35.820	29.851	29.940
198	35.640	35.880	29.910	29.970
199	35.820	35.940	29.970	30.000
200	36.000	36.000	30.030	30.030
201	36.180	36.000	30.090	30.060
202	36.360	36.000	30.149	30.089
203	36.540	36.000	30.208	30.118
204	36.720	36.000	30.267	30.147
205	36.900	36.000	30.326	30.176
206	37.080	36.000	30.384	30.204
207	37.260	36.000	30.442	30.232

THE TRANSITION BETWEEN INSPECTION POLICIES

(Old Policy = 24 months, New Policy = 36 months, Fleet Size = 200)
(Continued)

208	37.440	36.000	30.499	30.260
209	37.620	36.000	30.557	30.287
210	37.800	36.000	30.614	30.314
211	37.980	36.000	30.670	30.341
212	38.160	36.000	30.727	30.368
213	38.340	36.000	30.783	30.394
214	38.520	36.000	30.839	30.421
215	38.700	36.000	30.894	30.447
216	38.880	36.000	30.949	30.472
217	39.060	36.000	31.004	30.498
218	39.240	36.000	31.059	30.523
219	39.420	36.000	31.113	30.548
220	39.600	36.000	31.167	30.573
221	39.780	36.000	31.221	30.597
222	39.960	36.000	31.274	30.622
223	40.140	36.000	31.327	30.646
224	40.320	36.000	31.380	30.670
225	40.500	36.000	31.433	30.693
226	40.680	36.000	31.485	30.717
227	40.860	36.000	31.537	30.740
228	41.040	36.000	31.588	30.763
229	41.220	36.000	31.640	30.786
230	41.400	36.000	31.691	30.809
231	41.580	36.000	31.741	30.831
232	41.760	36.000	31.792	30.853
233	41.940	36.000	31.842	30.876
234	42.120	36.000	31.892	30.897
235	42.300	36.000	31.941	30.919
236	42.480	36.000	31.990	30.941
237	42.660	36.000	32.039	30.962
238	42.840	36.000	32.088	30.983
239	43.020	36.000	32.136	31.004
240	43.200	36.000	32.184	31.025
241	43.380	36.000	32.232	31.046
242	43.560	36.000	32.279	31.066
243	43.740	36.000	32.326	31.086
244	43.920	36.000	32.373	31.107
245	44.100	36.000	32.420	31.127
246	44.280	36.000	32.466	31.146
247	44.460	36.000	32.512	31.166
248	44.640	36.000	32.557	31.185
249	44.820	36.000	32.603	31.205
250	45.000	36.000	32.648	31.224
251	45.180	36.000	32.692	31.243
252	45.360	36.000	32.737	31.262
253	45.540	36.000	32.781	31.281
254	45.720	36.000	32.825	31.299
255	45.900	36.000	32.868	31.318
256	46.080	36.000	32.911	31.336
257	46.260	36.000	32.954	31.354
258	46.440	36.000	32.997	31.372
259	46.620	36.000	33.039	31.390
260	46.800	36.000	33.081	31.408
261	46.980	36.000	33.123	31.425

THE TRANSITION BETWEEN INSPECTION POLICIES

(Old Policy = 24 months, New Policy = 36 months, Fleet Size = 200)
(Continued)

262	47.160	36.000	33.164	31.443
263	47.340	36.000	33.205	31.460
264	47.520	36.000	33.246	31.477
265	47.700	36.000	33.287	31.494
266	47.880	36.000	33.327	31.511
267	48.060	36.000	33.367	31.528
268	48.240	36.000	33.406	31.545
269	48.420	36.000	33.446	31.561
270	48.600	36.000	33.485	31.578
271	48.780	36.000	33.523	31.594
272	48.960	36.000	33.562	31.610
273	49.140	36.000	33.600	31.626
274	49.320	36.000	33.638	31.642
275	49.500	36.000	33.675	31.658
276	49.680	36.000	33.712	31.674
277	49.860	36.000	33.749	31.690
278	50.040	36.000	33.786	31.705
279	50.220	36.000	33.822	31.720
280	50.400	36.000	33.858	31.736
281	50.580	36.000	33.894	31.751
282	50.760	36.000	33.929	31.766
283	50.940	36.000	33.964	31.781
284	51.120	36.000	33.999	31.796
285	51.300	36.000	34.034	31.811
286	51.480	36.000	34.068	31.825
287	51.660	36.000	34.102	31.840
288	51.840	36.000	34.135	31.854
289	52.020	36.000	34.169	31.869
290	52.200	36.000	34.202	31.883
291	52.380	36.000	34.234	31.897
292	52.560	36.000	34.267	31.911
293	52.740	36.000	34.299	31.925
294	52.920	36.000	34.331	31.939
295	53.100	36.000	34.362	31.953
296	53.280	36.000	34.393	31.966
297	53.460	36.000	34.424	31.980
298	53.640	36.000	34.455	31.993
299	53.820	36.000	34.485	32.007
300	54.000	36.000	34.515	32.020
301	54.180	36.000	34.545	32.033
302	54.360	36.000	34.574	32.046
303	54.540	36.000	34.603	32.059
304	54.720	36.000	34.632	32.072
305	54.900	36.000	34.661	32.085
306	55.080	36.000	34.689	32.098
307	55.260	36.000	34.717	32.111
308	55.440	36.000	34.744	32.123
309	55.620	36.000	34.772	32.136
310	55.800	36.000	34.799	32.148
311	55.980	36.000	34.825	32.161
312	56.160	36.000	34.852	32.173
313	56.340	36.000	34.878	32.185
314	56.520	36.000	34.904	32.197
315	56.700	36.000	34.929	32.210

THE TRANSITION BETWEEN INSPECTION POLICIES

(Old Policy = 24 months, New Policy = 36 months, Fleet Size = 200)
(Continued)

316	56.880	36.000	34.954	32.222
317	57.060	36.000	34.979	32.233
318	57.240	36.000	35.004	32.245
319	57.420	36.000	35.028	32.257
320	57.600	36.000	35.052	32.269
321	57.780	36.000	35.076	32.280
322	57.960	36.000	35.099	32.292
323	58.140	36.000	35.122	32.303
324	58.320	36.000	35.145	32.315
325	58.500	36.000	35.168	32.326
326	58.680	36.000	35.190	32.337
327	58.860	36.000	35.212	32.349
328	59.040	36.000	35.233	32.360
329	59.220	36.000	35.255	32.371
330	59.400	36.000	35.276	32.382
331	59.580	36.000	35.296	32.393
332	59.760	36.000	35.317	32.404
333	59.940	36.000	35.337	32.414
334	60.120	36.000	35.357	32.425
335	60.300	36.000	35.376	32.436
336	60.480	36.000	35.395	32.446
337	60.660	36.000	35.414	32.457
338	60.840	36.000	35.433	32.467
339	61.020	36.000	35.451	32.478
340	61.200	36.000	35.469	32.488
341	61.380	36.000	35.487	32.499
342	61.560	36.000	35.504	32.509
343	61.740	36.000	35.521	32.519
344	61.920	36.000	35.538	32.529
345	62.100	36.000	35.555	32.539
346	62.280	36.000	35.571	32.549
347	62.460	36.000	35.587	32.559
348	62.640	36.000	35.602	32.569
349	62.820	36.000	35.618	32.579
350	63.000	36.000	35.633	32.589
351	63.180	36.000	35.647	32.598
352	63.360	36.000	35.662	32.608
353	63.540	36.000	35.676	32.618
354	63.720	36.000	35.690	32.627
355	63.900	36.000	35.703	32.637
356	64.080	36.000	35.716	32.646
357	64.260	36.000	35.729	32.655
358	64.440	36.000	35.742	32.665
359	64.620	36.000	35.754	32.674
360	64.800	36.000	35.766	32.683
361	64.980	36.000	35.778	32.693
362	65.160	36.000	35.789	32.702
363	65.340	36.000	35.800	32.711
364	65.520	36.000	35.811	32.720
365	65.700	36.000	35.822	32.729
366	65.880	36.000	35.832	32.738
367	66.060	36.000	35.842	32.747
368	66.240	36.000	35.851	32.755
369	66.420	36.000	35.861	32.764

THE TRANSITION BETWEEN INSPECTION POLICIES

(Old Policy = 24 months, New Policy = 36 months, Fleet Size = 200)
(Continued)

370	66.600	36.000	35.870	32.773
371	66.780	36.000	35.878	32.782
372	66.960	36.000	35.887	32.790
373	67.140	36.000	35.895	32.799
374	67.320	36.000	35.903	32.807
375	67.500	36.000	35.910	32.816
376	67.680	36.000	35.917	32.824
377	67.860	36.000	35.924	32.833
378	68.040	36.000	35.931	32.841
379	68.220	36.000	35.937	32.850
380	68.400	36.000	35.943	32.858
381	68.580	36.000	35.949	32.866
382	68.760	36.000	35.954	32.874
383	68.940	36.000	35.959	32.883
384	69.120	36.000	35.964	32.891
385	69.300	36.000	35.969	32.899
386	69.480	36.000	35.973	32.907
387	69.660	36.000	35.977	32.915
388	69.840	36.000	35.980	32.923
389	70.020	36.000	35.984	32.931
390	70.200	36.000	35.987	32.938
391	70.380	36.000	35.989	32.946
392	70.560	36.000	35.992	32.954
393	70.740	36.000	35.994	32.962
394	70.920	36.000	35.996	32.970
395	71.100	36.000	35.997	32.977
396	71.280	36.000	35.998	32.985
397	71.460	36.000	35.999	32.992
398	71.640	36.000	36.000	33.000
399	71.820	36.000	36.000	33.008
400	72.000	36.000	36.000	33.015
401	72.180	36.000	36.000	33.022
402	72.360	36.000	36.000	33.030
403	72.540	36.000	36.000	33.037
404	72.720	36.000	36.000	33.045
405	72.900	36.000	36.000	33.052
406	73.080	36.000	36.000	33.059
407	73.260	36.000	36.000	33.066
408	73.440	36.000	36.000	33.074
409	73.620	36.000	36.000	33.081
410	73.800	36.000	36.000	33.088