MIL-STD-2173(AS)
21 JANUARY 1986

SUPERSEDING
MIL-HDBK-266(AS)
14 AUGUST 1981

# MILITARY STANDARD

## RELIABILITY-CENTERED MAINTENANCE REQUIREMENTS FOR NAVAL AIRCRAFT, WEAPONS SYSTEMS AND SUPPORT EQUIPMENT

AMSC No. N3769 AREA-ILSS

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Department of Defense
Washington, DC 20301

# Reliability-Centered Maintenance Requirements for Naval Aircraft, Weapon Systems and Support Equipment

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2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to Commanding Officer, Naval Air Engineering Center, Engineering Specifications and Standards Department (ESSD), ATTN: Code 93, Lakehurst, NJ 08733, by using the self addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

# FOREWORD

## 1. Background

Early approaches to preventive maintenance programs were based on the concept that periodic overhauls ensure reliability, and therefore operating safety. However, tests by the airlines in 1965 showed that scheduled overhaul of complex equipment has little or no effect on the reliability of the equipment in service. These tests identified the need for a new concept for preventive maintenance, which was eventually developed in 1968.

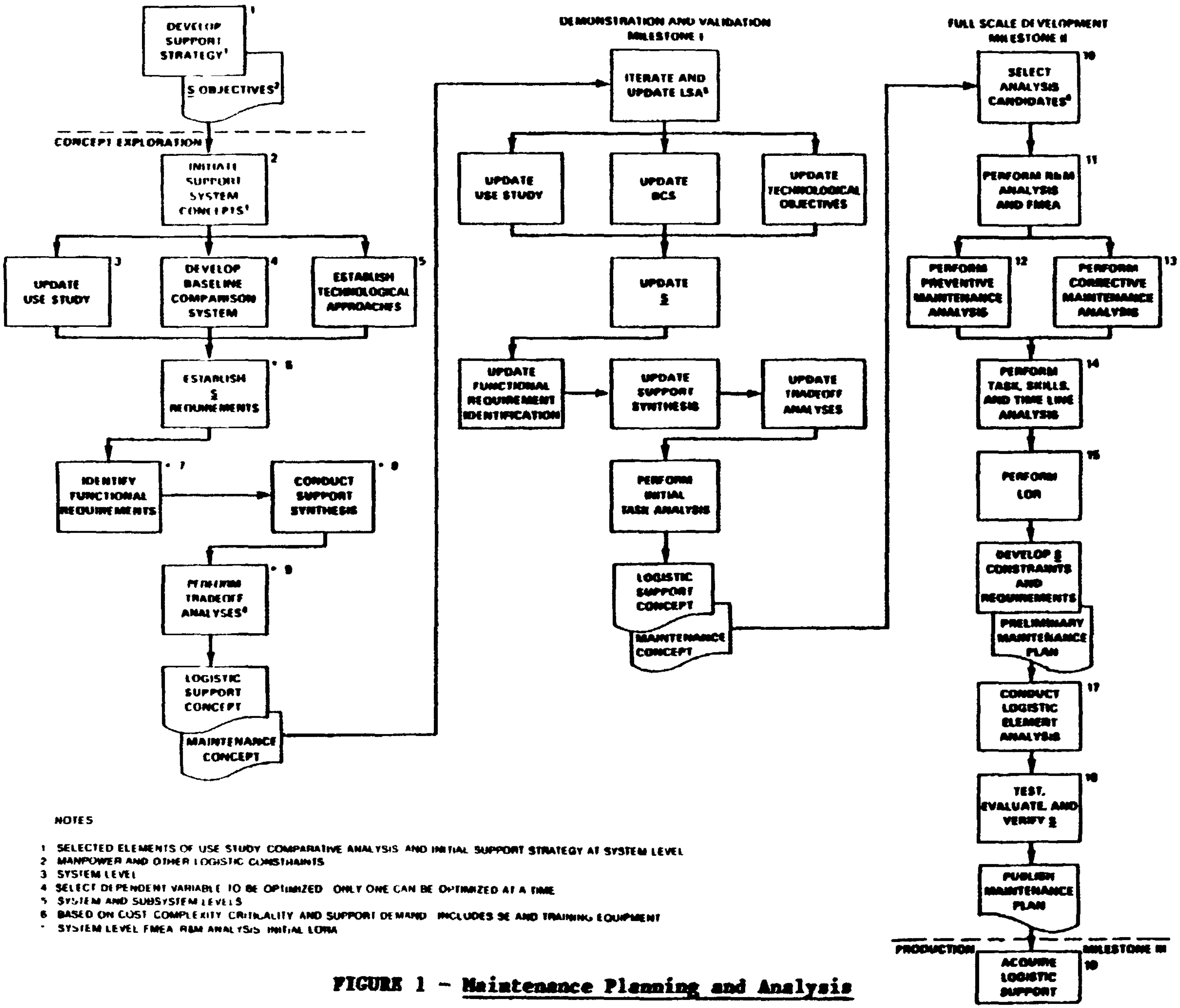
a. Representatives of the airlines and manufacturers constituted a Maintenance Steering Group (MSG) and developed the document, MSG-1, "Handbook: Maintenance Evaluation and Program Development". MSG-1 included decision logic and procedures for developing the initial preventive maintenance program for the Boeing 747 aircraft. Later the decision logic of MSG-1 was updated and certain detailed procedural information for the 747 was deleted. The result was a universal document applicable to the development of preventive maintenance programs on new procurement aircraft. The product of this effort, published in 1970, is known as MSG-2, "Airline/Manufacturers Maintenance Program Planning Document". In 1979, an Air Transport Association (ATA) task force reviewed those portions of MSG-2 which required revision for application to newly developed aircraft. The result of the task force was MSG-3, "Airline/Manufacturer Maintenance Program Planning Document."

b. The MSG-2 techniques were first applied to Navy aircraft in 1972 on the P-3A and S-3A and later on the F-4J program. The Navy rewrote the MSG-2 procedures into a series of manuals, culminating with the Naval Air Systems Command (NAVAIR) 00-25-400, for application to in-service naval aircraft. This manual was utilized to revise the preventive maintenance requirements for most of the Navy's in-service aircraft. The MSG-2 concepts revolutionized Navy procedures for developing preventive maintenance programs. However, much of the RCM philosophy was left unsaid in the MSG-2 document and was not included in the NAVAIR 00-25-400 document. For example, NAVAIR 00-25-400 did not cover the procedures for developing intervals for inspections and for refining the initial analysis. To remedy this problem and to bring MSG-2 up to date, the Department of Defense (DOD) sponsored the original authors of MSG-1 and MSG-2 to write a comprehensive thesis on Reliability-Centered Maintenance (RCM). Their report "Reliability-Centered Maintenance" (DOD report AD-A066579) clarified the analysis process and broadened the scope of the program substantially. This DOD report was used as a basis for the development of MIL-HDBK-266 (AS).

c. This standard supersedes NAVAIR 00-25-400 for all applications of RCM decision logic. It also applies the principles of RCM, as covered by the DOD report and MSG-3, to Naval aircraft, weapons systems and support equipment.

2. **Logistics Support Analysis (LSA)/Reliability-Centered Maintenance (RCM) Interface.**

MIL-STD-1388 details the process for logistic support analysis that is conducted during the program initiation and full scale development phases of the weapon system or equipment life cycle. The maintenance planning and analysis process is shown in FIGURE 1. It is part of, and is integrated with, the logistic support analysis process. Preventive maintenance analyses, Reliability-Centered Maintenance and age exploration, are an important part of the maintenance planning and analysis process. This standard provides the procedures for preventive maintenance and age exploration analyses.




NOTES

1 SELECTED ELEMENTS OF USE STUDY COMPARATIVE ANALYSIS AND INITIAL SUPPORT STRATEGY AT SYSTEM LEVEL
2 MANPOWER AND OTHER LOGISTIC CONSTRAINTS
3 SYSTEM LEVEL
4 SELECT DEPENDENT VARIABLE TO BE OPTIMIZED ONLY ONE CAN BE OPTIMIZED AT A TIME
5 SYSTEM AND SUBSYSTEM LEVELS
6 BASED ON COST COMPLEXITY CRITICALITY AND SUPPORT DEMAND INCLUDES SE AND TRAINING EQUIPMENT
* SYSTEM LEVEL FMEA R&M ANALYSIS INITIAL LORA

FIGURE 1 – Maintenance Planning and Analysis

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APPENDICES - Continued

APPENDICES - Continued

APPENDICES - Continued

APPENDICES - Continued

# 1. SCOPE

1.1 Purpose. The purpose of this standard is to provide the procedures for a Reliability-Centered Maintenance (RCM) analysis for Naval Aircraft, weapons systems, and support equipment (SE).

1.2 Application. This standard is to be used by contractors during development of new systems and equipment, and by analysts and auditors within the Naval Air Systems Command for determining preventive maintenance requirements and developing age exploration requirements. The tasks shall also be used to update the initial Reliability-Centered Maintenance analysis and analyze newly discovered failure modes. For additional information on application, refer to Appendix F on additional guidance.

1.3 Logistics Support Analysis and Reliability-Centered Maintenance. This standard describes the procedures for preventive maintenance analysis and the development of age exploration and is to be used to determine these requirements as specified by DoD Directive 4151.16 and MIL-STD-1388. This standard uses inputs from MIL-STD-1629 for Failure Modes and Effects Analysis (FMEA). It provides preventive maintenance requirements for development of a maintenance plan. Applications of RCM for both new procurements and in-service equipment are satisfied by this standard. Age exploration requirements are initially developed from the results of the preventive maintenance analysis process. This standard provides the guidance for development of preventive maintenance and age exploration requirements.

1.4 Reliability-Centered Maintenance program. The goals of this standard are to provide organizational focus and systematic procedures to accomplish the following:

a. analyze the maintenance requirements for each type/model aircraft,

b. objectively justify every maintenance requirement,

c. enforce the performance of only the justified maintenance actions.

This standard provides the means to comply with Office of Secretary of Defense (OSD) and Chief of Naval Operations (CNO) planning and programming guidance for the application of Reliability-Centered Maintenance (RCM). At the same time, it is the basis of coordination necessary to implement and sustain all viable, progressive, cost effective improvements in the Naval Aviation Maintenance Program.

## 2. REFERENCED DOCUMENTS

### 2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this standard to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-M-23618 - Preparation of Manual, Technical, and Periodic Maintenance Requirements.

STANDARDS

MILITARY

MIL-STD-721 - Definition of Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety.
MIL-STD-780 - Work Unit Codes for Aeronautical Equipment; Uniform Numbering System.
MIL-STD-1388 - Logistic Support Analysis.
MIL-STD-1390 - Level of Repair.
MIL-STD-1629 - Procedures for Performing a Failure Mode, Effects and Criticality Analysis.

HANDBOOKS

MILITARY

MIL-HDBK-217 - Reliability Prediction of Electronic Equipment.

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this standard to the extent specified herein.

| | | |
|---|---|---|
| Manual 4160.21-M-1 | - | Defense Demilitarization Manual. |
| DoD Directive 4151.16 | - | DoD Equipment Maintenance Program. |
| OPNAVINST 3710.7 | - | NATOPS, Promulgation of General Flight and Operating Instructions Manual. |
| OPNAVINST 3750.6 | - | The Naval Aviation Safety Program. |
| OPNAVINST 4790.2 | - | The Naval Aviation Maintenance Program (NAMP). |
| OPNAVINST 5442.4 | - | Aircraft and Training Devices Material Condition Definitions Mission-Essential Subsystems Matrices and Mission Descriptions. |
| NAVAIRINST 4140.2 | - | Level of Repair (LOR) Analysis for Naval Air Systems Command (NAVAIR Material). |
| NAVAIRINST 4423.3 | - | Policies, Procedures and Responsibilities for Assignment and Application of Uniform Source, Maintenance and Recoverability (SM&R) Codes. |
| NAVAIRINST 4790.3 | - | Scheduled Removal Component (SRC)/Equipment History Record (EHR) Program. |
| NAVAIRINST 4790.4 | - | Maintenance Plan Program |
| NAVAIR 00-25-403 | - | Age Exploration Program Guide for Naval Aircraft and Equipment. |

(Copies of specifications, standards, handbooks, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. The issues of the documents which are indicated as DoD adopted shall be issue listed in the issue of the DoDISS specified in the solicitation. The issues of documents which have not been adopted shall be those in effect on the date of the cited DoDISS.

| | |
|---|---|
| AD-A066579 | Reliability-Centered Maintenance |
| AD-A085450 | Designing On-Condition Tasks for Naval Aircraft |

(Applications for copies should be addressed to the Defense Technical Information Center, ATTN: DDRA, Bldg. 5, Cameron Station, Alexandria, VA 22314)

MSG-1 - 747 Maintenance Steering Group, "Handbook: Maintenance Evaluation and Program Development (MSG-1)", July 10, 1968.
MSG-2 - "Airline/Manufacturer Maintenance Program Planning Document: MSG-2", R&M Subcommittee, March 25, 1970.
MSG-3 - "Airline/Manufacturer Maintenance Program Planning Document: MSG-3", October 1980.

(Applications for copies should be addressed to Air Transport Association, 1709 New York Ave., N.W., Washington, DC 20006)

(Nongovernment standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

2.3 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence.

## 3. DEFINITIONS

3.1 Definition of terms. The terms listed in this standard are defined as follows:

Actuarial Analysis - Statistical analysis of failure data to determine the age reliability characteristics of an item.

Age Exploration - The process of determining age-reliability relationships through controlled testing and analysis of chance or unintentional events for safety-critical items; and from operating experience for non-safety items.

Age Reliability Characteristics - The characteristics exhibited by the relationship between the operating age of an item and its conditional probability of failure.

Applicability Criteria - The specific set of conditions that must charac-terize an items failure behavior for a given maintenance task to prevent failures in operational use.

Bathtub Curve - A conditional probability curve which represents the age reliability relationship of certain items, characterized by an infant mortality region, a region of relatively constant hazard rate, and an identifiable wearout region.

Calibration - The comparison of a measuring device with a known standard.

Calibration Requirements Analysis - The systematic engineering analysis and review, conducted in early phases of acquisition, to select measurement elements for optimized calibration support to minimize work-arounds and after the fact calibration requirements.

Calibration Standard - A support equipment system or device of known accuracy with traceability to national standards.

Class Number - A number that is the lowest of the individual ratings for a structurally significant item or a zone, used to determine the comparative importance of structural inspections for the different modes of structural failures.

Conditional Probability of Failure - The probability that an item will fail during a particular age interval, given that it survives to enter that interval.

Consequences of Failure - The results of a given functional failure at the equipment level and for the operating organization, classified in RCM analysis as safety consequences, operational/economic consequences, safety hidden failure consequences and non-safety hidden failure consequences.

Corrective Maintenance - The actions performed, as a result of failure, to restore an item to a specified condition.

Cost Effectiveness - In RCM, the comparative costs of performing or not performing preventive maintenance.

Crack Initiation - The first appearance of a fatigue crack in an item subject to repeated loads, usually based on visual inspection, but sometimes based on the use of non-destructive testing techniques.

Crack Propagation Characteristics - The rate of crack growth, and the resulting reduction in residual strength, from the time of crack initiation to a crack of critical length.

Crew - Personnel normally assigned to operate equipment.

Critical Crack Length - The length of a fatigue crack at which the residual strength of the item is no longer sufficient to withstand the specified damage tolerant load.

Damage Tolerant Structure - Structure in which the crack propagation rate is slow enough for at least two inspections to be feasible between crack initiation and functional failure.

Default Answer - In a binary decision process, the answer to be chosen in case of uncertainty; employed in the development of an initial preventive maintenance program to arrive at a course of action in the absence of complete information.

Discard Task - The scheduled removal and discard of all units of an item or one of its parts at a specified life limit; one of the four basic tasks in an RCM program.

Economic Life Limit - A life limit imposed on an item based on cost effectiveness to reduce the frequency of age related failures.

Economic/Operational Consequences - The effect of a failure that does not have safety consequences, but which causes a loss of mission essential equipment or results in high repair costs, one of the four consequence branches of the RCM decision diagram.

Effectiveness Criterion - The criterion for judging whether a specific task is capable of reducing the failure rate or probability of failure to the required level.

Engineering Failure Mode - The specific engineering mechanism of failure which leads to a particular functional failure.

External Structural Item - Any portion of the structure that is visible without the opening of quick access panels or the removal of covering items.

Fail Safe System - A system whose function is duplicated, so that the function will still be available to the equipment after failure of one of its sources.

Failure Effects - The consequence a failure mode has on the operation, function, or status of an item. Failure effects are classified as local effect, next higher level, and end effect.

Failure Finding Task - Scheduled inspections of a hidden function item to find functional failures that have already occurred but were not evident to the operating crew.

Failure Mode - The manner by which a failure is observed. Generally describes the way the failure occurs and its impact on equipment operation.

Failure Rate - The total number of failures within an item population, divided by the total number of life units expended by that population, during a particular measurement interval under stated conditions.

Failure Symptom - An identifiable physical condition by which a potential failure can be recognized.

Fatigue - Reduction in resistance to failure of a material over time, as a result of repeated or cyclic applied loads.

Fatigue Life - For an item subject to fatigue, the total time to functional failure of the item (see crack initiation, crack propagation characteristics).

Fleet Leader Concept - The concentration of sample inspections on the pieces of equipment which have the highest operating ages to identify the first evidence of changes in their condition with increasing age.

Flight Cycles - A measure of exposure to the stresses due to individual flights, expressed as the number of ground-air cycles.

Function - The normal, characteristic actions of an item, sometimes defined in terms of performance capabilities.

Functional Failure - Failure of an item to perform its normal or characteristic actions within specified limits.

Functionally Significant Item - An item whose loss of function would have significant consequences at the equipment level.

Hard Time - Scheduled removal of all units of an item before some specified maximum age limit, to prevent functional failure.

Hazard Rate - The limit of the failure rate as the interval length approaches zero.

Hidden Failure Consequences - The risk of a multiple failure resulting from undetected earlier failure of a hidden function item; one of the four consequence branches of the RCM decision diagram.

Hidden Failure - A failure not evident to the crew or operator during the performance of normal duties.

Improvable Failure Rate - The difference between the failure rate of an item on newly designed equipment and the expected failure rate after product improvement to eliminate dominate constant hazard rate failure modes; this reduction in the failure rate is generally exponential and can be predicted from early failure data.

Infant Mortality - The relatively high conditional probability of failure during the period immediately after an item enters service. Such failures are due to defects in manufacturing not detected by quality control.

Inherent Reliability Value - A measure of reliability that includes only the effects of an item design and its application, and assumes an ideal operation and support environment.

Initial RCM Maintenance Program - The preventive maintenance tasks and associated intervals developed for equipment when the Reliabilty-Centered Maintenance concept is first applied. For new equipment, generation of this program is completed during full scale development.

Initial Task Intervals - The task intervals assigned in the initial RCM maintenance program, subject to adjustment on the basis of findings from in service information.

Inspection Task - A scheduled task requiring testing, measurement, or visual inspection for explicit failure evidence by maintenance personnel.

Internal Structural Item - Any structure that requires the opening of access doors or the removal of covering items for inspection or maintenance.

Lubrication Task - Preventive maintenance task to replenish lubricants expended during normal operation.

Maintainability - The measure of the ability of an item to be retained in or restored to specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.

Maintenance Package - A group of maintenance tasks scheduled for at the same time.

Mean Time Between Failures - A basic measure of reliability for repairable items: The mean number of life units during which all parts of the item perform within their specified limits, during a particular measurement interval under stated conditions.

MSG-1 - A working paper prepared by the 747 Maintenance Steering Group, published in July 1968 under the title Handbook: Maintenance Evaluation and Program Development (MSG-1); the first use of decision-diagram techniques to develop an initial scheduled maintenance program.

MSG-2 - A refinement of the decision-diagram procedures in MSG-1, published in March 1970 under the title, MSG-2: Airline/Manufacturer Maintenance Program Planning Document; the immediate precusor of RCM methods.

MSG-3 - Further refinement of MSG-2, developed for the 757, 767 series aircraft, published in October 1980 under the title, MSG-3: Airline/Manufacturer Maintenance Program Planning Document.

Multiple Failure - A failure event consisting of the sequential occurrence of two or more independent failures, which may have consequences that would not be produced by any of the failures occurring separately.

Non-Safety Hidden Failure Consequences - A hidden failure that does not have safety consequences, but does cause an operational capability loss or results in high repair costs.

Nonsignificant Item - An item whose failure (or a hidden function whose part in a multiple failure) has no direct effect on safety or on the operational capability of the equipment, and involves no exceptionally expensive failure modes. Nonsignificant items are not considered for preventive maintenance in an initial maintenance program.

On-Condition Task - Scheduled inspections to detect potential failures, or to meet calibration performance requirements.

Operator - Personnel who use or operate equipment during normal operation.

Opportunity Sample - An item available for inspection at the maintenance base during the normal disassembly of failed units for repair.

Partitioning Process - The process of dividing complex equipment into convenient entities for analysis.

Phase Inspections - A series of related inspections that are performed sequentially at specific intervals. These inspections are the results of dividing the maintenance requirements into small packages containing approximately the same workload.

Potential Failure - A quantifiable failure symptom which indicates that a functional failure is imminent. This includes out of tolerance condition or failure to provide accurate measurement for calibration requirements analysis.

Premature Removal - Removal of a unit prior to a scheduled hardtime removal because of a suspected or actual potential or functional failure.

Preventive Maintenance - Maintenance efforts performed to prevent in service functional failures of equipment. Primarily preventive maintenance is concerned with wearout failure.

Probability Density of Failure - The probability that an item will fail in a defined age interval; the difference between the probability of survival to the start of the interval and the probability of survival to the end of the interval.

Probability of Survival - The probability that an item will survive to a specified operating age, under specified operation conditions, without failure.

Product Improvement - Design modifications of an existing item to improve its reliability, usually in response to information derived from operating experience after the equipment enters service.

RCM Analysis - Use of the RCM decision concepts to devise a preventive maintenance program by evaluating maintenance required for an item according to the consequences of each significant failure possibility, the inherent reliability characteristics of each item, and the applicability and effectiveness of possible preventive maintenance tasks.

RCM Program - A preventive maintenance program consisting of a set of tasks each generated by RCM analysis.

RCM Task - A preventive maintenance task which satisfies the specific applicability criteria for that type of task.

Reliability - The probability that an item will perform its intended function for a specified interval under stated conditions.

Reliability-Centered Maintenance - A disciplined logic or methodology used to identify preventive maintenance tasks to realize the inherent reliability of equipment at least expenditure of resources.

Reliability Growth - The improvement in the reliability parameter caused by the successful correction of deficiencies in item design or manufacture.

Residual Failure Rate - The remaining failure rate of an item after all applicable and effective preventive maintenance tasks are performed.

Residual Strength - The remaining load carrying capability of a damage tolerant structural assembly after an elements failure.

Resistance to Failure - An item's ability to withstand the stresses to which it is exposed.

Rework Task - The scheduled removal of an item to perform whatever maintenance tasks are necessary to ensure that the item meets its defined condition and performance standards.

Safe Life Limit - A life limit imposed on an item that is subject to a critical failure established as some fraction of the average age which test data show that failures will occur.

Safe Life Structure - Structure that it is not practical to design to damage tolerant criteria; its reliability is protected by conservative safe life limits that remove elements from service before failures are expected.

Safety Consequence - A loss of a function or secondary damage resulting from a given failure mode which produces a direct adverse effect on safety. One of the four consequence branches of the RCM decision diagram.

Safety Hidden Failure Consequence - A hidden failure which has an adverse effect on operating safety.

Scheduled Maintenance - Periodic prescribed inspection and servicing of equipment accomplished on a calendar, mileage, or hours of operation basis.

Scheduled Removal - Removal of a serviceable unit at some specified age limit to prevent an in-service functional failure due to an explicit wearout failure mode, or to inspect for an incipient functional failure.

Secondary Damage - The immediate physical damage to other parts of items that results from a specific failure mode.

Servicing - The performance of any act needed to keep an item in operating condition, (i.e. lubricating, fueling, oiling, etc.), but not including preventative maintenance of parts or corrective maintenance tasks.

Significant Item - An item whose failure or hidden functions whose part in a multiple failure has safety, operational or major economic consequence.

Structural Rating Factors - Criteria based on fatigue, environmental damage, and accidental damage used to rate structurally significant items for determination of inspection frequencies.

Structurally Significant Item - The specific region or element of structure whose failure would result in a major reduction in residual strength or loss of the structural function.

Survival Curve - A graph of the probability of survival of an item as a function of age, derived by actuarial analysis of its service history. The area under the curve can be used to measure the average realized age (expected life) of the item under consideration.

Teardown Inspection - The complete disassembly of a serviceable item that has survived to a specified age limit to examine the condition of each of its parts as a basis for judging whether it would have survived to a proposed higher age limit.

Technologically Useful Life - The length of time equipment is expected to remain in service before technological changes in new designs render it obsolete.

Test and Monitoring Systems - The collective reference given to the array of gauges, indicators, calibration standards, and test equipment used to perform measurements. Test and monitoring systems include automatic test equipment, general and special purpose test equipment, built-in test, self test and related support equipment at all levels of maintenance. The devices are used for monitoring and testing all types of weapons systems and equipment for the purpose of assuring the specified level of accuracy and performance.

Time Since New - The operating age of a unit since it was initially installed and has not been zero timed.

Time Since Rework - The operating age of a unit since it was last reworked.

Unverified Failure - Units removed from the equipment because of suspected malfunctions and subsequently determined by shop inspections and tests to be in a unfailed condition.

Verified Failures - Units confirmed to have experienced a functional failure.

Wearout - The process which results in an increase of the failure rate or conditional probability of failure with increasing number of life units.

Wearout Characteristics - The conditional probability curve characteristics that indicate an increase in the conditional probability of failure of an item with increasing operating age.

Zero Time - To restore the operating age of a unit to zero by means of inspection, rework, or repair.

Zonal Inspections - A general inspection of a specific area of an aircraft at scheduled intervals. A zonal inspection is for obvious defects, such as leaks, frayed cables, cracks, corrosion, or physical damage.

3.2 Definition of acronyms. The acronyms listed in this standard are defined as follows:

a. AD - Accidental Damage.
b. AIDS - Airborne Integrated Data System.
c. AMP - Analytical Maintenance Program.
d. ATA - Air Transport Association.
e. CBR - Cost Benefit Ratio.
f. CDS - Constant Density Sampling.
g. CF - Configuration Code.
h. CFA - Cognizant Field Activity.
i. CILOP - Conversion in Lieu of Procurement.
j. CNO - Chief of Naval Operations.
k. COMB - Combination Task.
l. CPL - Crack Propagation Life.
m. CRA - Calibration Requirements Analysis.
n. D - Depot.
o. DAET - Directed Age Exploration Task.
p. DMMH - Direct Maintenance Man Hours.
q. DOD - Department of Defense.
r. DT - Damage Tolerant.
s. ED - Environmental Damage.
t. EDL - End Item Design Life.
u. EMT - Elapsed Maintenance Time.
v. ESSD - Engineering Specifications and Standards Department.
w. FD - Fatigue Damage.
x. FF - Failure Finding.
y. FFMC - Functional Failure Mode Code.
z. FLS - Fleet Leader Sampling.
aa. FMEA - Failure Mode and Effects Analysis.
ab. FMECA/MI - Failure Mode and Effects Criticality Analysis/Maintainability Information.
ac. FOD - Foreign Object Damage.
ad. FSCM - Federal Supply Code for Manufacturers.
ae. FSI - Functional Significant Item.

af. HT - Hard Time.
ag. I - Intermediate.
ah. IDL - Item Design Life.
ai. LDC - Life to Detectable Crack.
aj. LL - Life Limit.
ak. LOR - Level of Repair.
al. LSA - Logistic Support Analysis.
am. LSAR - Logistic Support Analysis Record.
an. LSACN - Logistic Support Analysis Control Number.
ao. MIR - Master Index of Repairables.
ap. MLG - Main Landing Gear.
aq. MPA - Maintenance Planning and Analysis.
ar. MESM - Mission Essential Subsystem Matrices.
as. MSG-1 - Maintenance Steering Group 1.
at. MSG-2 - Maintenance Steering Group 2.
au. MSG-3 - Maintenance Steering Group 3.
av. MTBF - Mean Time Between Failure.
aw. MTBMA - Mean Time Between Maintenance Actions.
ax. MTTR - Mean Time To Repair.
ay. NALC - Naval Ammunition Logistics Code.
az. NAMP - Naval Aviation Maintenance Program.
ba. NATOPS - Naval Air Training and Operating Procedures Standardization.
bb. NAVAIR - Naval Air Systems Command.
bc. NDI - Non-Destructive Inspection.
bd. NLG - Nose Landing Gear.
be. O - Organizational.
bf. OC - On-Condition.
bg. OSD - Office of the Secretary of Defense.
bh. OSP - Operating Service Period.
bi. PMRM - Periodic Maintenance Requirements Manual.
bj. RCM - Reliability-Centered Maintenance.
bk. RS - Residual Strength.
bl. RW - Rework.
bm. R&M - Reliability and Maintainability.
bn. SAET - Safety Age Exploration Task.
bo. SE - Support Equipment.
bp. SHF - Safety Hidden Failure.
bq. SLEP - Service Life Extension Program.
br. SLL - Safe Life Limit.
bs. S,M,&R - Source, Maintenance, and Recoverability (code).
bt. SRA - Shop Replaceable Assembly.
bu. SRC - Scheduled Removal Component.
bv. SRF - Structural Rating Factor.
bw. SSI - Structural Significant Item.
bx. TAMS - Test and Monitoring Systems.
by. TEC - Type Equipment Code.
bz. T/M/S - Type, Model, Series.
ca. VAST - Versatile Avionics Shop Test.
cb. WRA - Weapons Replaceable Assembly.
cc. WUC - Work Unit Code.

## 4. GENERAL REQUIREMENTS

4.1 MPA and RCM interface. Maintenance planning is part of the LSA for new weapons systems procurement. The Maintenance Planning and Analysis (MPA) gives the analysis procedures required to develop a maintenance plan. The preventive and corrective analyses are all included in the MPA process, as outlined in FIGURE 1. As directed by DoD Directive 4151.16, preventive maintenance requirements shall be identified by conducting an RCM analysis, based on results of the failure modes, effects and criticality analysis (FMECA) as described in task 301 of MIL-STD-1388. The RCM program is the basis for establishing and sustaining a preventive maintenance program for all DoD equipment. The RCM program comprises three major elements: (1) equipment design guidelines, (2) preventive maintenance program development, and (3) continuing review and update of preventive maintenance requirements. For new procurements, RCM design guidelines shall be provided to the equipment designers during concept exploration. Application of RCM methodology shall be started before Milestone II and a preventive maintenance program established before Milestone III. Refinement of the RCM program shall continue in parallel with equipment development, making adjustments as operational data and experience are accumulated. The RCM methodology skall be applied to in-service equipment as soon as practical. RCM also shall be applied to modifications of in-service equipment. Partial application or waiver of RCM may be authorized by NAVAIR when shown to be more cost-effective than a full RCM program. Equipment complexity, inventory quantities, scheduled phaseout, and the cost of establishing and sustaining an RCM program are factors which must be considered to justify a limited application or waiver. RCM decision logic is used to ensure that only justified preventive maintenance tasks are included in the organizational, intermediate, and depot level maintenance manuals. The RCM worksheets, included in appendix D, provide: (1) a means of documenting analysis decisions, (2) a means to monitor the effectiveness of the preventive maintenance program, and (3) an audit trail of all logic decisions.

4.2 RCM analysis process. The same RCM logic process is used to determine preventive maintenance requirements for both new procurement and in-service programs. RCM analysis requires the following:

a. developing significant items,

b. determining failure modes and effects analysis,

c. evaluating failure consequences,

d. evaluating proposed maintenance tasks.

Other sections of this standard explain any differences encountered when applying RCM to systems, powerplants, structures and support equipment. FIGURE 2 summarizes the RCM analysis process throughout the life cycle process. RCM, during early phases (concept exploration and demonstration/validation) of acquisition, concentrates on enhancing maintainability. This is done by designing into the equipment, or by otherwise providing, the means to inspect for impending failures. Once a significant item list is developed, the RCM logic process is followed to determine preventive maintenance requirements.

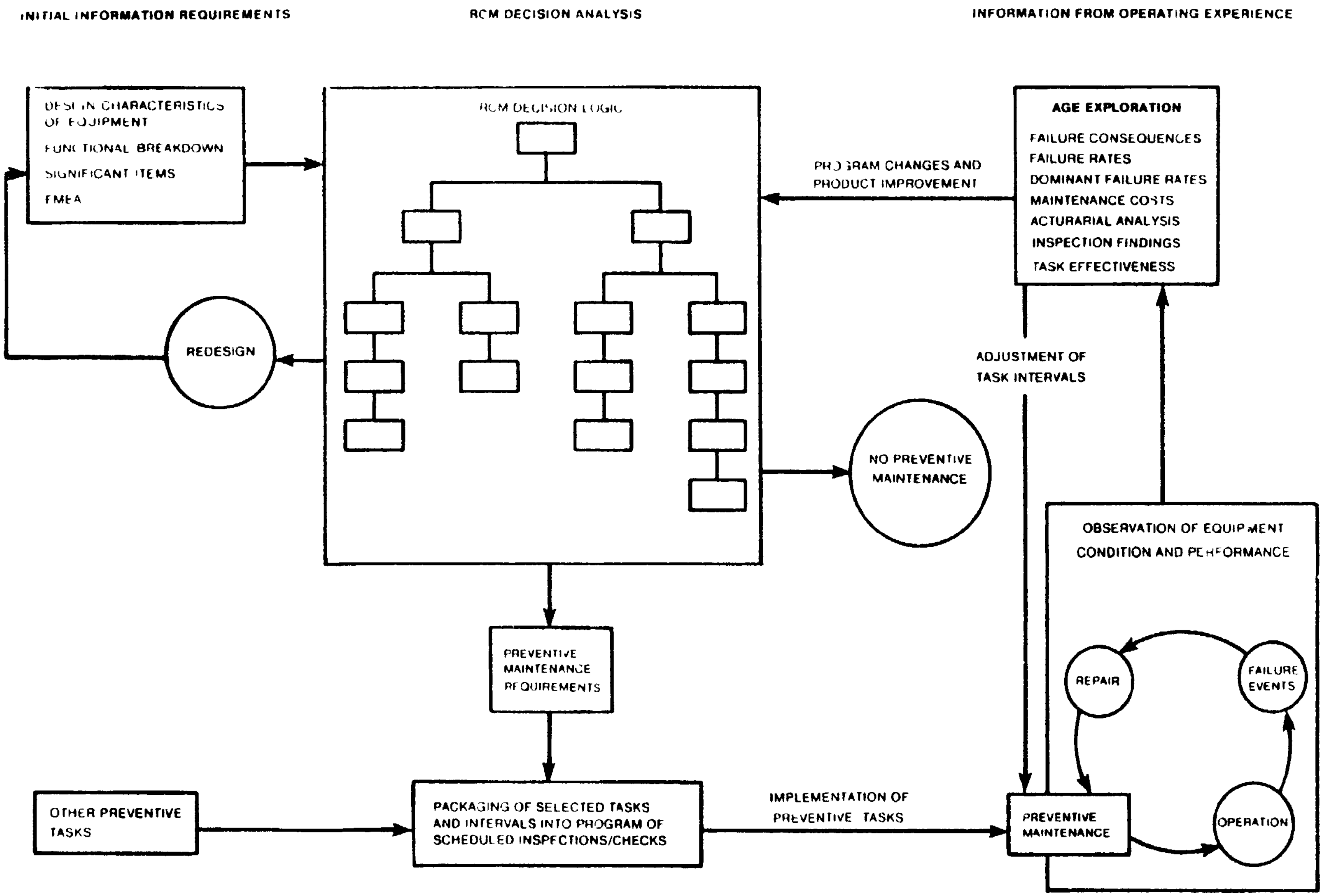



FIGURE 2. RCM analysis process

4.2.1 Determining significant items. RCM logic provides the means for selecting the most important items for analysis When applying RCM to different types of equipment, it is necessary to identify both Functionally Significant Items (FSIs) and Structurally Significant Items (SSIs). Separate decision logic diagrams are followed for RCM analysis depending on whether an item is functionally or structurally significant. The FSI/SSI selection diagram, FIGURE 3, is used to select both FSIs and SSIs. This is necessary because applying RCM logic to all components of a weapons system is neither necessary or cost effective. Selection of significant items for in-service and new equipment is the same process, only there is more data available for in-service equipment. Adequate support and timely identification of preventive requirements are necessary. To accomplish this, significant items for RCM analysis are identified as early as possible in the acquisition cycle. This is especially important for long lead time items, support equipment, and equipment used for calibration task.

4.2.1.1 Functional breakdown. A functional block diagram is constructed at the highest level of indenture possible for easy application of RCM logic. Normally, RCM logic is best applied at the system or subsystem levels. But, some more complex systems may require applying RCM logic to the WRA level. An example of a functional breakdown for aircraft systems is shown in FIGURE 4.

a. A functional block diagram is constructed by dividing equipment into functional systems, similar to the two digit WUC systems for aircraft. Each of these systems is then further broken down into progressively lower levels of indenture (subsystems, WRA, or SRA). This breakdown is necessary to visualize the functional relationship of the various components to each other, to the higher levels of indenture, and to the end item. The significant items for RCM analysis are selected from the functional block diagrams, when not predetermined by the procuring activity.

b. Some types of items, primarily avionics equipment, do not benefit greatly from RCM analysis. This must be considered in the functional breakdown and in the selection of significant items. To gain the maximum benefit from the application of RCM logic, all functional systems should be considered for significance. Some simple systems can be analyzed in this manner. More complex systems will go down to the next level of indenture and include subsystems as significant items. In some cases, it is necessary to continue to the WRA or SRA level for critical components.

c. RCM decision logic is designed to be applied at higher levels of indenture. Proliferation of WRAs and SRAs as significant items is unnecessary and costly. As the functional analysis progresses to increasingly lower levels of indenture, it is difficult to select a specific subsystem, WRA or SRA as significant over others of the same level. To select a subsystem, WRA, or SRA as significant, the questions in FIGURE 3 must be considered.

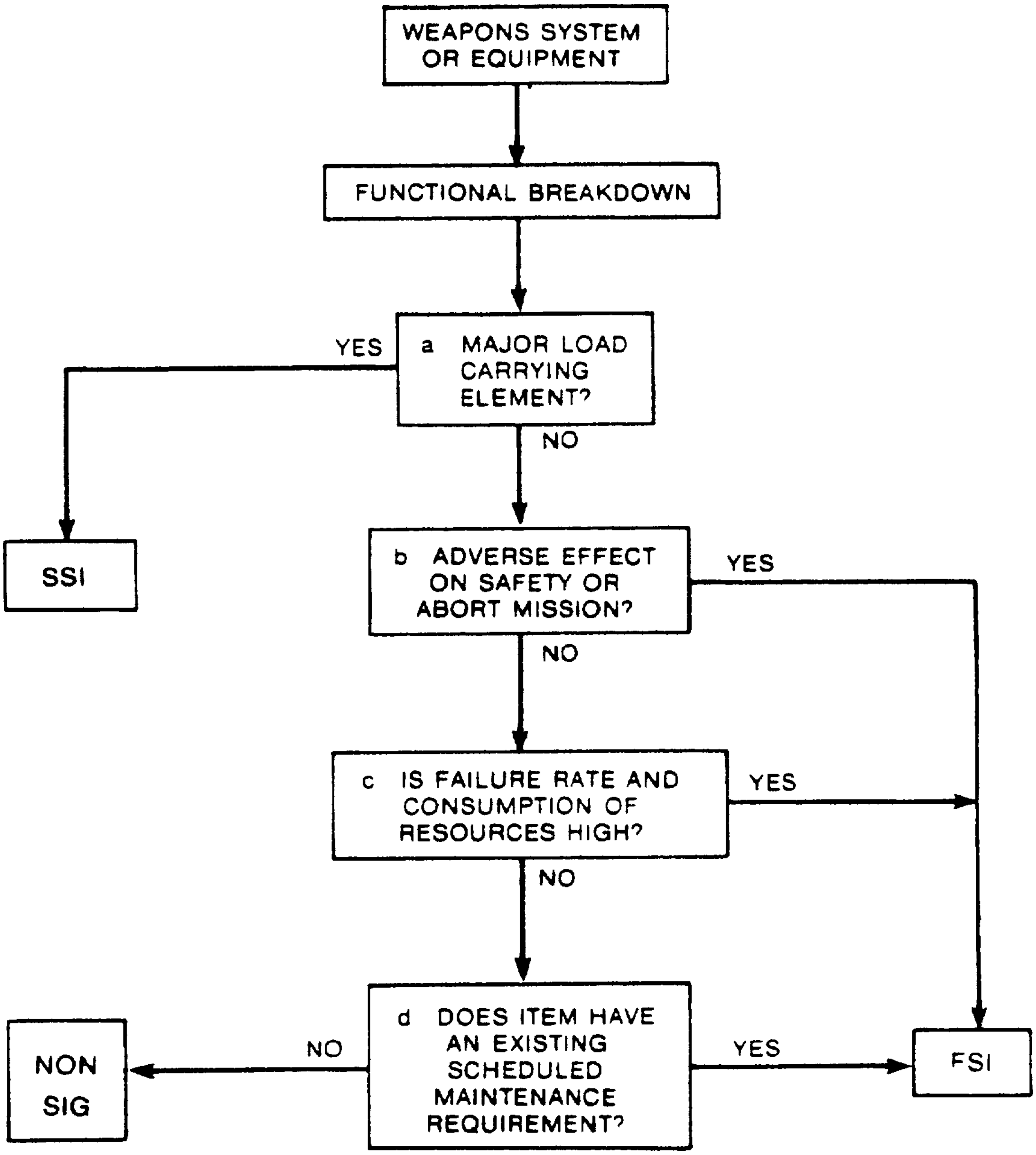



FIGURE 3 **FSI/SSI Selection Diagram for RCM**

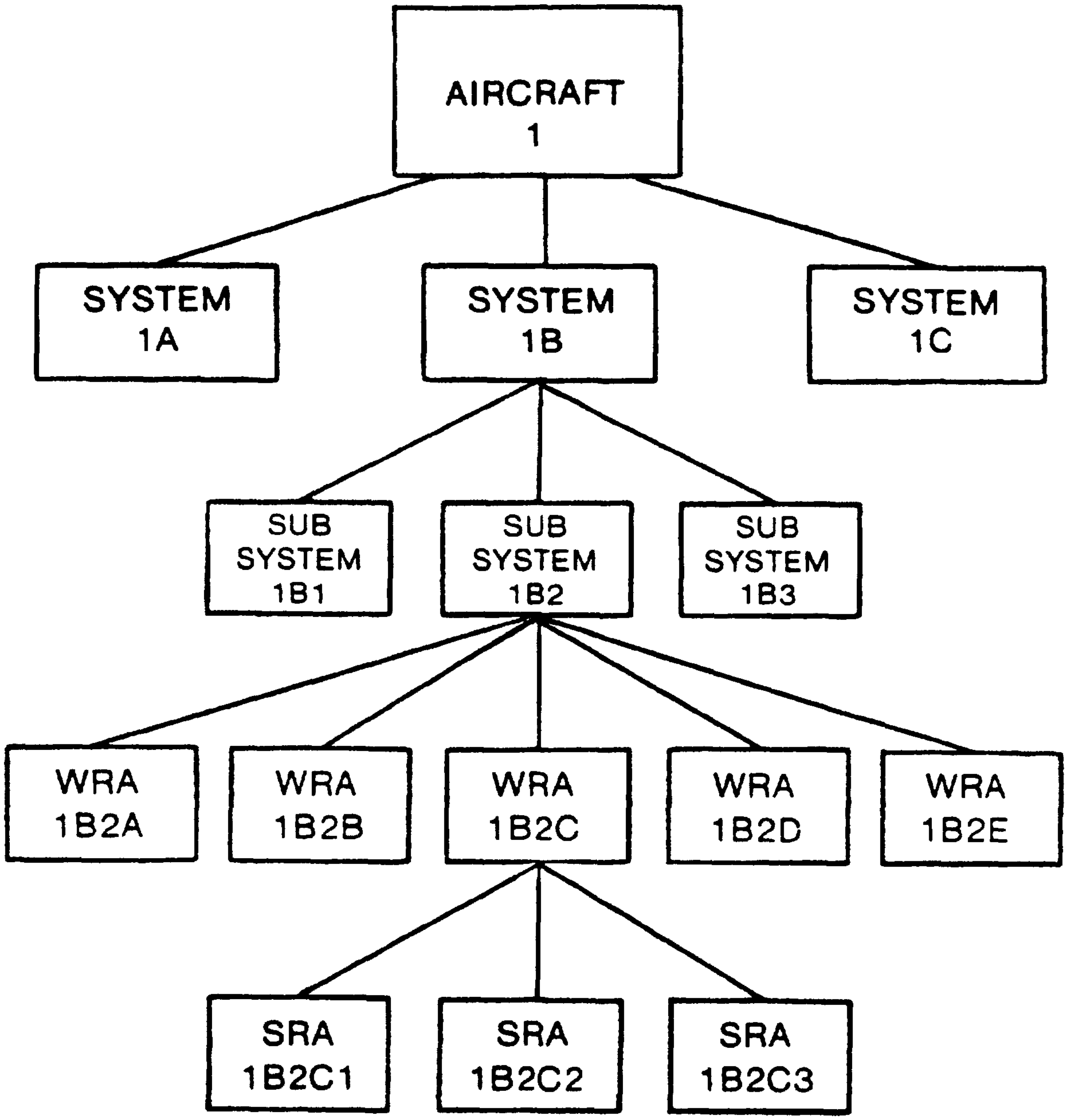



**FIGURE 4. Functional breakdown**

4.2.1.2 Significant item selection. FIGURE 3 assists in the selection of significant items by asking specific questions for each potentially significant item. Potentially significant items are determined from the functional breakdown for FSIs or a zonal breakdown for SSIs. Answers to the FIGURE 3 logic questions identify potentially significant items as FSIs, SSIs or non-significant items for an RCM analysis. Non-significant items, however, may not require RCM analysis. Every attempt should be made to accomplish the RCM analysis at the highest level of indenture possible (system or subsystem FIGURE 4). Significant items may be selected at the WRA level only if that WRA has a function. Performing RCM analysis at lower levels only serves to unnecessarily complicate the analysis process. Some items will have both structural and non-structural functions. The significance of each function of these items must be evaluated by answering the questions in FIGURE 3. This ensures that these items are correctly identified as both FSI and SSI.

a. Major load carrying element. Does the structural element carry major ground or aerodynamic loads? Only primary load-carrying structures should be identified. This question is asked for each function of a potential FSI or SSI.

b. Adverse effect on safety or abort mission. Does loss of the item's function cause adverse affect on operating safety or abort the mission? Consider how the loss of each function of an item affects safety or mission. This question is asked for each function of the item in its operating environment.

c. High failure rate and consumption of resources. Is the actual or predicted failure rate and consumption of resources high? Both considerations must be met to have the item chosen as significant. The determination of what is "high" is made by considering the item's affect on the next higher assembly in the functional breakdown. This question is asked for each potentially significant item.

d. Scheduled maintenance requirement. Does the item, or a like item on similar equipment, have existing scheduled maintenance requirements at the Organizational, Intermediate, or Depot maintenance level? All items for in-service equipment, which have existing requirements, should be analyzed to update these scheduled requirements. Also consider if the item's design requires lubrication or servicing.

4.2.2 Failure modes and effects analysis. The failure modes and effects analysis (FMEA) is an important part of the maintenance planning process. This analysis identifies (1) the equipment item, (2) its functions, (3) functional failures, (4) engineering failure modes, and (5) the effects of the failure on the item, system, and end item. Preventive maintenance analysis is then used to determine if there is some type of task which will reduce or prevent these consequences of failure. RCM analysis and decision logic rely on input from the FMEA, of the Reliability and Maintainability (R&M) program, for determining preventive maintenance tasks.

4.2.3 RCM decision logic. This standard discusses the detailed requirements of each question on the RCM decision diagram, FIGURE 5. Answers to questions one through three determine the consequences of failure for each failure mode of a significant item. Next, depending on the consequence of failure, the proposed maintenance tasks are evaluated for their applicability and effectiveness to avoid the failure mode. The logic diagram provides a clear path to follow in most cases. Where a yes or no answer is not evident, default logic is used (see paragraph 4.2.4.). The default logic specifies which path to follow if the answer to a question is uncertain. The age exploration program (see paragraph 4.2.5) then verifies the decisions made using default logic. Structurally significant items also follow the decision logic as shown in FIGURE 6.

4.2.3.1 Determining failure consequences. The first three RCM questions determine the failure consequences and categorize them into four types.

a. Safety consequences.

b. Economic/operational consequences.

c. Non-safety hidden failure consequences.

d. Safety-hidden failure consequences.

The type of failure consequence identifies the degree of urgency to perform a preventive maintenance task and the criteria for determining its effectiveness.

4.2.3.2 Evaluation of proposed tasks. After the failure consequences are determined, the proposed maintenance task, to avoid each failure mode is evaluated for its applicability and effectiveness. The criteria used to determine applicability depends on the type of preventive task while effectiveness depends on the failure consequences.

4.2.4 Default decision logic. To provide for decision making when there is insufficient information for a clearcut yes or no answer, a backup default strategy is given which dictates the course of action. FIGURE 7 displays these default answers. Each decision question has a default answer which is designed to protect the equipment from serious failure consequences. This default approach can conceivably lead to more preventive maintenance than is necessary. Some tasks may be included as protection against hazards that do not exist. Other tasks may be scheduled too frequently. Excessive maintenance costs are eliminated by the age exploration program which begins as soon as the equipment goes into service.

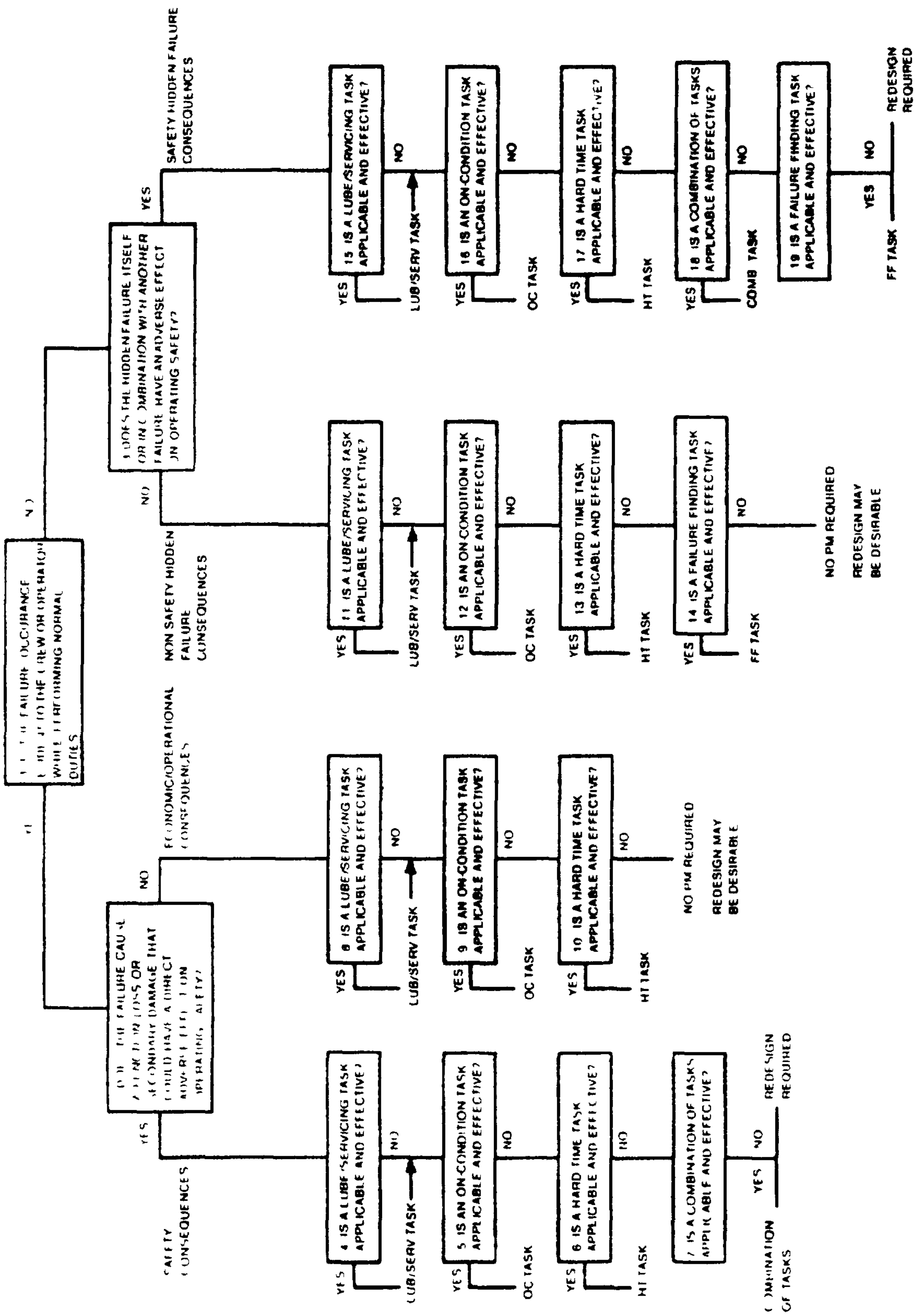



**FIGURE 5. RCM decision diagram for FSI's**

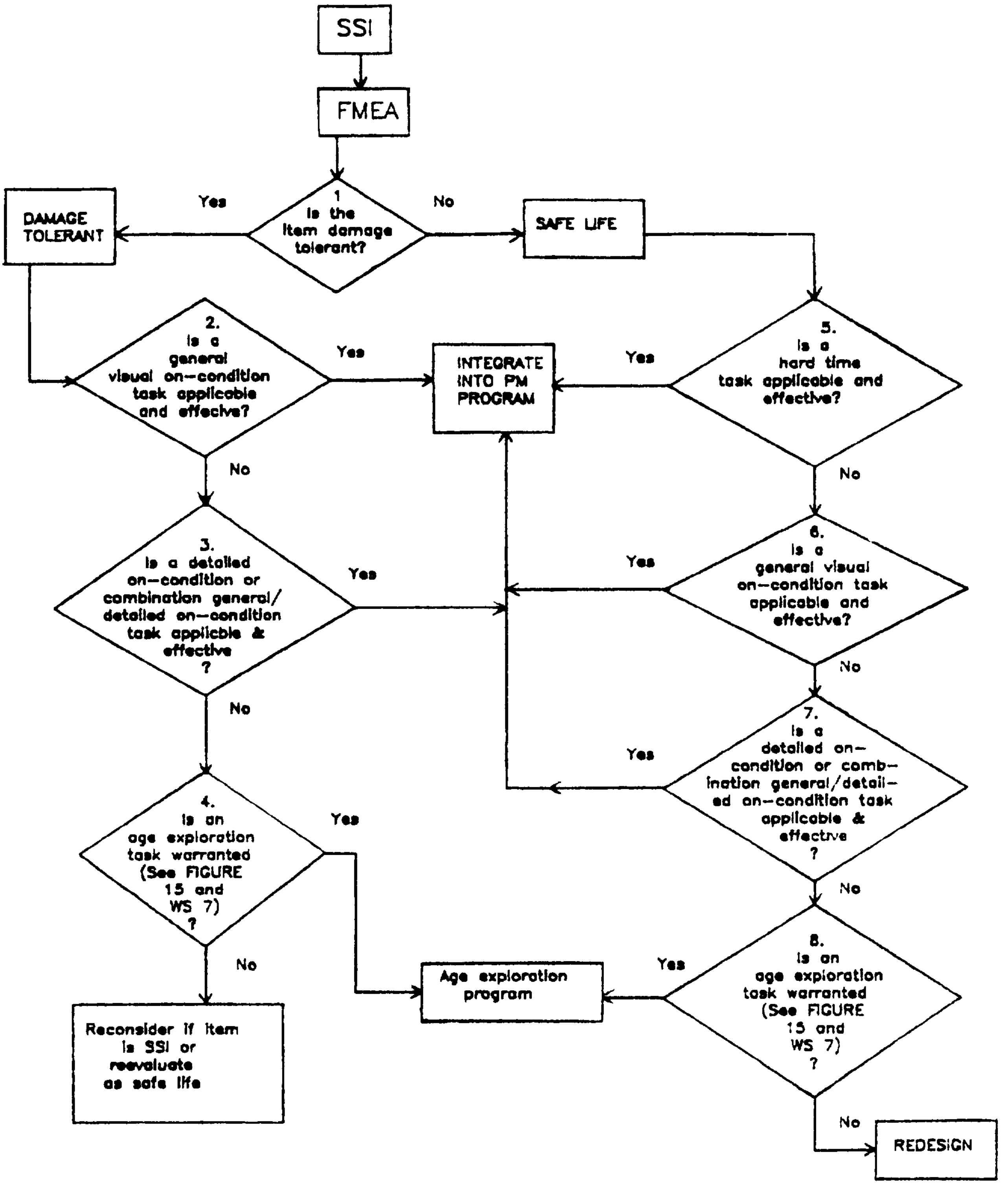



FIGURE 6. RCM decision diagram for SSIs.

| DECISION QUESTION | DEFAULT ANSWER IF UNCERTAIN | POSSIBLE ADVERSE EFFECTS OF DEFAULT |
|---|---|---|
| **SIGNIFICANT ITEM IDENTIFICATION** | | |
| Is the item significant? | Yes; Classify item as significant | Unnecessary analysis |
| **FAILURE CONSEQUENCE EVALUATION** | | |
| RCM Question 1 | No; Classify failure as hidden | Unnecessary maintenance or redesign |
| RCM Question 2 | Yes; Classify item as safety critical | Unnecessary redesign or maintenance that is not cost effective |
| RCM Question 3 | Yes; Classify item as safety hidden failure | Unnecessary redesign or maintenance that is not cost effective |
| **EVALUATION OF PROPOSED TASKS** | | |
| Is a servicing or lubrication task applicable and effective? | Yes; Include task at default interval | Unnecessary maintenance |
| Is an OC task applicable and effective? | Yes; Use start enough intervals to make task effective | Maintenance that is not cost effective |
| Is HT task applicable and effective? | No; (Yes if have real and applicable data or safe life items) | Delay in exploiting opportunity to reduce costs |
| Is a combination of tasks applicable and effective? | Yes; Include an OC task with a HT task | Maintenance that is not cost effective |

FIGURE 7 - Default decision logic chart

4.2.5 Development of age exploration tasks. During the RCM analysis, some logic decisions are made without sufficient data. For these decisions, default logic is used and age exploration tasks are developed to verify the decisions. Age exploration does not, however, exclude information gathered from the scheduled maintenance program, but stresses data gathering for specific reasons through a formal sampling program or on an opportunity basis.

a. Age exploration tasks systematically gather information needed to refine and revise initial evaluations. Age exploration tasks specify the actual criteria to be evaluated and the intervals for the sampling inspections. Age exploration tasks are not part of the scheduled maintenance program. This is because many of the tasks are performed on a sample of equipment or on an opportunity basis. Conversely, formal preventive maintenance requirements are included in the maintenance manuals as 100 percent inspections on all applicable equipment.

b. Age exploration tasks are also subject to economic and manpower constraints which may keep them from being performed. Age exploration tasks, while important to the RCM analysis, are not intended to require extra manpower and equipment. The tasks should use available manpower and equipment so that the maintenance program is not burdened with additional support requirements.

c. Many age exploration tasks are typically generated, especially for new procurement analysis. Because of this, the age exploration procedure prioritizes the proposed data gathering tasks. For example, this gives extra emphasis to safety age exploration tasks. The procedure also helps eliminate the cost of tasks for equipment which will not benefit from age exploration. Age exploration is covered in greater detail in NAVAIR 00-25-403.

4.3 Kinds of preventive maintenance. Preventive maintenance tasks, developed by RCM, are based on the reliability characteristics of the equipment. These tasks are either inspections or removals at a scheduled time period. Preventive tasks may be accomplished at any maintenance level. The RCM logic process determines requirements and initial intervals for the following preventive tasks:

a. Servicing/lubrication. Servicing tasks replenish consumables expended during normal operation. Lubrication tasks are required by the design of the equipment.

b. On-condition. On-condition tasks detect potential failures before they can cause a functional failure. On-condition tasks include inspections for symptoms of failure at organizational, intermediate, or depot level for all types of equipment. Calibration tasks for support equipment are considered on-condition tasks.

c. Hard time (rework or discard). Hard time tasks are scheduled removals of equipment or parts for either discard or rework.

d. Combinations. On-condition and hard time tasks are combined when safety consequences are an effect of failure, and neither task by itself proves applicable and effective.

e. Failure finding. Failure finding tasks are inspections or functional checks to prevent multiple failures or detect hidden failures.

All of the above tasks are scheduled for some interval at either the organizational or intermediate or depot level. Zonal inspections are not determined from the RCM decision logic. The zonal inspection is a general look at an area where an existing inspection is already being accomplished. A zonal inspection that requires looking into an area not already opened for other inspection requirements defeats the purpose of the zonal concept. Zonal inspections may be included only when the zone has a specific task justified by the RCM decision logic.

4.3.1 Applicability and effectiveness of preventive maintenance tasks. Developing a preventive maintenance program consists of determining which preventive tasks are both applicable and effective for a given item. Applicability depends on the failure characteristics of the item. Thus, an inspection for potential failures (on-condition tasks) are applicable only if it is possible to define a potential failure condition for the item. Similarly, a hard time task is applicable only if the failures at which the task is directed, are related to age. Effectiveness is a measure of the results of the task objective, which is dependent on the failure consequences. A proposed task might appear useful if it promises to reduce the overall failure rate; but it would not be effective if its purpose was to avoid all functional failures. A summary of applicability and effectiveness criteria for all tasks is provided by FIGURE 8. For inspection tasks, the distinction between applicability and effectiveness is usually obvious: The item either does or does not have characteristics that make such a task applicable. For hard time tasks, however, the distinction is sometimes obscured by the belief that since the task is applicable it is also effective. In reality, imposing an age limit on an item does not in itself guarantee that its failure rate will be reduced. The issue, in this case, is not whether the task can be done, but whether doing it will enable the item to realize its inherent reliability.

4.3.2 Servicing and lubrication tasks. Servicing and lubrication tasks, by themselves, are not caused by a failure consequence. These tasks are required by specific operational or design constraints. Servicing tasks replenish consumables (fuel, oxygen, etc.) which are depleted during normal operation. Lubrication tasks ensure proper lubrication of components, where design specifies a lubricant for proper operation. Servicing tasks are normally accomplished during preoperational or daily inspections. Lubrication tasks are scheduled based on the predicted or measured life of the lubricant.

| | FAILURE CONSEQUENCES | | | |
|---|---|---|---|---|
| | SAFETY | OPERATIONAL/ECONOMIC | NON-SAFETY HIDDEN FAILURE | SAFETY HIDDEN FAILURE |
| | **EFFECTIVENESS CRITERIA FOR ALL TASKS** | | | |
| | Must reduce risk of failure to an acceptable level | Must be cost effective; Cost of preventive maintenance must be less than cost of operational loss and/or cost of repair | | Must reduce risk of multiple failure to an acceptable level |
| **TASK** | **APPLICABILITY CRITERIA** | | | |
| SERVICING/ LUBRICATION | The replenishment of the consumable or lubricant must be due to normal operation by design | | | |
| ON-CONDITION | 1 Must be possible to detect reduced failure resistance<br>2 Must have a definable, detectable potential failure condition<br>3. Must have a consistent age from potential failure to functional failure | | | |
| HARD TIME | 1. Must have minimum age below which no failures will occur<br>2. (REWORK ONLY) Must be possible to restore to an acceptable level of failure resistance | 1. Must have age where conditional probability of failure shows a rapid increase<br>2. A large percentage of items must survive to this age<br>3. (REWORK ONLY). Must be possible to restore to an acceptable level of failure resistance | | 1. Must have minimum age below which no failures will occur<br>2. (REWORK ONLY) Must be possible to restore to an acceptable level of failure resistance |
| COMBINATION | Must have OC and HT tasks which can be made applicable in combination | | | Must have OC and HT tasks which can be made applicable in combination |
| FAILURE FINDING | | | No other task is applicable and effective | |

FIGURE 8. Applicability and effectiveness criteria summary.

4.3.3 On-condition tasks. Scheduled inspections to detect potential failures are termed on-condition tasks. These tasks call for the removal or repair of individual units of an item, "on the condition" that they do not meet a required standard. Such tasks are directed at specific failure modes which have identifiable physical evidence (symptom) of potential failures. Each unit is inspected at regular intervals and remains in service until its failure resistance falls below a defined level; that is, until a potential failure is discovered. On-condition tasks discriminate between units that require corrective maintenance to prevent a functional failure and those that will probably survive to the next inspection. This discrimination permits all units of the item to realize most of their useful lives. On-condition tasks are applicable to many parts of aircraft and support equipment systems, powerplants, and much of the structure. The applicability of an on-condition task depends on both maintenance technology and the equipment design.

a. For example, borescope and radioisotope techniques have been developed for inspecting turbine engines. These techniques are of value chiefly because the engines have been designed to facilitate their use.

b. Likewise, support equipment, avionics or instruments may need to be inspected for a specific condition, such as a calibration requirement. For the purposes of the RCM analysis, a calibration requirement is identical to an on-condition requirement. All calibration requirements will be determined in the same manner as on-condition tasks.

c. An applicable on-condition task is the most desirable type of preventive maintenance. It avoids the premature removal of units that are still in satisfactory condition. Also, the cost of correcting potential failures is often far less than the cost of correcting functional failures. DOD Report AD-A085450, "Designing On-Condition Tasks for Naval Aircraft" contains detailed information regarding on-condition tasks.

4.3.4 Hard time tasks. Many single-celled items and simple items display wearout characteristics. The probability of their failure becomes significantly greater after a certain operating age. The overall failure rate of an item with an identifiable wearout age can sometimes be reduced by imposing a hard time limit on it. This prevents operation of the item at an age where the probability of failure is high. There are two types of hard time tasks, rework and discard.

4.3.4.1 Rework tasks. If an acceptable level of failure resistance can be restored by rework or remanufacturing, a rework task may be selected. A rework task may be applicable for either a simple item, or for a complex item, to control a specific failure mode. Although an age limit may be wasteful or ineffective for some units of an item, the net effect on the entire population of that item can be favorable.

a. For example, an aircraft tire (a simple item) is scheduled for rework after a specified number of landings: Retreading restores the original failure resistance. However, this results in the retreading of all tires at the specified age limit, whether they need it or not. Also it does not prevent functional failures in those tires that fail earlier than anticipated.

b. For complete rework of a complex item, the considerations are different. Failures in complex items result from many different failure modes. Each mode may occur at a different average age. Consequently, the overall failure rate of a complex item remains relatively constant. In some items, reliability of units decreases gradually with age, but there is no particular age that can be identified as an item wearout zone. Thus, unless rework eliminates a dominant wearout failure mode, complete rework of a complex item will have little or no effect on its overall failure rate.

4.3.4.2 Discard tasks. Discarding items or their parts at some operating age is another type of hard time task. Such tasks are called life limit tasks and have two distinct purposes. The first, safe life limits, is established to avoid critical failures. The second, economic life limits, is established because they are cost effective in preventing noncritical failures.

4.3.4.2.1 Safe life limits. A safe life limit is imposed on an item only when safety is involved and there is no observable condition that can be defined as a potential failure. In this case, the item is removed at or before the specified maximum age. It is either discarded or disassembled for discard of a time-expired part. This practice is most useful for simple items or for individual parts of complex items. For example, pyrotechnic devices in ejection seats and parachutes have a limited shelf life, and turbine engine disks or nonredundant structural members are subject to metal fatigue. The safe life limit itself is usually established by the equipment manufacturer using developmental testing. Initially, a component whose failure would be critical is designed to have a very long life. It is then tested in a simulated operating environment to determine the average life actually achieved. A conservative fraction of this average life is then used as the safe life limit.

4.3.4.2.2 Economic life limits. In some instances, extensive operating experience may indicate that the scheduled discard of an item is desirable on purely economic grounds. An economic life limit, however, is established in the same manner as an age limit for scheduled rework. It is based on the relationship between actual age and reliability of the item rather than on some fraction of the average age at failure. The objective of a safe life limit is to avoid accumulating any failure data. However, the only justification for an economic life limit is cost effectiveness. Thus, the failure rate must be known in order to predict the effect that the total number of scheduled removals, at various age limits, will have on task effectiveness.

4.3.5 Combination tasks. For safety related consequences, it is necessary to evaluate every means of preventive maintenance before using a forced re-design alternative. If an on-condition or hard time task alone proves not to be applicable or effective, then combinations must be evaluated. A combination task has a safe life limit. This limit is protected by an on-condition task, performed at a fraction of the life limit. In other words, the safe life limit is uncertain or only a prediction and must be protected with another task to insure the lowest acceptable probability of failure.

4.3.6 Scheduled failure finding tasks. If an item is subject to a functional failure that is not evident to the operating crew, a scheduled task is necessary to protect that function's availability. Hidden function failures, by definition, have no immediate consequences. However, if undetected, they increase exposure to a possible multiple failure. Hence, if no other type of maintenance task is applicable and effective, then failure finding tasks, scheduled inspections for hidden failures, are assigned. Such tasks are intended to locate functional failures rather than potential failures. But, they can be viewed as a type of on-condition inspection, since the failure of a hidden function item can also be viewed as a potential multiple failure. The chief difference is in the level of item considered; a functional failure of one item may be a potential failure for the equipment as a whole.

4.4 RCM for different types of equipment. RCM logic is applicable, in similar ways, to many different types of weapons systems and equipment. How RCM is applied to an equipment's system differs from how it is applied to the same equipment's structure. Structurally significant items follow a different logic course than do systems. Applications of RCM logic require special considerations for:

a. Aircraft.
b. Support Equipment.
c. Targets/Drones.
d. Ordnance/airborne equipment.

The special considerations affect selection of a significant item and interpretation of safety effects.

4.4.1 Aircraft. Aircraft equipment can be divided into three major areas; systems, powerplants and structures. Systems and powerplant items use the RCM FSI logic diagram. SSIs follow the structural decision logic.

4.4.1.1 Systems. Most systems are made of many separate assemblies or components that are linked by electrical wiring, hydraulic lines or other connect-ing devices. Since most system components in a new design have been used in previous aircraft, the reliability of many system items is known. Redundancies, fail safe features, built-in test equipment, and instrumentation must all be examined to determine the severity of any system failure.

4.4.1.2 Powerplants. Powerplants include only the basic engine for RCM analysis purposes. Quick Engine Change (QEC) items will be analyzed as system items. Powerplants generally have several significant failure modes. The severity of these failures is greater in single engine aircraft. Powerplant failures are expensive to repair, and since they down the aircraft, they have operational consequences. For these reasons, there is a strong incentive to find effective preventive maintenance tasks for powerplants. Since powerplants may have a more detailed tracking system than other systems and structures, more data are available to generate these tasks.

4.4.1.3 Structures. For analysis purposes, the structure of the aircraft consists of all load carrying members (aerodynamic, propulsion, landing, arresting, etc). These members include the wings, fuselage, engine mountings, landing gear, flight control surfaces, and related points of attachment. Aircraft structure, as a whole, is not substantially changed over the life of the aircraft. Thus, most structures are designed to last far longer than expected aircraft life. The goal of preventive maintenance for structures is dependent on the design philosophy of the member being analyzed. For a safe life structural member, the principal objective is to prevent the first failure. For a damage tolerant structural member, the principal objective is to detect incipient failures. Because failure of a major load carrying element will have a direct adverse effect on safety, the failure consequences of SSIs are always safety critical. A separate logic is followed for SSIs. This logic identifies structural inspection requirements, based on whether the design philosophy for the SSI is safe life or damage tolerant.

4.4.1.3.1 Safe life structural members. Safe life structural members have a safe useable life. With this type of structure, a single failure can be catastrophic. Safety is achieved in two ways: (1) by building the structure with a large margin of strength above the expected loads; and (2) by limiting the life of the structure to a "safe life," less than that at which the structure was tested in the laboratory. For this type of structure, a symptom of failure cannot be detected: The crack propagation rate is too fast to allow for multiple inspections before failure. For these reasons, safe life structural members are replaced or modified before the age where failures are expected to occur.

4.4.1.3.2 Damage tolerant structural members. The damage tolerant design concept requires: (1) when one or more elements crack or fail completely, the rest of the structure must be capable of withstanding a given static load (fail safe); and (2) the rate at which a fatigue crack in an element grows should be slow enough to give ample time for detection before it reaches a critical length (slow crack growth). A typical damage tolerant design requirement is that, after a single primary structural failure, the airframe as a whole must withstand 80% of its design loading without catastrophic failure. Reliability for a damage tolerant structure is achieved in the following different ways:

a. By using multiple load paths, safety is assured by preserving load carrying capability through redundancy;

b. By choosing materials that exhibit slow crack growth, safety is assured by the ability to inspect for and discover damage before complete failure;

c. By using a crack arresting design, cracks are inhibited from reaching a critical size.

4.4.1.3.3 Application of RCM to aircraft structures. All Structurally Significant Items (SSIs), determined by FIGURE 3, are analyzed using a separate structures logic diagram (FIGURE 6) and RCM worksheet 6, which is included in the RCM process. Structural members are broken down into assemblies or critical elements, which are then analyzed for significance. Damage tolerant SSIs in most cases have an applicable and effective on-condition task. Safe life SSIs rely on a combination of safe life limits and on-condition tasks to ensure the age limit is realized. Since fatigue is directly related to operating age, the safe life limit is based on design predictions and validated with a fatigue test. When the safe life limit is based on such tests, a hard time task is applicable, but not effective by itself. The safe life structural member is exposed to other deterioration processes (environmental and accidental damage) that can prevent the safe life limit from being achieved. Therefore, safe life structural items must be supported by a combination of tasks.

4.4.2 Support equipment. The major divisions of support equipment are the same for aircraft: systems, powerplants and structure. Some support equipment may have only one of these divisions. For example, an aircraft sling may be analyzed as having only structural considerations, so only the structural logic diagram (FIGURE 6) is used. A hydraulic power cart, on the other hand, may fall into the categories of powerplants and systems. Thus, the analysis uses FIGURE 5. When analyzing support equipment, the effect of the failure must be examined against the system being supported and the personnel operating the equipment. For the most part, support equipment failures have operational consequences for the systems being supported.

4.4.2.1 Test and monitoring systems. A major segment of support equipment are those items used to perform measurements. They are identified as Test and Monitoring Systems (TAMS), which include gauges, indicators, calibration standards and test equipment. To ensure timely TAMS support, a Calibration Requirements Analysis (CRA) must be initiated early in the equipment acquisition cycle. Thus, equipment requiring calibration or measurement verification is identified as a significant item. The calibration requirement is identified when the FMEA reflects "out of tolerance" or "out of adjustment" as a failure mode. Based on the calibration requirements, calibration standards and limits are established, and the need for TAMS is documented as part of the CRA process.

4.4.3 Target/drones. Drones and targets are considered reusable equipment. They can be broken into similar categories as aircraft, depending on the type of equipment being analyzed. Since the operator is usually isolated from the target or drone, many equipment functions are hidden. Also as there is no flight crew, there may be fewer safety related failures. Thus, targets/drones usually have operational/economic or non-safety hidden failure consequences.

4.4.4 Ordnance/airborne equipment. The analysis of ordnance/airborne equipment must consider both the time that equipment is attached to the aircraft and the time that it is stored for future use. This includes equipment mounting functions on the ground. Ordnance equipment can fall into any of the categories listed for aircraft (paragraph 4.4.1). For example, a missile is broken down into systems, powerplants, and structures, whereas a bomb rack is broken down into structures and systems. Failures of ordnance equipment usually have operational effects. Normally, airborne equipment is entirely systems by design and falls into the system and structures category for aircraft (paragraph 4.4.1). Failures of airborne equipment usually have operational effects.

# 5. DETAILED REQUIREMENTS

5.1 Preventive maintenance analysis process. Preventive maintenance requirements are initially established as part of the LSA process. They require periodic re-analysis and update as equipment or operational changes occur. The age exploration program and other data sources provide the basic information needed to adjust preventive requirements and intervals for in-service equipment. FIGURE 9 shows the preventive maintenance analysis process, as described in this standard. This process is separated into the following areas:

a. Inputs to the preventive maintenance analysis process.

b. Documentation of RCM and age exploration analysis.

c. Determination of phase inspection and Operating Service Period (OSP) intervals.

d. Design changes and revisions to maintenance requirements.

e. Auditing the RCM analysis.

5.1.1 Inputs to the preventive maintenance analysis process. This standard contains the analysis and documentation procedures to accomplish an RCM analysis. Related analyses must be accomplished concurrently with the RCM decision logic process. These analyses are as follows: (1) the selection of significant items for the preventive maintenance analysis process, (2) a Failure Modes and Effects Analysis (FMEA) and (3) development of a maintenance plan. The FMEA provides a list of functions, functional failures, and engineering failure modes for each significant item. The FMEA format is FIGURE 103.1, MIL-STD-1629, change notice 1: The failure mode effects and criticality analysis maintainability information worksheet. This worksheet also provides other information which is used to answer questions on the RCM decision diagram (see FIGURE 5). With these inputs, the preventive maintenance process can be completed using the RCM worksheets, see appendix D, to document the analysis. RCM summary data are recorded on Worksheet 1, after the initial analysis is completed and the preventive maintenance requirements have undergone a packaging process. This process involves development of phase and operating service period packages. Worksheet 1 documents the results of the RCM process as input to the LSA/MPA process. When RCM logic decisions are made with default logic due to lack of information, they are recorded on age exploration worksheet 7. This worksheet is used to develop the initial age exploration requirement. In-service applications of RCM, which are not part of an LSA program, will require selection of significant items, an FMEA, and updates to the maintenance plan.

5.1.2 Preventive maintenance analysis documentation. Analysis decisions and results must be documented to provide inputs into the LSA/MPA process, which determines support requirements for new equipment. The completed worksheets also provide assurance that only justified preventive tasks are included in the organizational, intermediate, and depot maintenance packages. The documentation package for RCM analysis of a significant item consists of the

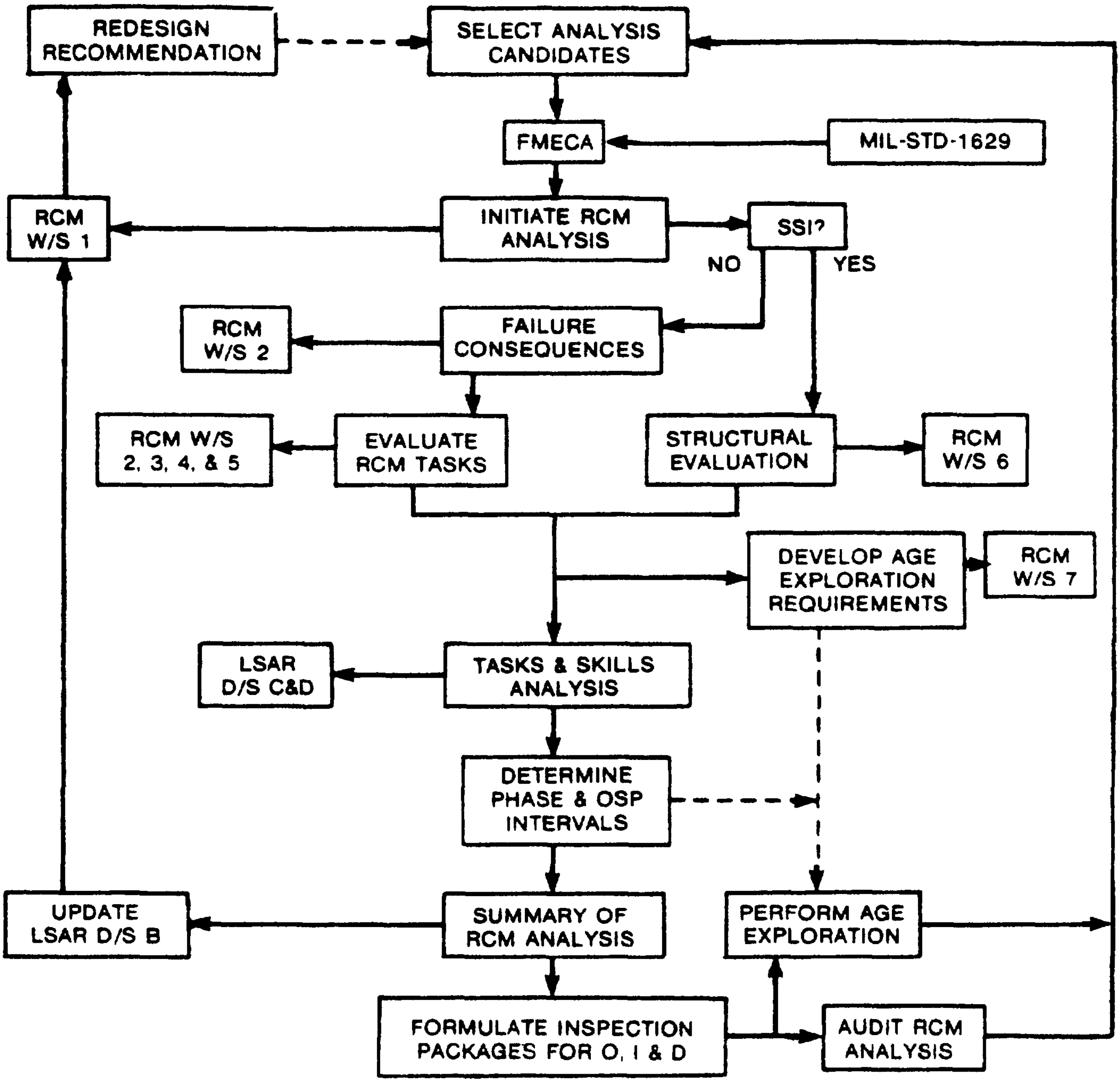



FIGURE 9. **Preventive maintenance analysis process**

FMECA/MI worksheet and the necessary RCM worksheets. For in service evaluation of preventive maintenance, the worksheets provide either a basis to work from or the starting point for an initial analysis. RCM worksheets require extensive research and data to properly document each decision of the RCM decisiondiagram. However, needed information may not be available initially to complete the worksheets. Provisions, such as the default logic, allow analysts to make conservative decisions in the absence of required data. These default decision compel the initial age exploration program to provide the necessary data for adequate completion of the RCM analysis. Some areas of the preventive maintenance analysis do not require documentation on specific worksheets. But, each RCM decision diagram question is documented completely on an RCM worksheet.

5.2 RCM logic documentation. The RCM worksheets, required by paragraph 6.2 and presented in appendix D, record the results of the RCM decision diagram questions (see paragraph 4.2.3). These worksheets also document the results of the structural evaluation and the age exploration development, and provide a summary of the RCM analysis. Each RCM worksheet may not be required for every significant item analyzed. No RCM worksheet stands alone; each worksheet is dependent on the data and analysis of the other worksheets. Each functionally significant item will require as a minimum RCM worksheets 1, 2, and 3. Worksheet 4 is completed only when on-condition tasks do not meet the applicability and effectiveness criteria. Worksheet 5 is completed either for items with hidden failures where an on-condition or hard time task is not applicable and effective, or for safety items where combination tasks must be evaluated. Worksheet 6 is required only for structurally significant items. Worksheet 7 is used only for those items having default answers on worksheets 2 through 6. The directions for completing each worksheet follows the process outlined in FIGURE 9. All data and logic answers on the RCM worksheets must be supported by adequate justification.

5.2.1 Summary of RCM analysis. Preventive maintenance requirements are input to the Logistics Support Analysis Record (LSAR) through RCM worksheet 1, which summarizes the results of the RCM analysis. On completion of RCM worksheets 2 through 6, the proposed RCM tasks and engineering intervals are input to the task analysis process. Once the proposed tasks have been refined and phase inspections and OSP intervals chosen, the tasks and RCM decision logic answers are documented on RCM worksheet 1. This worksheet also provides for quality assurance of the decisions made. When the summary worksheet is reviewed it is easy to determine obvious mistakes in the RCM logic. RCM worksheet 1, in appendix D, is completed using the following paragraphs.

5.2.1.1 Documentation of RCM summary data. This section contains the procedures for completing RCM worksheet 1.

RCM Worksheet 1, Heading Data. The heading data is contained in blocks (a) through (j):

BLOCK (a): System/Subsystem Nomenclature. The nomenclature of the system, subsystem, Weapons Replaceable Assembly (WRA), or Shop Replaceable Assembly (SRA) is listed.

BLOCK (b): System/Subsystem. The following information is provided for the system or subsystem level of indenture.

1) LSACN - List the Logistics Support Analysis Control Number (LSACN) for new procurement programs which applies to the system or subsystem identified in block (a).

2) MIR Index Code - The Master Index of Repairables (MIR) Index Code identifies each repairable item by using the Work Unit Code (WUC), Type Equipment Code (TEC), and a Configuration Code (CF). The WUC identifies the system or subsystem on which maintenance is performed by a 7 character alpha-numeric code. The TEC is a 4 character code identifying the aircraft, engine or support equipment type, model and series. The CF is a one character code used to identify by location items which have the same WUC and TEC.

BLOCK (c): Part/Model Number/FSCM - List the assigned part number, model number, or Federal Supply Code for Manufacturers (FSCM) of the system or subsystem in Block (a).

BLOCK (d): End Item Nomenclature, T/M/S, NALC Number - List the end item nomenclature, T/M/S, or Naval Ammunition Logistics Code (NALC) for cartridges and initiators which apply to the system or subsystem in Block (a). For support equipment, the Type Equipment Code (TEC) should be listed as a part of the nomenclature.

BLOCK (e): Indenture Level - List the number that identifies the indenture level of the system, subsystem, WRA or SRA previously listed in Block (a). The items listed in column one of these worksheets should normally be one level of indenture lower than the indenture level listed here.

BLOCK (f): Prepared by/Date - List the name of the analyst who prepares this worksheet and the date the worksheet is completed.

BLOCK (g): Reviewed by/Date - List the name of the person who reviews this worksheet and the date the review is completed.

BLOCK (h): Page of - List the page number of this worksheet and the total number of these worksheets in the package; for example, page 1 of 3.

BLOCK (i): Revision No./Date - List the number of the latest revision to this worksheet and the date that it was revised. Higher numbers refer to more recent revisions, e.g., 1 would be first revision, 2 the second, etc.

BLOCK (j): Approved by/Date - List the name of the person who approves this revision or original worksheet and the date of approval. Higher numbers will normally be granted by the Naval Air Systems Command or a representative of that command.

Column 1: Item LSACN/MIR Index Code - List the LSACN for new procurement items subject to an LSA. Refer to the LSA candidate list or to an equivalent significant item list for LSACN inputs to RCM worksheet 1. Include items from the LSA candidate list which are identified as significant items for preventive maintenance analysis. When the WUC and TEC are available for new or in service equipment, also list the MIR Index Code in this column. The WUC is a seven character code identifying the systems, subsystem, or component on which the RCM analysis is performed. The TEC is a four character code identifying the aircraft, engine, or support equipment type, model, and series. For unique items in just one type, model and series, the actual four digit TEC is used. For common items in all series of one type and model, the first three characters of the TEC are used with a 9 in the fourth position. For common items in different types and models, XXXX is listed for the TEC. The CF is one character configuration code used to differentiate between some non-interchangeable items.

Column 2: Item Nomenclature - List the nomenclature of each significant item listed in column 1.

Column 3: Functional Failure Mode Code (FFMC) - List in this column the FFMC from the FMECA/MI worksheet for the appropriate WUC/LSACN. The FFMC is an alpha-numeric code used to quickly and easily identify specific function, functional failure, and engineering failure mode. The first character is the number of the function which relates to the item's LSACN or WUC. The second character is the letter identifying the relevant functional failure. The third character is the number identifying the engineering failure mode. For example, a typical FFMC might be 1A2 or 3B1. Functions or engineering failure modes in excess of ten (10) are shown as 10A2 or 3B12.

Column 4: RCM Logic Question Answers (Y or N) - In this column, list either "Y" for yes or "N" for no for RCM FSI logic questions 1 through 19. Table I provides reference to the specific worksheet number and column number where completed answers from previous analysis were recorded. Do not complete this column until RCM worksheet 2 through 5 are completed. Record the word "structure" in this column for FFMCs evaluated using FIGURE 6.

Column 5: RCM Tasks - List, in these columns, the task number and description of each applicable and effective task previously entered in column 5 of RCM worksheets 2, 3, 4 and 5. Also list tasks recorded on RCM worksheet 6 for the SSIs in this column.

TABLE I. RCM worksheet reference list

| RCM Question Number | RCM Worksheet Number | Worksheet Column | RCM Decision |
|---|---|---|---|
| 1 | 2 | 3a | Evident Failure |
| 2 | 2 | 3b | Safety Failure |
| 3 | 2 | 3c | Safety Hidden Failure Servicing/Lubrication |
| 4, 8, 11, 15 | 2 | 6 | Task |
| 5, 9, 12, 16 | 3 | 7 | On-Condition Task |
| 6, 10, 13, 17 | 4 | 7 | Hard Time Task |
| 7, 18 | 5 | 7 | Combination Task |
| 14, 19 | 5 | 7 | Failure Finding Task |

Column 6: Inspection Interval - List the preliminary and packaged inspection intervals for each task documented in column 5 of worksheet 1. The preliminary interval is determined by RCM task evaluations and recorded on RCM worksheets 2, 3, 4, 5, or 6. The packaged inspection interval is assigned to each task after a task analysis is performed. It is included in the preventive maintenance package at the required level of maintenance. The packaged interval normally cannot be determined until the RCM analysis of all significant items has been completed. After all preliminary intervals are determined, the analyses in apprendices C and D are followed to determine the packaged intervals. Preliminary and packaged intervals may differ in most cases.

Column 7: LSA Task Code/Level of Maintenance - List, in this column, the LSA task code for new procurement LSA programs, developed from MIL-STD-1388. For programs where an LSA is not accomplished, list the level of maintenance (O, I, or D) as determined by the RCM analysis. The LSA task code is necessary only to track RCM generated requirements to the LSAR.

5.2.2 Failure consequence evaluation documentation (RCM Worksheet 2, Col. 1-4). As shown in FIGURE 9, failure consequences are documented on worksheet 2, of appendix D. Using the FMEA for each significant item as a basis, the first three RCM decision logic questions are answered to determine the consequences of failure. In the first part of RCM worksheet 2, these answers are recorded. These failure consequences are then categorized into the following four areas:

a. Safety consequences.

b. Operational/Economic consequences.

c. Safety Hidden Failure consequences.

d. Non-Safety Hidden Failure consequences.

The following paragraphs describe the details required to complete columns 1, 2, 3, and 4 of worksheet 2; see appendix D.

5.2.2.1 Functions and engineering failure mode data. The significant items and functional failure mode code from the FMEA are entered in columns 1 and 2 of RCM worksheet 2. This information is transcribed directly from the RCM worksheet 1 or the FMECA/MI worksheet.

Column 1: Item LSACN/MIR Index Code - List in this column, the LSACN or MIR Index Code as recorded in column 1 of RCM worksheet 1.

Column 2: Functional Failure Mode Code (FFMC) - List the FFMC from column 3 of RCM worksheet 1 in this column for the appropriate WUC/LSACN.

5.2.2.2 Determination of failure consequences. After the item's functional failure mode codes have been properly identified, the first three RCM decision diagram questions can be answered (see FIGURE 5). These answers, either yes or no, determine the consequence for each failure. The answers also identify which branch of the decision diagram to follow during task evaluation. In answering these three questions, use the failure modes and effects analysis data provided in the FMEA worksheet. Columns 3a, 3b, and 3c of RCM worksheet 2 refer directly to the first three RCM logic questions.

Column 3: Failure Consequence Determination - In columns 3a, 3b, and 3c, provide answers and justification for the first three RCM decision logic questions.

3a - Question 1 - Is the failure occurrence evident to the crew or operator while performing normal duties? This question is asked for each functional failure of each significant item. The question is answered by placing a "Y" for yes or "N" for no in the column and providing the required justification for the answer. Answer "N" means the failure is hidden, and question 3, column 3c, must be answered. Answer "Y" indicates the failure is evident, and question 2, column 3b, must be answered. To help determine if the failure is evident, refer to the item description, compensating provisions, and failure detection method on the FMEA worksheet. The FMEA identifies design features, instruments, or warning lights which make a failure evident to the operator.

a. For the purposes of RCM, a flight begins when an attempt is made to start the aircraft's engines with the intent to leave the ground. The flight ends after airborne flight when the aircraft is on the surface, the engines have stopped, and either the brakes are set or wheel chocks are in place. For item functions which were performed during flight, the flight crew or pilot would be the operator. For item functions handled only on the ground, the personnel responsible for operating the equipment would be the operator. For a functional failure to be evident, failure indications must be obvious to the operator while performing normal duties, without special monitoring. Normal duties for the flight crew are those procedures typically performed during flight to complete a mission. These duties do not include pre-flight, post-flight, or walk around inspections since the inspections do not ensure operational capability of an aircraft in flight. However, operational checks of systems during flight are considered valid methods of detecting failures if the checks are part of normal procedures. Flight crews operate some systems full time, others once or twice per flight, and some less frequently. All of these duties, providing they are done at some reasonable interval, qualify as "normal." On the other hand, most "emergency" operations are done at very infrequent periods. Therefore, they cannot be classified as "normal" duties.

b. The functional failure of an item is considered not evident to the operator if either of the following situations exist:

1. The item has a function which is normally active whenever the system is used, but there is no indication to the operator when that function ceases to perform.

2. The item has a function which is normally inactive and there is no prior indication to the operator that the function will not perform when called upon. The demand for active performance will usually follow another failure and the demand may be activated automatically or manually.

Consider the example of a bleed air system. A bleed air temperature controller limits the bleed air duct temperature to a maximum of 400°F. As a backup, there is a pylon shutoff valve which has a secondary temperature control should the temperature exceed 400°F. A duct overheat switch is set to warn the flight crew of a temperature above 480°F, so they can shut off the air supply from the engine by actuating the pylon shutoff valve switch. There is no duct temperature indicator. The bleed air temperature controller has an active function of controlling the air temperature. Although there is a secondary control in the pylon valve, the flight crew has no indication of when the function ceases to perform since there is no duct temperature indicator. Also, the flight crew has no indication, prior to its being called into use, that the secondary temperature control function of the pylon valve will perform. Therefore, the pylon valve has an inactive function. Similarly, the duct overheat warning system has an inactive function (manual shutoff) because at no time in normal use does the flight crew have to manually close the valve.

c. The evident failure question includes reference to "no indication to the operator" of failure's occurrence. If there are indications to the operator, the failure is evident. The justification should include the means the operator has of detecting the failure. In the case where no data is available or the answer is uncertain, the default logic is used and the answer is recorded as N-D, for no-default (see FIGURE 7). This question shows the importance of properly identifying all the functions for each significant item. Certain secondary, as well as primary, functions may have critical functional failures.

3b - Question 2 - Does failure cause a function loss or secondary damage that could have a direct adverse effect on operating safety? Consider this question only when the first RCM question in column 3a is answered yes. Then, answer question 2 for each engineering failure mode of each item. List the answer in this column, using a "Y" for yes or "N" for no, and provide required justification.

a. To determine the effect on operating safety, consider this question in parts. There are two areas to evaluate: first, the loss of the function (functional failure) and second, the effects of secondary damage. Each area must be assessed as to whether there is a "direct adverse effect on operating safety." The word "direct" means that the engineering failure mode must achieve its effect, by itself, and not in combination with other engineering failure modes. In other words, the engineering failure mode must independently be able to cause the adverse effect on operating safety. Also, for an engineering failure mode to be "direct", the failure must occur immediately upon a demand for the affected function. The phrase "adverse effect" is meant to imply that the direct consequences of the engineering failure mode are extremely serious or possibly catastrophic. For aircraft, "operating safety" refers to actual flight, as defined under column 3a. For support equipment the "operating safety" regime is that period of time when the unit is powered-up with the intent to perform a servicing action until the unit is secured at its designated place and power is off.

b. The engineering failure mode must affect a function that is not protected by redundant items or protective devices. That is, if the function is protected by a redundant item or by a protective device, its failure does not have a direct adverse effect on operating safety. An example of a protective device is the delta pressure bypass valve in the engine oil supply line filter. When the bypass valve activates, the filtering function is lost, but the function of flow oil is protected. Therefore, a clogged oil filter, if protected by a bypass valve, will not cause bearing nor engine seizure. In this case, it does not have a direct adverse effect on operating safety.

c. Finally, the engineering failure mode must affect a function that is required for normal aircraft operation during flight or for each use of the support equipment.

d. Fortunately, there are very few yes answers to this question. During design, engineering failure modes that immediately cause loss of a vital function are carefully identified. To mitigate the impact of these possible failures, redundant protective items are then designed into the aircraft or support equipment. As a result, most of these failure modes usually have been anticipated. Experience, therefore, has shown that there are few engineering failure modes that can have a "direct adverse effect on operating safety." Refer to the failure effects and compensating provisions provided on the FMEA worksheet to assist in answering this question.

e. A "Yes" answer to this question will require some task to prevent the safety consequence. A "No" answer indicates there are economic or operational consequences. In cases where no data is available or the answer is uncertain, the default logic answer is used. The default answer should be recorded as "Y-D", for Yes-Default in the column provided (see FIGURE 7).

3c - Question 3 - Does the hidden failure itself or in combination with another failure have an adverse effect on operating safety? This question is asked for each engineering failure mode whose functional failure has a "No" answer to question 1, column 3a. The above question is answered by placing a "Y" for yes or "N" for no in the column and providing the required justification for the answer listed. Consider this question in the same manner as question 2, column 3b, except that the effect of the failure is not immediate. When answering this question, consider two areas. First, analyze the hidden failure to determine if it has an adverse effect on operating safety. This adverse effect on safety will result either when the failure occurs or when the function is called upon. Second, if the hidden failure by itself, does not have an adverse effect on safety, look for a combination of failures. In this case, the hidden failure adversely affects safety only when it occurs in combination with one additional failure. This additional failure occurs after the hidden failure. It must be in a related system or a back-up to the system in which the hidden failure occurs. If the hidden failure causes an adverse effect on operating safety, enter a "Y" in this column. A "Yes" answer indicates there are safety hidden failure consequences. If a combination of failures is identified, include the additional failure in the justification. A "No" answer indicates the failure has nonsafety hidden failure consequences, which only involve economic or operational effects. In the case where the answer is uncertain, default logic is used and "Y-D" is entered for yes-default (see FIGURE 7).

Column 4: Failure Consequence - List in this column the failure consequence (Safety, Economic/Operational, Non-Safety Hidden Failure, Safety Hidden Failure) as determined by columns 3a, b, and c. The relationship of the first three RCM logic questions on worksheet 2 to identify the consequence of failure for each engineering failure mode. The consequence of failure determines both the objective of the preventive task and the criteria for evaluating task effectiveness. A preventive task for each failure is evaluated to satisfy one of the failure consequences determined by worksheet 2. Each of these consequences correspond to one branch of the RCM decision diagram (see FIGURE 5). Refer to TABLE II to determine the failure consequences.

TABLE II. RCM Consequences Determination
RCM Worksheet 2

| Failure Consequence Column 4 | Column 3a Question 1 | Column 3b Question 2 | Column 3c Question 3 |
|---|---|---|---|
| Safety | Yes | Yes | ----- |
| Economic/Operational | Yes | No | ----- |
| Non-Safety Hidden Failure | No | ----- | No |
| Safety Hidden Failure | No | ----- | Yes |

5.2.3 Evaluation of RCM tasks. After the consequences of failure have been determined on worksheet, evaluate each engineering failure mode to determine if a potential RCM task is applicable and effective. This is accomplished by evaluating questions 4 through 19 of the RCM decision diagram (see FIGURE 5). Not all RCM logic questions are answered for a particular engineering failure mode. For each consequence of failure, consider all potential preventive tasks in order of preference. Evaluate the following tasks, depending on the consequence of failure, to satisfy an engineering failure mode.

a. Servicing/lubrication task.

b. On-condition task.

c. Hard time task.

d. Combination task.

e. Failure finding task.

The RCM philosophy requires that these tasks be evaluated in this order. When one of the above tasks is found applicable and effective, that task is packaged into the preventive maintenance program. Servicing/lubrication tasks do not stand alone and always require, at least, an on-condition task evaluation. Therefore, except for servicing/lubrication tasks, after a task is selected, it is not necessary to evaluate another question.

5.2.3.1 RCM task preference. The characteristics of these tasks suggest a strong order of preference based on their overall effectiveness as preventive measures.

a. Servicing/lubrication tasks are evaluated first because they relate directly to the design and operation of the equipment.

b. The next choice is always an on-condition inspection, particularly if it can be performed without removing an item from the equipment. This type of preventive maintenance has a number of advantages, because on-condition tasks identify individual units at the potential failure stage. 1) They are particularly effective in preventing specific modes of failure and in reducing failure and operational consequences. 2) They also reduce the average cost of repair. Expensive secondary damage caused by a functional failure is avoided. 3) Each unit realizes almost all of its useful life. The number of removals for a potential failure is only slightly larger than the number that would result from an actual functional failure. Thus, repair costs and the number of spare units needed to support the repair process are kept to a minimum. 4) By scheduling on-condition inspections at a time when the equipment is out of service ensures that the responsibility for discovering potential failures is given to the maintenance organization that performs the inspections.

c. The next choice is a hard time task if no applicable and effective on-condition task can be found. There are two types of hard time tasks: scheduled rework and scheduled discard. Scheduled rework of single parts or components leads to a marked reduction in the overall failure rate of items that have a dominant engineering failure mode. (The failure resulting from this mode is concentrated at an average age.) This type of task may be cost effective if the failures have major economic consequences. A rework age limit usually permits the remanufacture and reuse of time expired units. Thus, material costs are lower than they would be if the entire unit were discarded. Any scheduled rework task, however, has certain disadvantages. 1) Because the age limit applies to all units of an item, many serviceable units will be removed that would otherwise have survived to higher ages. 2) Also, the total number of removals will consist of both failed units and units scheduled for removal. 3) Therefore, the total workload for this task is substantially greater than it would be with an on-condition inspection, and a correspondingly larger number of spares are needed to support the process. Scheduled discard is economically the least desirable of the preventive tasks. It does, however, have a few desirable features. A safe life limit on simple components can prevent critical failures caused by certain engineering failure modes. Similarly, an economic life limit can reduce the frequency of functional failures that have major economic consequences. However, a discard task is in itself quite costly. The average life realized by an item subject to a safe life limit is only a fraction of its potentially useful life. The average life of an item subject to an economic life limit is much less than the useful life of many individual units. In addition, a discard task involves the cost of replacement. New items or parts must be purchased to replace the time expired units. A life limit usually does not permit remanufacture and reuse.

d. For safety related consequences, combination tasks are evaluated next. A combination task is an alternative to redesigning the equipment to satisfy the safety failure consequence. For safety hidden failure consequences, a combination task is a more desirable alternative than a failure finding task.

e. For safety hidden failure consequences, failure finding tasks are only applicable where systems have built-in redundancy. For purely non-safety hidden failures, a failure finding task looks for failures which have already occurred. This is considered before re-design is chosen as an alternative.

5.2.3.2 Applicability and effectiveness criteria. The RCM task evaluation questions require that a task meet both the applicability and effectiveness criteria to be acceptable. FIGURE 8 summarizes the applicability and effectiveness criteria. The applicability of a task depends on the failure characteristics of an item, while the effectiveness of a task depends on the failure consequences. Therefore, an applicable task must satisfy the requirements of the type of failure. These requirements are different for on-condition and hard time tasks as shown in FIGURE 8. The applicability criteria is dependent solely on the type of task (on-condition or hard time), regardless of failure consequence. After the applicable task is chosen, the effectiveness of that task in preventing the failure consequences must be determined. Note that in FIGURE 8 the effectiveness criteria varies by failure consequences. Therefore, each type of task must meet the same effectiveness criteria under the same consequence of failure. The specific applicability criteria will be discussed in detail as the individual task worksheets are presented.

5.2.3.2.1 Effectiveness criteria for safety and safety hidden failure consequences. Although the criteria for each failure consequence is determined separately, RCM worksheets 2 through 5 follow the same criteria for effectiveness. For safety and safety hidden failure consequences, the effectiveness criteria requires that the task reduce the probability of critical failure to an acceptable level. Acceptable probability of failure must ensure that the task prevents critical failures from occurring. To determine an acceptable probability of failure, a goal of near zero failures over the life of all aircraft must be established (0.5 failures over the life is acceptable to obtain a finite probability). Acceptable probability of failure is determined by the equation:

$$P_{acc} = \frac{0.5}{(AC)(SCI)(FM)} \quad \text{where:}$$

$P_{acc}$ - acceptable probability of failure

AC - total aircraft inventory, greater than 50, of the T/M/S being analyzed (averaged over the planned remaining life).

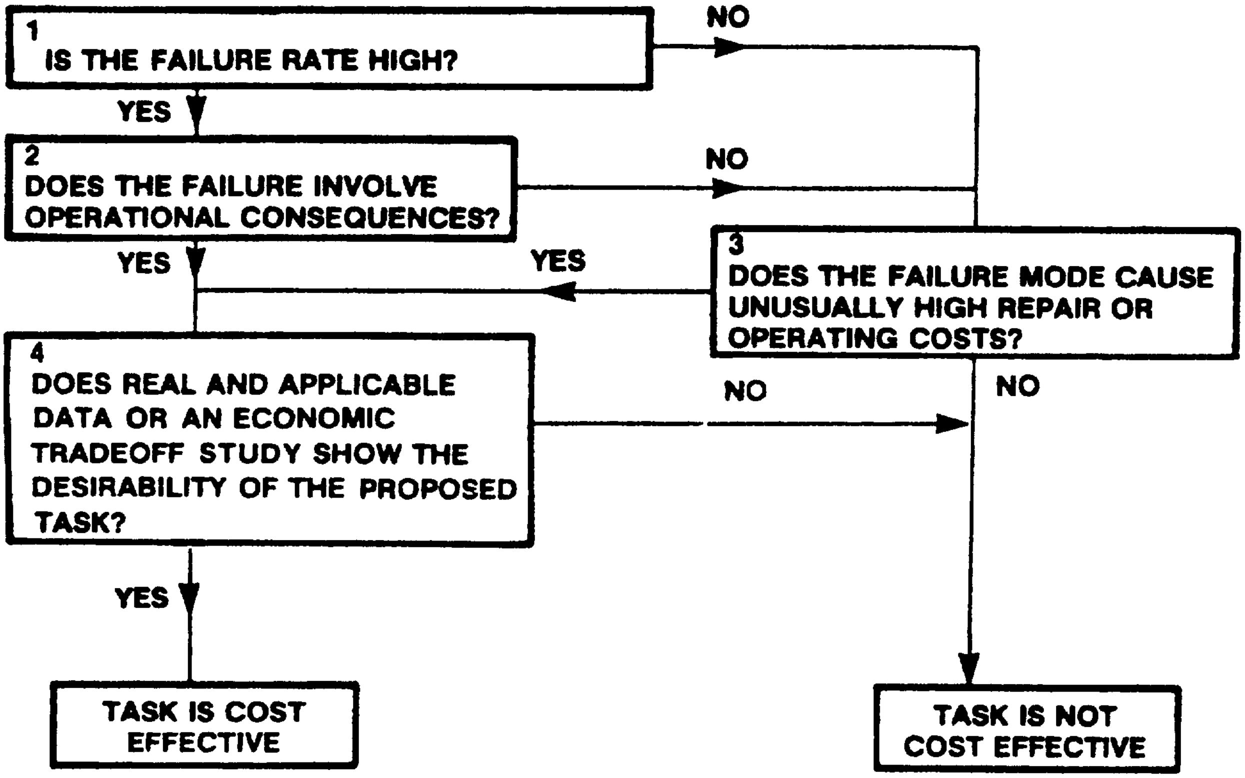
SCI - number of safety critical function of the significant item.

FM - number of severity class I and II (see FMEA) engineering failure modes for the item being analyzed.

Once the acceptable probability of failure has been determined, an iterative process, paragraph 5.2.4.3, is followed to assess the actual probability of failure. For the task to be effective, the actual probability of failure must be less than or equal to the acceptable probability of failure. For safety hidden failure consequences, the task must reduce the probability of multiple failure to an acceptable level. Effectiveness for safety hidden failure consequences is determined in the same manner as safety consequences, except the probability of multiple failures is also calculated (paragraph 5.2.4.3).

5.2.3.2.2 Effectiveness criteria for economic/operational and non-safety hidden failure consequences. For economic/operational and non-safety hidden failure consequences, the effectiveness criteria is cost related. For purely economic consequences, a task is effective if it costs less than the cost of the failure it prevents. For operational consequences, a task is effective if its cost is less than the combined cost of operational loss and the failures it prevents. FIGURE 10 helps determine cost effectiveness by evaluating the failure rate, operational consequences, repair or operating costs, and real and applicable data. If cost effectiveness cannot be determined from these data, an economic trade-off analysis must be performed. This analysis determines whether a task is cost effective and identifies the optimum interval at which to perform the task. If a task proves not to be cost effective, no preventive maintenance is required. However, in some cases redesign may be desirable. The following questions determine the cost effectiveness of a task. They correspond to the four cost effectiveness questions from FIGURE 10.

1. Is the failure rate high? - Compare the failure rate of the engineering failure mode to the failure rate of the item or system being




Decision diagram for evaluating the probable cost effectiveness of a proposed task when preventive maintenance is not required to protect operating safety or the availability of hidden functions. The purpose of the decision techniques is to reduce the number formal economic tradeoff studies that must be performed.

FIGURE 10. Decision diagram for cost effectiveness.

analyzed. If the engineering failure mode contributes to a significant percentage of the failures, then consider the failure rate high. If the failure rate is considered high, go on to question 2. If the failure rate is low, go on to question 3.

2. Does the failure involve operational consequences? - Ask this question only for those FFMCs which have a "Yes" answer to question 1. This question evaluates the relationship of the item's function to the mission phase. Answer this question "Yes" if the failure causes an immediate interruption of operations or a reduced mission capability or a delay/cancellation of subsequent flights to make unscheduled repairs. All of these consequences involve operational costs in addition to the cost of repair. A "Yes" answer to this question requires that question 4 be asked next. If the answer is "No", (the failure has no effect on operational capability) ask question 3 next.

3. Does the failure mode cause unusually high repair or operating costs?- Ask this question only for FFMCs which have a "No" answer to either question 1 or 2. Compare the repair costs of a particular engineering failure mode to similar failure modes for like items or systems. If the repair or operating costs are high in relation to other engineering failure modes, answer "Yes", then ask question 4 next. If repair or operating costs are low, the cost of a preventive task is higher than the cost of repair, thus the task is not cost effective.

4. Does real and applicable data or an economic trade-off study show the desirability of the proposed task? - Ask this question for FFMC's which have "Yes" answers to either questions 2 or 3. Real and applicable data, or other real world data which can be directly applied to the inspection being analyzed, must be used. These data include tasks for similar equipment which other services or manufacturers find effective. If real and applicable data support doing the proposed task, the task is considered cost effective. Where real and applicable data are not available, an economic tradeoff study must be accomplished. The economic tradeoff study must compare the cost of performing the proposed task with the cost of the consequences of not performing the task. A ratio of the cost of preventive maintenance to the cost of no preventive maintenance is called the Cost Benefit Ratio (CBR). The CBR can be expressed as follows:

$$CBR = \frac{C_{PM}}{C_{NPM}}$$ where:

$C_{PM}$ = Cost of preventive maintenance

$C_{NPM}$ = Cost of not doing preventive maintenance.

which implies the cost of the preventive task is less than the cost of not doing the task.

5.2.3.3 Servicing/lubrication task evaluation. As shown in FIGURE 5, servicing and lubrication tasks must be evaluated for each engineering failure mode. These tasks, by themselves, do not satisfy the complete requirements for preventive maintenance; other tasks must also be evaluated. Servicing tasks are applicable if they replenish a consumable that is expended during normal operation. A lubrication task is applicable if it is non-permanent (deteriorates with age or operation) and must be replenished periodically. When the FFMC, generated from the FMEA, identifies a malfunction due to lack of the consumable or lubricant, choose a servicing or lubrication task. Do not choose a servicing or lubrication task if it is not a design requirement. Documentation of servicing or lubrication tasks will be accomplished on RCM worksheet 2 (see Appendix D).

5.2.3.3.1 Servicing or lubrication task evaluation documentation (RCM Worksheet 2, Col. 5 & 6). Servicing or lubrication tasks are documented in columns 5 and 6 of RCM worksheet 2. Each FFMC in column 2 of this worksheet is evaluated to determine if the specific engineering failure mode can be prevented by a servicing or lubrication task. Describe applicable tasks in column 5. Answer the question in column 6 to ensure that the tasks are effective as well as applicable.

Column 5: Describe Servicing or Lubrication Task - In this column, identify proposed applicable servicing or lubrication tasks (see 5.2.3.3). Record the task number and give a brief description of the task. Also list the level of maintenance and preliminary interval. If a servicing or lubrication task is not applicable to a specific FFMC, leave this column blank and list "No" in column 6.

5a - Number - Identify each task with a task number. Consecutively number each task beginning with 001L and continue with 002L, 003L for remaining tasks. This task number will uniquely identify each servicing or lubrication requirement for traceability to the LSA data sheets and part III of the maintenance plan.

5b - Description - List a brief description of the applicable servicing or lubrication tasks. Identify servicing tasks with "SERV" prior to the description and lubrication tasks with "LUBE" prior to description.

5c - Preliminary task interval - List a preliminary task interval for each applicable task documented in column 5b. Base this interval on the operating time or age between servicing or lubrication requirements. Most servicing requirements are necessary between each flight or period of operation. Lubrication task intervals are based on durability of the lubricant, operating environment and design of item under consideration.

Some lubricants must be replenished after washing equipment with solvents or cleaners, which cause the lubricants to deteriorate.

5d - Proposed level of maintenance (O, I, or D) - Place an "X" in the column identifying the Organizational (O) or Intermediate (I) or Depot (D) level of maintenance for the proposed tasks.

Column 6: Is Servicing or Lubrication Task Applicable and Effective? - Each applicable task must also be effective to be accepted. List "No" in this column when no applicable servicing or lubrication tasks were documented in column 5. When column 5 lists an applicable task, its effectiveness must be evaluated. As the effectiveness is dependent on consequence of failure, review column 4 of this worksheet to determine consequence of failure. The effectiveness is then evaluated (see 5.2.3.2.1 and 5.2.3.2.2). Either a "Yes"or "No" answer is recorded in column 6. Justification must be provided to substantiate the effectiveness evaluations. The analysis process will progress to worksheet 3 regardless of a yes or no answer in this column (see FIGURE 5).

5.2.4 On-condition task evaluation. Applicability and effectiveness must be evaluated for each engineering failure mode and failure consequence. All documentation of on-condition tasks is accomplished on RCM worksheet 3, see appendix D.

5.2.4.1 On-condition task evaluation documentation (RCM worksheet 3). This worksheet is completed for all engineering failure modes and failure consequences. Input for documenting on-condition task evaluation partly comes from RCM worksheet 2, and the FMEA worksheet. Any other available sources of data may also prove helpful. Worksheet 3 records the specific on-condition applicability criteria, applicable tasks, and effectiveness criteria. Upon the completion of this worksheet, the analyst will proceed to worksheet 4 for those FFMCs where applicable and effective on-condition tasks were not found.

5.2.4.2 On-condition applicability criteria. On-condition tasks are discussed in paragraph 4.3.3, but to identify the applicability there are three considerations which must be covered. The three criteria for on-condition task applicability are:

a. It must be possible to detect reduced failure resistance for a specified engineering failure mode.

b. It must be possible to define a potential failure condition that can be detected by an explicit task.

c. There must be a reasonably consistent age interval between the time of potential failure and the time of functional failure.

As an example, suppose a visible crack is used as a measure of metal fatigue, as shown in FIGURE 11. Such an item is most failure resistant when it is new (point A). The resistance drops steadily with increasing age and is already somewhat reduced by the time a crack appears (point B). Thereafter, it is possible to monitor the growth of the crack (criteria a) and define a potential failure (point C, criteria b) so the item can be removed before a functional failure occurs (point D). Once a crack has appeared, the failure resistance drops more rapidly. The rate of crack growth in this item must be known in order to establish the interval T (criteria c). Thus, the inspection interval $\Delta$ T can be determined to effectively control the engineering failure mode. Though this example relates to structural items, on-condition tasks apply equally as well to other equipment. On-condition tasks for test equipment are generated on worksheet 3. Test equipment requirements are developed by identifying the means to detect (metrology equipment, criteria a) the potential failure condition (out of tolerance, criteria b). The inspection requirement is expressed by providing the limits under criteria b. The interval between the symptom and the out of tolerance condition is identified under criteria c and establishes the frequency for the proposed task. Any equipment listed under criteria a which is not currently available must itself be analyzed to ensure calibration support is established. Further detailed information concerning on-condition tasks is available in a booklet titled "Designing On-Condition Tasks for Naval Aircraft" dated, 1 March 1980. The applicability of an on-condition task may be re-evaluated in combination with another RCM task for safety and safety hidden failure consequences, whenever an RCM task, other than servicing or lubricating, was not chosen initially (see FIGURE 5, questions 6 and 14). The following information refers to the columns of RCM worksheet 3.

Column 1: Item LSACN/MIR Index Code - List the LSACN or MIR Index Code as listed in column one of RCM worksheet 2. Refer to paragraph 5.2.2.2. All items listed on worksheet 2 will be listed on this worksheet.

Column 2: Functional Failure Mode Code (FFMC) - List in this column the FFMC from column 2 of RCM worksheet 2 for the appropriate WUC/LSACN.

Column 3: Failure Consequence (Safety, Economic/Operational, Safety Hidden or Non-Safety Hidden Failure) - List in this column the consequence of failure from RCM worksheet 2, column 4, for each FFMC listed in column 2, worksheet 3.

Column 4: Applicability Criteria - Under the columns provided, list the specific applicability criteria as detailed below for each of the three conditions.

4a. Means to detect reduced failure resistance - In this column, for each FFMC in column 2, list the inspection technique used to detect reduced failure resistance, if possible. All possible inspection techniques should be considered, including any unique or unusual ones. However, after examining these techniques, only the most practical or effective method should be listed. If it is not possible to detect reduced failure resistance, enter "NA" for "not applicable" and proceed to column 7. If it is possible to detectthe reduced failure resistance, but the technique has not yet been proven reliable, list "Y-D" for "yes-default." Refer to FIGURE 7 for default logic decisions.

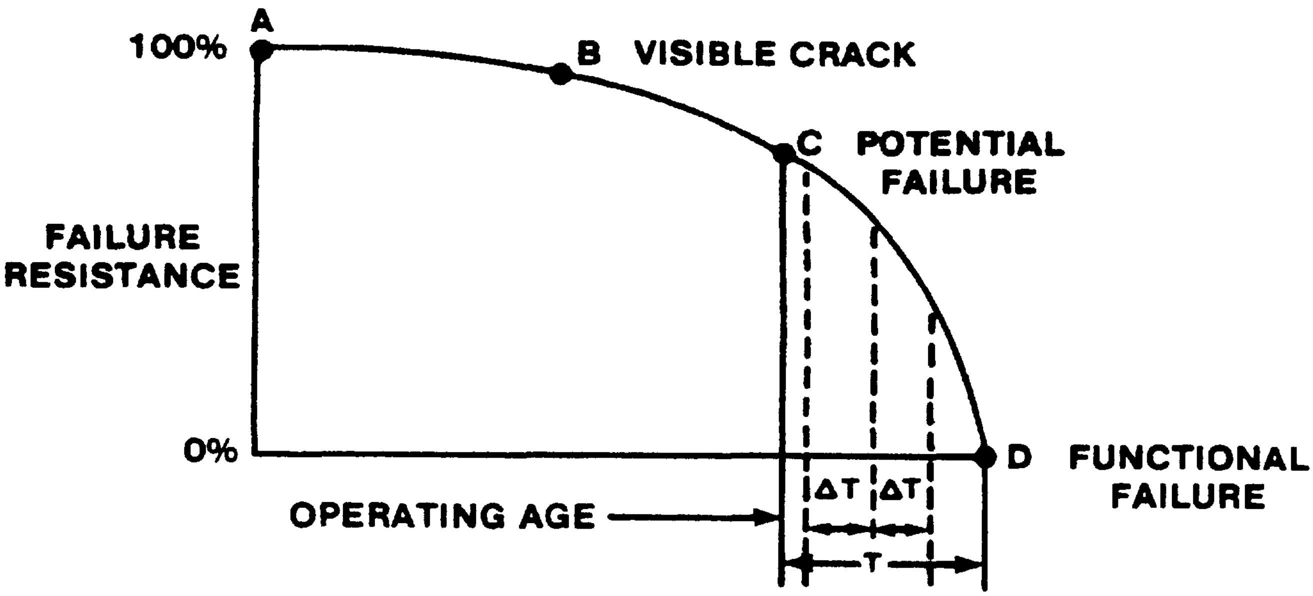
4b. Potential Failure condition detectable by an explicit task - This column is completed for FFMCs which have an applicable inspection technique listed in column 4a. List the specific limits or values, including their units, which identify the potential failure condition provided the reduced failure resistance is detectable. For structural items, list the repair limits which could be used as a potential failure condition. If support equipment has a calibration performance limit, list that as a potential failure condition. If a potential failure condition is totally unacceptable in an operating environment, then the on-condition task by itself is not applicable. If a potential failure cannot be defined or the item's design or function does not allow one to exist, enter "NA" for "not applicable" and go to column 7. When the reduced failure resistance can be detected, but the specific value of the potential failure condition is uncertain, list "Y-D" followed by a default limit.

4c. Interval between potential and functional failure - This column is completed for each FFMC which meets the applicability criteria of columns 4a and 4b. Interval T, shown in FIGURE 11, is the time between potential and functional failure. Inspection intervals are shown as $\Delta$ T. To determine interval T, first define the potential failure point (c) and the functional failure point (d). The potential failure point, is the limit listed in column 4b. The functional failure point, when defined, can be any point between potential failure and complete loss of function. Failure consequences may aid in determining the functional failure point. Once these points have been defined, determine the interval by examining test data and operational data. For an on-condition task to be applicable, this interval must be reasonably consistent. If data show that the interval varies greatly or is very short, enter "NA" and go to column 7. If real data are not available to find the interval, place a "D" and a default interval in column 4c. The default can be determined by using one of the following techniques. These techniques are listed in order of recommended use and each require adequate justification.

1. Use real data from like equipment to find the interval between potential and functional failure. Included in this category are special studies by other services or manufacturer's which provide the data to define an interval in column 4c for similar engineering failure modes.

2. If an identical on-condition task currently exists, the existing task interval can be used as default in column 4c and recorded again in column 5c.

3. When methods 1 and 2 are not available, use a good estimate based on experience. Consider the properties of the material, location of the item, operational stresses, etc. Provide rationale for developing the estimate and give reasons for not following methods 1 and 2.




Determining the interval for on-condition inspection of an item subject to metal fatigue. Once the rate of decline in failure resistance has been determined, an inspection interval $\Delta T$ is established that provides ample opportunity to detect a potential failure before a functional failure can occur.

FIGURE 11 - On-Condition task determination

Column 5: Describe Applicable On-condition Task - This column identifies the proposed on-condition task which met all three applicability criteria in column 4. Give a brief description of the task and identify it by a task number. Also identify the level of maintenance at which this task will be performed and the proposed task interval.

5a. Task number - Identify each task with a task number. Consecutively number each task beginning with 001P for the first task, and continue with 002P, 003P, etc. for remaining tasks. The task number allows the proposed tasks to be tracked through a task analysis process, provided the tasks prove to be effective, prior to assigning an LSA task code on worksheet 1. Refer to FIGURE 9 where proposed tasks from RCM worksheets 3 through 6 lead to the task analysis process and are eventually recorded on the maintenance plan. The task number uniquely identifies the preventive maintenance requirements from the RCM worksheets and provides an audit trail to Part III of the maintenance plans.

5b. Description - List a brief description of each on-condition task which meets all three applicability requirements. Identify the symptom being inspected for and the limits of the symptom.

5c. Preliminary Task Interval (Engineering) - The engineering task interval in column 5c is a fraction of the time between potential and functional failure in column 4c. This interval depends on the consequence of failure, accessibility of the item, and the skill level of the person performing the inspection. While items with economic consequences may require only one inspection task, during the interval in column 4c safety critical items may require many more inspections within the interval to ensure detection of the potential failure. A general rule is as follows: 1) safety and safety hidden failure items must have at least three inspections within the interval in column 4c. 2) Non-safety hidden failure and economic/operational consequence items have at least one inspection within the interval between potential and functional failure. 3) This rule must be tempered by the ability of the task listed in column 5b to detect any potential failure. If confidence in the inspection is low, then more inspections must be performed to meet the effectiveness criteria. Confidence is based on the type of inspection (accuracy of the test equipment) and the skill of the technician performing the task. For purposes of calibration, confidence is maintained by performance of inspections (calibration tasks) on the basis of a frequency limit. These tasks and their frequency are designed to detect, as soon as possible, an out of tolerance condition. This limit is the calibration interval. For newly developed equipment the recommended initial calibration interval shall be established. Use accepted statistical techniques to achieve a point where the target measurement reliability percentage (X) of the population of units to be calibrated will bein tolerance at the end of their interval. For special purpose test equipment, X shall be 85%; for general purpose test equipment X

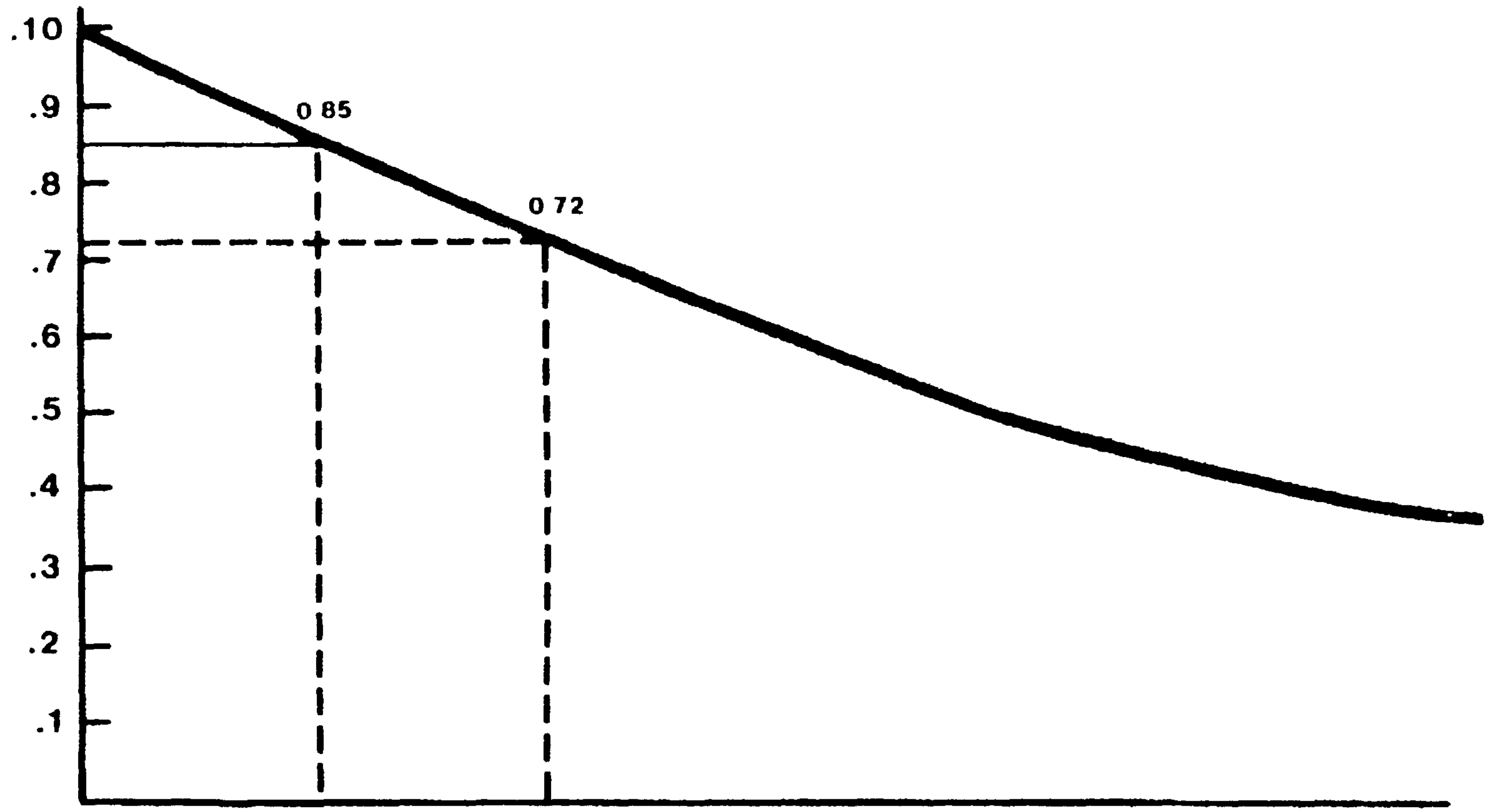



FIGURE 12 - Initial calibration interval

shall be 72% (unless otherwise assigned by the Navy cognizant equipment manager). FIGURE 12 expresses this relationship. The engineering interval is used to determine task effectiveness in column 6, but it is not necessarily the final inspection interval for the task.

5d. Proposed Level of Maintenance (O, I, or D) - Place an "X" in the column identifying the Organizational (O) or Intermediate (I) or Depot (D) level of maintenance at which the task will be performed. The selection of the maintenance level depends on the support equipment, skill level, and facilities required to complete the proposed task. The maintenance level and the task interval are used to evaluate task effectiveness.

5.2.4.3 Effectiveness criteria. Column 6 of worksheet 3 describes the procedures for documenting task effectiveness. Effectiveness criteria is completed only for FFMCs which have applicable tasks listed in column 5 of this worksheet.

Column 6: Effectiveness Criteria - The criteria for effectiveness are recorded in the appropriate failure consequences column. The initial evaluation will be based on the preliminary task interval and maintenance level listed in column 5. These may be changed to meet the effectiveness criteria when necessary.

6a. Safety - Probability of failure - In this column, first list the acceptable and then the actual probability of failure for each FFMC which has safety consequences. To evaluate task effectiveness, both the acceptable and actual probability of failure must be determined. Procedures for determining acceptable probability of failure are found in paragraph 5.2.3.2.1. Actual probability of failure is based on the preliminary task interval and the failure distribution. The equations used to determine actual probability of failure depend on the statistical distribution which best approximates the actual failure history. If the initial task interval does not result in an acceptable probability of failure, the interval should be shortened (if practical) and the probability redetermined. If the acceptable probability of failure cannot be met by shortening the interval, the task is not effective. When the probability of failure is based on a default interval, enter a "D" followed by the default probability. When a good estimate of the failure distribution cannot be made, list a "D" for default followed by the acceptable probability of failure. Refer to FIGURE 7 for the default decision for task effectiveness.

6b. Safety Hidden Failure - Probability of multiple failure - In this column, list both the acceptable probability of failure and the probability of failure or multiple failure for each FFMC which has safety hidden failure consequences. Task effectiveness is evaluated in the same manner as for safety consequences. However, for safety hidden failure consequences, two types of probabilities must be evaluated. The first is the probability of occurrence of a single hidden failure. This is determined in the same way as the actual probability of failure for safety consequences. The second is the probability of a hidden failure occurring in combination with another failure. This probability of multiple failure is determined using the equation:

$$P_{mf} = P_{hf} \times P_{af}$$ where:

$P_{mf}$ - probability of multiple failure

$P_{hf}$ - probability of hidden failure

$P_{af}$ - probability of failure for additional failure

When any of these probabilities is based on a default interval, enter "D" followed by the default probability. When a good estimate of the failure distribution cannot be made, list a "D" for default followed by the acceptable probability of failure. Refer to FIGURE 7 for the default decision for task effectiveness.

6c. Economic/Operational and Non-Safety Hidden Failure - This column records the effectiveness criteria for FFMC's with economic/operational or non-safety hidden failure consequences. Record only yes or no answers to the questions in the FIGURE 10 logic diagram. Adequate justification must be available to support the decisions (see 5.2.3.2.2). Record default decisions by entering "D" along with the default answer. Refer to FIGURE 7 for the default decisions for task effectiveness. "Yes" or "No" answers are recorded in columns 1 through 4, respectively, for questions 1 through 4 of FIGURE 10, see 5.2.3.2.2. If an economic trade-off study is to be performed to answer question 4, the CBR equation can be modified to optimize the on-condition inspection interval and gain maximum economic benefit. Express the optimum number of inspections, n, within the interval between potential and functional failures, T (see FIGURE 11), using the following equation:

$$n = \ln \left[ \frac{\dfrac{-\dfrac{MTBF}{T} C_i}{(C_{npm} - C_{pf}) \ln (1-\theta)}}{\ln (1-\theta)} \right]$$

assuming that

$C_{pm}$ = Cost of preventive maintenance

$C_{pm} = C_i + C_{pf}$ where;

$C_i$ = Cost of one preventive task

$C_i$ = (DMMH for inspection) $\left(\dfrac{\text{Labor Cost}}{\text{(hour)}}\right)$ + Consumable cost)

$C_{pf}$ = Cost of correcting one potential failure

= (DMMH to correct potential failures)(Labor Cost / hour) + (Spares and material cost)

$C_{npm}$ = Cost of not doing preventive maintenance

= $C_{cm} + C_{opc}$

Note that if $C_{npm}$ is equal to $C_{pf}$, the equation becomes invalid. If this is the case, then consider $C_{npm}$ minus $C_{pf}$ to be equal to $C_{npm}$.

$C_{cm}$ = Cost of corrective maintenance

= (DMMH for repair) (Labor Cost / hour) + (Spares and material costs)

$C_{opc}$ = Cost of lost operational time (for cases where the answers to question 2, FIGURE 10, is "Yes". If the answer is "No", then $C_{npm} = C_{cm}$)

$C_{opc}$ = (DMMH to repair) (Acquisition Cost (including support costs) / (total flight hours))

and $\theta$ = probability of detecting the failure in one inspection

The more subjective an inspection is (visual as compared to a specific measurement) the lower the value of $\theta$ will be. The value of T is the same as determined in column 4c, RCM worksheet 3. After all necessary factors have been determined, the number of inspections (n) during the interval T, can be determined. If the solution to the equation shows n to be less than one, then the task is not cost effective. If n is equal to or greater than one, the task is cost effective and the optimum interval is equal to T/n. If the task is cost effective, enter "Yes" in this column and list the optimal task interval in column 5c. If the task is not cost effective, enter "No" in this column. After completing the economic trade-off analysis, record task effectivness in column 7.

Column 7: Is Task Applicable and Effective? (Yes or No) - Complete this column for each FFMC listed in column 2 of this worksheet. If there are no OC tasks listed in column 5 of this worksheet, the word "No" is listed in this column. For tasks listed in column 5, their effectiveness for safety or safety hidden failure consequences (in column 6a or 6b) must meet acceptable probability of failure. If acceptable probability of failure is met, list "Yes" in this column. If it is not met, list "No". Refer to Table III for cost effectiveness criteria for economic/ operational or non-safety hidden failure consequences. The task effective column of Table III provides direct input to this column based on the answers to the questions in column 6c of this worksheet.

TABLE III. Cost effectiveness determination.

| Answer to questions on decision diagram for cost effectiveness (FIGURE 10) | | | | |
|---|---|---|---|---|
| 1. Is Failure Rate High? | 2. Operational Consequences? | 3. High Repair or Operating Costs? | 4. Real and Applicable Data or Economic Trade-off Study? | Is Task Effective? |
| Y | Y | - | Y | Yes |
| Y | Y | - | N | No |
| Y | N | Y | Y | Yes |
| Y | N | Y | N | No |
| Y | N | N | - | No |
| N | - | Y | Y | Yes |
| N | - | Y | N | No |
| N | - | N | - | No |

5.2.5 Scheduled hard time task evaluation. The next RCM task, in the order of preference, is the scheduled hard time task. These tasks are evaluated when on-condition tasks do not prove applicable and effective. Hard time tasks are evaluated for applicability and effectiveness, prior to their inclusion in the preventive maintenance requirements. The documentation of the task evaluation is accomplished on RCM worksheet 4 (see appendix D).

5.2.5.1 Scheduled hard time task evaluation documentation (worksheet 4). This worksheet is completed for all FFMCs which do not have applicable and effective on-condition tasks. Worksheet 4 records the specific applicability criteria, applicable task descriptions, and the effectiveness of hard time tasks. For safety and safety hidden failure consequences, if a hard time task is not applicable and effective, a combination of RCM tasks must be evaluated (see 5.2.6). For non-safety hidden failure consequences, a failure finding task must be evaluated if an applicable and effective hard time task is not found. For economic/operational consequences where no applicable and effective hard time ask is found, no preventive task is assigned. In this case, redesign may be desirable (see 5.3.2).

5.2.5.2 Hard time task applicability criteria. Scheduled hard time tasks are discussed in general in paragraph 4.3.3. There are two types of hard time tasks, scheduled rework and scheduled discard. The applicability criteria for each of these tasks depends on the failure consequences. If reworking an item restores its acceptable level of failure resistance, a rework task is analyzed. If the item cannot be reworked, a discard task is evaluated. The applicability criteria which must be met for each hard time task are as follows:

a. The item must be capable of having an acceptable level of failure resistance restored (for rework task).

b. The item must exhibit wearout characteristics which are identified by a rapid increase in the conditional probability of failure to establish a wearout age (for rework tasks) or a life-limit (for discard tasks).

c. A large percent of the items must survive to the wearout age or life-limit.

d. A safe life limit for an item must be established at an age below which no failures are expected to occur.

FIGURE 13 presents the last three conditions in graphical form. For any hard time task to be applicable, the item must exhibit wearout characteristics. Wearout is identified by a rapid increase in the conditional probability of failure, over time, as shown by condition (b). Once this age reliability relationship has been established, the wearout age or life-limit can be determined depending on the type of task. The wearout age, for rework tasks, is the age at which the item shows a rapid increase in the conditional probability of failure, condition (b). For non-safety consequences, a large percentage of the items must survive to the wearout age, as shown by condition (c). The life-limit, for safety related consequences, is the age below which no failures are expected to occur, condition (d). In each of these cases, a large percent of the items must survive to the established age (condition d). The acceptable percentage depends on the failure consequences of the engineering failure mode. For safety related consequences, 100% of the items must survive to the established age. This ensures that no safety related failures will occur before the item is reworked or discarded. For non-safety consequences, the percentage of items surviving can be less than 100%, since some failures can be tolerated. If an applicable and effective hard time task is not found, after the initial hard time task evaluation for safety consequences, a combination of tasks must be evaluated. An age limit is evaluated in combination with an on-condition task for applicability and effectiveness. The following information refers to the specific columns of RCM worksheet 4.

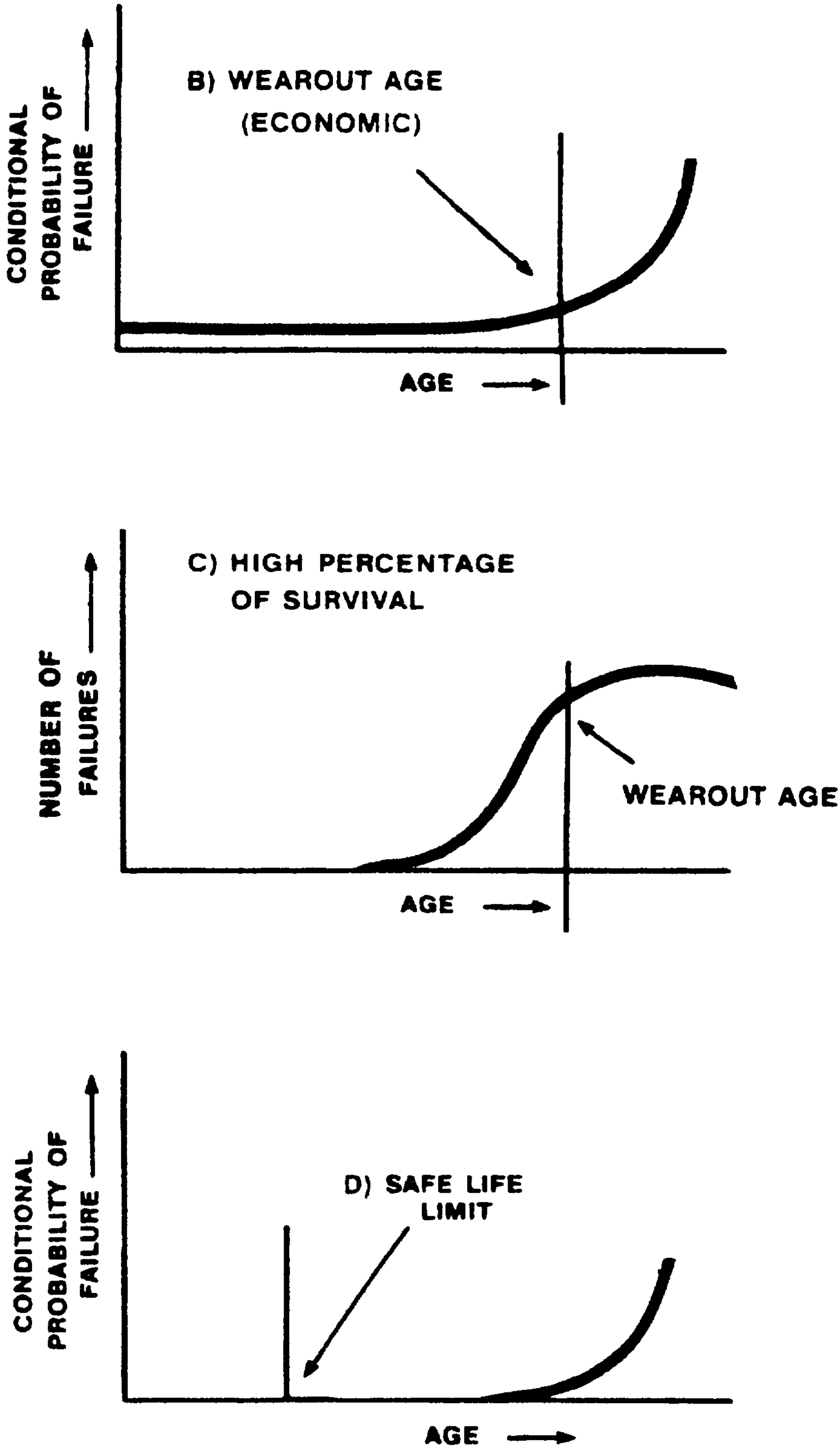



FIGURE 13 Applicability criteria for hard time tasks.

Column 1: Item LSACN/MIR Index Code - In this column, list the LSACN or MIR Index Code for all FFMCs which have a "No" answer listed in column 7 of RCM worksheet 3. The LSACN/MIR Index Code is recorded from column 1 of work-sheet 3.

Column 2: Functional Failure Mode Code (FFMC) - In this column, list the FFMC for each LSACN/WUC listed in column 1 of this worksheet which has a "No" answer in column 7 of RCM worksheet 3.

Column 3: Failure Consequence (Safety, Economic/Operational, Safety Hidden Failure, Non-Safety Hidden Failure) - In this column, list the consequence of failure for each FFMC listed in column 2 of this worksheet. Refer to column 4 of RCM worksheet 2.

Column 4: Applicability Criteria - In the appropriate consequence column, answer the specific applicability criteria described below. These columns are completed for each FFMC listed in column 2.

4a. Is it possible to restore failure resistance of item by rework task? (Yes or No) - This question is answered for all FFMCs listed in column 2. For a rework task to be applicable, the item must be capable of being reworked in the specific failure mode listed. If the item can be reworked, enter a "Yes" and evaluate a rework task (column 4b). For an item which cannot be reworked, enter a "No" and evaluate a discard task (non-safety column 4b or safety column 4d). If there is uncertainty about the answer, enter "No-D" for no-default and evaluate a discard task.

4b. Wearout age - For all rework and non-safety discard cases, evaluate appropriate FFMCs and list the age where the conditional probability of failure shows a rapid increase. To determine the wearout age, develop a conditional probability of failure versus age relationship (see condition (b), FIGURE 13). Examine all available default to determine this age reliability relationship. Once this relationship is developed, determine the wearout age: the point where the conditional probability of failure shows a rapid increase. If the data for a specific FFMC do not show a wearout type engineering failure mode, enter "NA" in this column. If there are no age reliability data available, apply the default condition. Examine real and applicable data to determine a wearout age. If a similar hard time task which is applicable and effective is currently being used on like equipment, enter "Yes-D" and the default wearout age of the current hard time task interval. If there are no real and applicable data on which to base an interval, enter "No-D" for no-default. Refer to FIGURE 7 for default logic decisions. If "NA" or "No-D" are listed in column 4b, go to column 4d for safety related cases. If safety is not a consequence, enter "No" column 7. Column 4c is answered next for all FFMCs which have a wearout age in column 4b.

4c. Percentage of items which survive to this age - For all FFMCs which have a wearout age listed in column 4b, list the percentage of items which survive to that age (see condition (c), FIGURE 13). For a hard time task to be applicable, this percentage must be high enough to reduce the economic or operational consequences to an acceptable level. If the wearout age in column 4b cannot be determined, enter "NA" in this column and "No" in column 7. If a default wearout age was listed in column 4b, enter a "D" in this column along with the percentage of items which survive to that age. Base this percentage on the same real and applicable data used in column 4b. Refer to FIGURE 7 for default logic decisions. Column 5 is answered next for all FFMCs which meet rework task applicability criteria listed in columns 4a, 4b and 4c.

4d. Life limit - Complete this column for FFMCs which have safety or safety hidden failure consequences listed in column 3 and do not have an applicable rework task. For a discard task to be applicable for safety related failure consequences, the task must prevent failures from occurring. In order to accomplish this objective, establish a life limit below which no failures are expected to occur. The life limit is obtained from the conditional probability of failure versus age relationship (see condition (d), FIGURE 13). In this relationship, the life limit is the point where the conditional probability of failure approaches zero. Use manufacturer's test data and applicable operational data to establish the age reliability relationship and the life limit. Since the correlation between a test environment and the actual operating environment is never perfect, examine both sources of data. Use operational data to verify the life limits calculated during testing. Sometimes the volume of test data are too small to accurately determine the age reliability curve. In this case, use a default method to establish a life limit. To establish this life limit, divide the average failure age by a safety factor of 2 or 3. If age reliability data cannot be found to determine the life limit, use real and applicable data. If a life limit for a similar engineering failure mode does not allow failures to occur, that life limit can be used as the default life limit. When either of these default methods are used, enter a "Yes-D" and the default life limit. If the FFMC is known to have wearout characteristics but no data are available to determine the life limit, enter the proposed limit followed by "No Data" in this column and "No" in column 7. Refer to FIGURE 7 for default decisions. If the data for specific FFMC do not show a wearout type engineering failure mode, enter "NA" in this column and "No" in column 7.

Column 5: Describe Applicable Hard Time Task - In this column, describe the proposed hard time task which met the required applicability criteria in column 4. Items which meet the applicability criteria have a wearout age (column 4b) or life limit (column 4d) including those based on default. Briefly describe the task and record a task number. Identify the level of maintenance at which the task will be performed and its proposed task interval.

5a. Task number - Refer to paragraph 5.2.4.2, column 5a, for the procedures to complete this column.

5b. Description - List a brief description of each hard time task which meets the required applicability criteria. Identify whether the task is a rework or discard task.

5c. Preliminary task interval (engineering) - List, in this column, the preliminary inspection interval for the hard time task. Base this interval on the wearout age or life limit entered in column 4 of this worksheet. (The engineering interval is used to determine task effectiveness in column 6, but may be adjusted to meet the effectiveness criteria.)

5d. Proposed Level of Maintenance (O, I, or D) - Refer to paragraph 5.2.4.2, column 5d, for the procedures to complete this column.

5.2.5.3 Effectiveness criteria. This section describes the procedures for documenting task effectiveness in column 6 of worksheet 4. Effectiveness criteria is completed only for FFMCs which have applicable tasks listed in column 5 of this worksheet.

Column 6 Effectiveness Criteria - Record the criteria for effectiveness in the appropriate failure consequences column. Base the initial evaluation on the preliminary task interval and maintenance level listed in column 5. These may be changed to meet the effectiveness criteria when necessary. However, the new interval and maintenance level must still meet the applicability criteria.

6a. Safety - Probability of failure - Refer to paragraph 5.2.4.3, column 6a, for the procedures to complete this column.

6b. Safety hidden failure - Probability of multiple failure - Refer to paragraph 5.2.4.3, column 6b, for the procedures to complete this column.

6c. Economic/Operational - This column is completed in the same manner as column 6c of RCM worksheet 3 (see 5.2.4.3). Make the following changes to the CBR equation for hard time tasks.

$$CBR = \frac{C_{PM}}{C_{NPM}}$$ As developed in 5.2.3.2.2

$C_{pm}$ is rewritten to be as follows:

$$C_{pm} = C_i + C_{ns}$$ where;

$C_i$ = Cost of a preventive task per flight hour

$$C_i = \frac{N_s \times C_{HTB}}{T_W}$$ where;

$N_s$ = Percentage of items that survive to the wearout age, Tw, and;

$T_w$ = Time to wearout from column 4c, and

$C_{HTB}$ = Cost to remove, replace and either rework as discard an item before failure. Similarly;

$C_{ns}$ = Cost of repairing items which do not survive to wearout age, $T_w$.

$$C_{ns} = \frac{(1 - N_s)C_{HTA}}{T_w} \qquad \text{where;}$$

$C_{HTA}$ = the cost to remove, replace and either rework or discard an item after failure.

$C_{NPM}$ can be determined as presented in 5.2.4.3 but must be normalized to compare with $C_{PM}$ as determined above. Divide the Mean Time Between Failure (MTBF) for the item by the wearout age, $T_w$. The cost of corrective maintenance $C_{CM}$ will be equal in this case to $C_{HTA}$. So, the equation for the CBR becomes:

$$CBR_{HT} = \frac{MTBF\ (N_s\ C_{HTB} + (1 - N_s)\ C_{HTA})}{T_W\ (C_{HTA} + C_{OPC})}$$

If the CBR is less than 1, enter "Yes" in this column to indicate that the task is cost effective. If a good conditional probability of failure curve is available, evaluate several different wearout ages to determine the most cost effective age (lowest CBR).

Column 7 Is Task Applicable and Effective? - Complete this column for each FFMC listed in column 2 of this worksheet. If no hard time task is listed in column 5 of this worksheet, there is no applicable task. Enter "No" in this column. If a task listed in column 5 meets the effectiveness criteria, enter "Yes" in this column. If the task does not meet the effectiveness criteria, enter "No" in this column. Refer to the task effectiveness column of Table III to determine task effectiveness of economic/operational or non-safety hidden failure consequences. For safety related consequences, evaluate a combination task if no hard time task proves to be applicable and effective. For non-safety hidden failure consequences, evaluate a failure finding task if no hard time task is chosen. For economic/operational consequences, no preventive maintenance is required if no hard time task is chosen. In this case, the option remains to evaluate the need for redesign (see paragraph 5.3.2).

5.2.6 <u>Evaluation of combination and failure finding tasks</u>. Combination tasks are evaluated for safety and safety hidden failure consequence cases to preclude redesigning the equipment to overcome the failure mode (see FIGURE 5). Combination tasks are discussed in paragraph 4.3.5. The failure finding task is used only if on-condition, hard time, or combination tasks are not applicable and effective for hidden failure (safety and nonsafety) consequences (see FIGURE 5). Because failures are allowed to occur in this case, only combinations of failures are evaluated for safety hidden failure consequences. Failure finding tasks are also discussed in paragraph 4.3.6. Combination and failure finding tasks are documented on RCM worksheet 5 (see appendix D).

5.2.6.1 Combination/failure finding task evaluation documentation (worksheet 5). This worksheet is completed after RCM worksheet 4 has been completed. For safety consequences, combination tasks are an alternative to item redesign. If a combination of tasks is not applicable and effective for safety consequences, redesign is required. If redesign is required by the logic diagram, questions may arise concerning the incorporation of the design change or whether the aircraft can be safely flown prior to redesign. In these cases concerning safety, conflicts are resolved by the Naval Air Systems Command Safety Office. The failure finding task is an alternative to the redesign of an item to prevent the hidden failure consequence. For safety hidden failure consequences, if a failure finding task is not effective, redesign is required. If the task is not effective for non-safety hidden failure consequences, no preventive maintenance is required. However, redesign may still be considered to avoid the failure consequence (see paragraph 5.3.2).

5.2.6.2 Combination/failure finding task applicability. A combination task is applicable if on-condition and hard time tasks can be combined to satisfy safety related failure consequences where no individual task is appropriate. Two criteria must be met. First, either a wearout age (RCM worksheet 4, column 4b) or a safe life limit (RCM worksheet 4, column 4d) will have already been listed on the hard time task worksheet, for the FFMC being evaluated for combination tasks. Second, it must be possible to detect reduced failure resistance (RCM worksheet 3, column 4a). In this case, it is necessary to establish a conservative safe life limit, as it will be developed without benefit of applicable reliability data. If these two criteria are met, a safe life limit can be established and then protected by an on-condition task accomplished at some fraction of that life limit. The applicability criterion for a failure finding task is a default condition. FIGURE 5 shows that if an item is subject to a hidden failure, the failure finding task can only be applicable if no other RCM task is applicable and effective. The two criterion therefore are:

a. The item must be subject to a functional failure that is not evident to the crew or operator during performance of normal duties.

b. The item must be one for which no other type of task is applicable and effective.

The following applies to the specific columns of RCM worksheet 5.

Column 1: Item LSACN/MIR Index Code - In this column, list the LSACN or MIR Index Code for all items which have "No" answers in column 7 of worksheet 4 and safety, safety hidden-failure or non-safety hidden failure consequences listed in column 3 of worksheet 4. Record the LSACN or MIR Index Code from column 1 of worksheet 4.

Column 2: Functional Failure Mode Code (FFMC) - In this column, list the FFMC for each situation where (on worksheet 4) a "No" is recorded in column 7 and safety, safety hidden failure, or non-safety hidden failure is recorded in column 3. Record the FFMC as found in column 2 of worksheet 4.

Column 3: Failure Consequence (Safety, Safety Hidden Failure, Non-safety Hidden Failure) - In this column, list the consequence of failure for each FFMC listed in column 2 of this worksheet. Refer to column 4 of RCM worksheet 2.

Column 4: Applicability Criteria - For combination and failure finding tasks, respectively, answer the applicability questions in columns 4a and 4b.

4a. Combination task - Do the tasks meet their individual applicability criteria? Complete this column only for safety and safety hidden failure consequences as listed in column 3. Refer to RCM worksheets 3 and 4 to verify that the specific applicability criteria are met. A conservative safe life limit must have been developed during the hard time task evaluation (column 4b or 4d, worksheet 4). The safe life limit must be protected by a practical on-condition task which meets the criteria of column 4a, worksheet 3. This on-condition task will be accomplished at some fraction of the safe life limit to ensure the limit is safely reached. Enter "Yes" in this column if both criteria are met. Enter "No" if only one or neither criterion is met. If "Yes," go to column 5, skipping column 4b, and provide a task description. If the answer is "No" for safety consequences then record "No-C" in column 7. Redesign is required. For safety hidden failure consequences, if the answer is "No", continue to column 4b and evaluate a failure finding task.

4b. Failure finding task - Is an OC, HT or combination (for safety hidden failures) task applicable and effective for this FFMC? - Complete this column for FFMCs which have either non-safety hidden failure consequences in column 3 or safety hidden failure consequences and a "No" answer in column 4a. Refer to RCM worksheets 3 and 4 to verify that no on-condition or hard time tasks were selected. If no other tasks were selected, enter "No" in this column and continue to column 5. If other tasks exist, then this question should never have been asked (see FIGURE 5). Enter "Yes" in this column. If "Yes" is recorded here, enter "No-F" in column 7. Redesign may be considered (see paragraph 5.3.2).

Column 5: Describe Applicable Task - Identify the proposed tasks which meet the applicability criteria in column 4. Briefly describe the task and give it a task number. Also identify the proposed task interval and level of maintenance at which the tasks will be performed.

5a. Task number - Refer to paragraph 5.2.4.2, column 5a for the procedures to complete this column.

5b. Description - Briefly describe the combination of tasks or failure finding tasks which meet the applicability criteria in column 4. Identify combination tasks by "(COMB)" before the description of both on-condition and hard time (rework or discard) tasks. Record "(FF)" before the failure finding task descriptions. For failure finding task descriptions, identify the failure being inspected. For safety hidden failure consequences, failure finding tasks consist primarily of functional or operational checks to verify proper operation of non-redundant safety or emergency equipment.

5c. Preliminary task interval (engineering) - List the preliminary interval for combination tasks and failure finding tasks described in column 5b. Base the intervals for combination tasks on the interval for the hard time task, developed from RCM worksheet 4, column 4b or 4d. The on-condition task interval is a fraction of the hard time limit. The number of on-condition inspections within the hard time interval depends on the failure consequence. A safety consequence warrants more inspections than a safety hidden failure consequence, due to the urgency of the failure consequence. The failure finding tasks interval is normally some fraction of the MTBF, depending on the severity class of the engineering failure mode. Base this interval on the MTBF of the hidden failure (for redundant items) since a failure may have already occurred. Use the engineering interval to determine task effectiveness in column 6. This, however, is not necessarily the final inspection interval for the task.

5d. Proposed level of maintenance (O, I, or D) - Refer to paragraph 5.2.4.2, column 5d for the procedures to complete this column.

5.2.6.3 Effectiveness criteria. This section describes the procedures for documenting task effectiveness in column 5 of worksheet 5. Complete effectiveness criteria only for FMMCs which have applicable tasks listed in column 5 of this worksheet. Since the effectiveness criteria depends on the failure consequences, use paragraph 5.2.4.3 except for the default decisions.

Column 6: Effectiveness Criteria - Record responses to effectiveness criteria in the appropriate failure consequence column. Base the initial evaluation on the preliminary task interval and maintenance level listed in column 4. These may be changed to meet the effectiveness criteria, when necessary.

6a. Safety and safety hidden failure - Probability of failure or multiple failure - Refer to paragraph 5.2.4.3, column 6 for procedures to determine the probability of failure or multiple failure. These probabilities must be low enough to reduce the risk of failure to acceptable levels. For combination tasks to be effective, increase the number of on-condition tasks within the hard time interval to insure an acceptable level of probability. For failure finding tasks to be effective, the MTBF must be high enough to reduce the risk of multiple failure to an acceptable level.

6b. Non-safety hidden failure - Refer to paragraph 5.2.4.3, column 6c and FIGURE 7 for the procedures to complete this column.

Column 7: Is Task Applicable and Effective? - Complete this column for each FFMC listed in column 2. If no task is listed in column 5, enter either "No-C" or "No-F" in this column. Safety related tasks, listed in column 5, must meet the effectiveness criteria in column 6a to be acceptable. For non-safety hidden failure consequences, refer to Table III to determine task effectiveness. The task effectiveness column of Table III provides direct input to this column based on the answers to the questions in column 6b of this worksheet. For safety and safety hidden failure consequences, if an applicable and effective failure finding task is not found, redesign is required. For non-safety hidden failure consequences, if no task is found, no preventive task is assigned. Redesign, however, may be desirable (see paragraph 5.3.2). List the yes or no answers in this column as either "Yes-C" or "No-C" for combination tasks and "Yes-F" and "No-F" for failure finding tasks.

5.2.7 Structural evaluation. The structural analysis using RCM is accomplished for each SSI identified by FIGURE 3. Analyze SSIs using the structures decision logic, FIGURE 6. Structures are subjected to a separate logic process because failures of most SSIs have a direct adverse effect on safety. Structural items for aircraft structure or other types of equipment for which failures will not effect safety are treated as FSIs. Conversely, some SSIs have non-structural functions. For those cases, a functional RCM analysis using FIGURE 5 is required. After an FSI or SSI is identified using FIGURE 3, an FMEA is accomplished. For an SSI, an FMEA is necessary to identify functions (both structural and non-structural), failure modes, and effects. Normally, the failure modes associated with metallic structure are fatigue (cracks), environmental damage (corrosion), and accidental damage. Composite structure may exhibit other failure modes which must not be overlooked on the FMEA (see 5.1.1). All SSIs are evaluated using the FIGURE 6 logic process. The results of the logic evaluation are documented on RCM worksheet 6. Due to the design of aircraft structure, only the most critical failure modes warrant a preventive task on the entire fleet. When it is determined through evalua-tion of specific rating factors that SSIs are less critical, they will not have 100% on-condition tasks required. But, they will be subject to age exploration on a sample of the fleet. Even if structural design data is available to develop an applicable preventive task (unless the data is backed by testing) an age exploration task may be required to verify the selection of that task.

5.2.7.1 Structural Rating Factors - Structures are designed to carry loads, and their failure may affect safety. There are two separate design philosophies for structures; these philosophies are damage tolerant and safe life. Once an item has been designated as an SSI, it will enter a preventive maintenance analysis program. Not all SSIs are of the same significance. The failure of some redundant SSIs, for example, cause a much greater loss of residual strength than the failure of others. Moreover, SSIs have varying degrees of susceptibility to environmental and accidental damage. These differences are evidenced in the designer's information and the manufacturer's test data. As a result, base an initial structures program on a rating scheme that makes full use of that available information. Obtain Structural Rating Factors (SRFs) by assessing the design characteristics in terms of their sensitivity to three types of damage: fatigue, accidental, and environmental. Use SRFs as input to RCM task evaluation. By definition, the fracture of a safe life item reduces the residual strength to zero. Thus, safe life items are not allowed to reach the point of crack initiation and, as a result, are not rated for fatigue damage. The structural rating factors are developed as follows:

a. Fatigue damage (damage tolerant items) - Rate each damage tolerant SSI for fatigue in three ways: residual strength, life to a detectable crack and the crack, propagation life. For damage tolerant items, the residual strength after a single element fails is lower than that desired for continued operation. But it is high enough to ensure safety until the failed element is discovered and repaired. Of course, this concept of damage tolerant design depends upon an adequate inspection program. 1) Base the Residual Strength (RS) SRF on the percentage of strength remaining after the fracture of a structural element. 2) Base the Life to Detectable Crack (LDC) SRF on a percentage, determined by the ratio of the time of crack initiation to the fatigue life design goal of the overall structure, that is End Item Design Life (EDL). In assessing crack initiation characteristics, consider whether the item underwent fatigue tests which identified crack initiation. If testing was not done, all rating factors would be lower. 3) Base the Crack Propagation Life (CPL) SRF on a percentage, determined by the ratio of the crack propagation rate to the fatigue life of the SSI, Structural Significant Item's Design Life (IDL). In assessing crack propagation characteristics, consider whether the item underwent crack propagation tests. If not, all the ratings would be lower. Using the SSI technical data determine the fatigue damage SRFs from Table IV.

b. Environmental damage - Environmental deterioration is caused by an adverse environment. All parts of a structure are susceptible to environmental damage; for example, corrosion on metallic structures. Unless it is discovered in its earliest stages, this localized loss of material reduces the load carrying capability of the affected structure, accelerating the fatigue process. Its occurrence is usually proportional to calendar time, increasing as the age of the structure becomes greater. Rate each SSI for environmental damage in three areas: material type (MT), surface protection (SP), and exposure to corrosion (EP). Base the ratings for environmental deterioration on an item's susceptibility to environmentally influenced damage. This SRF evaluation must analyze the potential effectiveness and durability of surface protection systems. (Give attention to the item's anticipated operating environment and the likelihood of damage from contact between dissimilar metals and exposure to a deteriorating environment.

TABLE IV. Structural Rating Factors

| | RATING FACTOR | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| FATIGUE DAMAGE | Residual Strength (RS), percent of damage tolerant load | less than 100 | 100-125 | 126-150 | greater than 150 |
| | Life to detectable crack (LDC), percent of EDL | less than 100 | 100-110 | 111-120 | greater than 120 |
| | Crack propagation life (CPL), percent of IDL | less than 20 | 21-40 | 41-60 | greater than 60 |
| ENVIRONMENTAL DAMAGE | Material type (MT) | Magnesium | Forged Al, dissimilar metals | Clad Al, steel, Titanium | Stainless steel, composite materials |
| | Surface protection (SP) | Bare | Primer | Anodized, painted | Coated, plated |
| | Exposure Internal item | Human waste | Trapped fluids | Vented | Sealed |
| | External item | Salt water | Air pollutants ground water | Rain | Dry air |
| ACCIDENTAL DAMAGE | Design, Manufacturer errors (DS) | Complex Assembly, difficult fabrication | Complex Assembly, simple fabrication | Simple Assembly, difficult fabrication | Not susceptable |
| | Ground Operations (GO) | Carrier | Ashore, training, high sortie rate | Ashore, low sortie rate | Not susceptable |
| | Flight Operations (FO) | Carrier | Ashore, training, high sortie rate | Ashore, low sortie rate | Not Susceptable |
| | Location (LO) | External, ground access | External, special access | Internal, accessible | Internal, covered, heavy surface protection |

Generally, areas exposed to moisture, dirt, and heat are the most susceptible to corrosion and must be properly maintained with protective coatings (anti-corrosion treatment). The environmental damage SRFs can be directly determined from Table IV.

c. Accidental Damage - Accidental damage is caused by the occurrence of some discrete event which reduces the inherent residual strength of the item. Such events are random in nature and have equal probability of occurrence throughout the life of the item. Rate each SSI for accidental damage in the following areas: damage caused by the environment (both ashore and afloat operations and in-flight), damage caused by poor quality control during manufacturing, and damage caused by the location of the SSI. An item's susceptibility to accidental damage is affected by frequency of exposure to harsh weather conditions (high winds, lightning, hail, etc.), operating environment (Ground Operations (GO) and Flight Operations (FO)), manufacturing deficiencies (DS), and its location on the end item (LO). One such manufacturing problem is termed "preload" a condition caused by design, fabrication, or assembly errors. For example, the accidental damage SRF is lower for external items exposed to foreign objects on runways and higher for internal areas subject to little traffic from operating or maintenance personnel. Thus, while the ratings for susceptibility to accidental damage cannot be expressed in terms of a reference age, they are based on the item's resistance to damage as well as the type and frequency of damage to which it is exposed. The accidental damage SRFs are obtained from Table IV.

5.2.7.2 RCM structures evaluation logic. The RCM logic for SSIs is shown in FIGURE 6. Because the logic assumes a safety failure consequence, it first differentiates between damage tolerant and safe life structure (see paragraph 4.4.1.3). The logic then requires that preventive tasks be evaluated for SSIs applicability and effectiveness. Preventive tasks for structures are either on-condition (general or detailed) for damage tolerant SSIs or a combination of on-condition and hard time tasks for safe life SSIs. Damage tolerant structures require the establishment of a life historical file to record the results of all inspections and maintenance performed on each SSI. Applicability and effectiveness criteria for these tasks for SSIs are different than for FSIs. For SSIs, the criteria are based on the structural rating factors and the design of the item. These criteria are summarized in FIGURE 14. This section describes the procedures for analyzing task applicability and effectiveness which are determined by answering the questions in the structures decision logic (FIGURE 6). An inspection program for an SSI must consider all areas of damage (FFMCs) separately then, afterwards, combine the tasks developed for each FFMC on RCM worksheet 1. The SSI logic in FIGURE 6 must be followed for each FFMC for all SSIs. As with FSI's, once a task is selected which meets the specified applicability criteria, it must then be tested for effectiveness. The following applies to the logic questions in FIGURE 6:

Question 1: Is the item damage tolerant? Ask this question for all items identified as SSI's. Paragraphs 4.4.1.3.1 and 4.4.1.3.2 present

| Task | | SSI Design | |
|---|---|---|---|
| | | Safe Life | Damage Tolerant |
| General Visual On-Condition | Applicability | 1 Damage detectable at "O" Level of Maintenance.<br>2. SSI externally accessible<br>3. Damage detectable without the use of visual aids.<br>4. SSI highly susceptible to accidental damage (AD SRF < 3.7). | Same as safe life **in addition to**:<br>1 Consistant Crack Propagation Life (CPL)<br>2. Item Residual Strength (RS) less than 100% of the damage tolerant (DT) load (SRF=1). |
| | Effectiveness | Task (or combination of tasks) must prevent all failures of the SSI. | Must detect visible damage in inspections on a daily or between flight basis. |
| Detailed On-Condition | Applicability | 1. Damage detectable at "O","I",or "D" Level of maintenance.<br>2. Item on interior or exterior of end item<br>3. Damage detectable with use of NDI equipment.<br>4. SSI highly susceptible to accidental damage (AD SRF < 2).<br>5. Environmental Damage-(ED SRF < 3.7). | Same as safe life **in addition to**:<br>1. Consistant Crack Propagation Life(CPL)<br>2. Item residual strength (RS) less than 100% of the damage tolerant (DT) load (SRF=1). |
| | Effectiveness | Task (or combination of tasks) must prevent all failures of the SSI. | Must detect damage in the specified inspection interval. |
| Hard Time | Applicability | 1. To support safe life limit (SLL) some test data must exist.<br>2. An on-condition task must be used in conjunction with the SLL. | X |
| | Effectiveness | SLL in combination with on-condition task(s) must prevent all failures of the SSI. | X |

FIGURE 14 - Applicability and effectiveness criteria for SSIs

the concept of damage tolerant and safe life structures. A safe life item is characterized by a rapid crack propagation life and a large reduction in residual strength. A damage tolerant item, on the other hand, has a slow crack growth propagation rate and a small reduction in residual strength. If a "Yes" response is given to this question, further analysis must be done on the damage tolerant branch of FIGURE 6. A "No" response prompts further analysis on the safe life branch of the diagram.

Question 2: Is a general visual on-condition task applicable and effective? Ask this question for all failure modes on damage tolerant SSIs. a) Identify a general visual on-condition task for those SSIs which are externally accessible and whose damage is detectable without the use of visual aids. This external evidence is often a specific design feature in damage tolerant items. b) Schedule general inspections of the external structure frequently (usually on a daily or turnaround basis). External structural items are those portions of the structure that can be seen without removing any covering items or opening any access doors which require the use of tools. Due to the short inspection interval, the applicability of such a task requires that the damage be detectable at the "O" level of maintenance. c) Since general visual inspections are performed on the entire fleet, in order to justify such an expansive program the SSIs must be susceptible to Accidental Damage (AD) and have a residual strength of less than 100% of the damage tolerant load. This criticality is evidenced by a residual strength SRF of 1 and an average accidental damage SRF less than 3.7. d) The final applicability criterion demands a constant crack propagation life to ensure damage tolerance. The effects of environmental damage (corrosion) are minimal during the inspection interval. e) If a general visual on-condition task is found to be applicable, check it for effectiveness. If such a task by itself on a daily or between flight basis detects visible damage, it satisfies the effectiveness criteria. If a general visual on-condition task satisfies all applicability and effectiveness criteria, answer the question "Yes". Otherwise, answer "No" and evaluate question 3.

Question 3: Is a detailed on-condition or combination general/detailed on-condition task applicable and effective? Ask this question for all failure modes on damage tolerant SSIs with an answer of "No" for question 2. Applicability depends largely on the design of the item. a) The purpose of a detailed or combination task is to detect internal as well as external damage. Any part of the structure that is not visible externally or that cannot be opened manually without the use of any tools is classified as internal. Internal items are more difficult to inspect. Some require only the opening of access doors by the removal of screws. Others demand the removal of floorboards, lining and insulation, or the disassembly of other parts of the structure. This damage may vary widely in severity, support equipment, skill level and facilities needed to finish the task. Thus, this damage may be detectable at the "O", "I", or "D" level of maintenance. b) Both detailed and general/detailed combination tasks are, by definition, inspections of the entire item population. Thus, the damage must be severe enough to justify a 100% inspection program of the fleet. As in the case of general tasks, SSIs must be highly susceptible to accidental damage and have a residual strength of less than 100% of the damage tolerant load. This includes SSIs with an average SRF of 1 for residual strength and an average SRF less than 2 for AD. The damage tolerant design and constant load environment are further guaranteed by a uniform crack propagation rate. Detailed inspections usually consist of special phase or depot inspections that are performed at given intervals based on the crack propagation life. c) If the SSI is highly prone to Environmental Damage (ED), the effects of corrosion may well be significant within the inspection interval. Therefore, if the average ED SRF is less than 3.7, the applicability of a detailed or combination task becomes more definite. d) As with the on-condition tasks, applicability demands some definable potential failure condition. In the case of detailed or combination tasks, this condition may be detectable with or without the use of visual aids (NDI equipment). e) If a detailed or general/detailed combination on-condition task is found applicable, then consider the effectiveness criteria. These criteria are satisfied if the proposed task is effective at detecting damage within an initial inspection interval (developed in accordance with paragraph 5.2.7.3). If a task satisfies all applicability and effectiveness criteria, answer the question "Yes". If the criteria are not met, answer "No" and evaluate question 4.

Question 4: Is an age exploration task warranted? An age exploration program is required for SSIs when no applicable and effective general visual and detailed on-condition tasks are found. Age exploration is applied to a subset of the entire item population (i.e., less than 100% of the fleet). Thus, as FIGURE 6 shows, if neither of the 100% inspection plans are applicable and effective, then an age exploration sampling program may be warranted. While the primary goal of an age exploration program is to gather necessary age reliability information, it is clear that an additional benefit of such a program is the preventive maintenance of a sample of structures. To determine if an age exploration task is required, use the age exploration decision diagram (see FIGURE 15 and worksheet 7). If assessment reveals that an age exploration task is warranted, answer "Yes" to question 4. If such a task is not justified answer this question "No".

a. A "No" response implies that either the SSI was incorrectly classified as damage tolerant or that the item is not an SSI. Consider the design philosophy. If the item should have been classified as safe life, send it again through the decision diagram with its correct classification. If this is not the case, reevaluate the item's structural significance. For example, if it can be demonstrated, that the failure has no effect on operating capability, the item can be classified as nonsignificant.

b. If an age exploration task is supported, this program will consist of detailed or general visual on-condition tasks but will be performed on only a portion of the fleet. There are two basic ways to conduct sampling programs for inspections of damage tolerant structures to prevent fatigue failures: Constant Density Sampling (CDS) and Fleet Leader Sampling (FLS). 1) Constant Density Sampling examines a constant percentage, but a different set of each SSI at specific intervals. So, all SSIs are inspected before reaching the fatigue design life. This process provides a constant flow of knowledge about the condition of an SSI with increasing age while permitting a significant reduction in required inspections as compared with a requirement for 100% inspections at each opportunity. It is particularly useful when the equipment will be operated in a highly variable load environment and when analyzing redundant structures. In the context of age exploration, constant density sampling is used to inspect damage tolerant items for fatigue damage only. Thus, all items are inspected but at separate, rational opportunities. The specific sample size for the inspections is then based on the residual strength structural rating factors (see RS SRF table below). 2) The second technique, Fleet Leader Sampling (FLS), is the concentration of sampling inspections on the items which are either the oldest or which have the most operating hours, in order to identify the first evidence of changes in their condition. The fleet leader sample identifies the first end items to reach the age or number of flight hours at which sampling begins (initial interval). Fleet leader sampling is best used on slow crack growth (SCG) damage tolerant structures. It is used to inspect damage tolerant items having a residual strength SRF of 2, 3, or 4 for fatigue. If an SSI has a high load tolerance remaining after some element's failure, it is not necessary to age explore a large portion of the fleet. This is because there is a high level of confidence in the design of the structure. Specific sample sizes follow:

| | Sample Size | |
|---|---|---|
| RS SRF | CDS (R) | FLS (SCG) |
| 1 | 50% (20) | All items |
| 2 | 35% (20) | 50 items |
| 3 | 35% (20) | 25 items |
| 4 | 25% (20) | 10 items |

Since fatigue is essentially a function of usage, FLS in this case defers the inspections until a specific number of operating hours is reached. When FLS is directed at detecting fatigue damage, this sampling threshold or initial interval is determined from the Life to Detectable Crack (LDC) SRF. When performing CDS, the sampling intervals remain constant throughout the life of the item. The intervals for CDS and the initial interval for FLS determination are as follows:

Initial Sampling Interval

| LDC SRF | CDS (R) | FLS (SCG) |
|---|---|---|
| 1 | 10% EDL | 20% EDL |
| 2 | 20% EDL | 30% EDL |
| 3 | 20% EDL | 40% EDL |
| 4 | 20% EDL | 40% EDL |

The EDL, End Item Design Life, is expressed in flight hours, sorties, or some other measure of usage. Once the initial sampling interval has been established, the repeat sampling interval must now be determined for FLS. This repeat interval follows the threshold repeat and is repeated throughout the life of the SSI. The sample sampling interval is determined from the crack propagation life (CPL) SRF as follows:

Repeat Sampling Interval

| CPL SRF | CDS (R) | FLS (SCG) |
|---|---|---|
| 1 | Same | 1/4 CPL |
| 2 | as | 1/3 CPL |
| 3 | LDC | 1/3 CPL |
| 4 | SRF | 1/2 CPL |

Age Exploration sampling techniques are not feasible for Accidental Damage (AD) failure modes because of their random nature of failure. However, age exploration routine monitoring can be performed on AD to investigate or evaluate failure consequences and adjust inspection intervals.

Question 5: Is a Hard Time Task Applicable and Effective? Ask this question for a "No" answer to question 1. Question 5 must be asked for each FFMC of all safe life SSIs. For each safe life SSI a hard time task must be established at the Safe Life Limit (SLL) to ensure the safety of this structure. Corrosion and accidental damage can affect the life of a safe life item and may prevent the structural item from reaching its defined SLL which is usually established on the basis of testing in a less hostile environment than its true operating environment. A hard time task alone does not prevent all critical failures. Since the crack propagation rate for safe life SSIs is too rapid to allow for multiple inspections for fatigue before failure, the SLL is imposed on the structure, forcing its removal or modification before failures are expected to occur. If an SLL is not obtainable, age exploration is mandatory to project and test a life limit. Applicability criteria for a hard time task further demands that not only must an SLL exist, but it must also be supported by test data. Failure to meet that criterion also requires that an age exploration program be implemented to validate the SLL (i.e., laboratory testing to failure of a sample of items). In this situation the SSIs are sampled on a fleet leader basis and an accelerated Safety Age Exploration Task (SAET) is implemented to validate the proposed SLL. During this SAET, no items are allowed to age beyond the initial proposed SLL. A hard time task is effective only if the SLL, together with an on-condition task for accidental or environmental damage, prevents all failures of the SSI. As with detailed and general visual on-condition tasks, hard time tasks are performed on the entire fleet.

Question 6: Is a general visual on-condition task applicable and effective? Ask this question for all failure modes on SSI identified as safe life. All general, visual, on-condition tasks are performed in combination with a hard time task for safe life SSIs. Applicability criteria are a function of the type of task. Thus, the applicability criteria for a general, visual, on-condition task for safe life items are very similar to those for damage tolerant items. Crack propagation is irrelevant. By definition, the fracture of such a structure reduces the residual strength to zero. Crack propagation is not considered because a safe life item cannot be allowed to reach the point of crack initiation. For the latter reason, in particular, the effectiveness criteria in the case of safe life items is that the task prevent all failures of the SSI. This question concentrates on detection of accidental damage which may influence the safe life of the SSI. For more details on the applicability of general on-condition tasks, see question 2.

Question 7: Is a detailed on-condition or combination general/detailed on-condition task applicable and effective? Ask this question for safe life SSIs with a "No" answer to question 6. Safe life items will have "No" answers for question 6 for FFMCs relating to fatigue damage, but may have applicable and effective OC tasks for accidental or environmental damage FFMCs. As in question 6, these tasks must also be performed in combination with a hard time task. The applicability criteria for detailed on-condition tasks are the same for both damage tolerant and safe life items, except that crack propagation rates need not be considered for safe life items. Because effectiveness criteria for a detailed on-condition task and a general visual on-condition task as pertinent to safe life items are the same, the task(s) must prevent all failures of the SSI. This question evaluates a detailed inspection for either environmental or accidental damage to protect the safe life. For more details on the applicability of detailed on-condition tasks, see question 3.

Question 8: Is an age exploration task warranted? As this question for all safe life SSIs with no applicable and effective detailed on-condition or combination general/detailed on-condition tasks. Age exploration is enacted when a 100% on-condition task is not applicable and effective, and when an SLL is not available and reliable. The resulting program consists of routine monitoring or a laboratory controlled SAET or both. Age exploration sampling is not feasible for determining intervals for accidental damage failure modes because of the random nature of these failures. However, age exploration can be used to evaluate failure consequences and make adjustments to inspection intervals if data is lacking in these areas. Evaluate the proposed age exploration task (see FIGURE 15 and worksheet 7), and record a "Yes" or "No" as appropriate. In this case, a "No" response results in the requirement for redesign of the SSI. It may be modified to facilitate replacement of a failed unit or to incorporate features which would make on-condition inspections feasible.

5.2.7.3 Development of structural inspection intervals. Using FIGURE 6, assign applicable and effective tasks for each deterioration process of an SSI. By relating FFMCs to appropriate rating factors, a basis for determining inspection intervals for 100% of the fleet can be established for on-condition tasks. The objective of such structural inspections is the detection of fatigue (for damage tolerant items), accidental damage, and environmental damage. For each SSI, the inspections must meet the detection requirements for each engineering failure mode.

a. For both damage tolerant and safe life items, when a general visual on-condition task is found to be applicable and effective, the inspection interval is, by definition, daily or on a turnaround basis. A detailed or combination on-condition task to detect fatigue damage is performed on damage tolerant items at specific intervals. These intervals are chosen so that the growth of any crack can be monitored carefully enough so as to avoid reaching "critical crack length". This is the length at which the SSI can no longer withstand the specified design load without damage or permanent deformation. The intervals are selected based on the SSI's Crack Propagation Life (CPL). The following intervals are chosen in the same manner as the repeat sampling intervals for CDS and FLS:

| CPL SRF | Inspection Interval |
|---|---|
| 1 | 1/4 CPL |
| 2 | 1/3 CPL |
| 3 | 1/3 CPL |
| 4 | 1/2 CPL |

b. Since environmental damage is primarily dependent upon calendar time instead of usage, inspection intervals are equally spaced over the life of the end item. For both damage tolerant and safe life items, a detailed or combination task, which detects Environmental Damage (ED), is performed at a period determined by the simple arithmetic mean of the three ED SRFs (material, surface protection, and exposure) and by the location of the item itself (i.e., internal or external). Specific requirements for ED failure modes are as follows:

Environmental Inspection Interval

| ED Average SRF | General Visual On-Condition | Detailed On-Condition |
|---|---|---|
| 1-2.0 | 7/14 Day | $\frac{EDL}{3}$ |
| 2.1-3.7 | 28 Day | $\frac{EDL}{3}$ |
| 3.8-4 | 56 Day | None |

c. Although the effects of accidental damage are primarily random, certain relationships do, in fact, exist. For example, an aircraft which is frequently exposed to carrier operations is more certainly subject to a greater deal of risk than an aircraft training ashore. Additionally, trends may indicate that design manufacture error occurs mainly on only a few different types of SSIs. Detailed or combination tasks for damage tolerant and safe life items to detect accidental damage (AD) are performed at intervals based on the simple arithmetic mean of the four AD SRFs. These factors are design/manufacturer error, ground operations, flight operations, and location on end item. Specific requirements for AD failure modes are as follows:

| AD Average SRF | General Visual On-Condition | Detailed On-Condition |
|---|---|---|
| 1-2.0 | Daily/TA | $\frac{EDL}{3}$ |
| 2.1-3.7 | PCHK | None |
| 3.8-4 | None | None |

TA - Turn Around Interval
PCHK - Phase Check Interval

5.2.7.4 Documentation of structural evaluation. The structural evaluation is documented by recording structural design data, the structural rating factors, the answers to the structural logic questions, and the proposed structural inspection requirements on RCM worksheet 6. The RCM analysis of SSIs requires RCM worksheets 1, 6 and 7. For SSIs, it is not necessary to complete RCM worksheet 2 through 5, unless the SSI has non-structural functions that make the item also functionally significant. The procedures for completing the other RCM worksheets are also provided in paragraph 5.2.

5.2.7.4.1 SSI task evaluation worksheet. The following paragraphs describe the specific procedures for completing RCM worksheet 6. Only one SSI is recorded on a worksheet.

Block 1: SSI Identification - Record the information necessary to uniquely identify the SSI for analysis.

a. Nomenclature - List the nomenclature of the SSI determined by using FIGURE 3.

b. LSACN - If an LSA is accomplished, list the LSACN for the SSI identified in block 1a.

c. MIR Index Code - List the MIR Index Code, when available, for new equipment and for all in service equipment. The MIR Index Code is made up of the WUC, TEC and the configuration code (see paragraph 5.2.1.1.). List each code in the space provided.

d. Location - Record the location of the SSI in this block. List the Fuselage System (FS), Wing Station (WS), and the Water Line (WL) to uniquely identify the location of the SSI. If the SSI is an area, record the boundaries of the area in the respective blocks.

Block 2: SSI Technical Data - The technical design data required here are necessary to establish inspection and age exploration (sampling) programs for SSIs. Much of this data is also used to determine the structure rating factors. Complete blocks a, b, c, and e for damage tolerant SSIs and blocks a, d, and e for safe life SSIs.

a. Fatigue design life - List the fatigue life design goals for the end item and for the SSI being analyzed. This is required for both damage tolerant and safe life items.

b. Crack life - In the space provided, list both the detectable crack life and the critical crack life length for damage tolerant structures. The detectable crack life is the age at which it is unlikely that an existing crack will be missed by an on-condition inspection. The critical crack life is the age at which a crack reaches critical length (slow crack growth SSIs) or the age at which the first load bearing element fails (redundant fail safe SSIs).

c. Residual strength - List the residual strength for damage tolerant SSIs in this block. Residual strength is the percentage of design limit load that can be sustained at the critical crack length (slow crack growth SSIs) after the first load bearing element fails (redundant fail safe SSIs).

d. Safe life limit - In this block, list the safe life limit for all safe life SSIs. The safe life limit is the age at which the SSIs must be removed from service or modified for extension of service life.

e. Access - In the appropriate box, enter an "X"to note whether access to the SSI is internal or external. SSIs which are visible externally require that they be easily visible without opening access doors or panels. For internal SSIs, also identify the applicable door or panel necessary to gain access.

Column 3: SSI Rating Factors - In this column list the SSI rating factors determined in paragraph 5.2.7.1 and Table IV. The column is broken down as follows:

3a. Fatigue Damage - Residual Strength (RS), Life to Detectable Crack (LDC), and Crack Propagation Life (CPL). Remember column 3a is completed for damage tolerant SSIs only.

3b. Environmental Damage - Material Type (MT), Surface Protection (SP), and Exposure (EP) to corrosion. AVG is the simple arithmetic average computed from the three ED SRFs.

3c. Accidental Damage - Design Manufacturer Errors (DS), Ground Operations (GO), Flight Operations (FO), and Location (LO). AVG is the simple arithmetic average computed from the four AD SRFs.

Column 4: FFMC - In this column, list the functional failure mode code from the FMECA/MI worksheet for each SSI. For SSI failure modes and effects analysis, identify three basic failure modes: 1) fatigue, 2) corrosion (environmental damage), and 3) accidental damage (see 5.2.1.1). Evaluate each SSI for each FFMC and develop a preliminary inspection.

Column 5: SSI Structures Logic Answers (Y or N) - In this column, list either "Y" for yes or "N" for no for RCM SSI logic questions 1 through 8 from FIGURE 6 (see paragraph 5.2.7.2 for question explanations). These logic questions are not recorded on RCM worksheet 1.

Column 6: Task Description - This block identifies the applicable and effective tasks chosen using the SSI logic diagram, FIGURE 6. Briefly describe the task, enter a task number, and identify the type of task, level of maintenance, and a preliminary inspection interval.

a. Number (No.) - Identify each task with a task number. Refer to 5.2.4.2 for procedures to develop the task number.

b. Type - List the type of task chosen for each FFMC in this column. The types of tasks are general visual, detailed on-condition, combination and hard time. If age exploration is required, then enter "AE."

c. Description - Briefly describe each task chosen as applicable and effective. Identify the damage being inspected and the limits if an on-condition task exists. If a hard time task exists, state whether a discard or rework (modification) is required.

d. Preliminary inspection interval - For SSIs, base the preliminary inspection interval on the structural rating factors (see column 4) and the type of task selected. Although all SSIs have an effect on safety, some items are more critical than others. The most critical items will receive 100 percent inspections at frequent intervals. General, visual, on-condition inspections occur either between flights or on a daily basis. Detailed on-condition inspections are accomplished less frequently, depending on criticality and accessibility. Safe life structures require that a safe life limit be established to preclude failure. SSIs which do not require 100 percent inspections ("NO" answers to questions 3 and 7, FIGURE 6) are subject to an age exploration program. Age exploration requirements for SSIs establish inspections on a sampling basis to gather the necessary age reliability information and are documented on RCM worksheet 7. See paragraph 5.2.7.3 for more detailed information on developing inspection intervals for SSIs. Preliminary intervals may be subjected to adjustment before finally "packaged" into O, I, or D level maintenance packages.

e. Level of Maintenance (LOM) - Identify the proposed level of maintenance for the task listed in this block. Refer to 5.2.4.2 for procedures affecting the selection of the level of maintenance.

Column 7: Age Exploration Candidate - Record an "X" in either the "Yes" or "No" block depending on whether or not the SSI will be subjected to an age exploration task. If question 4 or 8 in column 5 is answered "Yes", then mark the "yes" column in this block. If question 4 or 8 is "No", then mark "No" here as well. Note that "No" answers to questions 3 and 7 in column 5 will necessitate an age exploration evaluation on RCM worksheet 7 to enable questions 4 and 8 to be answered.

5.2.8 Age exploration. During the initial RCM analysis, it is necessary to establish the basis for the age exploration program. Since many of the RCM logic decisions and inspection intervals are selected without sufficient data, default logic must be applied. Age exploration is used to accurately determine the failure characteristics which were unknown during the logic evaluation and selection of intervals. To document those decisions which require verification by an age exploration analysis, an age exploration worksheet is provided (see RCM worksheet 7, appendix D). This worksheet records all RCM decisions and inspection intervals which used default logic. For each default decision, a preliminary age exploration task and sampling program are developed to determine the required information. These preliminary age exploration tasks are then screened using the age exploration decision diagram (FIGURE 15) to determine the need for performing the task. NAVAIR 00-25-403 provides detailed procedures for:

a. Determining sample size, study period, and site selection.

b. Developing detailed age exploration tasks.

c. Analyzing the data collected by age exploration tasks.

d. Age exploration tasks may be developed from sources other than the RCM decision logic process (see NAVAIR 00-25-403). In these cases the proposed age exploration tasks are screened using FIGURE 15 and worksheet 7, to ensure only valid age exploration requirements are included.

5.2.8.1 Documentation of age exploration requirements. RCM worksheet 7 is used to record FFMCs which used default logic decisions. It is also used to develop preliminary age exploration tasks and to document the answers to the decision diagram questions to screen the tasks. Detailed age exploration tasks are developed from this worksheet and designed to collect the data needed to verify or correct the default decisions. The procedures for completing RCM worksheet 7 are detailed in the following paragraphs.

5.2.8.1.1 Identification of items requiring age exploration. Columns 1 and 2 of RCM worksheet 7 identify the items for which age exploration tasks must be developed.

Column 1: Item LSACN/MIR Index Code - In this column, list the LSACN or MIR Index Code from RCM worksheets 2 through 6 which used default logic to answer the failure consequences determination questions or to determine applicability and effectiveness of a task or to select a task interval based on insufficient data. Record the LSACN or MIR Index Code directly from the other RCM worksheets.

Column 2: Item Nomenclature - In this column, list the nomenclature for each item listed in column 1. Copy the nomenclature from RCM worksheet 1, column 2.

5.2.8.1.2 Documentation of default decisions for age exploration. Columns 3, 4, and 5 of this worksheet record the FFMCs which used default logic and the default decisions made for each FFMC. These decisions are documented on RCM worksheets 2 through 6.

Column 3: Default FFMC - In this column for each item listed in column 2, enter each FFMC which used default logic on RCM worksheets 2 through 6.

Column 4: Default Failure Consequence - In this column, list the default failure consequences for each FFMC listed in column 3. The default answers to RCM questions 1 through 3 are documented on RCM worksheet 2, columns 3a through 3c. Leave this column blank if default logic was not used to determine failure consequences.

Column 5: Default Task Evaluation - For each FFMC listed in column 3, identify the type of tasks which were evaluated using default logic. Default task evaluation answers are found in column 4 or column 6 of RCM worksheets 3 through 6.

5.2.8.1.3 Development of age exploration requirements. For each default decision made during the RCM analysis, it is necessary to collect data to verify the decision. Each preliminary age exploration task developed on this worksheet identifies the information required to satisfy the default condition and the sample size, site, and study period for the task.

Column 6: Age Exploration Requirement - Identify the requirements for developing the preliminary age exploration task. Each of the columns identifies specific information needed to establish a preliminary age exploration task.

6a. Information required - In this column, list the information needed to resolve the default condition identified in column 4 or 5. Identify the data, related to the FFMC, which was not available during the RCM analysis. For on-condition default conditions, the required information must relate the failure mode to a predictable standard or to the rate at which failure resistance decreases. For hard time default conditions, the information relates to the age at which functional failures occur.

6b. Preliminary task - In this column, list a general description of the preliminary age exploration task which will collect the information identified in column 6a. Give a brief description of how the data will be collected, who will perform the task, and what equipment is needed for the task. No special support equipment should be required for the age exploration task. This preliminary age exploration task will be assessed later to determine if the task should be performed. If the task is to be performed, a detailed task will be developed before completion of RCM worksheet 7. The procedures for developing the detailed task are provided in NAVAIR 00-25-403.

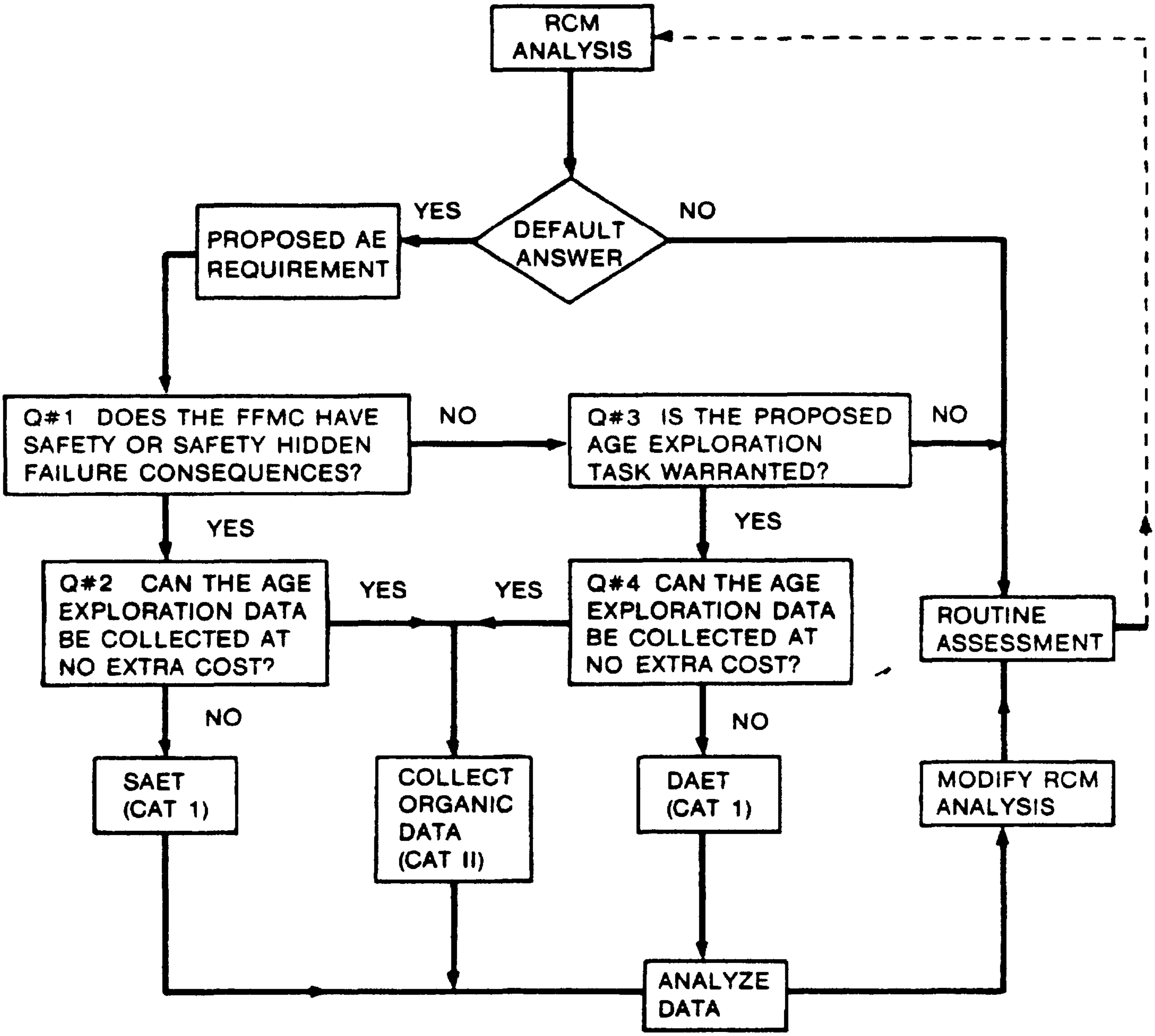



FIGURE 15. Age exploration decision diagram.

6c. Sample size - In this column, list the number of items or aircraft on which to perform the age exploration task described in column 6b. Determine an appropriate sample size using statistical methods dependent on the required degree of precision and the assumptions which must be made regarding the expected characteristics of the data. As a result, the sample size should include adequate justification. See paragraph 5.2.7.2 for SSIs subject to age exploration.

6d. Level of maintenance - In this column, list the level of maintenance (O, I, or D) responsible for performing the age exploration task. The necessary skills and equipment required to perform the age exploration task must be available at the level of maintenance selected. Also consider the types of data being collected by the age exploration task. For example, if a large amount of operational data are needed for an easily accessible item, a fleet organization should be specified to perform the task.

6e. Study period - In this column, list the time period over which the age exploration task is to be performed. The length of the study period depends on the type of information required, the hardware, and the sample size of the task. For example, if an age exploration task is performed to determine the wear rate of a brake assembly, a long study period will be needed because previous experience shows that the brake wear rate is slow.

5.2.8.1.4 Assessment of age exploration tasks. Since the application of default logic results in a potentially large workload, a screening process is needed to reduce the number of preliminary age exploration tasks. FIGURE 15 depicts the logic process used to screen the preliminary age exploration tasks developed on RCM worksheet 7. Age exploration tasks are developed for all FFMCs which have a "Yes" answer to either question 1 or 3. The logic process depicted in FIGURE 15 screens the preliminary age exploration tasks into two types: Safety Age Exploration Tasks (SAET) and Directed Age Exploration Tasks (DAET).

a. A SAET is an age exploration task directed exclusively at default decisions made for safety items. These tasks fall into one of two categories, either: (1) controlled tests performed under laboratory conditions where safety considerations prohibit the collection of operational failure data, or (2) tasks performed in the operational environment, normally preventive requirements, to collect data on the degradation of failure resistance with age (exclusive of actual failures). These tasks collect data up to a predetermined symptom or to a point at which the item is removed. The operational SAET must be carefully monitored with very conservative age exploration intervals to eliminate the risk of failure.

b. A DAET is an age exploration task directed at default decisions made for non-safety items. These tasks are usually preventive requirements performed in the operational environment to collect the required data.

c. A routine assessment task uses existing data sources to continually monitor operational data. This task is used to identify problem areas on all items which have maintenance tasks, including equipment that was not analyzed by RCM. Each type of age exploration task requires the collection of certain information. Sometimes this information can only be obtained at extra cost to the Navy. Other times it is possible to obtain the required information from existing data sources at no extra cost. If the task requires additional costs to obtain the data, designate it as a category I task. When the required data are obtained without additional cost or within routine overhead constraints (i.e., in-house), designate the task as category II. Because routine assessment tasks require the use of existing data systems at no extra cost, these tasks are always designated as category II.

Column 7: Age Exploration Task Assessment - Complete this column for each preliminary age exploration task listed in column 6b of this worksheet. Each of the following columns corresponds to the questions on the age exploration diagram (see FIGURE 15). Include justification for making the decisions with each answer.

7a. Question 1: Does the FFMC have Safety or Safety Hidden Failure consequences? - For FSIs, the answer to this question is found in column 4 of RCM worksheet 2. For SSIs, this question is answered "Yes", if the SSI logic (FIGURE 6) questions 3 or 7 are answered "No". If this question is answered "Yes", answer question 2 next. If a "No", answer question 3 next.

7b. Question 2: Can the age exploration data be collected at no extra cost? - Ask this question for each FFMC which has a "Yes" answer in column 7a. If the required data can be obtained at no extra cost from Navy or existing data sources, enter "Yes" in this column and go to column 8. Collecting information at no extra cost also refers to any existing or planned task for other purposes from which information may be collected and analyzed for age exploration purposes. For example, the manufacturer may be conducting a special test to measure the amount of tire wear per number of landings. If brake wear is the information required by an age exploration task, the data from the tire wear tests may be used provided a correlation exists between brake wear and tire wear. If a preventive task exists or is planned, it may satisfy the data collection requirement for age exploration. If additional costs are required to obtain the necessary data, develop a SAET. Enter a "No" in this column and go to column 8. Procedures for developing a SAET are provided in NAVAIR 00-25-403.

7c. Question 3 Is the proposed age exploration task warranted? - Ask this question for all FFMCs which have a "No" answer in column 7a. Determine if the collection of information obtained by the age exploration task will improve the operational reliability of the equipment being studied. When evaluating this question, review certain issues: (1) the threat associated with failure, i.e., the impact that failure of the item has on operational downtime or repair costs; and (2) the level of effort required to conduct the age exploration task in terms of manpower, equipment, time, etc. There is no exact methodology for making this decision. A careful analysis of all factors is required to make a judicious decision. If the performance of the task is found to be warranted, enter "Yes" in this column and develop a DAET. Instructions for developing a DAET are provided in NAVAIR 00-25-403. A "Yes" answer to this question requires that question 4 be answered next. A "No" answer indicates that a DAET is not warranted and a routine monitoring task is performed.

7d. Question 4 Can the age exploration data be collected at no extra cost? - Ask this question for each detailed DAET developed as a result of a "Yes" answer in column 7c. Refer to question 2, column 7b, of this worksheet for the procedures to answer this question. A "No" answer to this question requires a DAET be accomplished.

Column 8 Task/Category - For each detailed age exploration task, developed from the preliminary age exploration task listed in column 6 of this worksheet, indicate the type and category of age exploration task to be performed. Refer to Table V to determine the type and category of each detailed age exploration task.

TABLE V. Age exploration task/category determination

| Task/Category | Question 1 | Question 2 | Question 3 | Question 4 |
|---|---|---|---|---|
| DAET I | No | --- | Yes | No |
| DAET II | No | --- | Yes | Yes |
| SAET I | Yes | No | --- | --- |
| SAET II | Yes | Yes | --- | --- |
| Routine Assesment | No | --- | No | --- |

5.2.9 Determination of phase inspection and Operating Service Period OSP) intervals. Once RCM worksheets 2 through 7 have been completed, determine the initial phased inspection intervals for organizational level maintenance activities and the initial OSP intervals for the depot activities. The preliminary intervals on worksheets 2 through 6 are recommended engineering intervals. These must be analyzed to determine the most appropriate interval for the phased package and the OSP.

a. The phased Periodic Maintenance Requirement Manual (PMRM) package interval is developed by generating matrices of the organizational level tasks and their intervals for each type of event, calendar, flight hours, operating hours, landings, starts, etc. From these matrices it is possible to determine the type of interval for which the most O level tasks were generated (usually flight or operating hours) and a specific interval of that type where the majority of tasks will occur. Therefore, the initial phased inspection interval can be determined and the other RCM O level tasks (except safety) can be revised to the nearest multiple of that interval. Other tasks with different scheduling parameters and tasks which do not fit the phase interval or a multiple are to be included in one of the other O level PMRMs (turnaround, daily, or special packages). The development of phased PMRMs is covered in detail in appendix B.

b. The OSP interval can be determined through analysis of the depot level RCM tasks for structural items which cannot be removed from the aircraft and have a safety impact. The OSP can be based either on flight hours if the structural items failures are caused by fatigue or on calendar months if corrosion is the most significant cause of failure. The OSP is reviewed periodically by following the OSP logic in Appendix C. Appendix C covers the determination of OSP in greater detail.

5.2.9.1 Task and skills analysis. FIGURE 9 shows that the proposed RCM tasks from worksheets 2 through 6 are input into the task and skills analysis process. A tasks and skills analysis should be accomplished in accordance with MIL-STD-1388. The task and skills analysis verifies that the proposed level of maintenance from RCM worksheets 2 through 6 is correct. This analysis also determines the specific step-by-step task requirements, elapsed maintenance time, number of technicians per task, etc. Use this task analysis data in the formulation of the PMRM package covered in paragraph 5.2.9.2 and in appendix B of this standard. For tracking purposes, from the RCM process to the LSA/MPA process and back, each RCM task must be recorded on the LSAR datasheets accurately. The LSA task code is not developed at this point in the process. Therefore, use the LSACN or WUC together with the task number developed on the RCM worksheets (see paragraph 5.2.4.2) to define the unique RCM task on the LSAR datasheet. RCM programs on in-service equipment not done in conjunction with an LSA program must also perform a task and skills analysis. But, they are not required to use LSAR format to document the tasks analysis. Once the task and skills analysis is complete, the RCM tasks including the packaged intervals (see paragraph 5.2.9) can be recorded on the RCM summary worksheet 1.

5.2.9.2 Formulation of phased PMRM packages. Formulate the list of preven-tive tasks and recommended intervals,generated by the RCM analysis into practical and efficient maintenance manuals. At the organizational and intermediate levels of maintenance, preventive maintenance is accomplished using Periodic Maintenance Requirements Manuals (PMRMs). Military specification MIL-M-23618 details the preparation and format required for PMRMs. In forming workable maintenance packages, consider criteria from the tasks analysis such as the following: 1) Elapsed maintenance time per task, 2) number of personnel per task, 3) task work area, 4) power requirements, 5) safety, 6) consumables, and 7) support equipment. The phased maintenance package consists of series of related inspections performed sequentially at specific intervals. To generate phases, divide the preventive tasks into small packages of approximately the same workload. Develop special inspection packages from tasks which do not fit in the phased package due to interval or type of schedule base, e.g., weeks, starts, landings, cycles, etc. Appendix B of this standard details the formulation of phased maintenance packages.

5.2.9.2.1 Updating Periodic Maintenance Requirements Manuals (PMRMs). The results of age exploration and analysis of the operational maintenance data should be effectively implemented to gain the optimum benefit. Sustaining the RCM analysis is the major portion of the maintenance program. The question of how often to update the PMRMs is an important matter. Updates depend on many factors: aircraft equipment changes, safety, and new maintenance procedures are a few of these factors. An equipment problem which effects operational safety may require a rapid action change or other immediate change to the manuals. Another problem which does not effect safety or mission effectiveness, might be put off until a scheduled revision to the PMRM. The results of an age exploration or sampling program may recommend revisions to the inspection intervals for certain tasks. Changes to the RCM analysis package as a result of operational experience data may generate update requirements due to:

a. Unforeseen failure consequences.

b. Higher or lower than predicted failure rate.

c. Functions which were thought to be apparent to the crew that are actually hidden.

d. Either high preventive or high corrective maintenance costs.

e. Low operational readiness figure.

f. Unforseen failure modes.

5.3 Revisions to maintenance requirements and product improvement. Respond to unanticipated, serious failure modes by following these two approaches. First, determine if a preventive maintenance task or a revision to existing requirements would be effective as an interim solution. Then, consider a longer term fix, normally a recommendation for a redesign of the problem equipment to design out the serious failure mode or to make it more reliable. Redesign may be required for safety cases or only considered (nonsafety) as a result of RCM logic decisions (FIGURE 5). When redesign is a consideration, refer to paragraph 5.3.2 for procedures to determine the feasibility of product improvement.

5.3.1 Diagnostic inspection techniques. Most on-condition inspections are diagnostic techniques. They measure resistance to failure to identify specific problems. The earliest and simplest technique used for aircraft was visual examination, perhaps aided by a magnifying glass. This visual inspection was extended by development of the borescope. Numerous other techniques have been developed to detect cracks in metallic items such as eddy current, magnaflux, and dye penetrant inspections. Radiography is also widely employed, not only for detecting cracks, but also to check clearances and changes in configuration without disassembling the item.

a. A useful diagnostic technique must be able to detect a specific condition that confidently defines a potential failure. The technique should be sufficiently accurate to identify all units that have reached this condition without including a large number of units for which failure is remote. In other words, such techniques must provide a high power of discrimination. The demand for such discrimination depends in part on the consequences of failure. A technique with low resolving power might be of value for single engine aircraft if it prevents even a small number of engine failures while also causing numerous unjustified removals. For a multi-engine aircraft, the same technique would be unnecessary as a safety precaution and undesirable in economic terms.

b. Certain diagnostic techniques appear to have great potential but require further development before the full potential is realized. For example, spectrographic analysis detects wear in metal parts by measuring the concentration of metallic elements in lubricating oil. In many cases, however, it has been difficult to define a failure condition related to the metal concentrations. Parts have failed without the expected warning, and warnings have not always resulted in imminent failure. Even a change in the brand of oil may necessitate new criteria for interpreting the analysis. Nevertheless, if the failure has major consequences, even a low incidence of successful interpretations (and prevented failures) may offset the cost of other inspections that produce no useful information.

c. Another recent technique is the use of computerized Airborne Integrated Data Systems (AIDS). It measures and records the performance characteristics of many items for later study. Some of these characteristics, especially in powerplants, are also monitored by the normal flight instrumentation, but the data are not automatically recorded and integrated with other data. This procedure opens up the possibility of correlating performance trends with the likelihood of failures or "establishing a signature" for the failure mode. By revealing a previously overlooked indication of reduced resistance to failure, AIDS may make it possible to prevent certain functional failures by on-condition maintenance. The new data systems have assisted in troubleshooting, and they have indicated engine conditions that increase the stress on certain internal parts. However, their success in performing a true and continuous on-condition surveillance has been limited so far. This system may be worthwhile if analysis proves that the value of its contribution outweighs its costs.

d. Scheduled rework tasks have limited applicability, and discard tasks apply only under rather special circumstances. Major improvements in maintenance effectiveness depend, therefore, on expanded use of diagnostic techniques. The search for additional techniques continues, and the economic desirability of such new developments must be reevaluated from time to time.

5.3.2 Design changes. Design changes must be considered as alternatives to preventive maintenance requirements in some cases and are required by other (safety) cases. The product improvement process is also a factor in changing maintenance requirements: design modifications may change the reliability characteristics of items either intentionally or inadvertently. Hidden failures may be added or removed. Critical failure modes may be added or removed. Dominant failure modes and age reliability characteristics may be altered. Redesign may change the applicability of on-condition tasks. Whenever an item is substantially modified, its maintenance requirements must be reviewed. It may also be necessary to repeat the age exploration process for such items both to find out whether the modifications have achieved their intended purpose and to determine how these modifications affect existing maintenance requirements for the item. Finally, entirely new items are added to most equipment during its service life. Initial requirements must be developed for each of these items, to be modified as necessary when operating data on them become available.

5.3.2.1 Product improvement process. During the evaluation of maintenance requirements for complex equipment, many items will be found that cannot benefit from preventive maintenance. Either there is no applicable preventive task or available forms of prevention cannot provide the level of reliability necessary. There is inherent conflict between performance requirements and reliability requirements. The reliability problems identified and corrected during early operations are really part of the normal development cycle of high performance equipment. The degree of reliability that can be achieved by preventive maintenance is limited by the design of equipment itself. A product may be deemed unsatisfactory for any of the following reasons:

a. Exposure to critical failures.

b. Exposure to failures that unduly reduce operational capability.

c. Unduly high maintenance costs.

d. A demonstrated need to make a hidden function visible.

Failures may result from the stress and wear associated with the normal operation of the item, or they may be caused by external factors such as lightning strikes, bird ingestion, or corrosive environments. Product improvement to increase resistance to these external factors may be just as necessary as modifications to withstand the effects of the normal operating environment.

5.3.2.2 Determining the need for product improvement. Product improvement directed toward better reliability may take a number of forms. An item may be modified to prevent critical failures or to eliminate a particularly expensive failure mode or to reduce its overall failure rate. The equipment or an item on it may be modified to facilitate replacement of a failed unit or to make a hidden failure visible or to incorporate features that make on-condition inspections feasible or to add redundant features which alter the consequences of failure. Product improvement is expensive; it involves the cost of redesign and the manufacture of new parts or whole new items. The operating organization also incurs the direct cost of modifying the existing equipment and perhaps the indirect cost of taking it out of service while such modifications are being incorporated. Further risks are always introduced when the design of high performance equipment is changed. There is no assurance that the first attempt at improvement will eliminate or even alleviate the problem at which improvement is directed. For this reason, be certain to distinguish between situations where product improvement is necessary and where it is only desirable. Use the decision diagram in FIGURE 16 to evaluate the necessity or desirability of initiating design changes. In this case, base the answers to the decision questions on operating experience. As always, consider safety first.

5.3.2.2.1 Adverse effect on safety. Answer this question in the same manner as RCM logic question 2 (FIGURE 5). If the answer to this question is "Yes," then consider whether such failures can be controlled at the maintenance level.

5.3.2.2.2 Are present or proposed new preventive measures effective in avoiding such failure? If the answer is "No," then the safety hazard has not been resolved. In this case, the only recourse is to remove the equipment from service until the problem can be solved by redesign. Clearly, product improvement is required. If the present preventive measures effectively control critical failures, then product improvement is not necessary for safety reasons. However, the problem may seriously restrict operating capability or or result in unduly expensive maintenance requirements. Therefore, investigate the possibility of reducing these costs by doing further analysis.

5.3.2.3 Determining the cost effectiveness of product improvement. There is no hard and fast rule for determining when product improvement will be cost effective. The major variables can be identified, but the monetary values assigned in each case depend not only on direct maintenance costs but also on a variety of other shop and operating costs as well as on the plans for continuing use of the equipment. Weigh all these factors against the costs of product improvement. An organization is always faced with a larger number of apparently cost effective improvement projects than are physically or economically feasible. The remaining logic questions are helpful in ranking such projects and determining whether a proposed improvement is likely to produce discernible results within a reasonable length of time. The next question concerns the anticipated further use of the equipment.

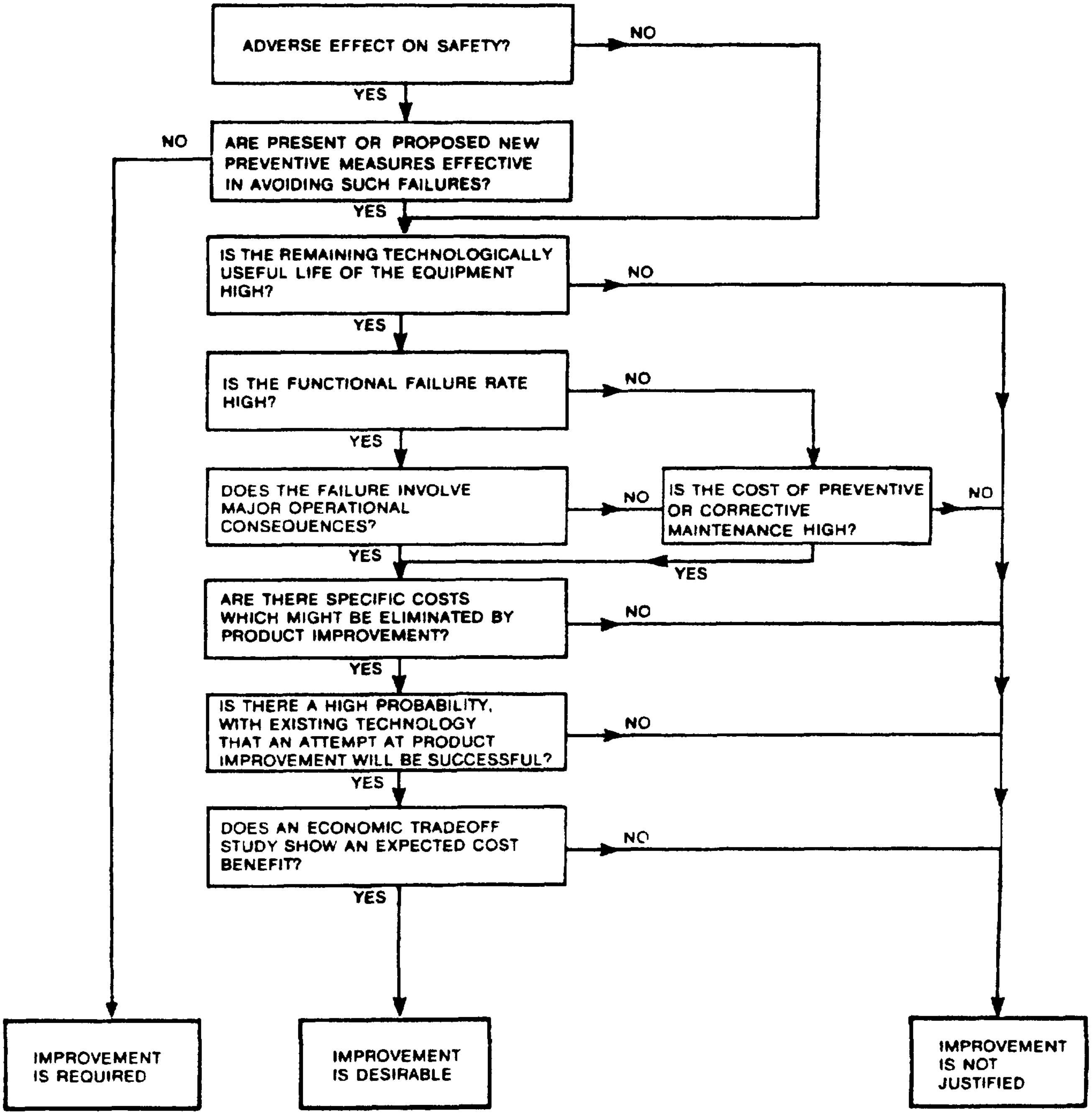



FIGURE 16 - Decision diagram for evaluating the necessity or desirability of initiating design changes

5.3.2.3.1 Is the remaining technologically useful life of the equipment high? Any equipment, no matter how reliable, will eventually be outmoded by new developments. Product improvement is not likely to result in major savings when the equipment is near the end of its technologically useful life. However, the elimination of excess costs over a span of eight or ten years of continued service might represent a substantial saving. One way of evaluating cost effectiveness is to have the costs of product improvement become self liquidating over a short period of time. This sets the operational horizon of the equipment at two years. This method reduces the number of projects initiated on the basis of projected cost benefits and ensures that only those projects with relatively high payback are approved. Thus, if the answer to this first question is "no," we can usually conclude that product improvement is not justified. If the economic consequences of failure are very large, it may be more economical to retire the equipment early than to attempt to modify it. The case for product improvement is obviously strengthened if an item that will remain in service for some time is also experiencing frequent failures.

5.3.2.3.2 Is the functional failure rate high? If the answer to this question is "yes," consider the economic consequences of failure.

5.3.2.3.3 Does the failure involve major operational consequences? Even when the failures have no operational consequences, there is another economic factor to be taken into account.

5.3.2.3.4 Is the cost of either preventive or corrective maintenance high? Note that this question may be reached by more than one path. A "no" answer to the failure rate question may mean that preventive maintenance is effectively preventing functional failures but only at great cost. Likewise a "no" answer to the question of operational consequences may mean that functional failures are not affecting operating capability, but the failure mode results in exceedingly high repair costs. Thus, a "yes" answer to this question results in a consideration of product improvement.

5.3.2.3.5 Are there specific costs which might be eliminated by product improvement? This question concerns both the costs attributed to reducedoperational capability and the more tangible costs associated with maintenance activities. These costs must be related to a specific design characteristic or the problem will not be eliminated by product improvement. Hence, a "no" answer to this question means the economic consequences of this failure will probably have to be borne. If the problem can be pinned down to a specific cost element, then the economic potential of product improvement is high. But is this effort likely to produce the desired results?

5.3.2.3.6 Is there a high probability, with existing technology, that an attempt at product improvement will be successful? Although a particular improvement might be very desirable economically, it may not be feasible. An improvement directed at one failure mode may unmask another failure mode requiring several attempts before the problem is solved. If informed technical opinion indicates that the probability of success is low, the proposed improvement is unlikely to be economically worthwhile. If the improvement under consideration has survived the screening process thus far, it warrants a formal economic tradeoff study.

5.3.2.3.7 Does an economic tradeoff study show an expected cost benefit? The tradeoff study must compare the expected reduction in costs during the remaining useful life of the equipment with the costs of obtaining and incorporating the improved item. There are various ways to compute tradeoff. One of these is that the expected benefit equals the projected savings (if the first attempt at improvement is successful) multiplied by the probability of success at the first try. Another is to consider that the improvement will always be successful, but only a portion of the potential savings will be realized. In some situations, it may be necessary to proceed with an improvement even though it does not result in an actual cost benefit. To verify this, work back through the set of decision questions and determine the values necessary for the project to break even. Also, improvements that increase redundancy can often be justified when redesign of the offending item is not. Justifica-tion for redesign is not necessary, of course, when the in-service reliability characteristics of an item are specified by contractual warranties or when there is a need for improvement for reasons other than cost.

5.3.2.4 Information requirements. No organization has unlimited resources for product improvement. Each needs to know which modifications to the product are necessary and which are sufficiently desirable to risk the cost of developing them. This information must come from the CFA who is in the best position to determine the consequences and costs of various types of failures, to measure their frequency, and to define the specific conditions that thev consider unsatisfactory. Opinions will differ from one organization to another about the desirability of specific improvements because of differences in failure experience and differing definitions of a failure. A failure with safety consequences in one operating environment may have only operational consequences in another, and operational consequences that are major for one organization may not be significant for another. Similarly, the costs of preventive and corrective maintenance will vary and have different economic impacts depending on the resources of each organization. Nevertheless, theaggregate experience of the various users must be assessed. It must be decided which improvements will be of greatest value to the entire group. With any new type of equipment, therefore, one must start with the following assumptions:

a. Certain items on the equipment will need improvement.

b. Requests for improvement must be supported by reliability and cost data.

c. Specific information on the failure mode must be provided as a basis for redesign.

Critical failures must be reported by a safety alert system so that all operating organizations can take immediate action against identified safety hazards. Failures, with other operational consequences, are reported at short intervals so that the cost effectiveness of product improvement can be assessed as soon as possible. It is important that operating data, especially peacetime exercise data, be examined carefully for its implications for operational readiness. For items whose failure has no operational consequences, the only justification for product improvement is a substantial reduction in support costs. Many of these items will be ones for which there is no applicable and effective form of preventive maintenance. In this case statistical reliability reports at monthly or quarterly intervals are sufficient to permit an assessment of the desirability of product improvement. The economic benefits of redesign will usually not be as great under these circumstances. In general, the information requirements for product improvement are similar to those for management of the ongoing maintenarce program. In one case the information is used to determine necessary or desirable design modifications and in the other it is used to determine necessary or desirable modifications in the maintenance program.

5.4 Auditing the RCM analysis. Auditing the RCM analysis is a program requirement. An objective of RCM is to provide an audit trail as budgetary reinforcement to support a justifiable preventive maintenance program. Other documents providing inputs to the preventive maintenance process may generate inconsistencies which require a type of quality assurance. Auditing the RCM analysis is useful to the analyst in learning how to correctly apply the RCM logic questions. The procedures for completely auditing the RCM process are detailed in Appendix E.

# 6. NOTES

6.1 Intended use. This standard is to be used for determining preventive maintenance requirements and developing age exploration requirements for both new procurements and in-service equipment.

6.2 Data requirements. When this standard is used in an acquisition which incorporates a DD Form 1423, Contract Data Requirements List (CDRL), the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved CDRL incorporated into the contract. When the provisions of the DoD FAR Supplement, Part 27, Sub-part 27.410-6 are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this standard is cited in the following paragraphs.

| Paragraph No. | Data Requirement Title | Applicable DID No. | Option |
|---|---|---|---|
| 5.2 | RCM Analysis Data | DI-ILSS-80111 | RCM worksheet form standard |

(Data item descriptions related to this standard, and identified in section 6 will be approved and listed as such in DoD 5000.19-L, Vol. II, AMSDL. Copies of DIDs required by contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.)

6.3 Subject term (key word) listing.

Age Exploration
Conditional Probability of Failure
Damage Tolerant Structure
Engineering Failure Mode
Failure Finding Task
Fleet Leader Concept
Hard Time
Infant Mortality
On-Condition Task
Residual Failure Rate
Rework Task
Secondary Damage
Technologically Useful Life
Wearout Characteristics
Zonal Inspections

6.4 Changes from previous issue. Asterisks or vertical lines are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

# APPENDIX A

# EXAMPLES OF THE RCM LOGIC PROCESS

## 10. GENERAL

10.1 Scope. This appendix shows examples of the RCM analysis in areas of aircraft systems and structures.

## 20. REFERENCED DOCUMENTS

Not applicable.

## 30. DEFINITIONS

Not applicable.

## 40. GENERAL REQUIREMENTS

40.1 RCM analysis examples. These examples are intended to be instructional and are not worksheets which actually have been completed through a formal RCM analysis. The basis for the examples may be actual systems, components, or equipment; however, the failure modes and effects are examples only. The answers to the RCM decision logic questions are intended to represent a realistic trail of the logic answers. These examples include only some of the supporting information required to support the logic decisions. Each sample does not contain all seven RCM worksheets. This will normally be the case for most items analyzed, because only structural items require worksheet 6 and not all items will require age exploration (worksheet 7). A diagram is provided with each example. Also included is a Failure Mode, Effects and Criticality Analysis (FMECA) worksheet which is an input from MIL-STD-1629. References to the appropriate sections of this standard are in parenthesis.

## 50. DETAILED REQUIREMENTS

50.1 RCM worksheet reference. To adequately interpret each example, it may be necessary to refer to the detailed requirements section of this standard. The following is a list of the references for the detailed requirements of each worksheets.

a. FMEA worksheet - MIL-STD-1629.

b. RCM worksheet 1 - paragraph 5.2.1.

c. RCM worksheet 2 - paragraph 5.2.2.

d. RCM worksheet 3 - paragraph 5.2.4.

e. RCM worksheet 4 - paragraph 5.2.5.

f. RCM worksheet 5 - paragraph 5.2.6.

g. RCM worksheet 6 - paragraph 5.2.7.

n. RCM worksheet 7 - paragraph 5.2.8.

50.2 Detailed examples. The following examples of the RCM analysis are presented in this appendix:

a. Catapult Launch Bar for Z-9Z - contains a Design Description, Supplemental Information, Rationale Sheet, FMECA and RCM worksheets 1 through 7, page 103.

b. Wheel Brake Assembly for Z-9Z - contains a Design Description, Supplemental Information, Rationale Sheet, FMECA and RCM worksheets 1 through 5 and 7, page 138.

c. Test Chamber Assembly - contains a Design Description, Supplemental Information, Rationale Sheet, FMECA, and RCM Worksheets 1 through 5 and 7, page 157.

## EXAMPLE 1- CATAPULTING SUBSYSTEM

## DESIGN DESCRIPTION

The catapulting system provides catapult handling and attachment capabilities for carrier operations. The system consists of a catapult launch bar, a launch bar actuating cylinder, a cockpit controlled selector valve, leaf retracting springs, and a catapult tension bar socket. The luanch bar is swivel mounted on the forward side of the nose gear outer cylinder and may be extended and redtracted during taxiing. The launch bar is automatically retracted after catapulting. A launch bar warning light, on the main instrument panel, comes on any time the launch bar control switch is in EXTEND, the selector valve is in bar extend position, the launch bar is not up and locked with weight off the landing gear or the launch bar control switch is in RETRACT and launch bar actuator is not up and locked. Accessories for the catapulting system include a tension bar and a catapult holdback bar. The catapult tension bar socket is mounted on the nose gear axle beam and provides for attachement of the tension bar for tensioning of the airplane prior to catapulting.

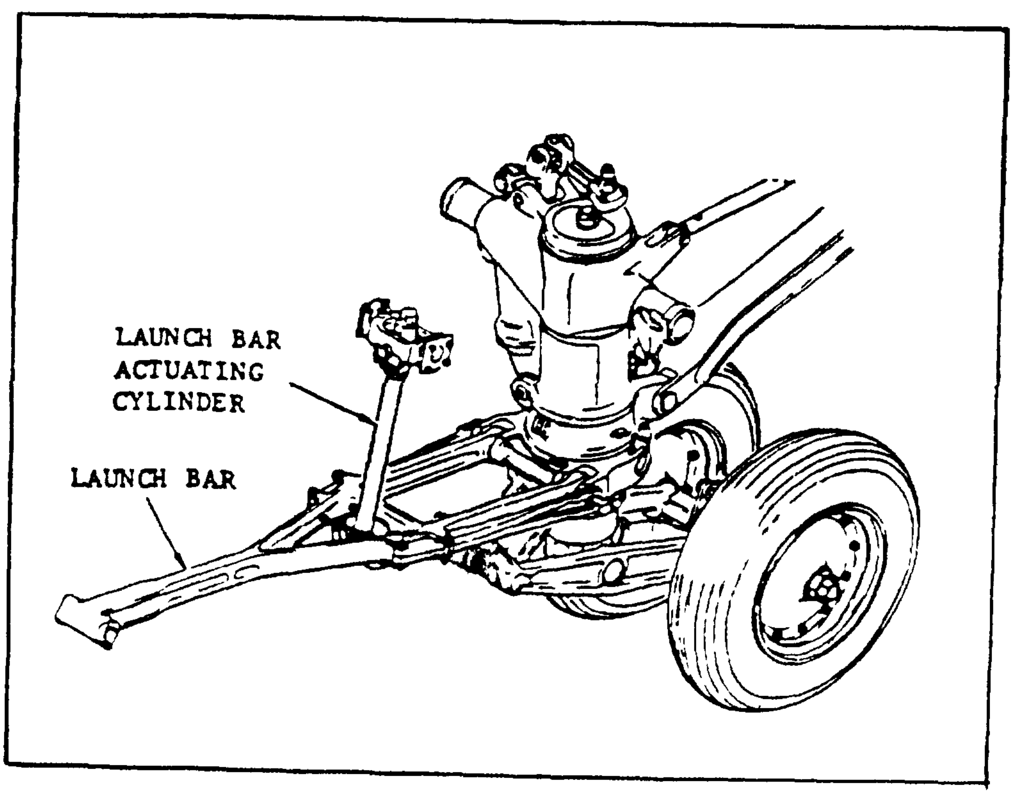



FIGURE 17 - Z-9Z NLG assembly

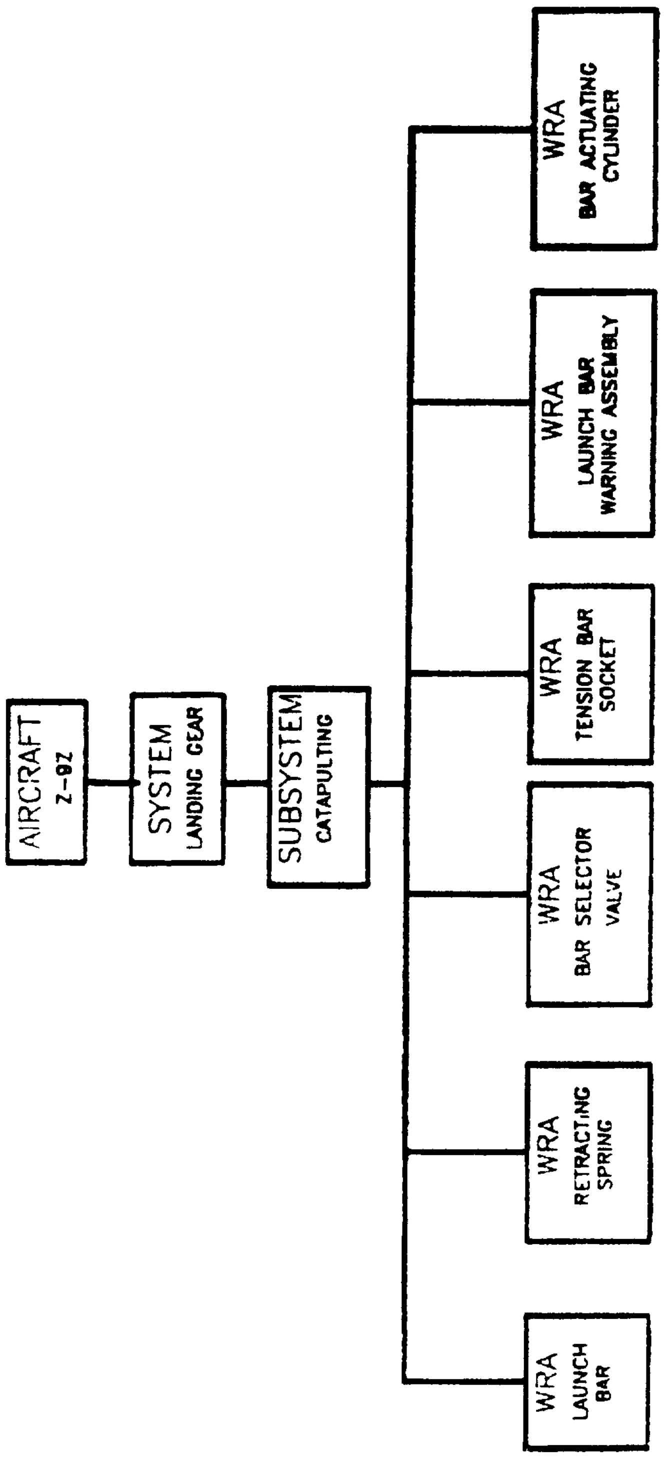



FIGURE 18 Catapulting system functional block diagram

| LSACN | Part No. | Nomenclature | FSI | SSI |
|---|---|---|---|---|
| A4 | 302-653-23 | Landing Gear System | | |
| A40C | 21812997/80378 | Catapulting Subsystem | X | X |
| A40C01 | 76566667762 | Launch Bar | | |
| A40C02 | 475353-03-85 | Retracting Springs | | |
| A40C03 | 356565255-03 | Bar Selector Valve | | |
| A40C04 | 5455565375 | Tension Bar Socket Assembly | | |
| A40C05 | 477221-46 | Actuating Cylinder | | |
| A40C06 | 5-26756735-21 | Launch Bar Warning Assembly | | |
| A40D | 182738-37638 | Wheel/Brake Subsystem | X | |

FIGURE 19 - LSA candidate list Z-9Z assembly

SUPPLEMENTAL INFORMATION

Data obtained from the Navy's 3M system was used to calculate the engineering failure mode Mean Time Between Failure (MTBF) and Mean Time Between Maintenance Action (MTBMA).

The manufacturer of the catapulting system established lubrication requirements for the launch bar assemblies. These requirements were established from sample testing and collection of historical data. When the 28 day task interval was established, the equipment usage, environmental conditions, and loading factors were attributed to the launch bar assembly.

Launch Bar Fatigue Test Results

During the fuselage fatigue tests, seven launch bars were used. Six failures occurred, all at the tee section. The seventh had not failed at the conclusion of the test. The engineering estimation of the design life for the bar was calculated to be 350 catapult loads. The results are tabulated below:

| Specimen | Cycles at Failure | Crack Initiation | Cycles Remaining |
|---|---|---|---|
| 1 | 341 | 180 | 161 |
| 2 | 272 | 145 | 127 |
| 3 | 519 | 310 | 209 |
| 4 | 304 | 170 | 134 |
| 5 | 290 | 160 | 130 |
| 6 | 407 | 245 | 162 |
| 7* | 352 | 210 | |
| | | mean = | 154 |
| | | standard deviation = | 31 |

*Test terminated, no failure

The launch bars were inspected every twenty cycles for visible cracks of .25 inches or greater. Previous testing indicated that a crack .10 inches in length is the minimum crack length that can be detected by a visual inspection. This ensures that cracks originating at the tee section can be easily detected. Because of the length of time between crack initiation and failure, numerous repeat inspections can be made to detect a fatigue crack before failure occurs.

During fatigue testing, vibration of the strut was noted. Upon examination it was found that wear of the launch bar bearing and cam pin was responsible. This was monitored until vibration became excessive. The average cycles between initial and excessive vibration was 54 with the minimum being 40.

Laboratory Fatigue Test Results for Tension Bar Socket

Laboratory fatigue testing was performed on the tension bar socket to determine the assembly's fatigue life and crack propagation rate. The testing was performed in a corrosive environment to simulate actual operating conditions. Testing was performed on six specimens and all were tested to failure. Design life was estimated to be 8500 catapults. The results are tabulated below:

| Specimen | Cycles at Failure | Crack Initiation |
|---|---|---|
| 1 | 8256 | 8198 |
| 2 | 8131 | 8091 |
| 3 | 8489 | 8459 |
| 4 | 8217 | 8186 |
| 5 | 8304 | 8270 |
| 6 | 8283 | 8254 |

A conditional probability of failure curve was drawn to determine the wearout life of the launch bar actuating cylinder. The data was obtained from an actuarial analysis performed on another type aircraft which uses the same actuating cylinder. The curve is shown in FIGURE 20. The actuating cylinder has operational failure consequences. This allowed the analyst to establish the wearout age at the point where the curve shows a rapid increase.

The catapult bar leaf retracting springs did not have any specific reliability or failure data available for review. After researching similar assembles, the analyst found a spring assembly of approximately the same size and build from a different aircraft for which reliability information was available. These data revealed a crack propagation rate to be approximately 1950 load cycles and the wear to failure of the assembly parts to be approximately 5125 cycles.

| FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION | | | | | DATE 5/9/85 | PAGE 1 OF 6 |
|---|---|---|---|---|---|---|
| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER [illegible] | SYSTEM/SUBSYSTEM NOMENCLATURE Catapulting Subsystem | INDENTURE LEVEL 3 | REFERENCE DRAWING 215-24060-7-9 | MISSION Aircraft Catapult Launch | PREPARED BY | APPROVED BY |
| SYSTEM/SUBSYSTEM DESCRIPTION The catapult launch subsystem consists of a [illegible] launch bar [illegible] cylinder [illegible] selector valve, retractor [illegible] bar warning assembly. The system is mounted [illegible] launch bar [illegible] provide catapult handling, attachment [illegible] from [illegible] catapulting launch load | | | COMPENSATING PROVISIONS Leaf retracting springs - the springs will retract the launch bar if actuating cylinder fail. Bar warning assembly - cockpit warning light warns crew the launch bar is in the extended position | | | |

| ITEM IDENT NO | ITEM NOMENCLATURE | FUNCTION NUMBER | FUNCTION | FUNCTIONAL FAILURE LETTER | FUNCTIONAL FAILURE | ENGINEERING FAILURE MODE NUMBER | ENGINEERING FAILURE MODE | LOCAL EFFECTS | NEXT HIGHER LEVEL | END EFFECTS | MEL | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | Catapult launch [illegible] | 1 | Transfers catapult loads to nose landing gear | A | Failure to transfer catapult loads | 1 | Fractured bar at [illegible] section | Launch bar breaks during catapult shot | Soft catapult launch | Loss of aircraft | N | I | Soft catapult launch | Catapult launch | MTBF = 3455 cats MTBMA = 261 cats |
| | | | | | | 2 | Severely corroded launch bar | Loss of residual strength bar breaks | Same as 1A1 | Same as 1A1 | N | I | | | MTBF = 6824 cats MTBMA= 176 cats |
| | | | | | | 3 | Nicked, scratched, bent launch bar (accidental damage) | Same as 1A2 | Same as 1A1 | Same as 1A1 | N | I | | | MTBF = 6123 cats MTBMA - 212 cats |
| [illegible] | Catapult launch [illegible] | 2 | Transfer tension bar loads to nose landing gear | A | Fails to transfer tension bar load | 1 | Fractured tension bar socket | Tension bar socket breaks | Aircraft lunges forward | Possible injury to catapult crew | N | II | Aircraft lunges forward | Catapult launch | MTBF = 5851 cats MTBMA = 1786 cats |

FIGURE 20- Catapult launch subsystem FMECA/MI

| FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION | | | | | DATE 5/9/85 | PAGE 2 OF 6 |
|---|---|---|---|---|---|---|
| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER 13700 218-12997/80378 | SYSTEM/SUBSYSTEM NOMENCLATURE | INDENTURE LEVEL | REFERENCE DRAWING | MISSION | PREPARED BY<br>APPROVED BY | |
| SYSTEM/SUBSYSTEM DESCRIPTION | | | COMPENSATING PROVISIONS | | | |

| ITEM IDENT NO | ITEM NOMENCLATURE | FUNCTION NUMBER | FUNCTION | FUNCTIONAL FAILURE LETTER | FUNCTIONAL FAILURE | ENGINEERING FAILURE MODE NUMBER | ENGINEERING FAILURE MODE | FAILURE EFFECTS: LOCAL EFFECTS | FAILURE EFFECTS: NEXT HIGHER LEVEL | FAILURE EFFECTS: END EFFECTS | MINIMUM EQUIPMENT LIST | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2 | Corroded tension bar socket | Loss of residual strength socket breaks | Same as 2A1 | Same as 2A1 | N | II | | | MTBF = 21258 cats<br>MTBMA = 213 cats |
| | | | | | | 3 | Socket nicked or dented (accidental) | Same as 2A2 | Same as 2A1 | Same as 2A1 | N | II | | | MTBF = 18751 cats<br>MTBMA = 7026 cats |
| 1370 | Catapult launch subsystem | | | B | Fails to retain tension bar during/after launch | 1 | Broken or weak retaining springs | Springs do not apply pressure to the tension bar in socket | Tension bar does not remain in socket during/after launch | Possible engine FOD or injury to flight deck crew | N | II | None | Catapult launch | MTBF = 5160 cats<br>MTBMA = 3985 cats |
| | | 3 | Aligns nose gear with catapult shuttle | A | Misalignment of nose wheel during catapult launch | 1 | Swivel joint bushings, pins and cams worn | Nose gear improperly aligned with catapult shuttle | Excessive tire wear and nose gear vibration | Mission abort | N | III | Catapult crew | | MTBF = 4125 cats<br>MTBMA - 3522 cats |

FIGURE 21- Catapult launch subsystem FMECA/MI

**FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION**

| | | | | | |
|---|---|---|---|---|---|
| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER: 13700 218-12997/80378 | SYSTEM/SUBSYSTEM NOMENCLATURE | INDENTURE LEVEL | REFERENCE DRAWING | MISSION | DATE 5/9/85 · PAGE 3 OF 6 · PREPARED BY · APPROVED BY |
| SYSTEM/SUBSYSTEM DESCRIPTION | | | COMPENSATING PROVISIONS | | |

| ITEM IDENT NO | ITEM NOMENCLATURE | FUNCTION NUMBER | FUNCTION | FUNCTIONAL FAILURE LETTER | FUNCTIONAL FAILURE | ENGINEERING FAILURE MODE NUMBER | ENGINEERING FAILURE MODE | FAILURE EFFECTS: LOCAL EFFECTS | FAILURE EFFECTS: NEXT HIGHER LEVEL | FAILURE EFFECTS: END EFFECTS | MINIMUM EQUIPMENT LIST | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13700 | Catapult Launch Subsystem | 4 | Extends launch bar | A | Fails to extend launch bar | 1 | Internal failure of actuating cylinder | Actuating cylinder jams | Bar fails to extend | Mission abort | N | III | Catapult crew and cockpit warning light | Catapult launch | MTBF = 1732 cats MTBMA = 1114 cats |
| | | | | | | 2 | Leaking actuating cylinder | Insufficient fluid to operate | Same as 4A1 | Same as 4A1 | N | III | | | MTBF = 4447 FH MTBMA = 1826 FH |
| | | | | | | 3 | Internal failure of the bar selector valve | Fails to direct hydraulic pressure to actuating cylinder | Same as 4A1 | Same as 4A1 | N | III | | | MTBF = 1591 cats MTBMA = 1311 cats |
| | | | | | | 4 | Leaking bar selector valve | Fails to provide sufficient hydraulic pressure to actuating cylinder | Same as 4A1 | Same as 4A1 | N | III | | | MTBF = 4269 FH MTBMA = 1576 FH |

FIGURE 22- Catapult launch subsystem FMECA/MI

**FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION**

| DATE | PAGE | OF |
|---|---|---|
| 5/9/85 | 4 | 6 |

| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER | SYSTEM/SUBSYSTEM NOMENCLATURE | INDENTURE LEVEL | REFERENCE DRAWING | MISSION | PREPARED BY / APPROVED BY |
|---|---|---|---|---|---|
| 13700 218-12997/80378 | | | | | |

| SYSTEM/SUBSYSTEM DESCRIPTION | COMPENSATING PROVISIONS |
|---|---|
| | |

| ITEM IDENT NO | ITEM NOMENCLATURE | FUNCTION NUMBER | FUNCTION | FUNCTIONAL FAILURE LETTER | FUNCTIONAL FAILURE | ENGINEERING FAILURE MODE NUMBER | ENGINEERING FAILURE MODE | FAILURE EFFECTS: LOCAL EFFECTS | FAILURE EFFECTS: NEXT HIGHER LEVEL | FAILURE EFFECTS: END EFFECTS | MEASUREMENT | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13700 | Catapult Launch Sub tem | | | B | Intermittent operation | 1 | Faulty or corroded electrical connections bar selector valve | Same as 4A3 | Same as 4A1 | Same as 4A1 | N | III | Same as 4A1 | Catapult launch | MTBF = 14012 FH MTBMA = 2743 FH |
| | | 5 | Retracts launch bar | A | Failure to hydraulically retract launch bar | 1 | Internal failure of actuating cylinder | Actuating cylinder jams | Retracting springs retract launch bar | None | N | IV | None | | MTBF = 1732 cats MTBMA = 1114 cats |
| | | | | | | 2 | Leaking actuating cylinder | Insufficient fluid to operate | Same as 5A1 | None | N | IV | | | MTBF = 4447 FH MTBMA = 1826 FH |
| | | | | | | 3 | Internal failure of bar selector valve | Fails to discontinue hydraulic pressure to actuating cylinder | Same as 5A1 | None | N | IV | | | MTBF = 1591 cats MTBMA = 1311 cats |

FIGURE 23- Catapult launch subsystem FMECA/MI

| FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION | | | | | DATE 5/9/85 | PAGE 5 OF 6 |
|---|---|---|---|---|---|---|
| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER 13700 218-1[illegible] 80378 | SYSTEM/SUBSYSTEM NOMENCLATURE | INDENTURE LEVEL | REFERENCE DRAWING | MISSION | PREPARED BY<br>APPROVED BY | |
| SYSTEM/SUBSYSTEM DESCRIPTION | | | COMPENSATING PROVISIONS | | | |

| ITEM IDENT NO | ITEM NOMENCATURE | FUNCTION NUMBER | FUNCTION | FUNCTIONAL FAILURE LETTER | FUNCTIONAL FAILURE | ENGINEERING FAILURE MODE NUMBER | ENGINEERING FAILURE MODE | FAILURE EFFECTS: LOCAL EFFECTS | FAILURE EFFECTS: NEXT HIGHER LEVEL | FAILURE EFFECTS: END EFFECTS | MINIMUM EQUIPMENT LIST | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13700 | Catapult launch Subsystem | | | | | 4 | Leaking bar selector valve | Fails to provide sufficient hydraulic pressure to actuating cylinder | Same as 5A1 | None | N | IV | | Catapult launch | MTBF = 4269 FH<br>MTBMA = 1576 FH |
| | | | | B | Fails to retracts launch bar | 1 | Broken or worn leaf retracting springs | Springs do not apply pressure to launch bar | Launch bar fails to retract | Mission abort | N | III | Catapult crew to cockpit warning light | | MTBF = 2765 cats<br>MTBMA = 878 cats |
| | | | | C | Intermittent operation | 1 | Faulty or corroded electrical connecting bar selector valve | Same as 5A3 | Same as 5A1 | Same as 5A1 | N | IV | NONE | | MTBF = 10843 FH<br>MTBMA = 1810 FH |

FIGURE 24- Catapult launch subsystem FMECA/MI

| FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION | | | | | DATE 5/9/85 | PAGE 6 OF 6 |
|---|---|---|---|---|---|---|
| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER: 13700 218-12997/80378 | SYSTEM/SUBSYSTEM NOMENCLATURE | INDENTURE LEVEL | REFERENCE DRAWING | MISSION | PREPARED BY<br>APPROVED BY | |
| SYSTEM/SUBSYSTEM DESCRIPTION | | | COMPENSATING PROVISIONS | | | |

| ITEM IDENT NO. | ITEM NOMENCLATURE | FUNCTION | | FUNCTIONAL FAILURE | | ENGINEERING FAILURE MODE | | FAILURE EFFECTS | | | MINIMUM EQUIPMENT LIST | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NUMBER | | LETTER | | NUMBER | | LOCAL EFFECTS | NEXT HIGHER LEVEL | END EFFECTS | | | | | |
| 13700 | Catapult launch subsystem | 6 | Indicates to crew that the bar is in the extended position | A | Fails to indicate to crew that the bar is in the extended position | 1 | Shorted | Sensor/s fail to report bar in the extended position | Warning light may not illuminate | Mission abort | Y | III | Warning light does not illuminate | Catapult launch | MTBF = 2287 cats<br>MTBMA = 991 cats |
| | | | | | | 2 | Worn or corroded sensor (3) | Same as 6A1 | Same as 6A1 | Same as 6A1 | Y | III | | Catapult launch | MTBF = 734 FH<br>MTBMA = 424 FH |

FIGURE 25- Catapult launch subsystem FMECA/MI

## RCM WORKSHEET NO. 1 SUMMARY DATA

| | | | |
|---|---|---|---|
| a) SYSTEM/SUBSYSTEM NOMENCLATURE: Catapulting Sub system | c) PART/MODEL NUMBER FSCM: 218-12937/80378 | e) INDENTURE LEVEL: 3 | h) PAGE 1 OF 16 |
| b) SYSTEM/SUBSYSTEM — LSACN: A40C; MIR INDEX CODE — WUC: 13700; CF: | d) END ITEM NOMENCLATURE, T/M/S NALC NUMBER: 7-9Z | f) PREPARED BY/DATE: 5/10/85 | i) REVISION NO/DATE: #3 |
| | | g) REVIEWED BY/DATE: | k) APPROVED BY/DATE: |

| 1) ITEM LSACN/ MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) RCM DECISION LOGIC ANSWERS (Y OR N) — FAILURE CONSEQUENCES EF 1 | ES 2 | SHF 3 | SAFETY SL 4 | OC 5 | HT 6 | CB 7 | ECONOMIC/ OPERATIONAL SL 8 | OC 9 | HT 10 | NON SAFETY HIDDEN FAILURE SL 11 | OC 12 | HT 13 | FF 14 | SAFETY HIDDEN FAILURE SL 15 | OC 16 | HT 17 | CB 18 | FF 19 | 5) RCM TASKS NO | DESCRIPTION | 6) INSPECTION INTERVAL PRELIM | PACKED | 7) LSA TASK CODE / LEVEL OF MAINTENANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A40C 13700 | Catapulting subsystem | 1A1 | Structure | | | | | | | | | | | | | | | | | | | | | | | |
| | | 1A2 | Structure | | | | | | | | | | | | | | | | | | | | | | | |
| | | 1A3 | Structure | | | | | | | | | | | | | | | | | | | | | | | |
| | | 2A1 | Structure | | | | | | | | | | | | | | | | | | | | | | | |
| | | 2A2 | Structure | | | | | | | | | | | | | | | | | | | | | | | |
| | | 2A3 | Structure | | | | | | | | | | | | | | | | | | | | | | | |
| | | 2B1 | N | | Y | | | | | | | | | | | | N | Y | | | | 001P | Visually inspect tension bar socket springs for sufficient spring tension | 400 cats | | / 0 |
| | | 3A1 | Y | N | | | | | | Y | Y | | | | | | | | | | | 001L | (Lube) Lubricate all bushing pins and cam points subject to wear | 28 Days | | / 0 |
| | | | | | | | | | | | | | | | | | | | | | | 002P | Visually inspect launch bar bushings, pins and cams for excessive wear | 27 cats | | / 0 |

FIGURE 26- RCM worksheet no.1- summary data

## RCM WORKSHEET NO. 1 SUMMARY DATA

| | | | | |
|---|---|---|---|---|
| a) SYSTEM/SUBSYSTEM NOMENCLATURE: Catapulting Sub system | c) PART/MODEL NUMBER FSCM | e) INDENTURE LEVEL | f) PREPARED BY/DATE: 5/10/85 | h) PAGE 2 OF 18 |
| b) SYSTEM/SUBSYSTEM — LSACN: A40C; MIR INDEX CODE — WUC: 13700; CF | d) END ITEM NOMENCLATURE T/M/S NALC NUMBER | | g) REVIEWED BY/DATE | i) REVISION NO./DATE; k) APPROVED BY/DATE |

| 1) ITEM LSACN/MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) RCM DECISION LOGIC ANSWERS (Y OR N) — FAILURE CONSEQUENCES | | | SAFETY | | | | ECONOMIC/OPERATIONAL | | | NON SAFETY HIDDEN FAILURE | | | | SAFETY HIDDEN FAILURE | | | | | 5) RCM TASKS | | 6) INSPECTION INTERVAL | | 7) LSA TASK CODE / LEVEL OF MAINTENANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EF 1 | ES 2 | SHF 3 | SL 4 | OC 5 | HT 6 | CB 7 | SL 8 | OC 9 | HT 10 | SL 11 | OC 12 | HT 13 | FF 14 | SL 15 | OC 16 | HT 17 | CB 18 | FF 19 | NO | DESCRIPTION | PRELIM | PACKED | |
| A40C 13700 | Catapulting sub system | 4A1 | Y | N | | | | | | Y | N | Y | | | | | | | | | | 002L | (Lube) Lubricate all gimbal fittings and areas subject to wear | 28 days | | / 0 |
| | | | | | | | | | | | | | | | | | | | | | | 011P | Remove actuating cylinder and send to higher level of maintenance for rework | 1950 FH | | / 0 |
| | | 4A2 | Y | N | | | | | | N | Y | | | | | | | | | | | 003P | Visually inspect actuating cylinder for fluid leaks resulting from cracks, chafing, damage or worn seals | 125 FH | | / 0 |
| | | 4A3 | Y | N | | | | | | N | N | N | | | | | | | | | | | No PM | | | |

FIGURE 27- RCM worksheet no.1- summary data

## RCM WORKSHEET NO. 1 SUMMARY DATA

| | | | |
|---|---|---|---|
| a) SYSTEM/SUBSYSTEM NOMENCLATURE: Catapulting Subsystem | c) PART/MODEL NUMBER FSCM | e) INDENTURE LEVEL | h) PAGE 3 OF 18 |
| b) SYSTEM/SUBSYSTEM — LSACN: A40C; MIR INDEX CODE: WUC 13700, CF | d) END ITEM NOMENCLATURE T/M/S NALC NUMBER | f) PREPARED BY/DATE 5/10/85 | i) REVISION NO/DATE |
| | | g) REVIEWED BY/DATE | k) APPROVED BY/DATE |

| 1) ITEM LSACN/ MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) RCM DECISION LOGIC ANSWERS (Y OR N): FAILURE CONSEQUENCES EF 1 | ES 2 | SHF 3 | SAFETY SL 4 | OC 5 | HT 6 | CB 7 | ECONOMIC/ OPERATIONAL SL 8 | OC 9 | HT 10 | NON SAFETY HIDDEN FAILURE SL 11 | OC 12 | HT 13 | FF 14 | SAFETY HIDDEN FAILURE SL 15 | OC 16 | HT 17 | CB 18 | FF 19 | 5) RCM TASKS NO | DESCRIPTION | 6) INSPECTION INTERVAL PRELIM | PACKED | 7) LSA TASK CODE / LEVEL OF MAINTENANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A40C 13700 | Catapulting Subsystem | 1A4 | Y | N | | | | | | N | Y | | | | | | | | | | | 004P | Visually inspect bar selector valve for fluid leaks resulting from cracks, chafing, damage or worn fittings | 125 FH | | / 0 |
| | | 4B1 | Y | N | | | | | | N | Y | | | | | | | | | | | 005P | Visually inspect electrical connections of the bar selector valve for corroded, worn or broken connectors | 200 FH | | / 0 |
| | | 5A1 | N | | N | | | | | Y | N | Y | | | | | | | | | | 003L | Same task as 002L | 28 days | | / 0 |
| | | | | | | | | | | | | | | | | | | | | | | 012P | Same task as 011P | 1950 FH | | / 0 |
| | | 5A2 | N | | N | | | | | N | Y | | | | | | | | | | | 006P | Same task as 002P | 125 FH | | / 0 |
| | | 5A3 | N | | N | | | | | | | | N | N | N | N | | | | | | | No PM | | | |
| | | 5A4 | N | | N | | | | | | | | N | Y | | | | | | | | 007P | Same task as 003P | 125 FH | | / 0 |

FIGURE 28- RCM worksheet no.1- summary data

**RCM WORKSHEET NO. 1 SUMMARY DATA**

| | | | |
|---|---|---|---|
| a) SYSTEM/SUBSYSTEM NOMENCLATURE: Catapulting Subsystem | c) PART/MODEL NUMBER FSCM | e) INDENTURE LEVEL | h) PAGE 4 OF 18 |
| | | f) PREPARED BY/DATE: 5/10/85 | i) REVISION NO./DATE |
| b) SYSTEM/SUBSYSTEM — LSACN: A40C; MIR INDEX CODE — WUC: 13700; CF: | d) END ITEM NOMENCLATURE T/M/S NALC NUMBER | g) REVIEWED BY/DATE | k) APPROVED BY/DATE |

| 1) ITEM LSACN/MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) RCM DECISION LOGIC ANSWERS (Y OR N): FAILURE CONSEQUENCES | | | SAFETY | | | | ECONOMIC/OPERATIONAL | | | NON SAFETY HIDDEN FAILURE | | | | SAFETY HIDDEN FAILURE | | | | | 5) RCM TASKS | | 6) INSPECTION INTERVAL | | 7) LSA TASK CODE / LEVEL OF MAINTENANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EF 1 | ES 2 | SHF 3 | SL 4 | OC 5 | HT 6 | CB 7 | SL 8 | OC 9 | HT 10 | SL 11 | OC 12 | HT 13 | FF 14 | SL 15 | OC 16 | HT 17 | CB 18 | FF 19 | NO | DESCRIPTION | PRELIM | PACKED | |
| A40C 13700 | Catapulting Subsystem | 5R1 | Y | N | | | | | | Y | Y | | | | | | | | | | | 004L | (Lube) Lubricate all bushings pins and cam points subject to wear | 28 days | | / 0 |
| | | | | | | | | | | | | | | | | | | | | | | 008P | Visually inspect launch bar leaf retracting springs for wear or cracks | 975 cats | | / 0 |
| | | 5C1 | Y | N | | | | | | Y | Y | | | | | | | | | | | 009P | Same as task 004P | 200 FH | | / 0 |
| | | CA1 | Y | N | | | | | | N | N | N | | | | | | | | | | | No PM | | | |
| | | 6A2 | Y | N | | | | | | Y | Y | | | | | | | | | | | 010P | Visually inspect for broken sensors or corrosion | 150 FH | | / 0 |

FIGURE 29- RCM worksheet no.1- summary data

| RCM WORKSHEET NO. 2 FAILURE CONSEQUENCE/SERVICING/LUBRICATION TASK EVALUATION | | | | | | | | | | | | DATE 5/10/85 | | PAGE 1 OF 18 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCE DETERMINATION: a) QUESTION 1 IS THE FAILURE OCCURRENCE EVIDENT TO THE CREW OR OPERATOR WHILE PERFORMING NORMAL DUTIES? | | b) QUESTION 2 DOES THE FAILURE CAUSE A FUNCTION LOSS OR SECONDARY DAMAGE THAT COULD HAVE A DIRECT ADVERSE EFFECT ON OPERATING SAFETY? | | c) QUESTION 3 DOES THE HIDDEN FAILURE ITSELF OR IN COMBINATION WITH ANOTHER FAILURE HAVE AN ADVERSE EFFECT ON OPERATING SAFETY? | | 4) FAIL CONSEQ | 5) DESCRIBE SERVICING OR LUBRICATION TASK: a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL | d) PROPOSED LEVEL OF MAINTENANCE | | | e) IS SERVICING OR LUBRICATION TASK APPLICABLE AND EFFECTIVE? |
| | | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | | | | | O | I | D | |
| A4[illegible] 1370 | 1C1 | N | Crew will not know tension bar separated from socket | | | Y | Tension bar could FOD engine or injure flight deck crew | Safety Hidden | --- | None | ---- | -- | -- | -- | No |
| | 1A1 | Y | Inability to properly align launch bar with catapult shuttle | Y | Mission abort before damage or safety can be effected | | | Econ/ oper | 0011 | (Lube) Lubricate all bushing pins and cam points subject to wear | 28 days | X | | | Yes |
| | 1A1 | Y | Launch bar warning light will not illuminate (plus) catapult crew will notice launch bar bar not extended | N | Mission abort because bar does not extend | | | | 0021 | (Lube) Lubricate all gimbal fittings and area subject to wear | 28 days | X | | | Yes |
| | 1 | | | N | Same as 4A1 | | | | - | None | ----- | -- | -- | -- | No |
| | 1A3 | | | N | Same as 4A1 | | | | - | None | ----- | -- | -- | -- | No |
| | 1A4 | | | N | Same as 4A1 | | | | - | None | ----- | -- | -- | -- | No |
| A4[illegible] 13700 | 4B1 | Y | Launch bar warning light may not illuminate and catapult crew will notice improper operation of launch bar | N | Same as 4A1 | | | Econ/ Oper | - | None | ----- | -- | -- | -- | No |

FIGURE 30- RCM worksheet no.2- failure consequence/servicing/lubrication task evaluation

| RCM WORKSHEET NO. 2 FAILURE CONSEQUENCE/SERVICING/LUBRICATION TASK EVALUATION | | | | | | | | | | | DATE 5/10/85 | PAGE 6 OF 18 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCE DETERMINATION: a) QUESTION 1 IS THE FAILURE OCCURRENCE EVIDENT TO THE CREW OR OPERATOR WHILE PERFORMING NORMAL DUTIES? | | b) QUESTION 2 DOES THE FAILURE CAUSE A FUNCTION LOSS OR SECONDARY DAMAGE THAT COULD HAVE A DIRECT ADVERSE EFFECT ON OPERATING SAFETY? | | c) QUESTION 3 DOES THE HIDDEN FAILURE ITSELF OR IN COMBINATION WITH ANOTHER FAILURE HAVE AN ADVERSE EFFECT ON OPERATING SAFETY? | | 4) FAIL CONSEQ | 5) DESCRIBE SERVICING OR LUBRICATION TASK: a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL | d) PROPOSED LEVEL OF MAINTENANCE | | | 6) IS SERVICING OR LUBRICATION TASK APPLICABLE AND EFFECTIVE ? |
| | | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | | | | | O | I | D | |
| | [illegible]A1 | N | Launch bar will retract b means of the leaf retracting spring with no indication of failure | | | N | Launch bar will retract by means of leaf retracting prings | Non-safety hidden | 003L | Same as 4A1 | ------ | -- | -- | -- | Yes |
| | [illegible]A2 | | | | | N | Same as 5A1 | Non-safety hidden | --- | None | ------ | -- | -- | -- | No |
| | [illegible]A3 | | | | | N | Same as 5A1 | Non-safety hidden | --- | None | ------ | -- | -- | -- | No |
| | [illegible]A4 | | | | | N | Same as 5A1 | Non-safety hidden | --- | None | ------ | -- | -- | -- | No |
| A4[illegible] 137[illegible] | B1 | Y | Launch bar warning light will warn crew the bar has not retracted | N | Mission abort before damage or safety can be effected | | | Econ/ Oper | 004L | (lube) Lubricate all bushings, pins and cam points subject to wear | 28 days | X | | | Yes |
| | [illegible]1 | Y | Launch bar warning light will remain lit if launch bar does not retract | N | Same as 5B1 | | | | ---- | None | ------ | -- | -- | -- | No |

FIGURE 31- RCM worksheet no.2- failure consequence/servicing/lubrication task evaluation

## RCM WORKSHEET NO. 2 FAILURE CONSEQUENCE/SERVICING/LUBRICATION TASK EVALUATION

DATE 5/10/85 PAGE ___ OF 10

| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCE DETERMINATION | | | | | | 4) FAIL CONSEQ | 5) DESCRIBE SERVICING OR LUBRICATION TASK | | | | | | 6) IS SERVICING OR LUBRICATION TASK APPLICABLE AND EFFECTIVE ? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a) QUESTION 1 IS THE FAILURE OCCURRENCE EVIDENT TO THE CREW OR OPERATOR WHILE PERFORMING NORMAL DUTIES? | | b) QUESTION 2 DOES THE FAILURE CAUSE A FUNCTION LOSS OR SECONDARY DAMAGE THAT COULD HAVE A DIRECT ADVERSE EFFECT ON OPERATING SAFETY? | | c) QUESTION 3 DOES THE HIDDEN FAILURE ITSELF OR IN COMBINATION WITH ANOTHER FAILURE HAVE AN ADVERSE EFFECT ON OPERATING SAFETY? | | | a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL | d) PROPOSED LEVEL OF MAINTENANCE | | | |
| | | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | | | | | O | I | D | |
| | A1 | Y | Crew will not [illegible] warning light [illegible] not illuminated when bar is in the extended position | N | Same as 5B1 | | | | --- | None | ------- | -- | -- | --- | [illegible] |
| | A2 | | | N | Same as 5B1 | | | | --- | None | ------- | -- | -- | --- | [illegible] |

FIGURE 32- RCM worksheet no.2- failure consequence/servicing/lubrication task evaluation

**RCM WORKSHEET NO. 3 ON-CONDITION TASK EVALUATION** DATE 5/10/85 PAGE 8 OF 18

| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) ON-CONDITION TASK APPLICABILITY CRITERIA a) MEANS TO DETECT REDUCED FAILURE RESISTANCE | 4) b) POTENTIAL FAILURE CONDITION DETECTABLE BY AN EXPLICIT TASK | 4) INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | 5) DESCRIBE APPLICABLE ON-CONDITION TASK a) NUMBER | 5) b) DESCRIPTION | 5) c) PRELIMINARY INTERVAL (ENG) | 5) d) PROPOSED MAINTENANCE LEVEL O | I | D | 6) EFFECTIVENESS CRITERIA a) SAFETY PROB OF FAILURE | 6) b) SAFETY HIDDEN FAILURE PROB OF MULTIPLE FAILURE | 6) c) OPERATIONAL/ECONOMIC AND NON SAFETY HIDDEN FAILURE 1) IS FFR HIGH? | 6) c) 2) OPERATING COSTS? | 6) c) 3) HIGH REPAIR OR OPERATING COSTS? | 6) c) 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A40C 13700 | 2B1 | Safety | Visual Inspection | Insufficient spring tension | 0-1200 cats | 001P | Visually inspect and test the tension bar socket springs for sufficient spring tension | 300 cats | X | | | Pacc= 1.02X $10^{-4}$ Pf = 1.00X $10^{-4}$ | | | | | | Yes |
| A40C 13700 | 3A1 | Econ/ Oper | Visual Inspection | Excessive play between launch bar bushings and cam pins | 54 cats | 002P | Visually inspect launch bar bushings, pins, and cams for excessive wear | 27 cats | X | | | --- | --- | Yes | Yes | | Yes | Yes |
| | 4A1 | | NA | ------ | ------ | --- | ------------- | ---- | | | | --- | --- | --- | --- | --- | ---- | No |
| | 4A2 | | Visual Inspection | Leaking fluid | 0-250 FH | 003P | Visually inspect actuating cylinder for fluid leaks resulting from cracks, chafing, damage or worn seals | 125 FH | X | | | ---- | --- | No | | Yes | Yes | Yes |
| | 4A3 | | NA | ------ | ------ | --- | ------------- | ---- | | | | --- | --- | --- | --- | --- | ---- | No |

FIGURE 33- RCM worksheet no.3- on-condition task evaluation

# RCM WORKSHEET NO. 3 ON-CONDITION TASK EVALUATION

DATE 5/10/85 PAGE 9 OF 18

| 1) ITEM LSACN/MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) ON-CONDITION TASK APPLICABILITY CRITERIA: a) MEANS TO DETECT REDUCED FAILURE RESISTANCE | 4) b) POTENTIAL FAILURE CONDITION DETECTABLE BY AN EXPLICIT TASK | 4) c) INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | 5) DESCRIBE APPLICABLE ON-CONDITION TASK: a) NUMBER | 5) b) DESCRIPTION | 5) c) PRELIMINARY TASK INTERVAL (ENG) | 5) d) PROPOSED MAINTENANCE LEVEL: O | I | D | 6) EFFECTIVENESS CRITERIA: a) SAFETY: PROB OF FAILURE | 6) b) SAFETY HIDDEN FAILURE: PROB OF MULTIPLE FAILURE | 6) c) OPERATIONAL/ECONOMIC AND NON SAFETY HIDDEN FAILURE: 1) IS FFR HIGH? | 6) c) 2) OPERATING COSTS? | 6) c) 3) HIGH REPAIR OR OPERATING COSTS? | 6) c) 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A40C 13700 | 4A1 | Non/ Oper | Visual Inspection | Leaking fluid | D-250 FH | 004P | Visually inspect bar selectors valve for fluid leaks resulting from cracks, chafing, damaged or worn fittings | 125FH | X | | | --- | --- | NO | | Yes | Yes | Yes |
| | 4B1 | Non/ Oper | Visual Inspection | Worn or corroded connector | D-400 FH | 005P | Visually inspect electrical connections of the bar selector valve for corroded worn, and broken connectors | 200FH | X | | | --- | --- | No | | Yes | Yes | Yes |
| | 5A1 | Non safety hidden | NA | ----- | ----- | -- | -------------- | --- | | | | --- | --- | --- | ---- | --- | ------ | No |
| | 5A2 | Non safety hidden | Visual Inspection | Leaking fluid | D-250 FH | 006P | Same as task 00[illegible]P | 125FH | x | | | --- | ---- | No | | Yes | Yes | Yes |
| | 5A3 | | NA | ------ | ----- | --- | -------------- | ---- | | | | --- | ---- | --- | ---- | --- | ------- | No |
| | 5A4 | | Visual Inspection | Leaking fluid | D-250 FH | 007P | Same as task 004P | 125FH | x | | | --- | ---- | No | | Yes | Yes | Yes |

FIGURE 34- RCM worksheet no.3- on-condition task evaluation

| RCM WORKSHEET NO. 3 ON-CONDITION TASK EVALUATION | | | | | | | | | | | | | | | | | | | DATE 5/10/85 | PAGE 10 OF 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) ON-CONDITION TASK APPLICABILITY CRITERIA: a) MEANS TO DETECT REDUCED FAILURE RESISTANCE | 4) b) POTENTIAL FAILURE CONDITION DETECTABLE BY AN EXPLICIT TASK | 4) c) INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | 5) DESCRIBE APPLICABLE ON-CONDITION TASK: a) NUMBER | 5) b) DESCRIPTION | 5) c) PRELIMINARY TASK INTERVAL (ENG) | 5) d) PROPOSED LEVEL OF MAINTENANCE: O | I | D | 6) EFFECTIVENESS CRITERIA: a) SAFETY: PROB OF FAILURE | 6) b) SAFETY HIDDEN FAILURE: PROB OF MULTIPLE FAILURE | 6) c) OPERATIONAL/ECONOMIC AND NON SAFETY HIDDEN FAILURE: 1) IS FFR HIGH? | 2) OPERATING COST | 3) HIGH REPAIR OR OPERATING COSTS? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? | | |
| M?C 1?/?? | ?1 | Econ/ Oper | Visual Inspection | Crack and wear greater than [illegible] | D-1950 cats | 008I | Visually inspect launch bar leaf retracting spring for wear and cracks | 975 cats | x | | | --- | ---- | No | | Yes | Yes | Yes | | |
| | 1 | Econ/ Oper | Visual Inspection | Worn or corroded connector | D-400 FH | 009P | Same as task 005P | 200FH | x | | | --- | --- | No | | Yes | Yes | Yes | | |
| | ?1 | Econ/ Oper | NA | ----- | ----- | -- | ---------------- | --- | | | | --- | --- | --- | -- | --- | --- | No | | |
| | | Econ/ Oper | Visual Inspection | Worn or corroded [illegible] | D-300 FH | 010P | Visually inspect for broken sensors or corrosion | 150FH | x | | | --- | --- | No | | Yes | Yes | Yes | | |

FIGURE 35- RCM worksheet no.3- on-condition task evaluation

**RCM WORKSHEET NO. 4 HARD TIME TASK EVALUATION** DATE 5/10/85 PAGE 11 OF 18

| 1) ITEM LSACN/MIR CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) HARD TIME TASK APPLICABILITY CRITERIA — COMPLETE FOR REWORK TASKS ONLY: a) IS IT POSSIBLE TO RESTORE FAILURE RESISTANCE OF ITEM BY REWORK TASK | NON SAFETY DISCARD TASKS ONLY: b) WEAROUT AGE | c) PERCENTAGE OF ITEMS WHICH SURVIVE TO THIS AGE | SAFETY OR SHF DISCARD TASKS: d) LIFE LIMIT | 5) DESCRIBE APPLICABLE HARD TIME TASK: a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL (ENG) | d) PROPOSED MAINTENANCE LEVEL: O | I | D | 6) EFFECTIVENESS CRITERIA: a) SAFETY PROB OF FAILURE | b) SAFETY HIDDEN FAILURE PROB OF MULTIPLE FAILURE | c) OPERATIONAL/ECONOMIC AND NON SAFETY HIDDEN FAILURE: 1) IS FFR HIGH? | 2) OPERATING COST? | 3) HIGH REPAIR OR OPERATING COSTS? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M40C 13700 | 1A1 | Econ/Oper | Yes | 1950 FH | 85% | --- | 011P | Remove actuating cylinder and send to higher level of maintenance for rework | 1950 FH | x | | | --- | ---- | No | | Yes | Yes | Yes |
| | 4A3 | Econ/Oper | Yes | No-F | ---- | --- | --- | ----------------- | --- | | | | --- | ------ | ----- | --- | ------ | ---------- | No |
| | 5A1 | Non Safety hidden | Yes | 1350 FH | 15% | --- | 012P | Same as task 011P | 1950 FH | x | | | --- | ------ | No | | Yes | Yes | Yes |
| | 5A3 | Non Safety hidden | Yes | No-D | ---- | --- | --- | ----------------- | --- | | | | --- | ------ | ----- | --- | ------ | ---------- | No |
| | 6A1 | Econ/Oper | No | ---- | ---- | --- | --- | ----------------- | --- | | | | --- | ------ | ----- | --- | ------ | ---------- | No |

FIGURE 36- RCM worksheet no.4- hard time task evaluation

| RCM WORKSHEET NO. 5 COMBINATION/FAILURE FINDING TASK EVALUATION | | | | | | | | | | | | | | | | | DATE 5/10/85 | PAGE 17 OF 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQ | 4) APPLICABILITY CRITERIA: a) COMBINATION TASK (COMB) — DO THE TASKS MEET THEIR INDIVIDUAL APPLICABILITY CRITERIA? | 4) b) FAILURE FINDING TASK (FF) — IS AN OC, HT, OR COMB (FOR SAFETY HIDDEN FAILURES) TASK APPLICABLE AND EFFECTIVE FOR THIS FFMC? | 5) DESCRIBE APPLICABLE TASK: a) NO | 5) b) DESCRIPTION STATE IN PARENTHESIS IF TASK IS (COMB) OR (FF) | 5) c) PRELIM TASK INTERVAL (ENG) | 5) d) PROPOSED LEVEL OF MAINT: O | I | D | 6) EFFECTIVENESS CRITERIA: a) SAFETY AND SAFETY HIDDEN FAILURE — PROBILITY OF FAILURE OR MULTIPLE FAILURE | 6) b) NON SAFETY HIDDEN FAILURES (COST EFFECTIVENESS DIAGRAM): 1) IS FFR HIGH ? | 2) OPERAT CONSEQ ? | 3) HIGH REPAIR OR OPER COSTS ? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS THE TASK APPLIC-ABLE AND EFFECTIVE ? | | |
| A4 137 [illegible] | A2 | Non safety hidden | ---------- | No | | (FF) Perform functional test of catapult subsystem | 750 cats | ✓ | | | | No | --- | No | ------- | No | | |

FIGURE 37- RCM worksheet no.5- combination/failure finding task evaluation

**RCM WORKSHEET NO 6 — SSI TASK EVALUATION** — PAGE 1 OF [illegible]

**1) SSI IDENTIFICATION**

| a) NOMENCLATURE | d) LOCATION FS | WS | WL | b) LSACN | c) MIR INDEX CODE WUC | TEC | CF |
|---|---|---|---|---|---|---|---|
| Catapult Launch Bar | | | | A4[illegible] 1 | 137 | | |

**2) SSI TECHNICAL DATA**

| a) FATIGUE DESIGN LIFE: END ITEM | SSI | DAMAGE TOLERANT b) CRACK LIFE: DETECT | CRIT | c) RESIDUAL STRENGTH | d) SAFE LIFE LIMIT | e) ACCESS: INTERNAL | EXTERNAL |
|---|---|---|---|---|---|---|---|
| [illegible] FH | 350 cats | 201 cats | [illegible] cats | Less than 100% at critical crack | NA | | x |

**3) SSI RATING FACTORS, 4) FFMC, 5) SSI STRUCTURES LOGIC ANSWERS, 6) TASK DESCRIPTION, 7) AGE EXPL CAND?**

| a) FATIGUE DAMAGE RS | LDC | CPL | b) ENVIRONMENTAL DAMAGE MT | SP | EP | AVG | c) ACCIDENTAL DAMAGE DS | GO | FO | LO | AVG | 4) FFMC | 5) 1 DT | 2 GOC | 3 DOC | 4 AE | 5 HI | 6 GOC | 7 DOC | 8 AE | 6) NO | TYPE | DESCRIPTION | PREL INSP INTVL | LOW O | I | D | 7) YES | NO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | [illegible] | 4 | 1 | 1 | 1 | 1 75 | 1A1 | Y | N | Y | | | | | | 0110 | DOC | Clean bar at tee section and perform inspection using magnification to find cracks greater then 10 inches | 51 cats | x | | | | x |
| | | | | | | | | | | | | 1A2 | Y | Y | | | | | | | 0121 | COC | Perform visual inspection to find corrosion greater than 10 inches | Before each cat shot | x | | | | x |
| | | | | | | | | | | | | 1A3 | Y | Y | | | | | | | 0131 | COC | Perform visual inspection to find nicks and scratches greater than 10 inches | Before each cat shot | x | | | | x |

FIGURE 38- RCM worksheet no.6- SSI task evaluation

**RCM WORKSHEET NO 6 — SSI TASK EVALUATION** — PAGE 14 OF 18

**1) SSI IDENTIFICATION**

- a) NOMENCLATURE: Tension Bar Socket (catapult subsystem)
- b) LSACN: A40034
- c) MIR INDEX CODE: WUC 13700; TEC; CF
- d) LOCATION: FS; WS; WL

**2) SSI TECHNICAL DATA**

- a) FATIGUE DESIGN LIFE: END ITEM 10,000 FH; SSI 8500 cats
- DAMAGE TOLERANT: b) CRACK LIFE: DETECT NA; CRIT NA; c) RESIDUAL STRENGTH: NA
- d) SAFE LIFE LIMIT: 2700 cats
- e) ACCESS: INTERNAL; EXTERNAL √

| 3) SSI RATING FACTORS: a) FATIGUE DAMAGE RS | LDC | CPL | b) ENVIRONMENTAL DAMAGE MT | SP | EP | AVG | c) ACCIDENTAL DAMAGE DS | GO | FO | LO | AVG | 4) FFMC | 5) SSI STRUCTURES LOGIC ANSWERS 1 DT | 2 GOC | 3 DOC | 4 AE | 5 HT | 6 GOC | 7 DOC | 8 AE | 6) TASK DESCRIPTION NO | TYPE | DESCRIPTION | PREL INSP INTVL | LOM O | I | D | 7) AGE EXPL CAND? YES | NO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3 | 3 | 1 | 2.3 | 3 | 1 | 1 | 2 | 1.75 | 2A1 | N | | | | Y | | | | 014P | HT | Remove and discard socket | 2700 cats | x | | | | x |
| | | | | | | | | | | | | 2A2 | N | | | | N | Y | | | 015P | GOC | Visually inspect socket for corrosion | Before each cat shot | x | | | | x |
| | | | | | | | | | | | | | | | | | | | | | | HT | Same as task 014P | ----- | x | | | | x |
| | | | | | | | | | | | | 2A3 | N | | | | N | N | Y | | 016P | GOC | Visually inspect socket for nicks and scratches | Before each cat shot | x | | | | x |
| | | | | | | | | | | | | | | | | | | | | | | DOC | Perform NDI on socket for nicks and scratches Any marks deeper than .10 inches Discard socket assembly | 56 days | x | | | | x |

FIGURE 39- RCM worksheet no.6- SSI task evaluation

**RCM WORKSHEET NO 6 — SSI TASK EVALUATION** PAGE 15 OF 18

| 1) SSI IDENTIFICATION | | | | | 2) SSI TECHNICAL DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a) NOMENCLATURE | d) LOCATION | | | | a) FATIGUE DESIGN LIFE | | DAMAGE TOLERANT | | | d) SAFE LIFE LIMIT | e) ACCESS | |
| | FS | WS | WL | | | | b) CRACK LIFE | | c) RESIDUAL STRENGTH | | INTERNAL | EXTERNAL |
| b) LSACN | c) MIR INDEX CODE | | | | END ITEM | SSI | DETECT | CRIT | | | | |
| | WUC | TEC | CF | | | | | | | | | |

| 3) SSI RATING FACTORS | | | | | | | | | | | | 4) FFMC | 5) SSI STRUCTURES LOGIC ANSWERS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a) FATIGUE DAMAGE | | | b) ENVIRONMENTAL DAMAGE | | | | c) ACCIDENTAL DAMAGE | | | | | | | | | | | | | |
| RS | LDC | CPL | MT | SP | EP | AVG | DS | GO | IO | LO | AVG | | 1 DT | 2 GOC | 3 DOC | 4 AE | 5 HT | 6 GOC | 7 DOC | 8 AE |
| | | | | | | | | | | | | | | | | | | | | |

| 6) TASK DESCRIPTION | | | | | | | 7) AGE EXPL CAND? | |
|---|---|---|---|---|---|---|---|---|
| NO | TYPE | DESCRIPTION | PREL INSP INTVL | LOM | | | | |
| | | | | O | I | D | YES | NO |
| | HT | Same as task 014p | --- | X | | | | |

FIGURE 40- RCM worksheet no.6- SSI task evaluation

| RCM WORKSHEET NO. 7 DETERMINATION OF AGE EXPLORATION TASKS | | | | | | | | | | | | | | | | | | | DATE 5/1?/85 | | PAGE 16 OF 18 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) DEFAULT FAILURE CONSEQ (W/S 2) | 5) DEFAULT TASK EVALUATION TYPE TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) PROPOSED LEVEL OF MAINTENANCE O | I | D | e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 Y/N | b) QUESTION #2 Y/N | JUSTIFICATION | c) QUESTION #3 Y/N | JUSTIFICATION | d) QUESTION #4 Y/N | JUSTIFICATION | 8) TASK/CATEGORY OAEI I | OAEI II | SAEI I | SAEI II | RASS |
| 7400C 13700 | Catapult launch subsystem | 2B1 | Safety | SC | Internal between potential and functional failure | Visually inspect and test spring tension to determine potential failure and degradation of spring | 50 assemblies | | | | Until failure | Y | Y | I h testing to failure must be performed | | | | | | | X | | |
| | | 4A2 | Econ/Oper | OC | | Perform actuarial analysis | 30 assemblies | X | | | | Y | | | Y | Failure causes a mission abort | Y | Fleet personnel can perform task | | X | | | |
| | | 4A3 | | IT | Wearout age | | 30 assemblies | X | | | | Y | | | Y | | Y | | | X | | | |
| | | 4A4 | | H | Interval between potential and functional failure | | 30 assemblies | X | | | | Y | | | Y | | Y | | | X | | | |

FIGURE 41- RCM worksheet no.7- determination of age exploration tasks

| RCM WORKSHEET NO 7 DETERMINATION OF AGE EXPLORATION TASKS | | | | | | | | | | | | | | | | | | DATE 5/10/85 | | PAGE 17 OF 18 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/ MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) DEFAULT FAILURE CONSEQ (W/S 2) | 5) DEFAULT TASK EVALUATION TYPE TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) | | | e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 | b) QUESTION #2 | | c) QUESTION #3 | | d) QUESTION #4 | | 8) TASK/ CATEGORY UA | | SA | | RASS |
| | | | | | | | | O | I | D | | Y/N | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | i | ii | i | ii | |
| A40C 13700 | Catapult Launch Subsystem | 4B1 | Econ/ Oper | OC | Interval between potential and functional failure | Perform actuarial analysis | 30 assemblies | X | | | Until failure | Y | | | Y | Failure causes a mission abort | Y | Fleet personnel can perform task | | X | | | |
| | | 5A2 | | CC | | | 30 assemblies | X | | | | Y | | | N | No benefits will be gained by performing AE | | | | | | | X |
| | | 5A3 | | HT | Wearout age | | 30 assemblies | X | | | | N | | | N | | | | | | | | X |
| | | 5A4 | | OC | Interval between potential and functional failure | | 30 assemblies | X | | | | N | | | N | | | | | | | | X |

FIGURE 42- RCM worksheet no.7- determination of age exploration tasks

## RCM WORKSHEET NO 7 DETERMINATION OF AGE EXPLORATION TASKS

DATE 5/10/85 PAGE 18 OF 18

| 1) ITEM LCN/MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FMC | 4) DEFAULT FAILURE CONSEQ (W-2) | 5) DEFAULT TASK EVALUATION TYPE TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) O | d) I | d) D | e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 Y/N | b) QUESTION #2 Y/N | b) JUSTIFICATION | c) QUESTION #3 Y/N | c) JUSTIFICATION | d) QUESTION #4 Y/N | d) JUSTIFICATION | 8) TASK/CATEGORY DAET I | DAET II | SAET I | SAET II | PAES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A40C | Catapult Launch Subsystem | 5B1 | Econ/ Oper | OC | Interval between potential and functional failure | Perform actuarial analysis | 30 assemblies | X | | | Until failure | Y | | | Y | Failure causes a mission abort | Y | | | X | | | |
| | | 5C1 | | OC | | | 30 assemblies | X | | | | N | | | N | No benefits will be gained by AE study | | | | | | | ✓ |
| | | 6A2 | | OC | | | 30 assemblies | X | | | | N | | | Y | Failure causes a mission abort | Y | Fleet personnel can perform the task | | X | | | |

FIGURE 43- RCM worksheet no.7- determination of age exploration tasks

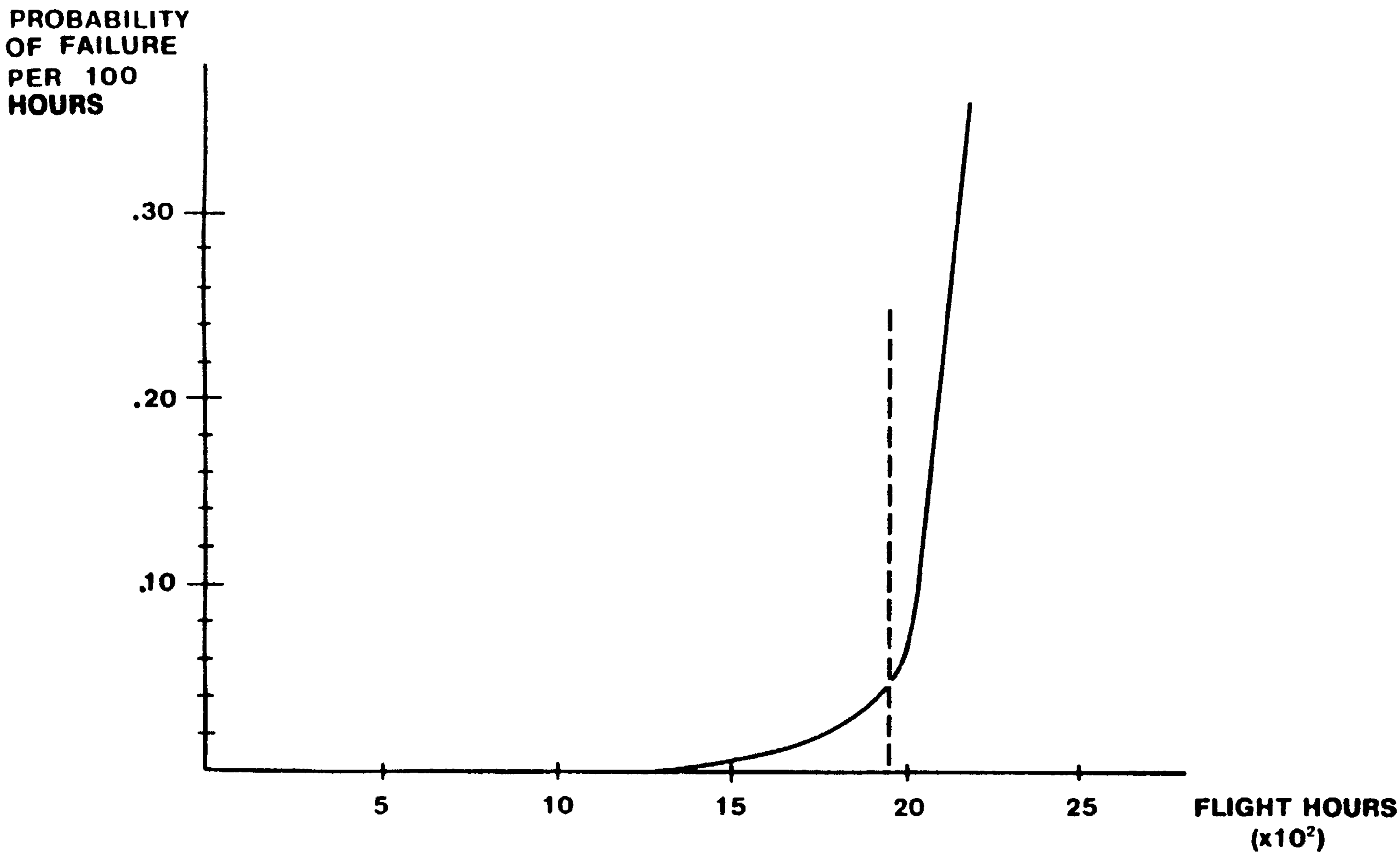



FIGURE 44- Conditional probability of failure curve for launch bar actuating cylinder

RATIONALE SHEET

Worksheet #6, Column 4 = Structural rating factors for the launch bar:

Residual Strength (RS) = 1 - The residual strength is 100% at critical crack length.

Life to Detectable Crack (LDC) = 1 - The mean life to detectable crack of 201 catapults was obtained from the test data. The estimated catapults for the life of the aircraft was obtained by using the projected aircraft life of 10,000 flight hours. The ratio was calculated in the following manner:

$$\frac{201 \text{ cats}}{10{,}000 \text{ FH} \times \frac{2.73 \text{ cats}}{10 \text{ FH}}} \times 100\% = 7.4\%$$

Crack Propagation Life (CPL) = 3 - The mean crack propagation rate of 154 catapults was obtained from the test data. The ratio was calculated as follows:

$$\frac{154 \text{ cats}}{350 \text{ cats}} \times 100\% = 44\%$$

Material (MT) = 3 - The bar is a steel casting.

Surface Protection (SP) = 3 - Primer/painted.

Exposure to Corrosion (EP) = 1 - The bar will be exposed to salt water.

Design, manufacturer, errors (DS) = 4 - The bar is a simple assembly and is easily manufactured.

Ground Operations (GO) = 1 - The aircraft will be based primarily on a carrier.

Flight Operations (FO) = 1 - The aircraft will be based primarily on a carrier.

Location (LO) = 1 - The bar is located externally with easy ground access.

FFMC 1A1 Column 5, worksheet 6:

Question #1(Y) - The launch bar has a slow crack growth, damage tolerant structure.

Question #2(N) - Task is not applicable, there is a need for NDI equipment to insure a crack of .10 inches is found.

Question #3(N) - The task meets the applicability and effectiveness criteria for a detailed on-condition task.

FFMC 1A2 Column 5 worksheet 6:

Question #1(Y) - The launch bar has a slow crack growth, damage tolerant structure.

Question #2(Y) - The task meets the applicability and effectiveness criteria for a general on-condition task.

FFMC 1A3 Column 5 worksheet 6:

Question #1(Y) - The launch bar has a slow crack growth, damage tolerant structure.

Question #2(Y) - The task meets the applicability and effectiveness criteria for a general on-condition task.

FFMC 1A1 Column 6, worksheet 6:

Preliminary Inspection Interval = 1/3 CPL

$$1/3\ (154) = 51.3 \simeq 51 \text{ CATS}$$

FFMC 2A1 Column 5, worksheet 6:

Question #1(N) - The tension bar socket has a rapid crack propagation life which makes it a safe life structure.

Question #5(Y) - The socket has a safe life limit and a hard time discard task will protect the life limit.

FFMC 2A2 Column 5, worksheet 6:

Question #1(N) - The tension bar socket has a rapid crack propagation life which makes it a safe life structure.

Question #5(N) - A hard time task by itself will not protect the socket from enviromental damage

Question #6(N) - A general on-condition task by itself will not protect the socket from enviromental damage.

Question #7(Y) - A combination general on-condition, detailed on-condition, and hard time task are applicable and effective.

FFMC 2A3 Column 5, worksheet 6:

Question #1(N) - The tension bar socket has a rapid crack propagation life which makes it a safe life structure.

Question #5(N) - A hard time task by itself will not protect the socket from enviromental damage.

Question #6(N) - A general on-condition task by itself will not protect the socket from enviromental damage.

Question #7(Y) - A combination general on-condition, detailed on-condition and hard time task are applicable and effective.

FFMC 2A1 Column 6, worksheet 6:

Safe Life Limit = 1/3 tested life limit

$$= 1/3\ (8091) = 2697 \simeq 2700 \text{ CATS}$$

The acceptable probability of failure (see paragraph 5.2.3.2.1) of this significant item was calculated as follows:

$$Pacc = \frac{.5}{(AC)(SCI)(FM)} = \frac{.5}{(350)(2)(7)}$$

$$= .000102 \text{ or } 1.02 \times 10^{-4}$$

Calculations for FFMC 2B1:

The analyst assumed that during one inspection insufficient spring tension can be detected 90% of the time because of the location and ease in finding defective springs. The following equation was used to determine the items probability of failure

$$P_f = (1 - \theta)^n$$

Using the acceptable probability of failure (Pacc) the analyst determines the number of inspections required.

$$1.02 \times 10^{-4} = (1 - .90)^n$$

$$n = \frac{\text{Log}\ (1.02 \times 10^{-4})}{\text{Log}\ (1 - .90)}$$

$$n = 3.99$$

Preliminary inspection interval is:

$$\frac{1200 \text{ CATS}}{3.99} = 300.75 \cong 300 \text{ CATS}$$

The actual Probability of Failure ($P_f$) is:

$$P_f = (1 - .90)^{\frac{1200}{300}} = 1.00 \times 10^{-4}$$

Calculation for FFMC 3A1:

The average cycles between initial and excessive vibration were used because the failure consequences were operational/economic. The calculations for the preliminary task interval are as follows:

$$\frac{54 \text{ cats}}{2} = 27 \text{ cats}$$

Calculations for FFMC 4A2, 4A4, 5A2, and 5A4:

No directly related data were obtained for a leaking actuating cylinder or bar selector valve. Therefore, engineering calculations were made to determine the interval between potential and functional failure. These calculations revealed it would take approximately 250 FH for a cylinder or valve to proceed to failure after it starts leaking. Calculation for the preliminary task interval is as follows:

$$\frac{250 \text{ FH}}{2} = 125 \text{ FH}$$

Calculations for FFMCs 4B1 and 5C1:

No directly related data was obtained for faulty electrical connectors, therefore engineering calculations were made to estimate the interval between potential and functional failure. These engineering calculations revealed it would take approximately 400 FH for the connectors to proceed to failure. Calculations for the preliminary task interval is as follows:

$$\frac{400 \text{ FH}}{2} = 200 \text{ FH}$$

Calculation for FFMC 5B1:

$$\frac{1950 \text{ cycles}}{2} = 975 \text{ cycles or CATS}$$

Calculation for FFMC 6A2:

Engineering calculations and estimations revealed it would take approximately 300 FH for the sensors to proceed to failure. Calculation for the preliminary task interval is as follows:

$$\frac{300 \text{ FH}}{2} = 150 \text{ FH}$$

APPENDIX A

## EXAMPLE 2 - WHEEL BRAKE ASSEMBLY

DESIGN DESCRIPTION

The brake is a hydraulically operated, multiple-disk brake designed to use hydraulic fluid MIL-H-83282.

When pressure is applied to the brake pedals, the hydraulic fluid is regulated through the meter valve and the brake is actuated by the hydraulic pressure applied to the piston housing assembly at either of two pairs of inlet ports. The shuttle valve automatically selects correct pair and blocks the ports not in use.

Hydraulic pressure in the piston housing assembly forces the pistons against the retractor plate. This overcomes the adjuster assemblies spring load and applies clamping forces to the stationary and rotating heat stack components. The clamping force of the stator end plate, stators, and plate on the wheel-drive rotors stops wheel rotation during braking.

Upon release of hydraulic pressure, springs in the adjuster assemblies retract pulling the retractor plate back against the piston housing assembly. This provides clearance between the retractor plate and heat stack for the next brake application.

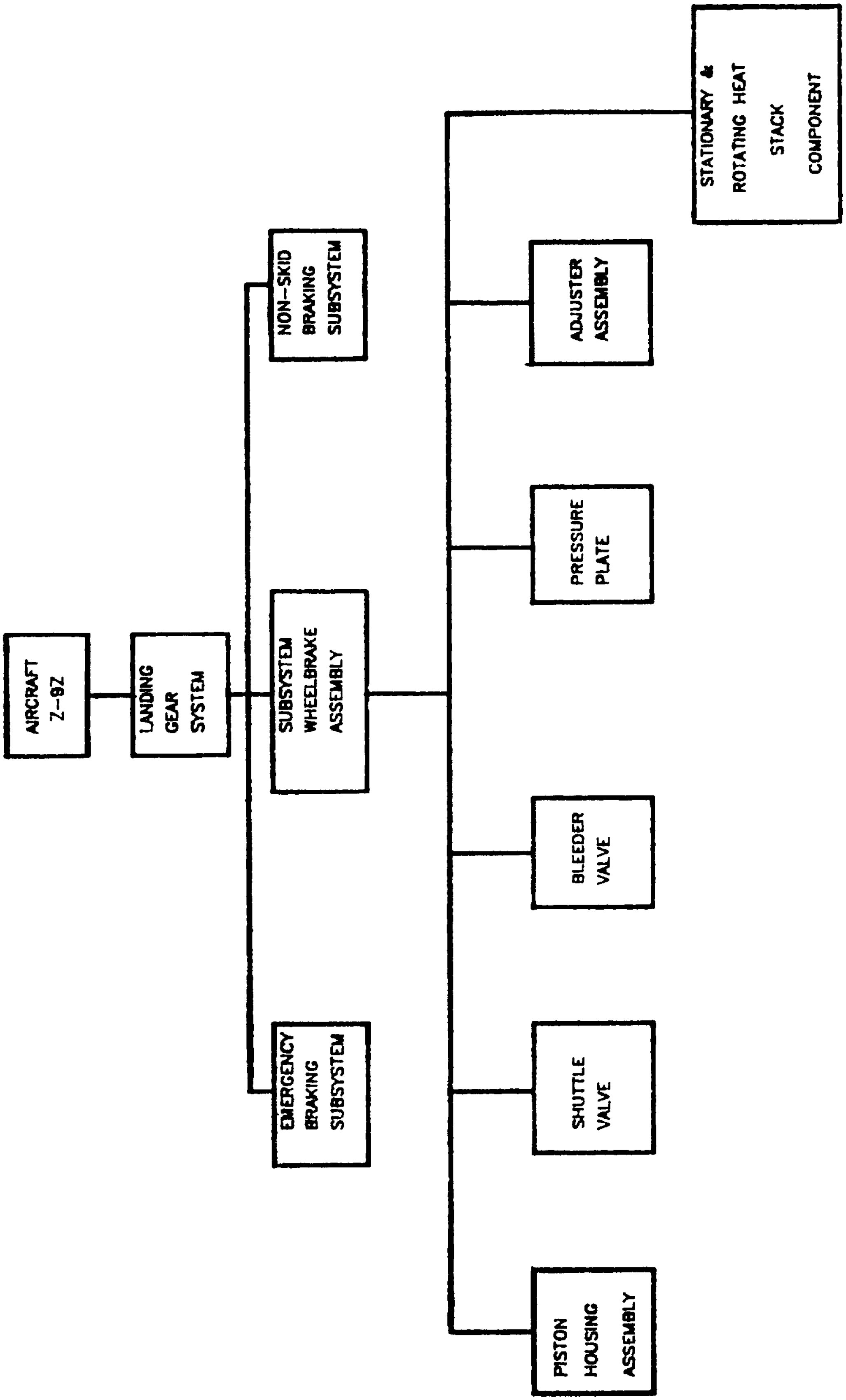
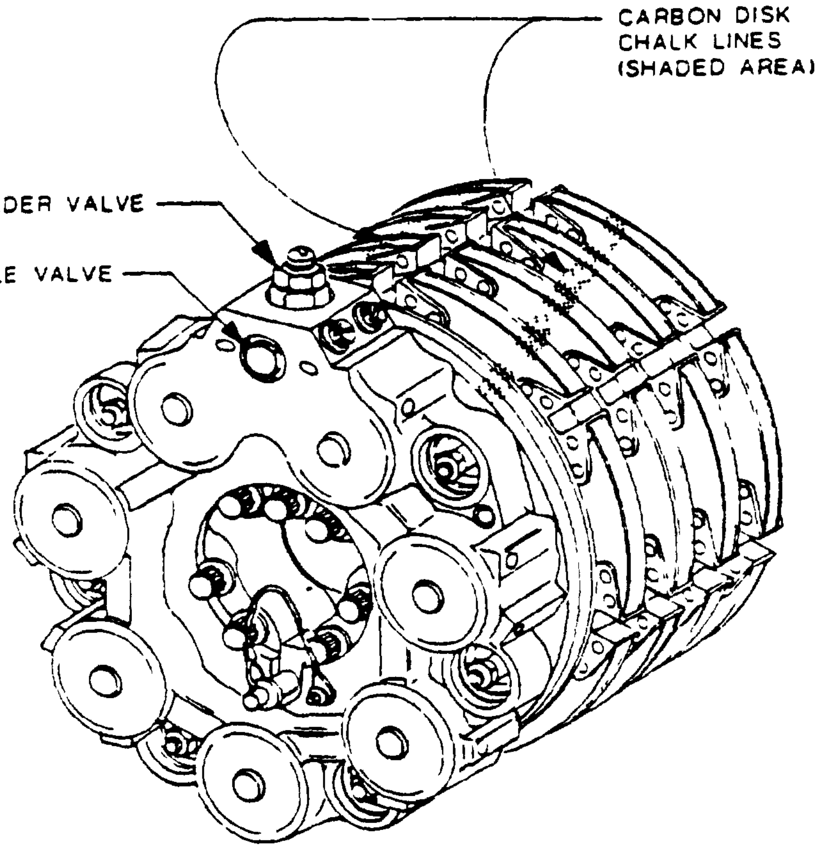



FIGURE 45- Functional block diagram wheelbrake assembly




TECHNICAL CHARACTERISTICS

| | |
|---|---|
| Size | 13.10x557x0.612 |
| Number of rotors | 4 |
| Number of stators | 3 |
| Rotor material | Beryllium |
| Weight | 85 pounds |
| Operating fluid | Mil-H-83282 |
| Operating pressure | 140 psi |

FIGURE 46 - Z-9Z MLG brake

SUPPLEMENTAL INFORMATION

No direct reliability information has been collected for this particular wheel brake assembly. The manufacturer estimated the intervals by comparing the assembly to like or similar pieces of equipment which had reliability analses performed on them. The following are the manufacturer's comments and interval estimates for the wheel brake assembly:

Shuttle Valve - Testing results from a similar valve assembly shows that from 1/16 inch of wear, which is the point at which potential failure exists, approximately 1200 flight hours remain before functional failure.

The analyst estimates that fittings and lines with minor visible damage will fail after approximately 600 flight hours.

Brake wear is measured by visually inspecting indicator wear pins. Indicator pin extension is measured from the base of the wheel brake assembly. Estimated results from a similar assembly show that it takes approximately 5 landing cycles, (landing cycle consists of landing of the aircraft, taxi, and parking), to cause the indicator pin to wear from 1/4 inch extension until it is flush with the brake assembly housing.

The analyst's estimates indicate that once contamination of the hydraulic fluid appears, approximately 300 flight hours remain before degradation of the operation of the wheel brake assembly appears.

Because of the specific material properties of the mechanical components, engineering estimates indicate it would take approximately 2,000 flight hours to fail from a detectable 1/16 inch of wear.

By reviewing information obtained from similar rotor segemnt assemblies the analyst determines that if a segment is warped by 1/20 of an inch, it will wear to failure in approximately 50 landing cycles.

The manufacturer's calculated estimate for the safe life limit of the priority valve is approximately 3000 flight hours of operation.

## FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION

DATE: 10/1/85 | PAGE 1 OF 1

| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER | SYSTEM/SUBSYSTEM NOMENCLATURE | INDENTURE LEVEL | REFERENCE DRAWING | MISSION | PREPARED BY / APPROVED BY |
|---|---|---|---|---|---|
| [illegible] | Wheel brake [illegible] | [illegible] | [illegible] | Taxi, take off and landing | [illegible] |

**SYSTEM/SUBSYSTEM DESCRIPTION**
[illegible] brake [illegible] rotor disk [illegible] three [illegible] stator [illegible] replaced [illegible] five piston [illegible] located [illegible] backplate, retractor plate, heat [illegible] from beryllium [illegible] torque tube, and a shuttle valve

**COMPENSATING PROVISIONS**
[illegible] indicator pin on brake housing [illegible] separate hydraulic lines [illegible] module to [illegible] steel [illegible] cables. Brake warning light, brake pressure gauge, handpump or chemical accumulator in emergency mode

| ITEM IDENT NO | ITEM NOMENCLATURE | NUMBER | FUNCTION | LETTER | FUNCTIONAL FAILURE | NUMBER | ENGINEERING FAILURE MODE | FAILURE EFFECTS: LOCAL EFFECTS | FAILURE EFFECTS: NEXT HIGHER LEVEL | FAILURE EFFECTS: END EFFECTS | MAINT IMPACT | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | Slow [illegible] and maneuver aircraft [illegible] ground operations | A | Fail to slow, stop or maneuver aircraft | 1 | Defective shuttle valve | No hydraulic fluid or pressure to brake piston housing | Wheel brake inoperative | Damage or loss of aircraft due to loss of braking function on one brake | N | I | Excessive brake pressure needed | Ground operation landing taxi or parking | MTBF 660 [illegible] |
| | | | | | | 2 | Defective disk stack | Rotors/stators excessively worn | Brake failure | Same as 1A1 | [illegible] | I | Insufficient braking action | Same as 1A1 | MTBF [illegible] |
| | | | | | | 3 | Clogged or contaminated shuttle valve | Insufficient fluid or pressure to extend pistons to retractor plate | Brake failure | Same as 1A1 | [illegible] | I | Same as 1A1 | Same as 1A1 | MTBF [illegible] |

FIGURE 47- Failure mode and criticality analysis maintainability information

## FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION

| | | | | | |
|---|---|---|---|---|---|
| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER: 13810 | SYSTEM/SUBSYSTEM NOMENCLATURE: Wheel Brake Assembly | INDENTURE LEVEL: 3 | REFERENCE DRAWING: 1593-017 | MISSION: Taxi, take off and landing | DATE: 10/1/85 — PAGE 2 OF 5 — PREPARED BY: AXI D. DEAN — APPROVED BY: |

SYSTEM/SUBSYSTEM DESCRIPTION:

COMPENSATING PROVISIONS:

| ITEM IDENT. NO. | ITEM NOMENCLATURE | FUNCTION NUMBER | FUNCTION | FUNCTIONAL FAILURE LETTER | FUNCTIONAL FAILURE | ENGINEERING FAILURE MODE NUMBER | ENGINEERING FAILURE MODE | FAILURE EFFECTS: LOCAL EFFECTS | FAILURE EFFECTS: NEXT HIGHER LEVEL | FAILURE EFFECTS: END EFFECTS | MINIMUM EQUIPMENT LIST | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | B | Dragging brakes | 1 | Failed adjuster | Rotors and stators binding | Degraded braking action | Poor aircraft ground handling | N | III | Rough movement of aircraft and/or squealing brake | Taxi, Parking or Take Off | MTBF 750 LDG's |
| | | | | | | 2 | Warped rotors or stators | Same as 1B1 | Same as 1B1 | Same as 1B1 | N | III | Same as 1B1 | Taxi, Parking or Take Off | 200 LDG's |
| | | | | | | 3 | Distorted/warped pressure plate | Rotors and stator binding | Same as 1B1 | Same as 1B1 | N | III | Same as 1B1 | Taxi, Parking or Take Off | 500 LDG's |
| | | | | C | Fails to contain fluid | 1 | Damaged or worn piston | Loss of system hydraulic fluid | Wheel brake inoperative | Damage or loss of aircraft | N | I | Same as 1A3 | Taxi Parking Take Off | 500 LDG's |

FIGURE 48- Failure mode and criticality analysis-maintainability information

| FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION | | | | | DATE 10/1/85 | PAGE 3 OF 3 |
|---|---|---|---|---|---|---|
| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER 13810 | SYSTEM/SUBSYSTEM NOMENCLATURE Wheel Brake Assembly | INDENTURE LEVEL 3 | REFERENCE DRAWING 1593-017 | MISSION Taxi, take off and landing | PREPARED BY AXI D DEAN | APPROVED BY |
| SYSTEM/SUBSYSTEM DESCRIPTION | | | COMPENSATING PROVISIONS | | | |

| ITEM IDENT. NO. | ITEM NOMENCLATURE | FUNCTION | | FUNCTIONAL FAILURE | | ENGINEERING FAILURE MODE | | FAILURE EFFECTS | | | MINIMUM EQUIPMENT | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NUMBER | | LETTER | | NUMBER | | LOCAL EFFECTS | NEXT HIGHER LEVEL | END EFFECTS | | | | | |
| | | 1 | | C | | 2 | Loose or damaged bleeder valve | Loss of system hydraulic fluid | Same as 1C1 | Same as 1C1 | N | I | Same as 1A3 | Same as 1A1 | 600 LDG's |
| | | | | | | 3 | Fractured housing | Loss of system hydraulic fluid | Same as 1C1 | Same as 1C1 | N | I | Same as 1A3 | Same as 1A1 | 1500 LDG's |

FIGURE 49- Failure mode and criticality analysis - maintainability information

## RCM WORKSHEET NO. 1 SUMMARY DATA

| | | | |
|---|---|---|---|
| a) SYSTEM/SUBSYSTEM NOMENCLATURE: WHEEL BRAKE ASSEMBLY | c) PART/MODEL NUMBER FSCM: 182738-37638 | e) INDENTURE LEVEL: 3 | h) PAGE 1 OF 9 |
| b) SYSTEM/SUBSYSTEM — LSACN: ; MIR INDEX CODE — WUC: 13811; CF: | d) END ITEM NOMENCLATURE T/M/S NALC NUMBER: 292 | f) PREPARED BY/DATE: AMSI C HISFY 10/1/85 | i) REVISION NO/DATE |
| | | g) REVIEWED BY/DATE | k) APPROVED BY/DATE |

| 1) ITEM LSACN/MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) RCM DECISION LOGIC ANSWERS (Y OR N): FAILURE CONSEQUENCES EF 1 | ES 2 | SHF 3 | SAFETY SL 4 | OC 5 | HT 6 | CB 7 | ECONOMIC/OPERATIONAL SL 8 | OC 9 | HT 10 | NON SAFETY HIDDEN FAILURE SL 11 | OC 12 | HT 13 | FF 14 | SAFETY HIDDEN FAILURE SL 15 | OC 16 | HT 17 | CB 18 | FF 19 | 5) RCM TASKS NO | DESCRIPTION | 6) INSPECTION INTERVAL PRELIM | PACKED | 7) LSA TASK CODE / LEVEL OF MAINTENANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13811 | Wheel brake assembly | 1A1 | Y | Y | | N | Y | | | | | | | | | | | | | | | 001P | Inspect shuttle valve for free movement of valve and wear greater than 1/16th in. | 200 LDGS | | /I |
| | | 1A2 | Y | Y | | N | Y | | | | | | | | | | | | | | | 002P | Inspect wear indicators for extension | 3 LDGS | | /O |
| | | 1A3 | Y | Y | | N | Y | | | | | | | | | | | | | | | 003P | Perform contamination patch test for class 3 or better | 200 LDGS | | /O |
| | | 1B1 | Y | N | | | | | | N | Y | | | | | | | | | | | 004P | Visually inspect adjuster assembly for wear and corrosion Perform spring compression test for less than 451 lbs | | | /I |
| | | 1B2 | Y | N | | | | | | N | Y | | | | | | | | | | | 005P | Disassemble and inspect segments for ward limits of 0 05 inches | 100 LDGS | | /I |

FIGURE 50- Summary data- RCM worksheet 1

**RCM WORKSHEET NO. 1 SUMMARY DATA**

| a) SYSTEM/SUBSYSTEM NOMENCLATURE | c) PART/MODEL NUMBER FSCM | e) INDENTURE LEVEL | h) PAGE |
|---|---|---|---|
| WHEEL BRAKE ASSEMBLY | 182738-37638 | 3 | 2 OF 9 |
| b) SYSTEM/SUBSYSTEM LSACN: — MIR INDEX CODE WUC: 13811 CF: — | d) END ITEM NOMENCLATURE T/M/S NALC NUMBER: 292 | f) PREPARED BY/DATE AMSI C HISEY 10/1/85 | i) REVISION NO./DATE |
| | | g) REVIEWED BY/DATE | k) APPROVED BY/DATE |

| 1) ITEM LSACN/MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) RCM DECISION LOGIC ANSWERS (Y OR N) FAILURE CONSEQUENCES EF 1 | ES 2 | SHF 3 | SAFETY SL 4 | OC 5 | HT 6 | CB 7 | ECONOMIC/OPERATIONAL SL 8 | OC 9 | HT 10 | NON SAFETY HIDDEN FAILURE SL 11 | OC 12 | HT 13 | FF 14 | SAFETY HIDDEN FAILURE SL 15 | OC 16 | HT 17 | CB 18 | FF 19 | 5) RCM TASKS NO | DESCRIPTION | 6) INSPECTION INTERVAL PRELIM | PACKED | 7) LSA TASK CODE / LEVEL OF MAINTENANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 11 | Wheel Brake Assembly | 1B | Y | | | | | | | N | Y | | | | | | | | | | | 006P | Disassemble and inspect pressure plate for warping | 300 LDGS | | /I |
| | | 1C1 | Y | Y | | N | Y | | | | | | | | | | | | | | | 007P | Disassemble and inspect piston for damage of 0.002 (max.) depth, or wear to a min diameter of 1.619 in at any point. Check for corrosion | 200 LDGS | | /I |
| | | 1C | Y | Y | | N | Y | | | | | | | | | | | | | | | 008P | Inspect bleeder valve, adapter, and hardware for damage and stripped threads | 200 LDGS | | /I |
| | | 1C5 | Y | Y | | N | Y | | | | | | | | | | | | | | | 009P | Disassemble and inspect housing for cracks in cylinder cavities and cleanliness of passageways | 400 LDGS | | /I |

FIGURE 51- Summary data- RCM worksheet 1

**RCM WORKSHEET NO. 2 FAILURE CONSEQUENCE/SERVICING/LUBRICATION TASK EVALUATION** DATE: 10/1/85 PAGE 3 OF 9

| 1) ITEM LSACN/MRR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCE DETERMINATION: a) QUESTION 1 IS THE FAILURE OCCURRENCE EVIDENT TO THE CREW OR OPERATOR WHILE PERFORMING NORMAL DUTIES? Y/N | JUSTIFICATION | b) QUESTION 2 DOES THE FAILURE CAUSE A FUNCTION LOSS OR SECONDARY DAMAGE THAT COULD HAVE A DIRECT ADVERSE EFFECT ON OPERATING SAFETY? Y/N | JUSTIFICATION | c) QUESTION 3 DOES THE HIDDEN FAILURE ITSELF OR IN COMBINATION WITH ANOTHER FAILURE HAVE AN ADVERSE EFFECT ON OPERATING SAFETY? Y/N | JUSTIFICATION | 4) FAIL CONSEQ | 5) DESCRIBE SERVICING OR LUBRICATION TASK: a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL | d) PROPOSED LEVEL OF MAINTENANCE O | I | D | e) IS SERVICING OR LUBRICATION TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13811 | 1A1 | Y | Operator will experience need for excessive pressure | Y | Loss of brake function could cause aircraft to be difficult during ground operations or crash on landing | | | SAFETY | | NONE | | | | | No |
| | 1A2 | Y | The operator will experience decreased braking action | Y | Same as 1A1 | | | SAFETY | | NONE | | | | | No |
| | 1A3 | Y | Same as 1A1 | Y | Same as 1A1 | | | SAFETY | | None | | | | | No |
| | 1B1 | Y | The operator will experience rough movement and/or hear a squealing noise | N | Operator can stop and shutdown safely | | | ECON/OPER | | None | | | | | No |
| | 1B2 | Y | Same as 1B1 | Y | Same as 1B1 | | | ECON/OPER | | None | | | | | No |
| | 1B3 | Y | Same as 1B1 | Y | Same as 1B1 | | | ECON/OPER | | None | | | | | No |
| | 1C1 | Y | Loss of brake pedal back pressure | Y | Same as 1A1 | | | SAFETY | | None | | | | | No |
| | 1C2 | Y | Same as 1C1 | Y | Same as 1A1 | | | SAFETY | | None | | | | | No |
| | 1C3 | Y | Same as 1C1 | Y | Same as 1A1 | | | SAFETY | | None | | | | | No |

FIGURE 52- Failure consequence/servicing/lubrication task evaluation- RCM worksheet 2

| RCM WORKSHEET NO. 3 ON-CONDITION TASK EVALUATION | | | | | | | | | | | | | | | | | | | DATE 10/1/85 | PAGE 4 OF 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) ON-CONDITION TASK APPLICABILITY CRITERIA: a) MEANS TO DETECT REDUCED FAILURE RESISTANCE | 4) b) POTENTIAL FAILURE CONDITION DETECTABLE BY AN EXPLICIT TASK | 4) c) INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | 5) DESCRIBE APPLICABLE ON-CONDITION TASK: a) NUMBER | 5) b) DESCRIPTION | 5) c) PRELIMINARY TASK INTERVAL (ENG) | 5) d) PROPOSED MAINTENANCE LEVEL: O | I | D | 6) EFFECTIVENESS CRITERIA: a) SAFETY PROB OF FAILURE | 6) b) SAFETY HIDDEN FAILURE PROB OF MULTIPLE FAILURE | 6) c) OPERATIONAL/ECONOMIC AND NON SAFETY HIDDEN FAILURE: 1) IS FFR HIGH? | 6) c) 2) OPERATING COSTS | 6) c) 3) HIGH REPAIR OR OPERATING COSTS? | 6) c) 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? | | |
| 13911 | 1A1 | SAFETY | Visual inspection | Shuttle valve play not greater than 1/16" | 0-100 FDGS | 001I | Inspect shuttle valve for free movement and wear greater than 1/16th in | 200 FDGS | | X | | Pacc 1.19 X 10^-1 Pf = 1.0 X 10^-5 | | | | | | YES | | |
| | 1A2 | SAFETY | Visual inspection of wear indicator | Indicators flush with housing | 0-10 FDGS | 002P | Inspect wear indicators for extension | 3 FDGS | X | | | Pacc= 1.19 X 10^-4 Pf = 5.0 X 10^-7 | | | | | | YES | | |
| | 1A3 | SAFETY | Hydraulic fluid sampling kit | Contamination of fluid lower than class 5 | 0-800 FDGS | 007I | Perform contamination patch test for class 5 or above | 200 FDGS | X | | | Pacc 1.19 X 10^-1 Pf= 1.28 X 10^-5 | | | | | | YES | | |
| | 1B1 | CON/OPER | Visual, spring tester | Any wear or corrosion | 0-100 FDGS | 001I | Inspect adjuster for wear and corrosion. Perform spring compression test for less than 451 lbs | 225 FDGS | | X | | | | NO | | YES | YES | YES | | |

FIGURE 53- On-Condition task evaluation- RCM worksheet 3

**RCM WORKSHEET NO. 3 ON-CONDITION TASK EVALUATION** DATE 10/1/85 PAGE 5 OF 9

| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) ON-CONDITION TASK APPLICABILITY CRITERIA a) MEANS TO DETECT REDUCED FAILURE RESISTANCE | b) POTENTIAL FAILURE CONDITION DETECTABLE BY AN EXPLICIT TASK | INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | 5) DESCRIBE APPLICABLE ON-CONDITION TASK a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL (ENG) | d) PROPOSED LEVEL O | I | D | 6) EFFECTIVENESS CRITERIA a) SAFETY PROB OF FAILURE | b) SAFETY HIDDEN FAILURE PROB OF MULTIPLE FAILURE | c) OPERATIONAL/ECONOMIC AND NON-SAFETY HIDDEN FAILURE 1) IS FFR HIGH? | 2) OPERATING CONSEQ? | 3) HIGH REPAIR OR OPERATING COSTS? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15811 | 1B2 | ECON/ OPER | Visual dial indicator | Warp limits of 0.05 in | 0-150 LDGS | 005P | Inspect rotating/stationary heat stack for warp limits of 0.05 in | 100 LDGS | | X | | | | NO | | YES | YES | YES |
| | 1B3 | ECON/ OPER | Visual dial indicator | Key slot width not greater than .33" and warping not greater than .01" | 0-150 LDGS | 006P | Inspect pressure plate for warping of more than 0.010 in and keyslot width of 0.330 in | 300 LDGS | | X | | | | NO | | YES | YES | YES |
| | 1C1 | SAFETY | Visual, dial indicator | Damage not to exceed .002" and minimum piston dia of 1.619" | 0-150 LDGS | 007P | Inspect piston for damage of 0.002 (max) and (min) diameter of 1.619 at any point, and corrosion | 200 LDGS | | X | | Pacc = 1.19 × $10^{-1}$ $P_f$ = 1.00 × $10^{-5}$ | | | | | | YES |
| | 1C2 | SAFETY | Visual | Any damage or stripped threads | 0-100 LDGS | 008P | Inspect bleeder valve, adapter, bleed screw and hardware for damage, cracks & stripped threads | 200 LDGS | | X | | Pacc = 1.19 × $10^{-1}$ $P_f$ = 3.00 × $10^{-7}$ | | | | | | YES |

FIGURE 54- On-Condition task evaluation - RCM worksheet 3

RCM WORKSHEET NO. 3 ON-CONDITION TASK EVALUATION | DATE 10/1/85 | PAGE 6 OF 9

| 1) ITEM LSACN/MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) ON-CONDITION TASK APPLICABILITY CRITERIA: a) MEANS TO DETECT REDUCED FAILURE RESISTANCE | 4) b) POTENTIAL FAILURE CONDITION DETECTABLE BY AN EXPLICIT TASK | 4) c) INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | 5) DESCRIBE APPLICABLE ON-CONDITION TASK: a) NUMBER | 5) b) DESCRIPTION | 5) c) PRELIMINARY TASK INTERVAL (ENG) | 5) d) PROPOSED LEVEL OF MAINTENANCE: O | 5) d) I | 5) d) D | 6) EFFECTIVENESS CRITERIA: a) SAFETY: PROB OF FAILURE | 6) b) SAFETY HIDDEN FAILURE: PROB OF MULTIPLE FAILURE | 6) c) OPERATIONAL/ECONOMIC AND NON-SAFETY HIDDEN FAILURE: 1) IS PFR HIGH? | 6) c) 2) OPERATING COSTS | 6) c) 3) HIGH REPAIR OR OPERATING COSTS? | 6) c) 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13811 | 1C3 | SAFETY | Visual | Any cracks, corrosion or damage | D-1200 LDGS | 009P | Inspect housing and cylinder cavaties for cracks corrosion and cleanliness of passageways | 400 LDGS | | X | | Pacc= 1.19 X $10^{-4}$ Pf 1.28 X $10^{-5}$ | | | | | | YES |

FIGURE 55- On-Condition task evaluation - RCM worksheet 3

**RCM WORKSHEET NO 7 DETERMINATION OF AGE EXPLORATION TASKS** DATE 10/1/85 PAGE 7 OF 9

| 1) ITEM (SAC N/ MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) DEFAULT FAILURE CONSEQ (W/S 2) | 5) DEFAULT TASK EVALUATION TYPE TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) O | d) I | d) D | e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 Y/N | b) QUESTION #2 Y/N | b) QUESTION #2 JUSTIFICATION | c) QUESTION #3 Y/N | c) QUESTION #3 JUSTIFICATION | d) QUESTION #4 Y/N | d) QUESTION #4 JUSTIFICATION | 8) TASK/CATEGORY | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13811 | Shuttle valve | 1A1 | SAFETY | OC | Interval between potential and functional failure | Measure valve dia for rate of wear | 30 | | X | | Until functional failure | Y | Y | Data can be collected by fleet activities | | | | | | | | \ | |
| | Disk Stack | 1A2 | ECON/OPER | OC | Same as 1A1 | Evaluate wear with landings to determine rate of wear | 100 | X | | | Until failure | N | | | N | Data will not provide an interval due to variable wear rate | | | | | | | |
| | Shuttle valve | 1A3 | SAFETY | OC | Same as 1A1 | Monitor hydraulic fluid class to determine rate of contamination | 50 | Y | | | Until failure | N | | | Y | Data will not provide an interval due to contamination rates vary | | | | | | | |
| | Adjuster | 1B1 | ECON/OPER | OC | Interval between potential and functional failure | Measure spring tension to determine rate of failure | 30 | | X | | Until failure | N | | | Y | Data will provide wearout time | Y | Data can be collected by fleet activities | | X | | | |

FIGURE 56- Determination of age exploration task - RCM worksheet 7

**RCM WORKSHEET NO 7 DETERMINATION OF AGE EXPLORATION TASKS** | DATE 10/1/85 | PAGE 8 OF 9

| 1) ITEM LSACN/ MIR INDEX CODE | 2) ITEM NOMEN CLATURE | 3) FFMC | 4) DEFAULT FAILURE CONSEQ (W/S 2) | 5) DEFAULT TASK EVALUATION TYPE TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | 6) b) PRELIMINARY TASK | 6) c) SAMPLE SIZE | 6) d) LEVEL OF MAINTENANCE O | 6) d) I | 6) d) D | 6) e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 Y/N | 7) b) QUESTION #2 Y/N | 7) b) QUESTION #2 JUSTIFICATION | 7) c) QUESTION #3 Y/N | 7) c) QUESTION #3 JUSTIFICATION | 7) d) QUESTION #4 Y/N | 7) d) QUESTION #4 JUSTIFICATION | 8) TASK/CATEGORY DAET I | DAET II | SAFE I | SAFE II | RASS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13811 | Disk Stack | 1B2 | ECON/ OPER | OC | Interval between potential and functional failure | Measure stack runout to identify rate of warping | 30 | | X | | Until failure | N | | | Y | Date can provide a potential failure rate | Y | Data can be collected by fleet activities | | X | | | |
| | Pressure Plate | 1B3 | ECON/ OPER | OC | Interval between potential and functional failure | Measure pressure plate for warping & keyslot width | 30 | | X | | Until failure | N | | | Y | Data can provide a potential failure rate | Y | Data can be collected by fleet activities | | X | | | |
| | Piston | 1C1 | SAFETY | OC | Interval between potential and functional failure | Measure piston diameter for wear | 50 | | X | | Until failure | Y | Y | Data can be collected by fleet activities | | | | | | | | X | |
| | Bleeder valve | 1C2 | SAFETY | OC | Interval between potential and functional failure | Monitor bleeder valve for cracks and damage | 30 | | X | | Until failure | Y | Y | Data can be collected by fleet activities | | | | | | | | X | |

FIGURE 57- Determination of age exploration task - RCM worksheet 7

| RCM WORKSHEET NO. 7 DETERMINATION OF AGE EXPLORATION TASKS | | | | | | | | | | | | | | | | | | | DATE 10/1/85 | | | PAGE 9 OF 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/ MIR INDEX CODE | 2) ITEM NOMEN CLATURE | 3) FFMC | 4) DEFAULT FAILURE CONSEQ (W/S 2) | 5) DEFAULT TASK EVALUATION TYPE TASK | 6) AGE EXPLORATION REQUIREMENT | | | | | | | 7) AGE EXPLORATION TASK ASSESSMENT | | | | | | | 8) TASK/ CATEGORY | | | | |
| | | | | | a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) PROPOSED LEVEL OF MAINTENANCE | | | e) STUDY PERIOD | a) Q#1 | b) QUESTION #2 | | c) QUESTION #3 | | d) QUESTION #4 | | DAL | | SAL | | RASS |
| | | | | | | | | O | I | D | | Y/N | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | I | II | I | II | |
| 13811 | Housing | IC3 | SAFETY | OC | Interval between potential and functional failure | Monitor housing and passageways for cracks and damage | 30 | | X | | Until failure | Y | Y | Data can be collected by fleet activities | | | | | | | | X | |

FIGURE 58- Determination of age exploration task - RCM worksheet 7

## ANALYSIS RATIONALE

For this analysis, the analyst calculated an acceptable probability of failure (see paragraph 5.2.3.2.1) as follows:

$$Pacc = \frac{.5}{(200)(15)(5)}$$

$$= 3.33 \times 10^{-5}$$

Calculations for FFMC 1A1:

The analyst assumed that defects are detected in one inspection 80% of the time and that the brakes are used on each mission. The analyst used the acceptable probability of failure (Pacc) to calculate the number of inspections required. The calculations are as follows:

$$P_f = (1 - \theta)^n$$

$$3.33 \times 10^{-5} = (1 - .80)^n$$

$$n = \frac{\text{Log}\ (3.33 \times 10^{-5})}{\text{Log}(1 - .80)}$$

$$n = 6.40$$

The preliminary inspection interval is:

$$\frac{1200\ FH}{6.40} = 187.5 \simeq 180\ FH$$

Actual Probability of failure is:

$$P_f = (1 - .80)^{\frac{1200}{180}} = 2.2 \times 10^{-5}$$

Calculations for FFMC 1A2:

Since damaged hydraulic lines and loose, leaking fittings are more visible and easier to detect, the analyst used θ = 90%. The calculations areas follows:

$$P_f = (1 - \theta)^n$$

$$3.33 \times 10^{-5} = (1 - .90)^n$$

$$n = \frac{\text{Log}\ (3.33 \times 10^{-5})}{\text{Log}\ (1 - .90)} = 4.48$$

The preliminary inspection interval is:

$$\frac{600\ \text{FH}}{4.48} = 133.9 \simeq 130\ \text{FH}$$

The actual probability of failure is:

$$P_f = (1 - .90)^{\frac{600}{130}} = 2.40 \times 10^{-5}$$

Calculations for FFMC 1A3:

Since the indicator pin is easily accessible and easy to read, the analyst used $\theta = 95\%$. The calculations are as follows:

$$P_f = (1 - \theta)^n$$

$$3.33 \times 10^{-5} = (1 - .95)^n$$

$$n = \frac{\text{Log}\ (3.33 \times 10^{-5})}{\text{Log}\ (1 - .95)}$$

$$n = 3.45$$

The preliminary inspection interval is:

$$\frac{5}{3.45} = 1.45 \simeq 1.0\ \text{Landings}$$

The actual probability of failure is:

$$P_f = (1 - .95)^{\frac{5}{1}} = 3.00 \times 10^{-7}$$

Calculations for FFMC 1A5:

Because of the simplicity and accuracy of this inspection task, the analyst used $\theta = 95\%$ for the following calculations:

$$P_f = (1 - \theta)^n$$

$$3.33 \times 10^{-5} = (1 - .95)^n$$

$$n = \frac{\text{Log}\ (3.33 \times 10^{-5})}{\text{Log}\ (1 - .95)}$$

$$n = 3.45$$

The preliminary inspection interval is:

$$\frac{300}{3.45} = 87.0 \simeq 85 \text{ FH}$$

The actual probability of failure is:

$$P_f = (1 - .95)^{\frac{300}{85}} = 2.60 \times 10^{-5}$$

Calculations for FFMC 1C1:

Since there is little difficulty in finding warps of 1/20 inch on the rotor segments, the analyst recommended that a long inspection interval be established. The analyst's recommendation was that at least two inspections be performed within the interval.

$$\frac{\text{50 Landings}}{2} = \text{25 Landings - inspection interval}$$

Worksheet #3, Column 6c, Decision Diagram for Cost Effectiveness:

Answers for FFMC 1B1:

Question #1 - No, the failure rate for contaminated hydraulic lines is low. This answer was obtained by comparing the individual failure rate to the failure rate of the wheel brake assembly.

Question #3 - Yes, this failure mode would have both a high repair cost and operational costs if it were allowed to proceed to functional failure. The wheel brake assembly would need to be drained and all associated parts would need to be cleaned, which would create high repair and lost operational costs.

Question #4 - Yes, real and applicable data indicate that the recommended preliminary interval will prevent a functional failure from occurring for this failure mode, under normal operating conditions.

Answers for FFMC 1C1:

Question #1 - No, the failure rate due to warped rotor segments is low when compared to the failure rate of the wheel brake assembly.

Question #3 - Yes, if the rotor segments are allowed to warp they will cause uneven wear in other brake assembly components resulting in their replacement. This will result in high repair and lost operational costs.

Question #4 - Yes, real and applicable data indicate that the recommended preliminary interval will prevent a functional failure from occurring for this failure mode, under normal operating conditions.

## EXAMPLE 3 - Test Chamber Assembly

The test chamber is one subsystem of the Hydraulic test Stand. It is used to test engine-driven hydraulic pumps, etc.

The chamber is fabricated from 1/4 inch steel plate with a hinged door containing a safety-type window. The rear panel of the chamber is designed to allow rapidly expanding gas to escape to the rear of the cabinet in the event of a burst of a pneumatic component during test. A test pump drive pad is located in the center of the rear panel of the test chamber. Fluid supply and return outlets are located inside the chamber. Pressure indicators and some shut-off valves are also located on the rear panel. Most of the hydraulic and pneumatic system operating controls are located on a sloping panel below and along the front of the chamber.

As a safety feature, the test chamber door is equipped with an interlock switch which precludes operation of the chamber with the door open.

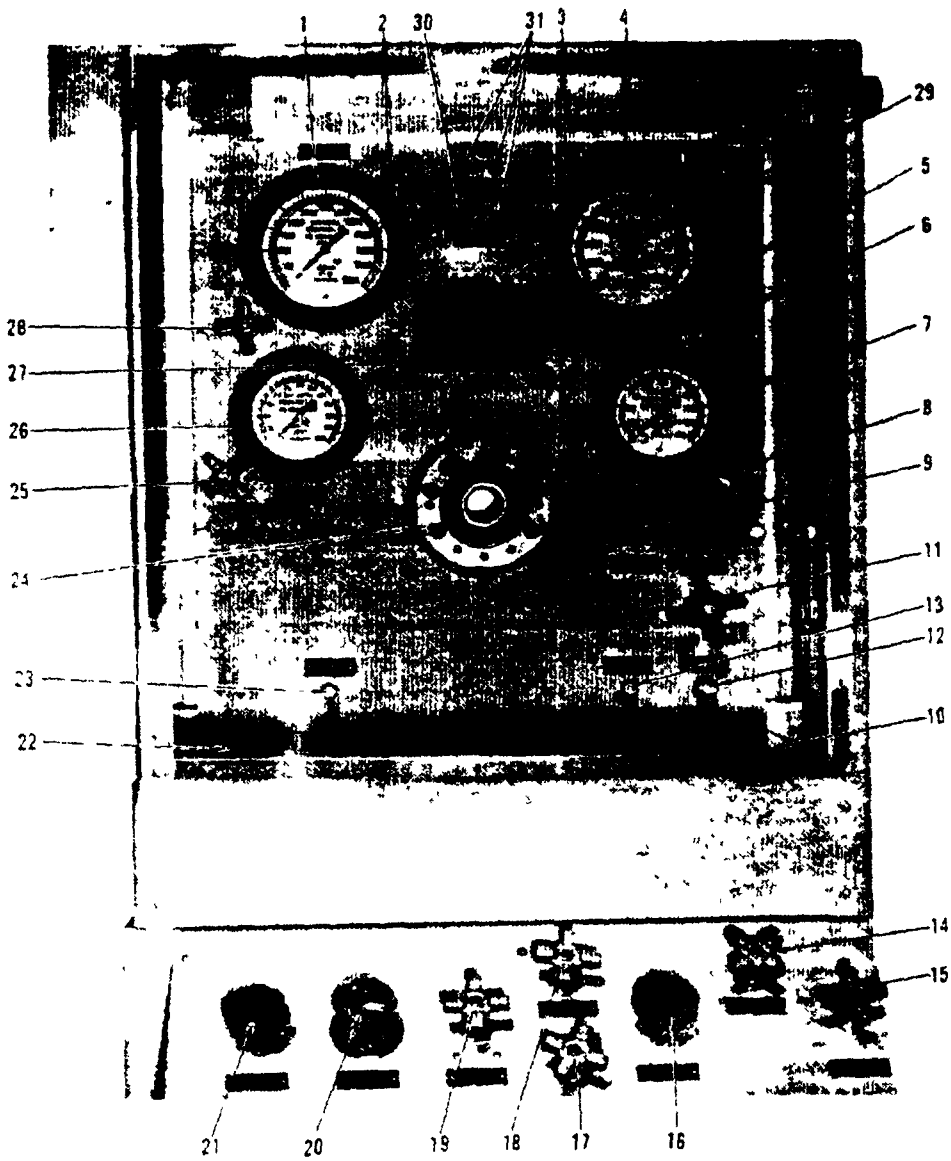



FIGURE 59 - Test chamber

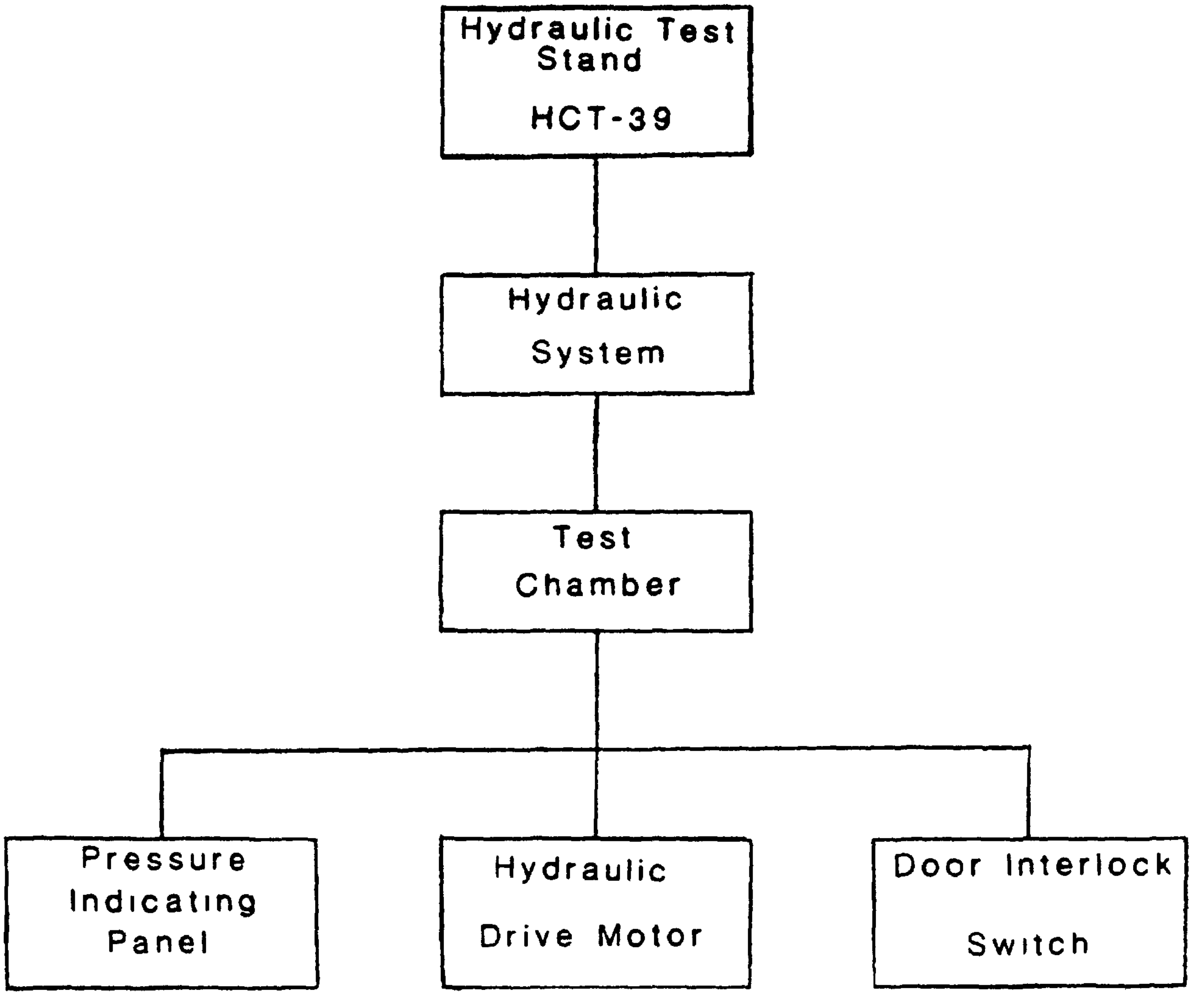



FIGURE 60 - Functional block diagram - Test chamber assembly

## Supplemental Information

The unit being analyzed is a hydraulic component test stand. Samples used are for the functionally significant items of the test chamber system.

There are 94 active units in the inventory. Each unit averages 29.0 hours per month operating time. Therefore, in a one year period all units will cumulate 32,712 hours.

The analyst estimated the MTBF would be 900 operating hours on the interlock switch. Data on like in-service equipment was used in determining intervals on the indicators, drive motor, and hydraulic fittings.

## FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION

| | | | | | |
|---|---|---|---|---|---|
| DATE 16 July 1985 | PAGE 1 OF 2 | | | | |
| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER 39ED300 | SYSTEM/SUBSYSTEM NOMENCLATURE TEST CHAMBER | INDENTURE LEVEL III | REFERENCE DRAWING NA 17-15XF-37 | MISSION TEST HYDRAULIC COMPONENTS | PREPARED BY AMS1 C. HISEY<br>APPROVED BY |

**SYSTEM/SUBSYSTEM DESCRIPTION** Provides a means to test engine driven hydraulic pumps. The enclosed chamber houses the pump drive pad, fluid supply and return outlets, pressure indicators and shutoff valves Operator controls are monitored on a panel below and along the front of the chamber

**COMPENSATING PROVISIONS** No redundancy. An interlock switch is installed to prevent operation with the chamber door open.

| ITEM IDENT NO | ITEM NOMENCLATURE | FUNCTION NUMBER | FUNCTION | FUNCTIONAL FAILURE LETTER | FUNCTIONAL FAILURE | ENGINEERING FAILURE MODE NUMBER | ENGINEERING FAILURE MODE | FAILURE EFFECTS: LOCAL EFFECTS | FAILURE EFFECTS: NEXT HIGHER LEVEL | FAILURE EFFECTS: END EFFECTS | MEI NUMBER | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39ED-300 | TEST CHAMBER | 1 | Provides operator with means to monitor test stand pressures | A | Fails to display pressures | 1 | Internal failure of gauge | No pressure reading on gauge | Test chamber unusable | Degraded test stand performance | | IV | Visual | Testing operations | 8178 MTBF<br>4673 1 MTBMA |
| | | | | | | 2 | Gauge out of calibration | Erroneous pressure reading | Test Chamber unreliable | Degraded test stand performance | | IV | None | Testing operations | 8178 MTBF<br>4673.1 MTBMA |
| | | 2 | Drives the test unit drive pad | A | Failed hydraulic drive motor | 1 | Drive shaft sheared | Motor fails to drive hydraulic pump | Test chamber inoperable | Degraded test stand performance | | IV | Loss of Pressure | Testing operations | 16356 MTBF<br>5452 MTBMA |
| | | | | | | 2 | Internal leakage insufficient pressure | Low hydraulic pressure | Loss of system hydraulic fluid | Same as 2A1 | | IV | Visual/ Loss of pressure | Testing operations | 16356 MTBF<br>6542.4 MTBMA |
| | | 3 | Contain hydraulic fluid | A | Fails to contain fluid | 1 | Leaks at hydraulic fittings | Low fluid level | High pressure pump will not run | Test stand inoperable | | IV | Visual/ Reservoir low light illuminates | Testing operation | 10904 MTBF<br>4098 MTBMA |

FIGURE 61- Hydraulic component test stand FMECA/MI

# FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION

| | | | | | | |
|---|---|---|---|---|---|---|
| SYSTEM/SUBSYSTEM IDENTIFICATION NUMBER 39ED300 | SYSTEM/SUBSYSTEM NOMENCLATURE TEST CHAMBER | INDENTURE LEVEL III | REFERENCE DRAWING NA 17-15XF-37 | MISSION TEST HYDRAULIC COMPONENTS | DATE 16 July 1985 | PAGE 2 OF 2 |
| | | | | | PREPARED BY AMSI C HISEY | |
| | | | | | APPROVED BY | |

SYSTEM/SUBSYSTEM DESCRIPTION

COMPENSATING PROVISIONS

| ITEM IDENT NO | ITEM NOMENCATURE | FUNCTION NUMBER | FUNCTION | FUNCTIONAL FAILURE LETTER | FUNCTIONAL FAILURE | ENGINEERING FAILURE MODE NUMBER | ENGINEERING FAILURE MODE | FAILURE EFFECTS: LOCAL EFFECTS | FAILURE EFFECTS: NEXT HIGHER LEVEL | FAILURE EFFECTS: END EFFECTS | MEI NUMBER | SEVERITY CLASS | FAILURE DETECTION METHOD | MISSION PHASE | ENGINEERING FAILURE MODE MTBF AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39ED-300 | | 3 | | A | | 2 | Leaks from cracked or rolled seals | Same as 3A1 | Same as 3A1 | Same as 3A1 | | IV | Visual/ Reservoir low light illuminates | Testing operations | 10904 MTBF 4089 MTBMA |
| | | 4 | Permits operation of test chamber only when door is closed | A | Permits unit to be operated with door open | 1 | Switch failed closed | Switch fails | None | Test stand unsafe to operate Possible operator injury with door open | | II | None | Testing Operations | 32712 MTBF 10904 MTBMA |
| | | | | B | Unit will not operate | 1 | Switch fails open | Switch fails | Test chamber unoperable | Test stand performance degraded | | IV | Unit will not operate | Testing operations | 32712 MTBF 10904 MTBMA |

FIGURE 62- Hydraulic component test stand FMECA/MI

**RCM WORKSHEET NO. 1 SUMMARY DATA**

- a) SYSTEM/SUBSYSTEM NOMENCLATURE: TEST CHAMBER
- b) SYSTEM/SUBSYSTEM — LSACN: ; MIR INDEX CODE — WUC: 39EDO; TEC: GGLX; CF:
- c) PART/MODEL NUMBER FSCM: 66A91-F319 05172
- d) END ITEM NOMENCLATURE T/M/S NALC NUMBER: HYDRAULIC TEST STAND HCT-39
- e) INDENTURE LEVEL: III
- f) PREPARED BY/DATE: AMS1 C. HISEY 7/16/85
- g) REVIEWED BY/DATE:
- h) PAGE 1 OF 8
- i) REVISION NO./DATE:
- k) APPROVED BY/DATE:

| 1) ITEM LSACN/ MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) RCM DECISION LOGIC ANSWERS (Y OR N): FAILURE CONSEQUENCES | | | SAFETY | | | | ECONOMIC/ OPERATIONAL | | | NON SAFETY HIDDEN FAILURE | | | | SAFETY HIDDEN FAILURE | | | | | 5) RCM TASKS | | 6) INSPECTION INTERVAL | | 7) LSA TASK CODE / LEVEL OF MAINTENANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | EF 1 | ES 2 | SHF 3 | SL 4 | OC 5 | HT 6 | CB 7 | SL 8 | OC 9 | HT 10 | SL 11 | OC 12 | HT 13 | FF 14 | SL 15 | OC 16 | HT 17 | CB 18 | FF 19 | NO | DESCRIPTION | PRELIM | PACKED | |
| 39ED-300 | Test Chamber | 1A1 | Y | N | | | | | | N | Y | | | | | | | | | | | 001P | Scan all indicators and gauges for condition and normal readings | 4 Hrs | | I |
| | | 1A2 | N | | N | | | | | | | | N | Y | | | | | | | | 002P | Calibrate gauges IAW NA 17-35MTL-1 | 4 Hrs | | I |
| | | 2A1 | Y | N | | | | | | N | Y | | | | | | | | | | | 003P | Visually inspect shaft for fractures | 10 Hrs | | I |
| | | 2A2 | Y | N | | | | | | N | Y | | | | | | | | | | | 004P | Pressure check hydraulic motor output with test gauge and check for leaks | 10 HRS | | I |
| | | 3A1 | Y | N | | | | | | N | Y | | | | | | | | | | | 005P | Visually inspect hydraulic drive motor fittings and seals for evidence of leakage | 2 HRS | | I |
| | | 3A2 | Y | N | | | | | | N | Y | | | | | | | | | | | 006P | Same as 005P | 2 HRS | | I |
| | | 4A1 | N | | Y | | | | | | | | | | | | N | N | N | N | Y | 007P | Apply power to test chamber with door open. There should be negative response. If test chamber operates switch is bad | 6 HRS | | I |
| | | 4B1 | Y | N | | | | | | N | N | N | | | | | | | | | | | | | | |

FIGURE 63- RCM worksheetno.1 - summary data

**RCM WORKSHEET NO. 2 FAILURE CONSEQUENCE/SERVICING/LUBRICATION TASK EVALUATION** DATE 7/16/85 PAGE 2 OF 8

| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCE DETERMINATION: a) QUESTION 1 IS THE FAILURE OCCURRENCE EVIDENT TO THE CREW OR OPERATOR WHILE PERFORMING NORMAL DUTIES? Y/N | JUSTIFICATION | b) QUESTION 2 DOES THE FAILURE CAUSE A FUNCTION LOSS OR SECONDARY DAMAGE THAT COULD HAVE A DIRECT ADVERSE EFFECT ON OPERATING SAFETY? Y/N | JUSTIFICATION | c) QUESTION 3 DOES THE HIDDEN FAILURE ITSELF OR IN COMBINATION WITH ANOTHER FAILURE HAVE AN ADVERSE EFFECT ON OPERATING SAFETY? Y/N | JUSTIFICATION | 4) FAIL CONSEQ | 5) DESCRIBE SERVICING OR LUBRICATION TASK: a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL | d) PROPOSED LEVEL OF MAINTENANCE: O | I | D | 6) IS SERVICING OR LUBRICATION TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39ED-300 | 1A1 | Y | Operator will notice abnormal reading on pressure gauge | N | Gauges are inside cabinet | | | ECON/ OPER | | | | | | | NO |
| | 1A2 | N | There may be no noticeable effects like fluctuation | | | N | Gauges are inside cabinet | Non-Safety Hidden | | | | | | | NO |
| | 2A1 | Y | Operator will notice loss of hydraulic pressure to drive pad | N | Motor is enclosed in structure of test stand | | | ECON/ OPER | | | | | | | NO |
| | 2A2 | Y | Operator will notice low pressure to drive pad | N | Motor is enclosed in structure of test stand | | | ECON/ OPER | | | | | | | NO |
| | 3A1 | Y | Operator will notice leak and reservoir low light will illuminate | N | Fittings are routed in structure of test stand | | | ECON/ OPER | | | | | | | NO |
| | 3A2 | Y | Operator will notice leak and reservoir low light will illuminate | N | Fittings are routed in structure of test stand | | | ECON/ OPER | | | | | | | NO |

FIGURE 64- RCM worksheet no.2 - failure consequence/servicing/lubrication task evaluation

**RCM WORKSHEET NO. 2 FAILURE CONSEQUENCE/SERVICING/LUBRICATION TASK EVALUATION** DATE 7/16/85 PAGE 3 OF 8

| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCE DETERMINATION: a) QUESTION 1 IS THE FAILURE OCCURRENCE EVIDENT TO THE CREW OR OPERATOR WHILE PERFORMING NORMAL DUTIES? Y/N | JUSTIFICATION | b) QUESTION 2 DOES THE FAILURE CAUSE A FUNCTION LOSS OR SECONDARY DAMAGE THAT COULD HAVE A DIRECT ADVERSE EFFECT ON OPERATING SAFETY? Y/N | JUSTIFICATION | c) QUESTION 3 DOES THE HIDDEN FAILURE ITSELF OR IN COMBINATION WITH ANOTHER FAILURE HAVE AN ADVERSE EFFECT ON OPERATING SAFETY? Y/N | JUSTIFICATION | 4) FAIL CONSEQ | 5) DESCRIBE SERVICING OR LUBRICATION TASK: a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL | d) PROPOSED LEVEL OF MAINTENANCE O | I | D | e) IS SERVICING OR LUBRICATION TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39ED-300 | 4A1 | N | Will not be evident unless unit is switched on with door open | | | Y | Personnel hazard if a component under test should fail | Safety Hidden | | | | | | | NO |
| | 4B1 | Y | Unit cannot be operated if switch fails open | N | Loss of power if switch fails | | | ECON/ OPER | | | | | | | NO |

FIGURE 65 - RCM worksheet no.2 - failure consequence/servicing/lubrication task evaluation

| RCM WORKSHEET NO. 3 ON-CONDITION TASK EVALUATION | | | | | | | | | | | | | | | | | | | DATE 7/16/85 PAGE 4 OF 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) ON CONDITION TASK APPLICABILITY CRITERIA a) MEANS TO DETECT REDUCED FAILURE RESISTANCE | b) POTENTIAL FAILURE CONDITION DETECTABLE BY AN EXPLICIT TASK | c) INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | 5) DESCRIBE APPLICABLE ON CONDITION TASK a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL (ENG) | d) PROPOSED LEVEL OF MAINTENANCE O | I | D | 6) EFFECTIVENESS CRITERIA a) SAFETY PROB OF FAIL URE | b) SAFETY HIDDEN FAILURE PROB OF MULTIPLE FAILURE | c) OPERATIONAL/ECONOMIC AND NON SAFETY HIDDEN FAILURE 1) IS FFR HIGH? | 2) OPERATING CONS? | 3) HIGH REPAIR OR OPERATING COSTS? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? | |
| 39FD-300 | 1A1 | ECON/ OPER | Visual | Fluctuating or stuck gauge | 8 Hrs | 001P | Scan all indicators and gauges for condition and normal readings | 4 Hrs | | X | | | | Y | Y | | Y | YES | |
| | 1A2 | Non Safety Hidden | Calibration Standard | + or 3% deviation from actual | 8 Hrs | 002P | Calibrate gauges in accordance with NAVAIR 17-35 MTL-1 | 4 Hrs | | X | | | | Y | Y | | Y | YES | |
| | 2A1 | ECON/ OPER | Visual | Any Visable crack | D-20 Hrs | 003P | Visually inspects shaft for fractures | 10 Hrs | | X | | | | N | | Y | Y | YES | |
| | 2A2 | ECON/ OPER | Visual | Any deviation from normal | D-20 Hrs | 001P | Pressure check hydraulic motor output with test gauge and inspect for leaks | 10 Hrs | | X | | | | N | | Y | Y | YES | |
| | 3A1 | ECON/ OPER | Visual | Any leakage | 4 Hrs | 005P | Visually inspect hydraulic drive motor fittings and seals for evidence or leakage | 2 Hrs | | X | | | | N | | Y | Y | YES | |

FIGURE 66- RCM worksheet no.3 - on-condition task evaluation

**RCM WORKSHEET NO. 3 ON-CONDITION TASK EVALUATION** — DATE 7/16/85 — PAGE 5 OF 8

| 1) ITEM LSACN/MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) ON-CONDITION TASK APPLICABILITY CRITERIA: a) MEANS TO DETECT REDUCED FAILURE RESISTANCE | 4) b) POTENTIAL FAILURE CONDITION DETECTABLE BY AN EXPLICIT TASK | 4) INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | 5) DESCRIBE APPLICABLE ON-CONDITION TASK: a) NUMBER | 5) b) DESCRIPTION | 5) c) PRELIMINARY TASK INTERVAL (ENG) | 5) d) PROPOSED LEVEL OF MAINTENANCE: O | I | D | 6) EFFECTIVENESS CRITERIA: a) SAFETY: PROB OF FAILURE | 6) b) SAFETY HIDDEN FAILURE: PROB OF MULTIPLE FAILURE | 6) c) OPERATIONAL/ECONOMIC AND NON-SAFETY HIDDEN FAILURE: 1) IS FFR HIGH? | 6) c) 2) OPERATING COSTS? | 6) c) 3) HIGH REPAIR OR OPERATING COSTS? | 6) c) 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39FD-300 | 3A2 | ECON/OPER | Visual | Any leakage | 4 Hrs | 006P | Same as 005P | 2 Hrs | | X | | | | N | | Y | Y | YES |
| | 4A1 | Safety Hidden | N/A | | | | | | | | | | | | | | | NO |
| | 4B1 | ECON/OPER | N/A | | | | | | | | | | | | | | | NO |

FIGURE 67- RCM worksheet no.3- on-condition task evaluation

| RCM WORKSHEET NO. 4 HARD TIME TASK EVALUATION | | | | | | | | | | | | | | | | | | DATE 7/16/85 PAGE 6 OF 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/MIR CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) HARD TIME TASK APPLICABILITY CRITERIA — COMPLETE FOR REWORK TASKS ONLY: a) IS IT POSSIBLE TO RESTORE FAILURE RESISTANCE OF ITEM BY REWORK TASK | 4) NON SAFETY DISCARD TASKS ONLY: b) WEAROUT AGE | c) PERCENTAGE OF ITEMS WHICH SURVIVE TO THIS AGE | SAFETY OR SHF DISCARD TASKS: d) LIFE LIMIT | 5) DESCRIBE APPLICABLE HARD TIME TASK: a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL (ENG) | d) PROPOSED INTERVAL | MAINTENANCE LEVEL O I D | 6) EFFECTIVENESS CRITERIA: a) SAFETY — PROB OF FAILURE | b) SAFETY HIDDEN FAILURE — PROB OF MULTIPLE FAILURE | c) OPERATIONAL/ECONOMIC AND NON SAFETY HIDDEN FAILURE: 1) IS FFR HIGH? | 2) OPERATING COSTS? | 3) HIGH REPAIR OR OPERATING COSTS? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS TASK APPLICABLE AND EFFECTIVE? |
| 39HD-300 | 4A1 | Safety Hidden | No | N/A | | | | | | | | | | | | | | NO |
| | 4B1 | FCON/OPER | No | N/A | | | | | | | | | | | | | | NO |

FIGURE 68- RCM worksheet no.4- hard time rask evaluation

## RCM WORKSHEET NO. 5 COMBINATION/FAILURE FINDING TASK EVALUATION

DATE 7/16/85 PAGE 7 OF 8

| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQ | 4) APPLICABILITY CRITERIA a) COMBINATION TASK (COMB): DO THE TASKS MEET THEIR INDIVIDUAL APPLICABILITY CRITERIA? | 4) b) FAILURE FINDING TASK (FF): IS AN OC HT OR COMB (FOR SAFETY HIDDEN FAILURES) TASK APPLICABLE AND EFFECTIVE FOR THIS FFMC? | 5) DESCRIBE APPLICABLE TASK a) NO | 5) b) DESCRIPTION STATE IN PARENTHESIS IF TASK IS (COMB) OR (FF) | 5) c) PRELIM TASK INTERVAL (ENG) | 5) d) PROPOSED MAINT LEVEL OF: O | I | D | 6) EFFECTIVENESS CRITERIA a) SAFETY AND SAFETY HIDDEN FAILURE: PROBILITY OF FAILURE OR MULTIPLE FAILURE | 6) b) NON SAFETY HIDDEN FAILURES (COST EFFECTIVENESS DIAGRAM) 1) IS FFR HIGH ? | 2) OPERAT CONSEQ ? | 3) HIGH REPAIR OR OPER COSTS ? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS THE TASK APPLIC-ABLE AND EFFECTIVE ? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39FD-300 | 4A1 | Safety/ Hidden | No | No | 007P | (FF) Apply power to test chamber with door open there should be negative response If test chamber operates, switch is bad | 187 OP Hrs | | X | | Pacc = 5319 X $10^{-3}$<br>PF = 5 14 X $10^{-3}$ | | | | | YES |

FIGURE 69- RCM worksheet no.5 - combination/failure finding task evaluation

**RCM WORKSHEET NO. 7 DETERMINATION OF AGE EXPLORATION TASKS** DATE 7/16/85 PAGE 8 OF 8

| 1) ITEM LSACN/ MIR INDEX CODE | 2) ITEM NOMEN CLATURE | 3) FFMC | 4) DEFAULT FAILURE CONSEQ (W/S 2) | 5) DEFAULT TASK EVALUATION TYPE TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | 6) b) PRELIMINARY TASK | 6) c) SAMPLE SIZE | 6) d) PERIOD OF MAINTENANCE LEVEL O | 6) d) I | 6) d) D | 6) e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 Y/N | 7) b) QUESTION #2 Y/N | 7) b) QUESTION #2 JUSTIFICATION | 7) c) QUESTION #3 Y/N | 7) c) QUESTION #3 JUSTIFICATION | 7) d) QUESTION #4 Y/N | 7) d) QUESTION #4 JUSTIFICATION | 8) TASK/ CATEGORY DEPT I | DEPT II | SAFET I | SAFET II | RASS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39FD-300 | TEST CHAMBER | 2A1 | ECON/ OPER | OC | Interval between potential and functional failure | Inspect in-service motors every 10 hrs for cracks in shaft and track to find times between potential and functional failure | 20 Units | | X | | Sample until functional failure of all 20 units | N | | | Y | Data is easily accessed | Y | Information can be collected by fleet personnel | | X | | | X |
| | | 2A2 | ECON/ OPER | OC | Interval between potential and functional failure | Inspect in-service motors every 10 hrs for evidence of leakage and pump pressure and track until functional failure | 20 Units | | X | | Sample until functional failure of all 20 units | N | | | Y | Data is easily accessed | Y | Information can be collected by fleet personnel | | X | | | X |

FIGURE 70- RCM worksheet no.7 - determination of age exploration tasks

## ANALYSIS RATIONALE

For this analysis, an acceptable probability of failure (see paragraph 5.2.3.2.1) was calculated as follows:

$$Pacc = \frac{0.5}{(AC)(SCI)(FM)} \quad \text{where:}$$

Pacc - acceptable probability of failure

AC - total equipment inventory greater than 50 of the T/M/S being analyzed (average over the planned remaining life)

SCI - number of safety critical functions of the SI

FM - number of severity class I and II (see FMEA) engineering failure modes for the item being analyzed

AC = 94
SCI = 1
FM = 1

$$Pacc = \frac{0.5}{(94)(1)(1)} = .005319 = 5.39 \times 10^{-3}$$

Calculations for FFMC 4A1 and 4B1:

Assume defects will be detected in one inspection 85% of the time. Also the test chamber is used frequently using the acceptable probability of failure (Pacc) to calculate the number of inspections required, the following calculations were performed:

$$P_f = (1 - \theta)^n$$

$$4.319 \times 10^{-3} = (1 - \theta)^n$$

$$n = \frac{\text{Log } 5.319 \times 10^{-3}}{\text{Log } (1 - .85)} = 2.76$$

The preliminary inspection interval is:

$$\frac{900 \text{ OP HRS}}{2.76} = 326$$

The actual probability of failure is:

$$P_f = (1 - .85)^{\frac{900}{326}}$$

$$P_f = .00514 = 5.14 \times 10^{-3}$$

APPENDIX B

DETERMINATION OF INSPECTION INTERVALS AND FORMULATION OF INSPECTION PACKAGES FOR O AND I LEVEL MAINTENANCE

10. GENERAL

10.1 Scope. This appendix identifies the methodology for developing the packaged inspection intervals from the engineering intervals which result from the RCM analysis. It also identifies the procedures for formulating inspec-tion packages for O and I level maintenance.

20. REFERENCED DOCUMENTS

Not applicable.

30. DEFINITIONS

30.1 Phase cycle. The phase cycle is the time required to complete all phase packages.

30.2 Phase interval. The phase interval is the increment of time (flight hours or calendar time) between the performances of individual phase packages.

40. GENERAL REQUIREMENTS

Not applicable.

50. DETAILED REQUIREMENTS

50.1 Inspection interval determination. The methodology in this appendix shall be used to develop packaged inspection intervals for O and I level maintenance on systems and equipment using this standard.

a. When the RCM analysis is completed, many varied inspection tasks of different engineering intervals must be packaged for the O and I level of maintenance. The output of RCM analysis only provides the inspection requirement, a proposed maintenance level, and the engineering interval for accomplishing the tasks. To properly set up these requirements in workable packages for the maintenance technicians to use, more extensive analysis of each requirement is necessary. The following procedure should be followed in the analysis:

1. Combine the RCM requirements with other scheduled maintenance requirements for the equipment. If RCM was only applied to part of the aircraft or weapons system, attempt to integrate the new requirements or intervals into the existing maintenance program. When the analyzed items comprise a large percentage of the

weapons system, consider revising the existing maintenance program to align with the new requirements.

2. Perform task analyses for each requirement to determine the skill level and number of personnel required, the Elapsed Maintenance Time (EMT), the support equipment requirements, and any special considerations, warnings, or cautions.

3. Update the RCM proposed level of maintenance based on the personnel, equipment, or facility constraints at O, I and D level. Valid considerations in maintenance level validation are the maintenance concept for a particular aircraft EMT and aircraft status. When reviewing the maintenance concept for the equipment, examine any existing directives which establish constraints on maintenance interval determination. If the preliminary inspection interval from the RCM analysis conflicts with the directive, then package the preliminary interval at the interval established "by direction." To request an official waiver from the established limits, contact the office responsible for the overriding directive. This is necessary as some directives may not have been kept current and new inspection techniques or materials may have made the directive obsolete.

4. Separate the requirements by maintenance level: one group for O level, and one for I level requirements and another group for D level. This facilitates the selection of phase inspection intervals. Use the D level requirements to determine the OSP as detailed in appendix C.

5. Develop the packaged inspection intervals using the matrix method. One matrix should be developed for each unit of preliminary intervals required (e.g., calendar, flight hours, landings, starts, etc.). Include in the appropriate matrix all of the LSACN or WUC task requirements which have the same unit of interval. This method allows graphical depiction of the array of intervals with the same unit from which the inspection intervals are chosen. The phase interval can now be developed from the O level matrices.

6. Base the phase interval on the unit (flight hours or calendar) which constitutes the majority of tasks at O level. That is, choose the matrix which has the most task requirements shown on it to determine the phase interval. The interval selected should be within the range of intervals nearest to where a majority of the tasks fall most closely together on the matrix. Be certain to consider that safety inspections cannot have preliminary intervals extended, only shortened to fit a selected phase interval. Also, the number of phases in each cycle will be dependent on the EMT of the phase and number of personnel. Tasks which cannot be made to fit the phase intervals chosen should beincluded in the special inspection package. Safety of flight tasks may be considered for inclusion in the turnaround or daily inspection.

b. Using the above procedures, rearrange the intervals of the preventive tasks developed by the RCM techniques, to make them more compatible with the operating requirements of the fleet. After these packaged intervals are documented on the RCM summary worksheet (see paragraph 5.2.1), compare packaged intervals with the engineering intervals. Record both intervals to provide helpful documentation for future revisions and updates to the preventive maintenance requirements. The scheduled tasks with the packaged intervals are used to develop O and I level preventive maintenance requirements manuals.

50.2 Phased maintenance formulation. The procedures in this appendix shall be used to develop a phased maintenance program as applied to paragraph 5.2.9 of this standard.

50.2.1 Phased inspection cycle and intervals. The following paragraphs provide guidance to the responsible organization which formulates phased maintenance programs for assigned aircraft. This information complements the requirement of specification MIL-M-23618, the details of Periodic Maintenance Requirements Manual (PMRM) preparation and format. At this point, all preventive maintenance requirements and their recommended intervals (frequencies) are listed. These requirements must now be formulated into a practical and efficient preventive maintenance program.

50.2.2 Interval adjustment considerations. Clear lines of communication must exist between maintenance engineering personnel and those responsible for the actual preparation of PMRMs. However, the assignment of the phase interval and phased program structure is the responsibility of maintenance engineering. If analytical techniques were not available which could generate precise maintenance intervals for each component, the formulation of practical preventive maintenance programs would be a difficult, if not impossible, task. Consider all the systems and components on a modern Naval aircraft requiring preventive maintenance at widely varying frequencies. A program could be developed to accommodate this situation, but it would be extremely cumbersome and economically unsatisfactory. Certain frequency compromises are often necessary to formulate a practical preventive maintenance program. Given the modern design characteristics of aircraft, very few preventive maintenance requirements rely upon strict adherence to a fixed frequency of accomplishment to ensure operating safety.

50.2.3 Determination of phased cycle structure. Use sound engineering judgement to effectively select phase intervals, the phased cycle, and the number of phases. Allow the requirements to suggest an arrangement, try it, and make adjustments as necessary. Different requirement arrangements will suggest different programs. Because the determination of phased cycle structures depends on interrelated and simultaneous considerations, step by step procedures are not practical. The following paragraphs outline the major considerations, interfaces, and limitations which apply to determining phased cycle structure.

50.2.4 Engine and airframe interface. In the past, multiple airframe application of the same basic engine and the assignment of different Cognizant Field Activities (CFAs) for each airframe and engine has created problems in formulating scheduled maintenance programs. Prior to the implementation of the phased maintenance concept, the major engine and airframe inspections were performed concurrently during the calendar inspection. The calendar inspection PMRMs were prepared by a single activity (i.e., CFA). Today, in some cases, different CFAs are assigned for the airframe and engine. This causes the generation of separate and isolated preventive maintenance programs for the airframe and the engine. Therefore, coordination and cooperation must exist between the groups responsible for generating the respective programs. Inspections performed on the installed engine should have an assigned frequency which is compatible with the airframe preventive maintenance program. If these adjustments are not made, an impractical fleet maintenance program results increasing preventive maintenance downtime to an unacceptable level. Engine requirements having frequencies less than the total airframe phased cycle shall be compatible with the airframe phased program. Those engine requirements which have frequencies longer than the airframe phased cycle shall be expressed in some multiple of the airframe phase interval.

50.2.5 Phase interval selection. To determine the number of phases, their interval, and the total phased cycle, carefully examine the total requirements package. Select a program arrangement which best accommodates the most requirements. This same philosophy applies to phase interval selection. The basic phase interval is determined by the significant group of requirements with the shortest interval. A significant group of requirements is one that affects aircraft status. Some examples are:

a. A ten minute inspection task which requires the aircraft to be sent to the hanger deck and placed on jacks makes the aircraft unavailable.

b. A task which requires an oil sample to be taken on the flight deck does not affect the aircraft status.

When determining the effect of requirements on aircraft status, consider the aircraft's operational environment. Although EMT considerations may cause the chosen phase interval to be divided in half later in the analysis, the basic interval has been established. Short interval tasks, with respect to the phased cycle, generate large downtime simply because of their frequencies. All such tasks should be critically examined and necessary adjustments made. Any task which applies to a failure mode that has a direct adverse effect on operating safety may be a candidate for inclusion in either the daily or turnaround inspection. These task intervals should not be extended to fit in another phase package. The frequencies of all other tasks should be adjusted to occur at the phase interval. Overall, the objective is to get as much scheduled work done as possible during the downtime created by the phased inspections.

50.2.6 Phased cycle determination. After determining the phase interval, choose the number of phases and the phased cycle concurrently because of their interdependence. The EMT required to perform a particular phase (look phase only) should be limited to eight hours (one working shift). Examine the existing program on the aircraft or for a similar aircraft and determine approximately how many man hours are consumed in each phase. This provides a rough approximation of how many man hours can be efficiently programmed in one phase. Again, let the requirements suggest the phased program structure. The phased cycle is determined by the significant group of requirements with the longest interval.

50.2.7 Program with an even number of phases. This arrangement deals with several groups of requirements with intervals expressed in multiples of some basic frequency. All existing U.S. Navy phased maintenance programs are of this type. The arrangement adopted is usually four, six, or eight phases. Programs with an even number of phases can only accommodate requirements whose frequencies are evenly divisible into the total phased cycle. For example:

a. Four (4) Phase Program - One, two, or four times the phase interval.

b. Six (6) Phase Program - One, two, three, or six times the phase interval.

c. Eight (8) Phase Program - One, two, four, or eight times the phase interval.

This fact requires close coordination between maintenance engineering and the PMRM preparation personnel. Assigning intervals for the requirements in isolation from those assembling the PMRMs is unacceptable. For example, consider a six phase program where each phase is performed at 100 hour phase intervals. This arrangement was selected to accommodate requirements with intervals of 100, 200, 300, and 600 hours. The 100 hour requirements are placed in each phase. The 200 hour requirements are divided and placed in every other phase. The 300 hour requirements are placed in every third phase (twice in the phased cycle). The 600 hour requirements are suitably divided and placed in single phases to occur once per phased cycle. Programs with an even number of phases offer good flexibility for future interval adjustment. The objective is to select a phased cycle which best fits the greatest number of requirements and then to adjust the remainder of the requirements to fit the selected phased cycle.

50.2.8 EMT adjustment considerations. If the EMT for performing the individual phase interval can be halved, the number of phases will be doubled. The greater the number of phases used in a program, the greater the number of interval groupings which can be accommodated in the phase inspection packages. Limiting EMT by increasing the number of phases does reach a point of diminishing returns: an increase in the number of phases always increases printing and update costs due to the duplication of requirements within two or more phases. Another method of cutting EMT per phase is to assign more personnel to the phase.

50.2.9 Phase formulation considerations. The success of any phased program is dependent on how well the individual phases are formulated. The following are provided for consideration:

a. Maintenance experiences on the particular aircraft being analyzed are invaluable.

b. The initial program for an aircraft is a trial and error process.

c. Detailed knowledge of the operational environment of the aircraft is essential (i.e., VP versus VA and VF, land based versus shipboard).

d. Limit the unnecessary duplication of those requirements which use the same support equipment, have difficult access, or need functional check flight after completion. Place these requirements in the same phase if possible. Splitting the requirements and placing them in alternate phases could possibly cause a check flight to be necessary after every phase.

e. Grouping requirements by work area (zone) or by functional system is sometimes beneficial. Grouping all the requirements with the same interval in a specific work area (zone) has its advantages, especially if access is time consuming. However, overloading a work area (zone) in a single phase is poor procedure. Attempt to evenly distribute the personnel in the different work areas (zones) of the aircraft. Zonal inspections should only be assigned when a requirement to gain access to an area already exists as part of a scheduled task. Opportunity inspections of aircraft zones should be encouraged as good maintenance policy.

50.2.10 Limiting special inspections. Special inspections are leftover tasks which, for a variety of reasons, cannot be accommodated into the phased maintenance program. If the phased program has been properly constructed, few specials will result. Specials are undesirable and are to be avoided unless absolutely necessary. The lower the number of specials, the more practical the overall phased maintenance program becomes. Special inspections may be necessary for several reasons, however:

a. The recommended interval for a requirement may be shorter than the phase interval or longer than the total phased cycle. Limit, as much as possible, those tasks with a frequency less than the phase interval. (The potential savings in downtime in this area are significant because such requirements are performed so frequently.) Consider any requirements performed at such an interval for the turnaround or the daily, particularly if there are any safety of flight or mission accomplishment implications. Consider performing the requirements in each phase especially if the task has a high EMT.

b. For any requirements with an interval larger than the phase cycle, define its frequency in some multiple of the phase interval. Then the requirement can be scheduled concurrently with a phase inspection.

c. The requirements interval may not be compatible with the established phase program (e.g., a task at three times the phase interval in a four phase program arrangement). The best solution is to adjust its compatibility and require its accomplishment once each phased cycle.

d. Specials are also required when a requirement's performance frequency is measured in a time variable different than the phased program, for example, a calendar time sensitive requirement (corrosion) in a phased flight hour program. Special requirements dealing with corrosion exists in most programs today. If aircraft utilization rates were constant, all requirements could be performed on the same time base. Unfortunately, this is not the case. The passage of calendar time has a definite effect on certain equipment regardless of usage. Parachutes, ejection seats, and life rafts are good examples. Whenever inspections are required, determine the feasibility of grouping requirements with similar intervals to better use the downtime created by the performance of the inspection(s).

50.2.11 Summary. Many decisions made to formulate a preventive maintenance program affect such things as the man hours consumed to schedule and perform maintenance, aircraft availability, and, in some cases, the structure of the fleet maintenance organization. It is of utmost importance that the preventive maintenance program be as simple and straightforward as possible. This will increase the probability of faithful implementation. Fleet maintenance personnel have an intimate knowledge of the hardware and can often lend invaluable assistance. Building an effective and efficient preventive maintenance program requires the insight of fleet maintenance personnel. Don't hesitate to ask for their assistance.

# APPENDIX C

# DETERMINATION OF OPERATING SERVICE PERIODS

## 10. GENERAL

10.1 Scope. This appendix provides specific guidance for the determination of Operating Service Periods (OSP). This guidance is further amplification of the general guidance provided in paragraph 5.2.9.

## 20. REFERENCED DOCUMENTS

Not Applicable.

## 30. DEFINITIONS

Not Applicable.

## 40. GENERAL REQUIREMENTS

Not Applicable.

## 50. DETAILED REQUIREMENTS

50.1 Operating service period determination. The Naval Air Systems Command has a requirement to provide the Chief of Naval Operations with a recommendation on the OSP for Naval aircraft, expressed as flying hours or calendar months. The OSP is the interval that the aircraft may be operated between scheduled visits to the depot for preventive maintenance. Aircraft which reach the OSP limit, called the period end date, must be inducted into the depot for preventive maintenance. Aircraft which are approaching the period end date, may be subjected to an inspection to determine their overall material condition. The material condition of individual aircraft determines if the aircraft must be inducted into the depot at the period end date or the period end date is adjusted. Just as the depot level requirements accomplished at OSP intervals must ensure safe and economical operation between depot visits, the inspections accomplished to adjust the period end date must ensure the same level of confidence throughout the adjustment period. To ensure this confidence is maintained and complies with DODD 4151.16, all preventive requirements, both at the depot and in the field, must be based on RCM logic and concepts. Inspections to assess material condition of an aircraft for period end date adjustment should be determined from RCM justified requirements on aircraft which have had the benefit of formal RCM analysis. The FSIs/SSIs which are determined by the CFA to be most indicative of aircraft material condition will form the basis for these inspections. Aircraft which have no plans for a formal RCM analysis will develop requirements from those items chosen by the CFA which are leading indicators of aircraft material condition. In either case, after the initial adjustment period, additional adjustment inspections will be based on the findings of the previous adjustment inspections. Follow the guidance outlined in the following paragraphs for developing an OSP recommendation.

a. All preventive maintenance actions attempt to prevent in-service failures in order to achieve safety and minimize cost. RCM prescribes a procedure to determine preventive maintenance requirements. It also prescribes methods of finding the engineering intervals of these requirements for each item's failure mode that significantly impairs safety or increases costs. Intervals of preventive maintenance actions may be expressed in units such as calendar time, operating months, flight hours, operating hours, fatigue life, or cycles (e.g., catapults, arrested landings, starts, rounds fired). Intervals of maintenance action are not necessarily invariant over the service life of the aircraft or equipment. Depot maintenance requirements and intervals reflect these considerations.

b. The OSP is established by 1) analyzing the sensitivity of the airframe structural items to material degradation, 2) establishing preventive maintenance requirements and intervals to prevent unacceptable degradation, 3) determining at which maintenance level these preventative maintenance requirements should take place, and 4) adjusting the intervals of depot level requirements to a common interval. Depot level maintenance requirements that impact safety are the primary determinants of OSP. These inspection intervals may be decreased, if necessary, to be compatible with other intervals in determining OSP.

c. OSPs directed toward functional failures for all significant preventive maintenance tasks should be expressed in calendar months, but in certain circumstances, flight hours can be used. It is preferred that the OSP be expressed as a number of equal intervals during the service life. However, if supported by justifiable results, unequal intervals may be established at cumulative periods. Fleet activities are aided by planned OSP intervals when scheduling aircraft for periods of depot level maintenance.

d. The OSP analysis will be based on depot level maintenance requirements which were derived by established Navy methods or individual NAVAIREWORKFAC processes. Depot level requirements which directly impact the OSP are inspections and hard time removals of candidates which are not normally separated from the aircraft (wing, fuselage empennage, etc.). The OSP is determined solely by justifiable scheduled depot maintenance requirements. Service Life Extension Program (SLEP), Conversion in Lieu of Procurement (CILOP) programs, and modification programs do not affect or establish the OSP.

e. The Depot Maintenance Program must be structured to achieve the required material condition at the least cost. Thus, the OSP analysis should not reflect any preconception that aircraft must visit a depot facility on a scheduled basis or that all scheduled depot maintenance must be done concurrently. To determine the optimum OSP, analysis must substantiate that the required material condition will be achieved at the least cost. This concept is one of the central principals of the RCM Program. It is possible that OSP analysis could show a tentative OSP which will not satisfy the objectives of the depot maintenance program.

f. The schedule for aircraft visits to a depot to perform preventive maintenance is determined by the frequency distribution of the preventive depot maintenance requirements. Also considered with the frequency distribution are safety of flight maintenance requirements, lowest possible cost to perform depot level maintenance to achieve the required material condition, and fleet operational requirements. Inspections required for the RCM Age Exploration Program will not dictate the OSP.

50.2 OSP Logic Diagram. The OSP analysis is performed by using the OSP logic diagram, FIGURE 71. In using the OSP logic diagram, a standard and concise method can be used to identify those specific tasks which are called OSP determinant tasks.

50.2.1 Documentation of OSP. OSP worksheets 1 through 4 are used to document the formulation of the OSP. The worksheets allow room for justification of all answers required on the worksheets.

50.3 OSP Worksheet 1. The OSP worksheet 1, FIGURE 72 is used as a documented summary. It serves as a means to record the candidate task descriptions, decision logic answers with justification, and the disposition of the tasks. The heading information shall list aircraft Type/Model/Series (T/M/S) as well as the persons preparing, reviewing, and approving worksheet 1 accompanied by the respective dates of each action. The page numbers will be recorded in the upper right hand corner of worksheets 1 through 4 for tracking purposes. The summary information for each candidate task will be recorded, as required, in the following columns of worksheet 1.

Column 1: Nomenclature - In this column, list the item nomenclature for which the candidate task is written.

Column 2: Task Description - This column identifies the OSP candidate task by number, r status and a brief description.

Task Number - List the task number from part III of the maintenance plan for the scheduled depot level. If an RCM analysis was performed, the task number of all depot level requirements can be found on RCM worksheet 1.

Task Status - The four columns relate to the present status of the candidate OSP task. In the first column (S), place an X if the candidate task in question is performed on a sampling basis. In the second column (A), place an X if the candidate task in question 1 is performed on a 100% basis (not on a sampling basis). In the third column (N), place an X if the task is a "New" task. In the fourth column (O), place an X if the candidate task is an "Old" task (a task which is presently being performed by depot workers and was proven to be an OSP determinate task in a past analysis).

Description - A brief description of each OSP candidate task should be written in this column.

Column 3: OSP Decision Logic Answers - In this column, list either "Y" for yes or "N" for no to answer OSP logic Questions 1 through 7. Justification for each answer must be written in column 4. The questions must be answered for each candidate task listed in column 2.

Question 1. Is this task an OSP candidate? If the task is associated with structural elements whose failures would result in a direct adverse effect on operating safety, answer "yes". Or, if not accomplishing the task would result in significant economic consequences, then answer "yes." If an RCM analysis was performed on this end item, the answer can be obtained from RCM worksheet 6.

Question 2. Does the task require depot level equipment, facilities or skills? If the answer is "yes", the justification written in column 4 should state the facilities, materials, skills, special equipment, economics, or the technical directives that require it to be performed at depot level. When answered "yes", it is assumed the task is performed for a justifiable reason at the depot level and Question 3 is then evaluated. If Question 2 is answered "No", the task is rejected as an OSP determinate task and should be reanalyzed in accordance with the RCM logic.

Question 3. Is task performance data available? Is there sufficient data available for determining effectiveness of the candidate task? If the question is answered "Yes", justification for the answer should be written in column 4 and Question 4 is evaluated. If answered "No", age exploration must be performed to obtain the data.

Question 4. Is the task effective? Historical data are useful for determining if a task has been successful in detecting defects and preventing failures. These data should include, but not be limited to task performance data, depot data, or fleet data. If task effectiveness cannot be proven, then list "No." The item then should be analyzed in accordance with RCM logic and its effectiveness re-evaluated. If the task can be proven effective, list "Yes" then proceed to Question 5. Justification for the answer must be written in column 4.

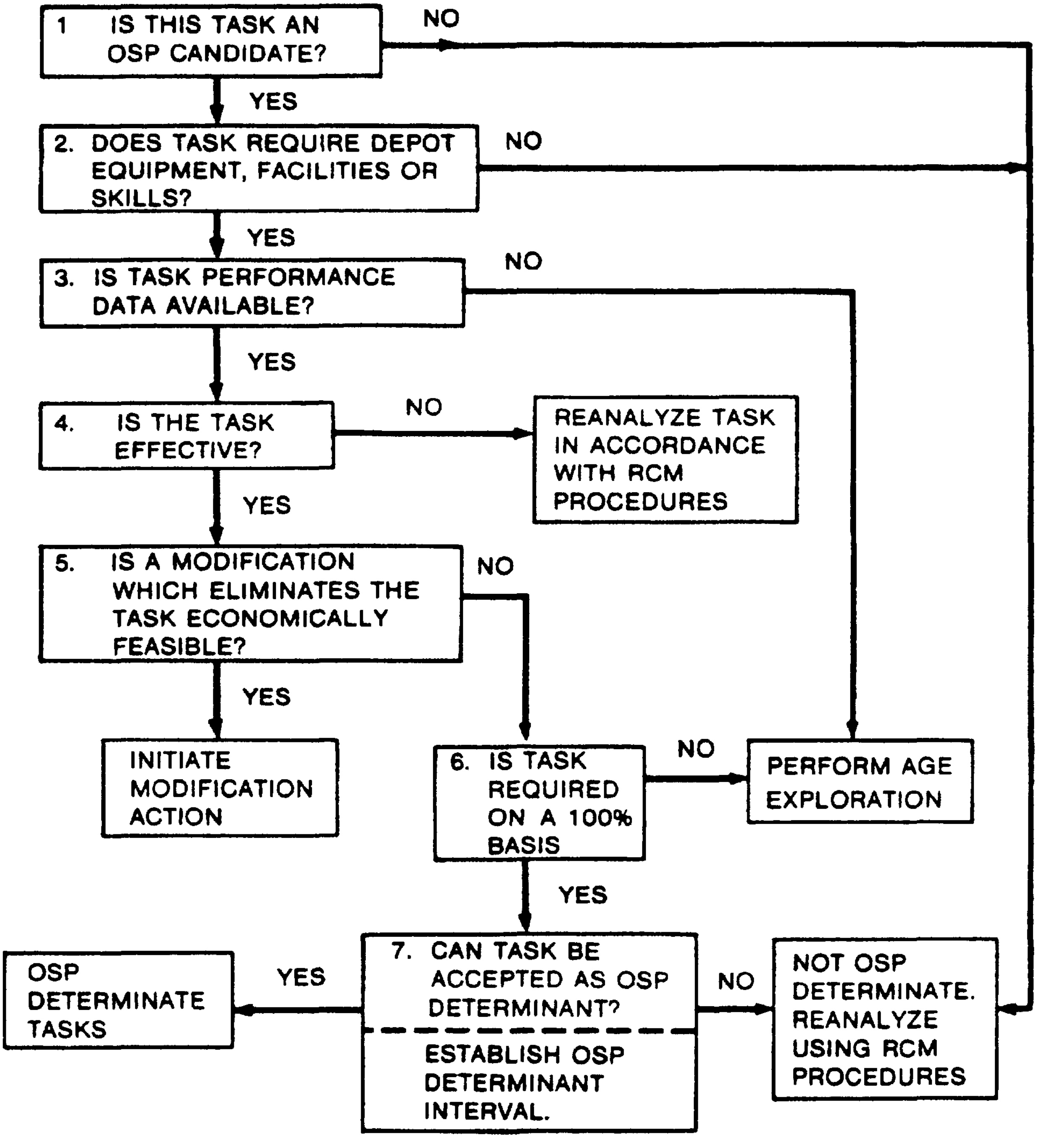



FIGURE 71 - OSP logic diagram

| OSP WORKSHEET NO. 1 OSP LOGIC EVALUATION SUMMARY | | | | PAGE ___ OF ___ |
|---|---|---|---|---|
| a) AIRCRAFT T/M/S | b) PREPARED BY<br>DATE | c) REVIEWED BY<br>DATE | d) APPROVED BY<br>DATE· | e) OSP RECOMMENDATION |

| 1) NOMEN-CLATURE | 2) TASK DESCRIPTION | | | | | | 3) OSP DECISION LOGIC ANSWERS (Y OR N) | | | | | | | 4) JUSTIFICATION FOR LOGIC ANSWERS | 5) DISPOSITION OF TASKS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NUMBER | S | A | N | D | DESCRIPTION | 01 | 02 | 03 | 04 | 05 | 06 | 07 | | REJECTED | | | ACCEPTED | | |
| | | | | | | | | | | | | | | | N | R | DS | E | AO | ALT |
| | | | | | | | | | | | | | | | | | | | | |

FIGURE 72- OSP logic evaluation - OSP worksheet 1

Question 5. Is a modification which would eliminate the need for a depot task economically feasible? If a modification/redesign is both mechanically and economically not possible, list "No" and proceed to Question 6. If a modification/redesign is feasible, list "Yes". Document the proof including comparative cost analysis between cost to modify and cost to continue the inspection over the life cycle of the aircraft. A logic diagram for product improvement is provided in FIGURE 16. Justification for the answer must be written in column 4.

Question 6. Is the task required on 100% basis? When this question is answered "Yes" the task is considered an OSP determinate task. This task is recommended to be performed on all aircraft entering the depot on a 100% basis, and justification must be provided in column 4. When providing the justification for this question many issues must be considered, some of which are: design life of T/M/S versus operational age, effect of a failure on residual strength, susceptibility to deterioration (corrosion, accidental damage), and type of structure for which the inspection task is assigned (safe life versus damage tolerant). Also, the justification should be based on the necessity of the task to be performed; that is, it ensures the structural integrity of the significant item which is essential to the safety of the aircraft of the aircraft. When this question is answered "No", the task is not OSP determinant, and justification for the answer must be written in column 4. When the question is answered "No", a 100% inspection is not recommended, and the task will be placed in the Age Exploration Program where a sampling plan will be developed for this significant item. An age exploration sampling plan must be performed so the age characteristics of the fleet can be determined. If Question 6 is answered "Yes" then proceed to Question 7.

Question 7. Can the Task be accepted as OSP Determinate? When this question is answered "Yes", the task is an OSP determinate task and is included in the determination of the OSP interval. The OSP determinate task's interval should also be established at this time and written in column 4. If for some reason this task should not be considered an OSP determinate task, the question should be answered "No", and the justification written in column 4.

Column 4: OSP Decision Logic Answer Justification - Written justification is required for each "Yes or No" answer from column 3.

Column 5: Disposition of Tasks - This column summarizes the final decision on the status of the proposed OSP determinate task. This column is completed after OSP worksheet 4 is evaluated. The column is divided into two groups: rejected tasks and accepted tasks. The group of rejected tasks are labeled as follows: (N), not OSP determinate because the task accomplishment does notrequire depot level skills equipment or facilities; (R), not OSP determinant because the task is not effective at detecting the anticipated defect, reanalysis required; (DS), not OSP determinant due to insufficient data to determine task effectiveness, task must be placed in an age exploration sampling plan. The group of accepted tasks are labeled as follows: (E), it is an OSP determinant task using the existing interval; (ADJ), it is an OSP determinate task using a newly adjusted interval for accomplishing the task; (ALT), it is an OSP determinant task which has a fixed interval and an alternative for accomplishing the task has been established.

50.4 Task Interval Determination. For those tasks proven to be OSP determinate by the OSP decision logic on worksheet 1, the next step is establishing the preliminary intervals and plotting them on a graph to assist in choosing the OSP. These preliminary intervals must be converted to calendar or flight hour intervals for development of the OSP graph. The preliminary intervals are event (cycles, flight hours, landing, etc.) oriented. They can be converted by determining the number of events which occur during a specified period of time and dividing that factor into the preliminary interval. For example:

Preliminary inspection = 2500 flight hours

Monthly usage rate = 50 flight hours/month

Calendar interval = 2500/50 = 50 months

For some of these tasks, a range for the inspection intervals may be established provided the safety limits established are not exceeded. In most cases, depot tasks developed using RCM logic will have a single interval rather than an interval range.

50.4.1 OSP Worksheet 2. Utilizing the information obtained from the OSP worksheet 1 and the information for the conversion of preliminary inspection intervals outlined above, the OSP worksheet 2, FIGURE 73 is completed. This worksheet is provided to list OSP determinant tasks from OSP worksheet 1, to document their preliminary intervals and then to convert them to calendar or flight hour intervals.

Column 1: Defect/Effect Correlation Summary - Identify the OSP determinate task and summarize the defects and effects which lead to its inclusion into the OSP evaluation.

a. Task Description - Briefly describe each OSP determinant task or related alternative.

b. Defect - List the defect for which the task is designed (cracks, wear, distortion, etc.).

c. Cycle Correlating to Defect - Describe the cycle (arrestments, flight hours, etc.) that is considered to be the primary factor in causing the initiation and growth of a particular defect.

d. Reason - Explain how or why the defect appears for the task being analyzed.

Column 2: Occurrence - Record the numerical range or interval (i.e., 20-30 arrestments, 100-120 flight hours etc.), determined by an RCM engineering analysis for the OSP determinant task to be performed. In some cases a single task interval will be given rather than a range. This single interval should be placed in the column designated minimum.

Column 3: Conversion Factor - Record the number, based on the aircraft's usage for individual T/M/S, which is used to convert the occurrence/interval to calendar time or flight hours.

Column 4: Source - Indicate the document or report from which the conversion factor data was obtained.

Column 5: Interval - List the range or individual interval for the OSP determinant task in calendar time or flight hours. This number should be based on the conversion factor from column 3.

50.5 OSP Worksheet 3. Utilizing the information obtained from the OSP worksheet 2, construct a graph on worksheet 3, FIGURE 74 showing the individual task number versus the individual preliminary interval.

Column 1: Number of Tasks - Enter the number of tasks with the same task interval. For example, 6 preliminary OSP determinant tasks have the interval of 20-25 months, so the number 6 is placed in column 1.

Column 2: Interval - List the task interval or range determined on worksheet 2, column 5.

Column 3: Individual Task Area (Midpoint) - If the interval from column 2 is a range, determine the midpoint of the range and multiply it by the number of tasks from column 1. For a single interval just multiply it with the number of tasks from column 1.

Column 4: Total Number of Tasks - Add the number of tasks from column 1 and place the total in this column.

Column 5: Total Histogram Area - Add the individual task areas from column 3 and place the total in this column.

**OSP WORKSHEET NO 2 OSP CALCULATION** PAGE ___ OF ___

| 1) DEFECT/EFFECT CORRELATION SUMMARY | | | | OCCURRENCE | | 3) CONVERSION FACTOR | 4) SOURCE | 5) INTERVAL |
|---|---|---|---|---|---|---|---|---|
| a) TASK DESCRIPTION | b) DEFECT | c) CYCLE CORRELATING TO DEFECT | d) REASON | INIMUM | b) MAXIMUM | | | |
| | | | | | | | | |

FIGURE 73- OSP logic evaluat

n - OSP worksheet 2

Column 6: Average Interval - The average interval (tentative OSP) is calculated and entered in this column. To calculate the average interval/tentative OSP, divide the total histogram area from column 5 by the total number of tasks from column 4.

Column 7: Interval and Task Graph - When drawing the graph, plot the individual tasks on the Y axis in ascending order and plot their respective interval on the X axis. Do this to determine the location of the tasks relative to the location of the average interval tentative OSP. Plot the average interval/tentative OSP on the graph by drawing a vertical dashed line at the interval which was determined in column 6.

50.6 OSP Worksheet 4. OSP worksheet 4, FIGURE 75 documents the evaluation of any stray tasks. It also provides space for justification of alternatives which can be performed in lieu of stray OSP determinant tasks.

Column 1: Stray Task Adjustment - Document the data required for adjustment of stray tasks in the following columns.

a. Task Number - Enter the task number from column 2 of worksheet 1.

b. Interval - Enter the interval from column 5 of worksheet 2.

c. Can the individual stray task interval be adjusted to the tentative OSP? - Provide a "Yes" or "No" answer to this question with justification. Longer tasks intervals may be shortened to fit the tentative OSP, but this results in the performance of more inspections than are actually needed for this significant item. Extension of stray tasks with shorter intervals than the tentative OSP must be considered carefully. If it is not possible to adjust the interval ("No" answer), then enter possible alternatives in column 2.

Column 2: Fixed Stray Task Alternatives - Document the data required for alternatives to fixed stray tasks in the following columns.

a. Task Number - Enter the task numbers for which no adjustments could made from column 1.

b. Interval - Enter the interval for each task number written in column 2a.

c. Are there alternatives for accomplishing each task? - For "No" answers in column 1c, alternatives must be considered. Alternatives must be accomplished for the required tentative OSP task at a specified interval, either at the depot (such as drive-in inspections, in-depth mid-term inspection etc.) or in the field by a depot team or by an organizational level team trained for the specific requirement.

**OSP WORKSHEET NO 3 OSP EVALUATION GRAPH** PAGE ___ OF ___

| 1) NUMBER OF TASKS | 2) INTERVAL | 3) INDIVIDUAL TASK AREA (USE MID POINT) | 4) TOTAL NO OF TASKS | 5) TOTAL HISTOGRAM AREA | 6) AVERAGE INTERVAL |
|---|---|---|---|---|---|
| | | | | | |

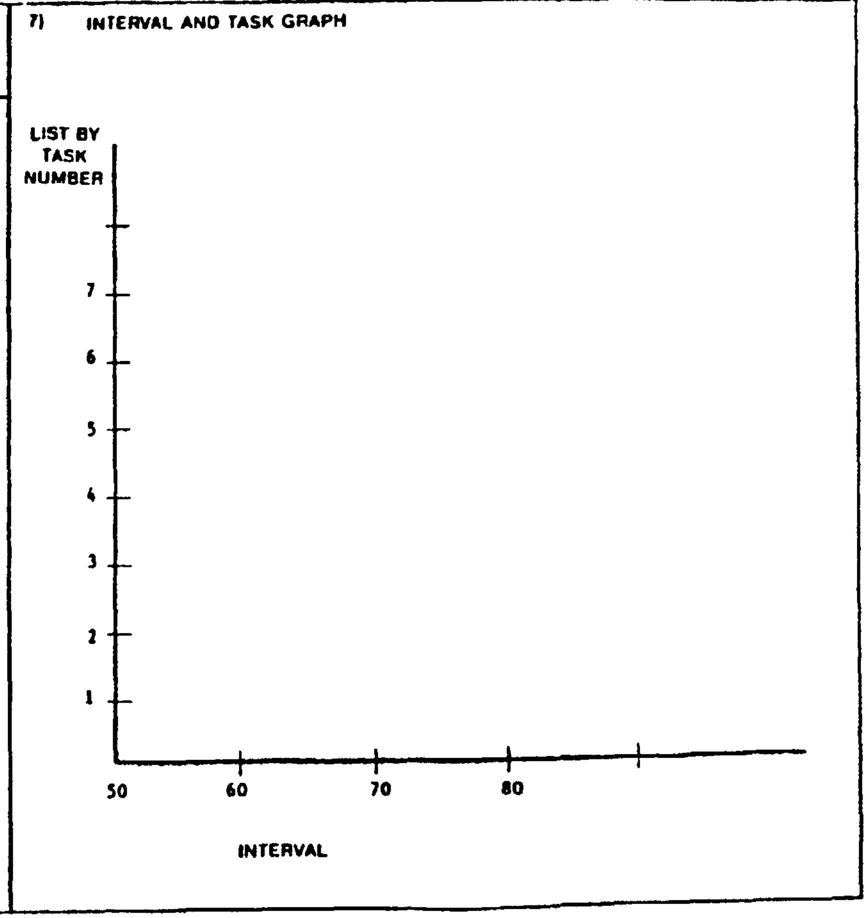



FIGURE 74- OSP logic evaluation - OSP worksheet 3

| OSP WORKSHEET NO. 4 STRAY TASK ADJUSTMENT/ALTERNATIVE | | | | | | | PAGE ___ OF ___ |
|---|---|---|---|---|---|---|---|
| 1) STRAY TASK ADJUSTMENT | | | | 2) FIXED STRAY TASK ALTERNATIVES | | | |
| a) TASK NO | b) INTERVAL | c) CAN THE INDIVIDUAL STRAY TASK INTERVAL BE ADJUSTED TO THE TENTATIVE OSP? | | a) TASK NO | b) INTERVAL | ARE THERE ALTERNATIVES FOR ACCOMPLISHING EACH TASK? | |
| | | Y/N | JUSTIFICATION | | | Y/N | JUSTIFICATION |
| | | | | | | | |

FIGURE 75- Stray task adjustment/alternative - OSP worksheet 4

50.7 OSP Summary. Once the stray tasks have either been adjusted or alternatives found, the OSP must be recorded. The final OSP decision is entered on OSP worksheet 1, Block e. This interval will be used for the T/M/S for which the analysis was performed. The OSP must be reviewed and updated annually. This same OSP process should be used each year to evaluate the next year's OSP. Preparations must be made to collect age exploration data and any other data which is pertinent to the evaluation of the OSP.

50.8 Example - OSP Determination for the Z-9Z. This example is intended to be instructional and is not taken from an actually completed OSP analysis. The basis for the example may be actual significant items or components; however, the intervals and results are only examples. The answers and justification for the OSP decision logic questions are intended to represent a realistic audit trail. This example does not include all the supporting information required to support the logic decisions.

**OSP WORKSHEET NO 1 OSP LOGIC EVALUATION SUMMARY** PAGE 1 OF 9

| a) AIRCRAFT T/M/S | b) PREPARED BY | c) REVIEWED BY | d) APPROVED BY | e) OSP RECOMMENDATION |
|---|---|---|---|---|
| Z-9Z | FRED FLOUNDER<br>DATE 10/1/84 | RON REPEAT<br>DATE 10/15/86 | BRUCE BUREAUCRACT<br>DATE 10/22/84 | |

| 1) NOMENCLATURE | 2) TASK DESCRIPTION NUMBER | S | A | N | D | DESCRIPTION | 3) OSP DECISION LOGIC ANSWERS (Y OR N) Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | 4) JUSTIFICATION FOR LOGIC ANSWERS | 5) DESCRIPTION OF TASKS REJECTED N | R | DS | ACCEPTED E | IO | ALT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Landing Gear Trunnion Lugs | 012P | | X | | X | Bushings must be removed from lugs. The lugs are inspected for cracks using a dye penetrant NDI | Y | Y | Y | Y | Y | Y | Y | Q1 - A structural failure of this item would have a direct adverse affect on operating safety.<br>Q2 - A special jig and extracting tool is required to remove the bushings from the lugs without causing damage. Special skills are required to operate the tool.<br>Q3 - Structural test data was collected during the fatigue test of the aircraft. A safe life limit was established for the landing gear using this data.<br>Q4 - Historical data reveals that all discrepancies were found before failure could occur.<br>Q5 - A modification would not eliminate the need for a Depot level task.<br>Q6 - This inspection is performed to ensure the structural integrity of the landing gear and is essential to the safety of the aircraft.<br>Q7 - 2800 landings | | | | X | | |
| Nose Landing Gear Trunnion Lugs | 013P | | X | | X | Same as 012P | Y | Y | Y | Y | N | Y | Y | Same as 012P | | | | X | | |

FIGURE 76- OSP logic evaluation summary- OSP worksheet 1

**OSP WORKSHEET NO 1 OSP LOGIC EVALUATION SUMMARY** PAGE 2 OF 9

| a) AIRCRAFT T/M/S | b) PREPARED BY | c) REVIEWED BY | d) APPROVED BY | e) OSP RECOMMENDATION |
|---|---|---|---|---|
| | DATE | DATE | DATE | |

| 1) NOMENCLATURE | 2) TASK DESCRIPTION NUMBER | S | A | N | D | DESCRIPTION | 3) OSP DECISION LOGIC ANSWERS (Y OR N) Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | 4) JUSTIFICATION FOR LOGIC ANSWERS | 5) DECISION OF TASK: REJECTED N | R | DS | ACCEPTED F | OD | ALT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WING SPAR CAPS | 024P | X | | | X | A dye penetrant NDI of caps must be performed to find cracks A visual inspection for corrosion is also performed | Y | Y | Y | Y | N | N | | Q1 - A structural failure of this item would have an adverse affect on operating safety<br>Q2 - Depot level skills are required to perform the task.<br>Q3 - Crack propagation data was provided during the fatigue testing of wing<br>Q4 - Historical data shows that all potential failures were found before functional failure could occur.<br>Q5 - A modification would not eliminate the need for depot level task.<br>Q6 - Test data showed there was significant time between potential and functional failure This would allow for a sampling plan rather than a 100% inspection program. | | | X | | | |
| WING FUSELAGE ATTACH POINTS FWD, AFT | 009P | | √ | | X | Wing must be separated from fuselage | Y | Y | Y | Y | N | Y | Y | Q1 - A structural failure of this item could have an adverse affect on operating safety.<br>Q2 - Depot level equipment and skills are required to perform task<br>Q3 - Crack data was provided during the fatigue testing of the aircraft<br>Q4 - Historical data and depot reports shows that all potential failures were found before functional failure could occur<br>Q5 - A modification would not eliminate the need for depot level task.<br>Q6 - The inspection is performed to ensure the structural integrity and safety of the aircraft.<br>Q7 - 2500 flight hours | | | X | | | |
| PIN WING-TO-FUSELAGE ATTACH FWD, AFT | 010P | X | | | X | Wing must be separated from fuselage to perform inspections. Remove pin and perform an eddy current inspection to locate cracks | Y | Y | Y | Y | N | Y | Y | Q1 - A structural failure of this item would have an adverse affect on operating safety<br>Q2 - Depot level equipment and skills are required to perform task<br>Q3 - Stress analysis and material studies were performed by the manufacturer to determine safe life of the pins.<br>Q4 - Historical data has shown the sampling plan has found numerous potential failures.<br>Q5 - A modification would not eliminate the need for depot level task. | | | | | X | |

FIGURE 77- OSP logic evaluation summary- OSP worksheet 1

**OSP WORKSHEET NO 1 OSP LOGIC EVALUATION SUMMARY** PAGE 3 OF 9

| a) AIRCRAFT T/M/S | b) PREPARED BY DATE | c) REVIEWED BY DATE | d) APPROVED BY DATE | e) OSP RECOMMENDATION |
|---|---|---|---|---|
| | | | | |

| 1) NOMENCLATURE | 2) TASK DESCRIPTION NUMBER | S | A | N | O | DESCRIPTION | 3) OSP DECISION LOGIC ANSWERS (Y OR N) Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | 4) JUSTIFICATION FOR LOGIC ANSWERS | 5) DESCRIPTION OF TASKS REJECTED N | R | DS | E | ACCEPTED IO | ALT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Horizontal Tail Fuselage Attach Points FWD, AFT | 058P | | X | | X | Horizontal tail must be separated from the fuselage to perform inspections. A dye penetrant NDI of both the tail and fuselage attach points must be performed to locate cracks. | Y | Y | Y | Y | N | Y | Y | Q6 - Since potential failures were being found on a regular basis with the sampling plan a 100% inspection program is now recommended.<br>Q7 - 2600 flight hours<br><br>Q1 - Q6-Answers are essentially the same as 009P<br>Q7 - 2200 Flight Hours | | | | | X | |
| Pin Horizontal to Fuselage Attach FWD, AFT | 059P | X | | | X | Horizontal tail must be Separated from the fuselage to perform inspections. An eddy current NDI is required to find cracks in this item. | Y | Y | Y | Y | N | Y | Y | Q1 - Q6-Answers are essentially the same as 010P.<br>Q7 - 2400 Flight Hours | | | | | X | |
| SPAR CAPS Horizontal | 077P | | ✓ | | ✓ | A visual inspection must be performed to find any corrosion. If corrosion is found, it must be cleaned away and a dye penetrant NDI must be performed to find stress cracks. | Y | Y | Y | Y | N | Y | Y | Q1 - A structural failure of this item would have a direct adverse affect on operating safety.<br>Q2 - Depot level skills are required to perform the task.<br>Q3 - Crack propagation data was provided during the fatigue testing of the aircraft.<br>Q4 - Historical data shows that all potential failures were found before functional failure could occur.<br>Q5 - A modification would not eliminate the need for depot level task.<br>Q6 - Because of the large variation in the aerodynamic loads experienced by horizontal stabilizer, this item should be inspected on a 100% basis.<br>Q7 - 1800-2100 Flight Hours | | | | | | X |

FIGURE 78- OSP logic evaluation summary- OSP worksheet 1

**OSP WORKSHEET NO 1 OSP LOGIC EVALUATION SUMMARY** PAGE 4 OF 9

| a) AIRCRAFT | b) PREPARED BY | c) REVIEWED BY | d) APPROVED BY | e) OSP RECOMMENDATION |
|---|---|---|---|---|
| | DATE | DATE | DATE | |

| 1) NOMENCLATURE | 2) TASK DESCRIPTION: NUMBER | F | A | N | D | DESCRIPTION | 3) OSP DECISION LOGIC ANSWERS Y OR N: 01 | 02 | 03 | 04 | 05 | 06 | 07 | 4) JUSTIFICATION FOR LOGIC ANSWERS | 5) DESCRIPTION OF TASKS: REJECTED N | R | DS | ACCEPTED E | IO | ALT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPAR CAPS VERTICAL STABILIZERS | 078P | Y | | Y | | A dye penetrant NDI of the spar caps must be performed to find cracks A visual inspection for corrosion must also be performed | Y | Y | N | | | | | Q1 - A structural failure of this item would have a direct adverse affect on operating safety<br>Q2 - Depot level skills are required to perform the task.<br>Q3 - Crack information was provided by Safety Center Reports and Depot information from a special inspection program. More information is required to determine a proper inspection interval, so an Age Exploration Sampling Plan must be established for this item. | | X | | | | |

FIGURE 79- OSP logic evaluation summary- OSP worksheet 1

**OSP WORKSHEET NO 2 OSP CALCULATION** PAGE 5 OF 9

| 1) DEFECT/EFFECT CORRELATION SUMMARY | | | | 2) OCCURRENCE | | 3) CONVERSION FACTOR | 4) SOURCE | 5) INTERVAL |
|---|---|---|---|---|---|---|---|---|
| a) TASK DESCRIPTION | b) DEFECT | c) CYCLE CORRELATING TO DEFECT | d) REASON | a) MINIMUM | b) MAXIMUM | | | |
| 012P - Bushings must be removed from lugs. The lugs are inspected for cracks using a dye penetrant NDI. | CRACKS | LANDINGS | FATIGUE, OVERSTRESS | 2800 LANDINGS | ----- | 1.2 Landings/FH<br>32.7 FH/Month<br>39.2 Landings/Month | 3M Status Report | 71.4 Months |
| 013P - Bushings must be removed from lugs. The lugs are inspected for cracks using a dye penetrant NDI. | CRACKS | LANDINGS | FATIGUE, OVERSTRESS | 1200 LANDINGS | ----- | 62.1 Landings/Month | 3M Status Report | 71.4 Months |
| 009P - Wing must be separated from fuselage to perform inspections. A dye penetrant NDI of both wing and fuselage attach points must be performed to locate cracks. | CRACKS | FLIGHT HOURS | FATIGUE OVERSTRESS | 2500 FH | ----- | 32.7 FH/Month | 3M Status Report | 76.5 Months |

FIGURE 80- OSP calculation - OSP worksheet 2

**OSP WORKSHEET NO 2 OSP CALCULATION** PAGE 6 OF 9

| 1) DEFECT/EFFECT CORRELATION SUMMARY | | | | 2) OCCURRENCE | | 3) CONVERSION FACTOR | 4) SOURCE | 5) INTERVAL |
|---|---|---|---|---|---|---|---|---|
| a) TASK DESCRIPTION | b) DEFECT | c) CYCLE CORRELATING TO DEFECT | d) REASON | a) MINIMUM | b) MAXIMUM | | | |
| 010P - Wing must be separated from fuselage to perform inspections. Remove pin and perform an eddy current inspection to locate cracks. | CRACKS | FLIGHT HOURS | FATIGUE, OVERSTRESS | 2600 FH | ----- | 32.7 FH/Month | 3M Status Report | 79.5 Months |
| 058P - The horizontal tail must be separated from the fuselage to perform inspections A dye penetrant NDI of both tail and fuselage attach points must be performed to locate cracks. | CRACKS | FLIGHT HOURS | FATIGUE, OVERSTRESS | 2200 FH | ----- | 32.7 FH/Month | 3M Status Report | 67.3 Months |

FIGURE 81 - OSP calculation - OSP worksheet 2

| OSP WORKSHEET NO. 2 OSP CALCULATION | | | | | | | | | PAGE 7 OF 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1) DEFECT/EFFECT CORRELATION SUMMARY | | | | 2) OCCURRENCE | | 3) CONVERSION FACTOR | 4) SOURCE | 5) INTERVAL | |
| a) TASK DESCRIPTION | b) DEFECT | c) CYCLE CORRELATING TO DEFECT | d) REASON | a) MINIMUM | b) MAXIMUM | | | | |
| 059P - The horizontal tail must be separated from the fuselage to perform inspections. An eddy current NDI is required to find cracks in this item. | CRACKS | FLIGHT HOURS | FATIGUE, OVERSTRESS | 2400 FH | ----- | 32.7 FH/Month | 3M Status Report | 73.4 Months | |
| 077P - A visual inspection must be performed to find any corrosion. If corrosion is found it must be cleaned away and a dye penetrant NDI must be performed to find stress cracks. | CORROSION/ CRACKS | FLIGHT HOURS | FATIGUE, OVERSTRESS and CORROSION | 1800 FH | 2100 FH | 32.7 FH/Month | 3M Status Report | 55.1 - 64.2 Months | |

FIGURE 82- OSP calculation - OSP worksheet 2

OSP WORKSHEET NO. 3 OSP EVALUATION GRAPH

PAGE 8 OF 9

| 1) NUMBER OF TASKS | 2) INTERVAL | 3) INDIVIDUAL TASK AREA (USE MID POINT) | 4) TOTAL NO OF TASKS | 5) TOTAL HISTOGRAM AREA | 6) AVERAGE INTERVAL |
|---|---|---|---|---|---|
| 2 | 71 4 | 142 8 | 7 | 499 2 | 71 3 Months |
| 1 | 76 5 | 76 5 | | | |
| 1 | 79 5 | 79 5 | | | |
| 1 | 67 3 | 67 3 | | | |
| 1 | 73 4 | 73 4 | | | |
| 1 | 55 1 to 64 2 | 59 7 | | | |

7) INTERVAL AND TASK GRAPH

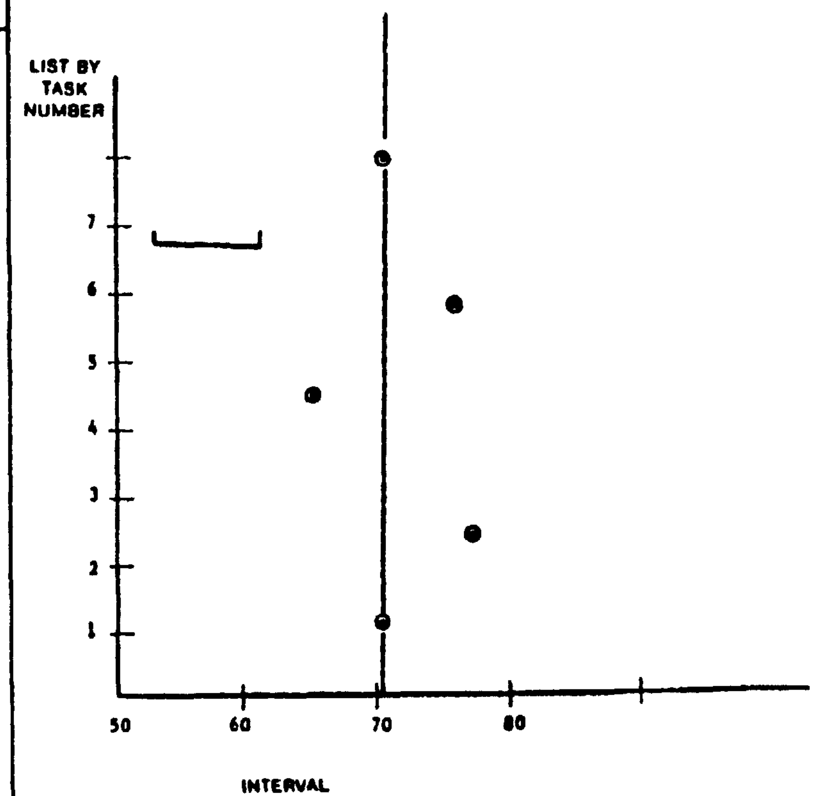



FIGURE 83 - OSP evaluation graph- OSP worksheet 3

**OSP WORKSHEET NO 4 — STRAY TASK ADJUSTMENT/ALTERNATIVE** PAGE 9 OF 9

| 1) STRAY TASK ADJUSTMENT | | | | 2) FIXED STRAY TASK ALTERNATIVES | | | |
|---|---|---|---|---|---|---|---|
| a) TASK NO | b) INTERVAL | c) CAN THE INDIVIDUAL STRAY TASK INTERVAL BE ADJUSTED TO THE TENTATIVE OSP? Y/N | JUSTIFICATION | a) TASK NO | b) INTERVAL | ARE THERE ALTERNATIVES FOR ACCOMPLISHING EACH TASK? Y/N | JUSTIFICATION |
| 012P | 71.4 | Y | The interval may be shortened to fit the tentative OSP. | 077P | 55.1 to 64.2 | Y | A special depot level team will be sent to perform the inspections at the interval of 55 months. |
| 013P | 71.4 | Y | Same as 012P | | | | |
| 009P | 76.5 | Y | The interval may be shortened to fit the tentative OSP, with the penalty being more inspections over the life of the aircraft than are actually needed. | | | | |
| 010P | 79.5 | Y | Same as 009P | | | | |
| 058P | 67.3 | Y | An engineering review of the item suggested that extending the interval by 4 months would not greatly increase the risk of failure. | | | | |
| 059P | 73.4 | Y | Same as 012P | | | | |
| 077P | 55.1 to 64.2 | N | Increasing the interval would greatly increase the risk of failure. | | | | |

FIGURE 84- Stray task adjustment/alternative- OSP worksheet 4

APPENDIX D

RCM WORKSHEETS

10. GENERAL

10.1 Scope. This appendix provides illustrations of worksheets to be used during an RCM analysis.

20. REFERENCED DOCUMENTS

Not applicable.

30. DEFINITIONS

Not applicable.

40. GENERAL REQUIREMENTS

Not applicable.

50. DETAIL REQUIREMENTS

50.1 RCM worksheets. The RCM worksheets are used to document the preventive maintenance analysis as described in section 5 of this standard. The format of the RCM worksheets shown here is for illustrative purposes. Other worksheet formats are acceptable, pending government approval, if all data elements provided by the RCM worksheets in this appendix are contained in the contractor proposed worksheet format.

| RCM WORKSHEET NO. 1 SUMMARY DATA | | e) INDENTURE LEVEL | h) PAGE ____ OF ____ |
|---|---|---|---|
| a) SYSTEM/SUBSYSTEM NOMENCLATURE | c) PART/MODEL NUMBER, FSCM | f) PREPARED BY/DATE | j) REVISION NO./DATE |
| b) SYSTEM/SUBSYSTEM<br>LSACN / MIR INDEX CODE: WUC, CF | d) END ITEM NOMENCLATURE T/M/S NALC NUMBER | g) REVIEWED BY/DATE | k) APPROVED BY/DATE |

| 1) ITEM LSACN/ MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) RCM DECISION LOGIC ANSWERS (Y OR N) | | | | | | | | | | | | | | | | | | | 5) RCM TASKS | | 6) INSPECTION INTERVAL | | 7) LSA TASK CODE / LEVEL OF MAINTENANCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | FAILURE CONSEQUENCES | | | SAFETY | | | | ECONOMIC/ OPERATIONAL | | | NON SAFETY HIDDEN FAILURE | | | | SAFETY HIDDEN FAILURE | | | | | NO | DESCRIPTION | PRELIM | PACKED | |
| | | | EF 1 | ES 2 | SHF 3 | SL 4 | OC 5 | HT 6 | CB 7 | SL 8 | OC 9 | HT 10 | SL 11 | OC 12 | HT 13 | FF 14 | SL 15 | OC 16 | HT 17 | CB 18 | FF 19 | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |

FIGURE 85 - Summary data - RCM worksheet 1

**RCM WORKSHEET NO. 2 FAILURE CONSEQUENCE/SERVICING/LUBRICATION TASK EVALUATION** | DATE | PAGE ___ OF ___

| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCE DETERMINATION | | | | | | 4) FAIL CONSEQ | 5) DESCRIBE SERVICING OR LUBRICATION TASK | | | | | | 6) IS SERVICING OR LUBRICATION TASK APPLICABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a) QUESTION 1 IS THE FAILURE OCCURRENCE EVIDENT TO THE CREW OR OPERATOR WHILE PERFORMING NORMAL DUTIES? | | b) QUESTION 2 DOES THE FAILURE CAUSE A FUNCTION LOSS OR SECONDARY DAMAGE THAT COULD HAVE A DIRECT ADVERSE EFFECT ON OPERATING SAFETY? | | c) QUESTION 3 DOES THE HIDDEN FAILURE ITSELF OR IN COMBINATION WITH ANOTHER FAILURE HAVE AN ADVERSE EFFECT ON OPERATING SAFETY? | | | a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL | d) PROPOSED LEVEL OF MAINTENANCE | | | |
| | | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | | | | | O | I | D | |
| | | | | | | | | | | | | | | | |

FIGURE 86- Failure consequence/ servicing/lubrication task evaluation- RCM worksheet 2

## RCM WORKSHEET NO. 3 ON-CONDITION TASK EVALUATION

| | | | DATE | PAGE ____ OF ____ |
|---|---|---|---|---|

| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) ON-CONDITION TASK APPLICABILITY CRITERIA | | | 5) DESCRIBE APPLICABLE ON-CONDITION TASK | | | | | | 6) EFFECTIVENESS CRITERIA | | | | | | 7) IS TASK APPLIC ABLE AND EFFECTIVE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | a) MEANS TO DETECT REDUCED FAILURE RESISTANCE | b) POTENTIAL FAILURE CONDITION DETECTABLE BY AN EXPLICIT TASK | INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL (ENG) | d) PROPOSED LEVEL OF MAINTENANCE | | | a) SAFETY | b) SAFETY HIDDEN FAILURE | c) OPERATIONAL/ECONOMIC AND NON SAFETY HIDDEN FAILURE | | | | |
| | | | | | | | | | O | I | D | PROB OF FAILURE | PROB OF MULTIPLE FAILURE | 1) IS FFR HIGH? | 2) OPERATING COSTS? | 3) HIGH REPAIR OR OPERATING COSTS? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | |
| | | | | | | | | | | | | | | | | | | |

FIGURE 87- On-Condition task evaluation- RCM worksheet 3

| RCM WORKSHEET NO. 4 HARD TIME TASK EVALUATION | | | | | | | | | | | | DATE | | | PAGE ___ OF ___ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/ MIR CODE | 2) FFMC | 3) FAILURE CONSEQUENCES | 4) HARD TIME TASK APPLICABILITY CRITERIA | | | | 5) DESCRIBE APPLICABLE HARD TIME TASK | | | | 6) EFFECTIVENESS CRITERIA | | | | | | 7) IS TASK APPLICABLE AND EFFECTIVE? |
| | | | COMPLETE FOR REWORK TASKS ONLY | NON SAFETY DISCARD TASKS ONLY | | SAFETY OR SHF DISCARD TASKS | a) NUMBER | b) DESCRIPTION | c) PRELIMINARY TASK INTERVAL (ENG) | d) PROPOSED LEVEL OF MAINTENANCE | a) SAFETY | b) SAFETY HIDDEN FAILURE | c) OPERATIONAL/ECONOMIC AND NON SAFETY HIDDEN FAILURE | | | | |
| | | | a) IS IT POSSIBLE TO RESTORE FAILURE RESISTANCE OF ITEM BY REWORK TASK | b) WEAROUT AGE | c) PERCENTAGE OF ITEMS WHICH SURVIVE TO THIS AGE | d) LIFE LIMIT | | | | O \| I \| D | PROB OF FAILURE | PROB OF MULTIPLE FAILURE | 1) IS FFR HIGH? | 2) OPERATING CONS? | 3) HIGH REPAIR OR OPERATING COSTS? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK ? | |
| | | | | | | | | | | | | | | | | | |

FIGURE 88- Hard time task evaluation- RCM worksheet 4

| RCM WORKSHEET NO. 5 COMBINATION/FAILURE FINDING TASK EVALUATION | | | | | | | | | | | | | | | DATE | PAGE ____ OF ____ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) | 2) | 3) | 4) APPLICABILITY CRITERIA | | 5) DESCRIBE APPLICABLE TASK | | | | | | 6) EFFECTIVENESS CRITERIA | | | | | 7) |
| ITEM LSACN/ MIR INDEX CODE | FFMC | FAILURE CONSEQ | a) COMBINATION TASK (COMB) | b) FAILURE FINDING TASK (FF) | a) NO | b) | c) PRELIM TASK INTERVAL | d) PROPOSED LEVEL OF MAINT | | | a) SAFETY AND SAFETY HIDDEN FAILURE | b) NON SAFETY HIDDEN FAILURES (COST EFFECTIVENESS DIAGRAM) | | | | IS THE TASK APPLIC ABLE AND EFFECTIVE ? |
| | | | DO THE TASKS MEET THEIR INDIVIDUAL APPLICABILITY CRITERIA? | IS AN OC, HT, OR COMB (FOR SAFETY HIDDEN FAILURES) TASK APPLICABLE AND EFFECTIVE FOR THIS FFMC? | | DESCRIPTION STATE IN PARENTHESIS IF TASK IS (COMB) OR (FF) | (ENG) | O | I | D | PROBILITY OF FAILURE OR MULTIPLE FAILURE | 1) IS FPR HIGH ? | 2) OPERAT CONSEQ ? | 3) HIGH REPAIR OR OPER COSTS ? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | |
| | | | | | | | | | | | | | | | | |

FIGURE 89- Combination/failure finding task evaluation- RCM worksheet 5

**RCM WORKSHEET NO 6** **SSI TASK EVALUATION** PAGE ____ OF ____

**1) SSI IDENTIFICATION**
- a) NOMENCLATURE
- b) LOCATION: FS | WS | WL
- b) LCN
- c) MIR INDEX CODE: WUC | TEC | CF

**2) SSI TECHNICAL DATA**
- a) FATIGUE DESIGN LIFE: END ITEM | SSI
- DAMAGE TOLERANT
  - b) CRACK LIFE: DETECT | CRIT
  - c) RESIDUAL STRENGTH
- d) SAFE LIFE LIMIT
- e) ACCESS: INTERNAL | EXTERNAL

| 3) SSI RATING FACTORS | | | | | | | | | | | | 4) FFMC | 5) SSI STRUCTURES LOGIC ANSWERS | | | | | | | | 6) TASK DESCRIPTION | | | | | | | 7) AGE EXPL CAND? | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a) FATIGUE DAMAGE | | | b) ENVIRONMENTAL DAMAGE | | | | c) ACCIDENTAL DAMAGE | | | | | | | | | | | | | | | | | | LOM | | | | |
| RS | LDC | CPL | MT | SP | EP | AVG | DS | GO | FO | LO | AVG | | 1 DT | 2 GOC | 3 DOC | 4 AE | 5 HT | 6 GOC | 7 DOC | 8 AE | NO | TYPE | DESCRIPTION | PREL INSP INTVL | O | I | D | YES | NO |

FIGURE 90- SSI task evaluation- RCM worksheet 6

| RCM WORKSHEET NO 7 — DETERMINATION OF AGE EXPLORATION TASKS | | | | | | | | | | | | | | | | | | DATE | | | PAGE ____ OF ____ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LSACN/WUC INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) DEFAULT FAILURE CONSEQ (W/S 2) | 5) DEFAULT TASK EVALUATION | 6) AGE EXPLORATION REQUIREMENT | | | | | | 7) AGE EXPLORATION TASK ASSESSMENT | | | | | | | 8) TASK/CATEGORY | | | | | |
| | | | | TYPE TASK | a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) PROP LEVEL OF MAINT | | | e) STUDY PERIOD | a) Q No 1 | b) QUESTION No 2 | | c) QUESTION No 3 | | d) QUESTION No 4 | | DAIT | | SAEI | | RASS |
| | | | | | | | | O | I | D | | Y/N | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | I | H | I | H | |
| | | | | | | | | | | | | | | | | | | | | | | | |

FIGURE 91- Determination of age exploration task- RCM worksheet 7

# APPENDIX E

# AUDITING RCM ANALYSIS

## 10. GENERAL

10.1 Scope. This appendix provides the means to review the RCM analysis process to ensure the RCM program goals are met.

## 20. REFERENCED DOCUMENTS

Not applicable.

## 30. DEFINITIONS

30.1 MESM - Mission Essential Subsystem Matrices.

30.2 FMEA - Failure Mode and Effects Analysis.

## 40. GENERAL REQUIREMENTS

40.1 Auditing the RCM analysis. Although an RCM analysis is conducted by highly experienced analysts, objective judgments of the RCM logic decisions may become biased during the analysis process. Therefore, an independent review of the analysis decisions ensures that logic is properly applied and identifies any errors in the decision process. This independent review shall be accomplished externally from the organization which performs the analysis. The review or audit process should include the following areas:

a. Significant item selection.

b. Determination of item functions, failure modes and effects.

c. Classification of failure consequences.

d. Evaluation of applicability and effectiveness criteria for task selection.

e. Overall RCM Program.

The following section discusses in detail the specific areas to be reviewed during an audit of the RCM analysis.

## 50. DETAILED REQUIREMENTS

50.1 Significant item selection. The chief prerequisite for auditing the RCM analysis is a clear understanding of RCM principles. As a preliminary step, the auditor screens out all obviously nonsignificant items and ensures that descriptive worksheets are provided for the items selected for analysis. It is important that analysts and auditors share common definitions of significant items and operational consequences.

a. Identification of significant items is based on their failure consequence, not on their costs and complexity. Failure consequences refer to the direct impact that a particular loss function has on the safety and operating capability of the equipment. It does not refer to the number of failure possibilities for the item or the effects these failures have on the item itself.

b. Circumstances that establish operational consequences and the relative costs attributed to these consequences must be clearly defined. This information is the basis for determining whether a given type of failure will have economic consequences on a particular organization. For example, if the MESM or other regulations stipulate that an aircraft cannot be flown with an inoperative item, then initially the item is always classified as one whose failure has operational consequences. However, the actual economic impact of the consequences may vary from one operational activity to another depending on the scheduled use of the aircraft, equipment, maintenance facilities, the ease of replacing failed units, and a variety of other considerations.

50.2 Item functions, failures, and effects. Several problems may come to light when the completed worksheets are examined. These problems include improper definition of functions, confusion between functional failures and engineering failure modes, and insufficient information about failure effects. One important way to ensure that auditors and analysts can identify these problems is through the design of the worksheets themselves. Although organizations have their own preferences about forms, the worksheets must cover all data to be considered in the analysis. Whenever worksheets are redesigned, basic elements are frequently overlooked or "improvements" are introduced that reflect misconceptions. In general, the design of the forms presented in Appendix D of this standard should be maintained. The RCM worksheets provide an adequate record of the decision process. The chief criterion is that each task should be completely traceable. At any time, either during or after analysis, it must be possible to start with any function and trace through to the task assigned to protect it or to backtrack from a given task to examine the reasoning that led to it. Obvious omissions of logic and tracking can often be spotted by examining the worksheet format, but more subtle difficulties may not come to light until the first few worksheets are completed.

50.2.1 Functions. One of the most important errors for the auditor to detect is improper definition of the functions of an item. Is the basic function stated precisely for the level of the item in question? Does this basic function relate directly to some higher level function that is essential to operating capability? If no, there may be some confusion about the level of indenture for this item. Have all secondary or characteristic functions been listed, and is each a separate function from the standpoint of the operating crew or the system as a whole? Are all hidden functions included and defined as they relate to the system as a whole? If there are failure possibilities with no related function, this is a clue that the functions themselves require further thought. For example, the basic function of a fuel pump is to pump fuel; however, if this item is also subject to leaks, one additional function must be to contain the fuel (be free of leaks). Remember, the level of indenture of an item will affect the way its functions are described. At the parts level, each part has a function within the assembly that contains it. But, a description of these functions will only lead to an analysis of failures of the assembly, not of the system or the aircraft as a whole. If the indenture of items is high, the number of functions and failure possibilities may be too great for efficient analysis. One test is to select a few items and combine them or divide them to see whether the list of functions changes. If it does, select the level that makes the analysis most efficient but still includes all the functions that can clearly be visualized from the aircraft level.

50.2.2 Failures. The statement of functional failures should be examined carefully to identify confusion between functional failures and engineering failure modes.

a. The statement should describe the condition defined as a functional failure (a loss of the stated function). It should not describe the manner in which this failure occurs. For example, if a failure such as external leaks is described only as "leaking oil seal", other failure modes that lead to external leaks may be overlooked or be erroneously attributed to some other function. This problem of confusing functional failures and failure modes is often a source of the difficulty in defining the item's functions. The statement describing the loss of a hidden function requires particular care to ensure that it does not refer to a multiple failure. For example, if the function of a check valve is to prevent backflow in case of a duct failure, the functional failure in this case is not backflow but no protection against backflow. Errors such as this can be quite subtle and difficult to spot. However, if they are not identified, they frequently lead to confusion about the failure consequences.

b. The identification of engineering failure modes is another problem area. Do the worksheets list failure modes that have never actually occurred? Are the failure modes reasonable in light of experience with similar equipment? Have any important failure modes been overlooked? In this area the auditors will have to rely on their own general engineering background to identify points on which further consultation with the manufacturers or other sources is advisable. One problem to watch for is a failure mode that is not the basic mode of failure. Another is the tendency to list all possible failure modes, regardless of their likelihood. This results in a great deal of unnecessary analysis and the possible inclusion of unnecessary tasks in the initial program. Just as failure modes may slide back into the description of functional failures, they also tend to elide into the description of failure effects. One point to watch for is a description of failure effects that relate to the cause of the failure, rather than to its immediate results. Again, the failure mode "leaking oil seal" will sometimes be stated as a failure effect (perhaps with "oil seal failure" given as the failure mode). This is a subtle error, but it obscures the effect of the functional failure in question on the equipment and its occupants.

50.2.3 Effects. The description of failure effects must include all the information necessary to support the analyst's evaluation of the failure consequences. Is a description of the physical evidence by which the operating crew will recognize that a failure has occurred included as part of the failure detection method? Are the effects of secondary damage stated as well as the effects of a loss of function? Is it clear from the description whether the secondary damage is critical? Does the description state the ultimate effects of the failure with no preventive maintenance? In the case of hidden functions, the ultimate effects will usually represent the combined effects of a possible multiple failure. This information helps to establish the frequency of maintenance required to protect the hidden function. The failure effects should be examined to ensure that they do not represent overreaction by inexperienced analysts. At the other extreme, serious effects may be overlooked where the structure cannot be shown to be damage tolerant for certain types of failures. In either case the effects stated, including secondary damage, must be a direct result of the single failure in question and not effects that will occur only in conjunction with some other failure or as a result of pilot error. As with hidden function items, protection against multiple failures is provided for in the decision logic by independent analysis of each single failure possibility.

50.3 Classification of failure consequences. The first three questions in the decision logic identify the consequences of each type of failure and the branch of the decision diagram in which proposed tasks are to be evaluated. The answers to these questions therefore warrant special attention during auditing to ensure that the tasks have been measured against the correct effectiveness criterion. The basis for each answer should be clearly traceable to the information recorded on the FMEA worksheet.

50.3.1 Evident and hidden functions. There are several common problems in identifying hidden functions. The first matter to be ascertained concerns the use of the decision diagram itself. Has the evident failure question been asked, not for the item, but for each of its functions? If not, the answer may be true only for the basic function, and other functions will be analyzed according to the wrong criteria. And if the basic function of the item happens to be evident, hidden functions that require scheduled tasks may be overlooked. Another common error is the tendency to overlook cockpit instrumentation as a means of notifying the operating crew of malfunctions that would otherwise not be evident. An error that is more difficult to spot occurs when a replicated function in an active system is identified as evident, when in fact a failure would not become evident until both units failed. Have the hidden functions of emergency items, such as ejection seat pyrotechnics and stored oxygen, been overlooked? Hidden function items with built-in test equipment may be improperly identified as having evident functions because failure finding tasks may be performed by the operating crew. On the other hand, items whose loss of function is evident during normal use may be mistakenly classified as hidden function items simply because they are not used during every flight.

50.3.2 Safety and safety hidden failures. Answers to the safety questions may reflect some misconceptions about the definition of a critical failure. Has a failure been identified as critical (or for that matter, as evident) on the basis of multiple failure consequences rather than the consequences of a single failure? Has it been identified as critical because it requires immediate corrective maintenance; that is, it has operational (but not safety) consequences? Has the analyst taken into account redundancy and fail safe protection that prevent a functional failure from being critical? Make certain the analyst has identified secondary damage as critical when the aircraft cannot be shown to be damage tolerant. The safety hidden failure question is answered in the same manner as the safety question except the consequences of failure are not immediate. This question must be applied carefully to ensure safety hidden failures are identified and provided for. Hidden function items which have no safety consequences fall into the non-safety branch of the logic diagram and are evaluated for economic consequences. All answers to the first three decision diagram questions should be examined in detail, at least for the first few items completed by each analyst. Even experienced analysts will have to refer to the RCM procedures to refresh their memories on certain points. The auditor's review of this aspect of the decision logic is essential not only to correct errors, but to ensure that the analyst fully understands the nature of these questions.

50.4 Task selection: applicability criteria. The answers to the remaining decision diagram questions represent the evaluation of proposed tasks. The most important point for the auditor to determine here is that the analyst understands the relative resolving power of the types of task and the specific conditions under which each type of task is applicable. One frequent error in evaluating an on-condition task is the failure to recognize all the applicability criteria. If the task is merely an inspection of the general condition of the item and is not directed at a specific failure mode, it does not constitute an on-condition task. The failure mode must also have a definable potential failure stage, with an adequate and fairly predictable interval for inspection. Another error is extending the task to include the detection of functional failures (as defined for the level of item being analyzed). The objective of an on-condition task is to remove units from service before the functional failure point.

50.4.1 Tasks. Servicing or lubrication tasks should only be assigned to those items which are designed to require servicing (periodic replenishment of a consumable) or lubrication. The selection of a servicing or lubrication task does not by itself satisfy the consequence of failure and the on-condition task must still be considered. It is important to evaluate proposed on-condition tasks according to their technical feasibility.

a. The failure mode may be one for which on-condition inspection is applicable, but is the item accessible for inspection? Is the task feasible within the maintenance framework of the organization? Analysts often suggest inspection techniques that are still in the developmental state or recommend methods that are feasible in theory but have not been tested. In the case of critical failure modes this may be necessary, but redesign of the item might eliminate the need for the task, and both alternatives should be investigated. Does each inspection task include the specific evidence the maintenance technician is to look for? If not, the technical writers may have difficulty converting the task to the proper job instruction, especially when the task is a visual inspection.

b. If a hard time task has been specified, have the age reliability characteristics of the item been established by actuarial analysis? Does the conditional probability curve show wearout characteristics at an identifiable age and a high probability of survival to that age? Is the failure mode one for which rework will, in fact, restore the original resistance to failure? The auditor should question assumptions that the item under study will prove to have the same reliability characteristics as a similar item that was shown to benefit from scheduled rework.

c. If there is reason to believe that scheduled removals will be of value, is there a cost effective interval for this task? Has the item been assigned to age exploration to obtain the necessary information? The only discard tasks that should appear in an initial program are for items that have been assigned safe life limits by the manufacturer. However, sometimes there is confusion about the difference between safe life limits and other age limits. Does the safe life limit represent a zero conditional probability of failure up to that age? Is the limit supported by manufacturer's test data? If the task interval only represents the average age at failure, the interval is incorrect. Safe life tasks are applicable only to items subject to critical failures; hence they should appear only in the safety and safety hidden failure branches of the decision diagram.

d. The auditor should question any safe life discard tasks that are not supported by on-condition inspections (where possible) to ensure that the safe life age will be achieved. The life limits assigned to hidden function emergency items (which are not in themselves subject to critical failures) are adjusted on the basis of failure finding tests and are not safe life limits. There are several points to watch for in auditing failure finding tasks. One is that these tasks are the result of default. They are the outcome of all "No" answers in the hidden function branches of the decision diagram. Another point is that these tasks are limited to the detection of functional failures not potential failures. The intervals for such tasks should be examined for mistaken assumptions concerning the required level of availability. Does the level of availability properly reflect the consequences of a possible multiple failure? Has the analyst overlooked the fact that the interval is based only on the required availability of the hidden function itself? Have failure finding tasks covered by routine crew checks been accounted for on the decision worksheets?

50.5 Task selection: effectiveness criteria. Applicability criteria for tasks pertain only to the type of task. These criteria are true for the task regardless of the nature of the failure consequences. However, effectiveness criteria depend solely on the objective of the task the category of failure consequences it is intended to prevent regardless of the nature of the task. Thus, the expected resolving power of a particular task can be measured only according to the branch of the decision diagram in which the failure is being analyzed. Some practical problems often come up in interpreting the effectiveness criterion for the safety branches. Do the tasks and intervals selected have a reasonable chance of preventing all critical failures? If not, what is the basis for judging that the remaining risk level is acceptable? It is important in this case to bear in mind the resolving power of the different types of tasks. On-condition tasks provide control of individual units and therefore have a good chance of preventing all functional failures if the inspection interval is short enough. In contrast, age limit tasks (scheduled removals) merely control the overall failure rate for the item. The auditors should therefore question the decision outcome of a hard time (rework) task in the safety branches, because a reduction in the failure rate is unlikely to reduce the risk of failure to an acceptable level. What is the policy or procedure concerning items for which no applicable and effective tasks can be found? Is there an established procedure for referring them back for redesign? Is there provision for a review with the designer prior to any such referrals?

50.5.1 Cost. For tasks in the operational/economic and non-safety hidden failure branches, the criterion for effectiveness is cost effectiveness. Does the analysis show the basis for determining that the task will be cost effective? What costs are attributed to the operational consequences, and what is the source of these costs? Is the number of operational interruptions shown in the analysis realistic? Is the expected reduction in this number resulting from the proposed task based on real data or at least real data for a similar item? Cost effectiveness is far more difficult to justify when operations consequences are not a consideration. If a task has been assigned, what is the basis for the cost tradeoff analysis? Does the analysis erroneously attribute costs of operational interruptions to failures with no operational consequences? In the safety hidden failure branch, a proposed task must ensure the end item's level of availability necessary to reduce the risk of a multiple failure to an acceptable level. Is there a policy concerning this risk level that can be used to interpret adequate availability? Does the policy differentiate between items on the basis of the consequences of the multiple failure?

50.6 Use of the default strategy. In any initial program, the decision paths reflect default answers. Thus, the analyst's use of the default strategy should also be audited. Sometimes it cannot be determined if failures are evident to the operating crew. If this occurs, have these failures always been classified as hidden? Sometimes it cannot be demonstrated that anticipated secondary damage will not be critical. If this occurs, has the failure been assigned on-condition inspections that may be partially effective in preempting functional failures? Have all items lacking necessary information been assigned to age exploration? In checking the analyst's understanding of the default strategy, the auditor may encounter some instances of its overuse. Have default answers been used when real and applicable data for the item are in fact available as the basis for a firm decision?

50.7 General use of decision logic. After examining individual aspects of the decision logic, the auditor must review the results of the analysis in larger perspective. Has every task been assigned through direct application of the decision logic? One major problem is the tendency to select a familiar maintenance task and then work back through the decision logic to justify it. This handicaps the analysis in several ways: unnecessary tasks may be included, inappropriate tasks may not be excluded, and new tasks may not be explored. Some analysts may have a strong preference for rework tasks and will specify them whether they are applicable or not. Others will favor on-condition inspections under any and all circumstances. The auditor should look for signs of individual bias during the review meetings and count each type of task selected by the various analysts. If there are more than a dozen rework tasks for the entire systems division of a new type of aircraft, the results of the analysis should be questioned. It is also important to check the disposition of items that have no preventive tasks. Is the number disproportionately high or low? The worksheets and all supporting information should be assembled for each item with the RCM worksheet 1 as a cover sheet. After this material has been audited for accuracy and completeness, and revised or corrected as necessary, the RCM analysis package can be submitted for approval.

50.8 Auditing analysis of the equipment. The auditing principles discussed thus far apply to all divisions of the equipment. However, each of the major divisions (systems, powerplant, and structure) has certain features that pose specific problems during analysis.

50.8.1 Analysis of systems items. The chief difficulty in analyzing systems items is choosing the appropriate level of analysis and correctly identifying the functions of the specific item under consideration. Does the list of significant items consist of systems and subsystems, perhaps with a few of the more important complex assemblies? If more than 500 items have been classified as significant at the aircraft level, the list is probably too long, and if there are fewer than 200, it may be too short. If any subsystem includes more than half a dozen functionally significant items, their classification should be re-examined.

a. Another problem is finding the dividing line between one system and another. Have the analysts agreed on the list of significant items and the specific hardware each analysis will cover? Does the procedure allow for later revisions as analysts delve into the details? Analysts occasionally overlook a significant item or a hidden function. The auditor should check for this by scanning the list of items classified as nonsignificant and questioning any that are doubtful.

b. The list of functions for each item should be thoroughly examined and questioned. Is the basic function for the system correctly stated on the worksheet? Is the system level clearly indicated on the worksheet? How does the analyst know that all the functions have been listed? Does each functional failure have at least one failure mode, and are the failure modes all real and possible? Do the failure effects reflect the complete impact of each type of failure on the rest of the equipment? It pays to play "what if" with the analyst for a sample of failure possibilities to determine whether the item has been analyzed in sufficient depth.

c. In auditing the tasks assigned to the item, the auditor should check to see that on-condition inspections are generally limited to installed items. There is a tendency to specify shop inspections for systems items simply because they will be in the shop often, which may unnecessarily increase the workload. Any hard time tasks must be substantiated by actuarial analysis. Does this analysis show that scheduled rework will in fact improve the reliability of the item? Rework is not cost effective for many systems items even when their failures are age related. If rework is applicable, has a cost effective interval been found? Is discard specified only for the few systems items to which the manufacturer has assigned life limits? Are safe life limits supported, where possible, by shop inspections of opportunity samples for corrosion or other damage? Do failure finding tasks, scheduled for installed systems items, duplicate either shop inspections or routine crew checks? Where such tasks are added to crew duties, what consideration has been given to the present workload of the operating crew? What provisions have been made for evident functions that the analyst knows will not be used regularly in the intended operating context?

50.8.2 Analysis of powerplant items. In auditing a powerplant program it is important to know exactly what the powerplant includes. In some cases the analysis covers only the basic engine; in others it includes all the quick engine change parts. If this has not been determined, some key items may escape analysis. Certain problems will be a matter of coordination. Was the systems analysis of essential engine accessories far enough along to be taken into account by the powerplant analysts? Did they have access to the structural analyses of the engine mounts and cowling? How do the failure possibilities for these items affect the basic engine?

a. The engine itself is subject to a number of failure modes that involve secondary damage. Whether this damage is critical, however, depends on both the engine and the type of aircraft. Does the analyst have a complete understanding of the specific design characteristics of this engine? The failure effects require particularly careful auditing. Has the analyst considered the ultimate effects in the absence of any preventive maintenance, or does the analysis presuppose that progressive failure modes will be halted before they reach the critical stage? Will a failure mode that meets the criteria for criticality be preempted by a noncritical loss of function? Where the failure evidence depends on cockpit instrumentation, what instrument indications are evidence of this particular type of failure? Unless the engine is installed in a single engine aircraft, an engine failure that does not involve critical secondary damage does not have safety consequences. Have evident failures been properly placed in the operational/economic consequences branch of the decision diagram?

b. Safe life items must be covered by safe life limits, but most of the tasks in an initial powerplant program will be on-condition inspections. Have these inspections been assigned to installed engines whenever possible, to avoid the need for engine removals? Are they limited to known problem areas with the remaining on-aircraft inspection capability reserved for troubleshooting and later preventive tasks, if necessary? The intervals for inspections of installed engines should be specified in operating hours or flight cycles.

c. Shop inspections of internal engine items should be scheduled to take advantage of opportunity samples. Have any shop inspections been specified in a way that will require scheduled removals or unnecessary disassembly to reach a single part?

d. The entire age exploration program for the powerplant should be reviewed. Does it included procedures for increasing task intervals on the basis of inspection findings? Does it provide for inspection of the oldest parts available on an opportunity basis without special disassembly for age exploration purposes? Does it include threshold limits or a similar plan to allow the removal of most units from service at or before the upper limit without special engine removals? If any of these features are missing, that aspect of the age exploration plan should be questioned.

50.8.3 Analysis of the structure. Auditing the structure program consists of reviewing the structural ratings and class numbers used to establish the initial inspection interval for each structurally significant item. The auditor and analysts must have a clear understanding of the difference between damage tolerant and safe life structure, the rating factors that apply in each case, the basis for rating each factor, and the basis for converting the final class number into an inspection interval. Some analysts may have more difficulty than others in grasping the distinction between resistance to failure and residual strength. Are all analysts using the same definition of fatigue life, and are the manufacturer's data expressed in these terms? Was the conversion of test data into safe life limits based on an adequate scatter factor?

a. The definition of a structurally significant item is one of the most important aspects of the analysis. Is the basis for this definition clearly understood by the analysts and auditors? Are the significant items generally confined to primary structure, or is needless effort being devoted to evaluation of much of the secondary structure as well? Has adequate consideration been given to the possibility of multiple failures at the same site? If significant items are correctly identified, most will represent small localized areas. If they are designated as whole structural members, they will require much more inspection time in the continuing program. Has the manufacturer's engineering department participated in the identification of significant items? No one else is in a position to identify the structural elements most susceptible to fatigue failure and its effect on the strength of the assembly.

b. If the structure includes any new material or manufacturing processes or if is to be operated under any new conditions, the inspection intervals will be far more conservative. Even if the materials and conditions of this situation are familiar, the analyst must use test data for this production model of the structure. Is a fatigue test being conducted for the whole structure? Will preliminary results be available in time for use in developing the initial program? Will inspection findings and any failure data from the flight test program be available? The fatigue data should be examined to determine whether the flight load profile is realistic. The usual test method is flight cycles. Is the conversion to operating hours realistic for the intended operating environment?

c. While structural strength and fatigue life are the manufacturer's responsibility, the operating organization is concerned in these matters as well. The organization's members must therefore have enough information about the design and the test results to be able to evaluate and question the manufacturer's maintenance recommendations. One point the auditor should check at an early stage is whether there is adequate interaction between the manufacturer's and the Navy's representatives to provide for full participation by all members. Before the analysis begins, there must be general agreement on the basis for the selection of significant items and for noting each factor. A sample of structurally significant items and their ratings should be audited to make sure they correspond to this agreement before significant items are selected for the whole structure. Do the ratings give proper recognition to areas prone to corrosion as a result of their location? Has external detectability been properly considered? What was the basis for converting class numbers to intervals? Are the intervals similar to those in current use for other aircraft?

50.8.3.1 Inspections. The number of structurally significant items on an aircraft will depend on the size of the aircraft, the size of the area designated as significant, and, in some cases, on the number of ways the item can be accessed. Has the exact location of each significant item been clearly designated? The analyst should verify the entire list of significant items by inspection of an aircraft in its fully assembled configuration. Some items assigned visual inspection may in fact be hidden beneath other structural elements or behind installations. In this case X-ray inspection or other approach to the area may have to be specified. The tasks should be audited to ensure that the inspection plan, as a whole, does not include unnecessarily expensive or sophisticated techniques. For example, is X-ray inspection limited to areas in which it is known to be useful, or is it specified for all items in the hope that it will prove useful? The basic inspection plan covers only structurally significant items. Therefore, the structure program should be reviewed in connection with these other programs to identify any obvious conflicts and to ensure that all nonsignificant portions of the structure have been accounted for. Has the external structure of the item that is not visible from the ground been taken into account? Do the inspections of structural elements in systems and powerplant items take into account other inspection requirements of these items?

50.8.4 Non-RCM program elements. These elements include zonal and walkaround inspection requirements. The zonal inspections should only include those zones of the aircraft accessed for inspections generated by the RCM analysis. Opening a zone of the aircraft for inspection solely to look for damage is not consistent with the RCM philosophy. Do zonal intervals correspond to the intervals assigned for detailed inspection of internal structurally significant items? Zonal inspections are general visual inspections. Are the elements to be inspected in the zone clearly described? The specifications for walkaround and other damage inspections should be audited to make sure that all important inspection areas are clearly indicated, especially those areas most likely to incur damage from ground operation, support equipment, and personnel traffic.

50.8.5 The completed program. After each section of the analysis is complete and the results have been audited separately, additional questions may arise when the program is examined as a whole. Some questions apply to the accuracy and completeness of the worksheets when they are summarized for each major portion of the aircraft.

a. Packaging questions may arise when all the tasks are grouped for implementation. Do the tasks for each portion of the aircraft cover all levels of maintenance? Have all of them been transcribed accurately? Do they still make sense when they are viewed together? One problem, that may come up at this stage, is a discrepancy in the level of task detail and the amount of explanatory material for different items. All the tasks should be reviewed to see that they meet the original definition of the final product. Are there any gaps or overlaps?

b. If the final product is simply a list of tasks and their intervals, has the flexibility of the intervals been indicated to facilitate packaging decisions? Packaging presents special auditing problems. Packaging standards depend on the organization, its operational requirements, its fleet size, the number and location of maintenance facilities, and a variety of other factors. Have these been taken into account? Are the most frequent tasks the kind that can be accomplished at "O" level maintenance with limited personnel and facilities? Auditing the packaging of tasks involves determining whether the tasks have been scheduled as efficiently as possible for a given set of circumstances.

c. Consideration should be given to the impact of the maintenance program on the intended use of the equipment. Will the proposed maintenance schedule permit each aircraft to meet its operational requirements without interruption? If not, can either the operating schedule or the maintenance schedule be revised? Does the program allow for all the operating environments that will be encountered, including a possible change from one set of operating conditions to another for the same aircraft? Does it provide for RCM analysis of any new systems or tasks that may be added as a result of age exploration?

50.9 Auditing the ongoing program. Once the initial RCM program has been completed and packaged for implementation, a group of analysts will also be needed to monitor failure data and the results of age exploration. They will then revise the prior-to-service program accordingly. The plans for these activities and overall management of the ongoing program are also subject to auditing. Certain information systems must be established before the aircraft goes into service:

a. Usually, the 3-M system will meet the requirements for reporting failures, their frequency, and their consequences.

b. An age exploration program for continual evaluation of age condition information with procedures for extending task intervals as rapidly as the data permit.

c. A system for controlling the addition of new preventive tasks to ensure that they meet RCM criteria before they are accepted.

d. A system for periodic re-evaluation of all tasks in the program to eliminate those which are no longer needed.

e. A system for reviewing the content of the work packages as the size of the fleet grows.

f. A system for evaluating problems not anticipated and for determining the appropriate action.

Are the present information systems adequate to meet all these requirements? Are they adequate for the size and age of the fleet? How familiar are the key personnel with basic RCM concepts, and how are differences of opinion resolved? Auditing an ongoing maintenance program may require different skills and experience from those needed to audit program development. The auditor's questions during program development are chiefly at the procedural level. At this stage, however, the auditor may be placed in an adversary situation, involving people with different viewpoints about what should or should not be done. Thus, the auditor will have to be both inquisitive and objective to discern the overall pattern of reliability information from various sources and interpret its impact on the maintenance program.

50.10 Auditing new programs for in-service fleets. The auditing principles in paragraphs 50.1 through 50.9 also apply to RCM programs for in service aircraft. The following are additional factors to be considered.

a. Older aircraft may not be as sophisticated or complex as those currently being developed. There are often fewer fail safe or damage tolerant features. Consequently, both the pattern of analysis and the resulting tasks may differ somewhat from those of a new aircraft. Another reason for the difference, however, is that much of the age exploration information is already available. Thus, the tasks that would ordinarily be added later to a prior to service program will appear from the outset in a new program for in-service equipment.

b. It is especially important for the auditor to determine that the new RCM program is not being developed by analysis of existing tasks, but represents a completely independent analysis of the equipment. The set of tasks resulting from this analysis should then be compared with the existing program to determine the differences. At this time, the current tasks that were not included in the new program should be reviewed but only to ensure that nothing has been missed. In developing a program for a new type of aircraft reliability data on similar items even when it is available may or may not apply to the item under study. In this case, however, the necessary information is available from actual operating experience. Thus one of the major differences in auditing the analysis itself is to determine that the data were in fact used and were used correctly.

c. For example, the auditor should make sure that rework has not been selected as a task without an actuarial analysis of data on this item. A sample of the actuarial analyses should be reviewed to see that they conform to the general methods outlined in this standard. The number of tasks in the program will ordinarily be somewhat greater for an in-service aircraft. In many cases, there will be quite a few rework tasks for systems items. These should be reviewed thoroughly to make sure they are necessary. However, an older aircraft may require more rework tasks than a new one for several reasons. First, the results of age exploration show that a few rework tasks are economically desirable and should be included in the program. Second, the older designs may actually have more assemblies that show wearout patterns. There may also be a larger number of scheduled tasks for hidden functions because of older design practices. The number of on-condition tasks may also be slightly higher because these are relatively inexpensive inspections and may have been used for a number of items.

50.10.1 Completed RCM program. In comparing the newly completed RCM program with an existing program, the auditor will have to take into account differences in terminology. Many older programs call some tasks on-condition that do not meet the criteria for this type of task. They may be inspections of the general condition of the item, or they may be inspections to find functional failures rather than potential failures. Similarly, the designation "condition monitoring" will actually include failure finding tasks for some items. When in doubt, the auditor (or the analyst) may have to refer to the PMRMs for the present task to determine its actual nature. As with any project, the results should be reviewed to ensure that they are in accordance with the definition of the final product. In the case of a program for in service equipment, the final product may consist only of the new RCM program or it may include a full cost comparison of the two programs and perhaps a list of recommendations.

APPENDIX F

APPLICATION AND TAILORING GUIDE

10. GENERAL

10.1 Scope. This appendix provides application and tailoring guidance to aid the procuring activity in generating the contractual requirement for Reliability-Centered Maintenance (RCM).

10.2 Purpose. The requirements of this military standard prescribe a complete RCM process that is integrated with the Logistic Support Analysis (LSA). Users of this standard who wish to tailor the complete analysis for varying applications may use the guidance herein.

10.3 Application. This appendix is presented as a guide only. It is not to be referenced or implemented in contractual documents. This appendix provides rationale and guidance for the selection and tailoring of RCM tasks. It is to be used to tailor RCM requirements in the most cost effective manner to meet program objectives.

20. REFERENCED DOCUMENTS

Military Standards

| | |
|---|---|
| MIL-STD-1388 | Logistics Support Analysis |
| MIL-STD-1629 | Procedures for Performing a Failure Mode, Effects and Criticality Analysis |

30. DEFINITIONS

30.1 General. Key terms used in this appendix are defined in paragraph 3 of this military standard.

40. GENERAL REQUIREMENTS

40.1 Applications of RCM to New Acquisitions. RCM procedures to determine preventive maintenance requirements are accomplished in conjunction with LSA for new acquisitions. The various LSA analysis processes, including RCM, must be smoothly integrated to work correctly. There are basically two cases to which RCM must be tailored properly.

a. Complete new weapons system applications, utilizing basically the total LSA process.

b. Partial new system acquisition or reprocurement/upgrade of existing systems, where a tailored LSA is required.

40.1.1 Complete New Weapons System Acquisition. In this case the LSA process starts during concept explanation to develop maintenance and logistics support concepts. Applications of RCM will differ during various phases of acquisition in the LSA process.

40.1.1.1 RCM Applications. During the RCM process, significant items must be selected, then subjected to the RCM decision logic. In early phases of acquisition it is not possible to accomplish a formal RCM analysis due to lack of specific design criteria. The level of indenture of the significant items for analysis must be at a level no lower than that for which meaningful functions (and functional failure and engineering failure modes) are defined.

40.1.1.1.1 Concept Exploration. Applications of RCM during this phase should stress applying on-condition maintenance philosophy to weapons systems design. This is accomplished by ensuring design considerations have provisions for detection of potential critical failures. Requiring the damage tolerant design philosophy for structures accomplishes the same for aircraft structures. Requiring RCM worksheet completion during concept exploration may allow for an early start In fact, the results of any formal RCM analysis at this point at any level of indenture, will have limited usefulness to the LSA process. Tailoring RCM for the concept exploration phase should not include RCM worksheet completion, but concentrate on determining whether the on-condition philosophy is possible for the various alternatives being evaluated.

40.1.1.1.2 Demonstration/Validation. It is possible, if the design is somewhat firm, to now choose significant items for an RCM analysis at the system level. RCM, by design, is a functionally oriented process, and during this phase functions for most systems should be well defined. One must ensure the FMEA properly integrates with the RCM process. The FMEA input must be prepared as described in section 5 of this standard, and documented on the LSAR data sheets. Tailoring the RCM during this phase will be to resrict the SI selection for RCM to no lower than the system level (i.e., 2 digit work unit code level). Completion of RCM worksheets will also, therefore, be limited to system level preventive requirements.

40.1.1.1.3 Full Scale Development. At this point the complete RCM process should be followed to develop total preventive requirements at all levels of maintenance. A complete list of significant items for RCM analysis is developed in accordance with the procedures of this standard. RCM will not be required on each LSA candidate and will be accomplished at a higher indenture level than is necessary for LSA. The RCM analysis will be based on the FMEA documented on LSAR data sheets B1 and B2. RCM summary results will be recorded on LSAR data sheet B. When RCM worksheets are finalized the initial phase inspection interval and cycles are determined following Appendix B. Initially OSP's are determined from procedures contained in Appendix C. It is not practical to accomplish these analyses prior to this phase. Age Exploration (AE) requirements for sampling in-service items should be finalized into an AE plan for the weapons system. The requirements for the initial AE plan will be based on the tasks from RCM worksheet 7.

40.1.1.1.4 Production/Deployment. RCM at this phase of the LSA process is basically accomplishing age exploration to refine the preventive tasks chosen. Age Exploration tasks are constantly added, deleted, or modified as the weapons system changes throughout the life cycle. If RCM re-analysis is required at some point, the original analysis must be used as a basis for any updates and AE data is used to justify modification or changes. Complete re-analysis of an item originally under RCM analysis and age exploration, is not required.

40.1.1.2 RCM Application to Different Equipment. Considering the application of RCM logic to different types of equipment is basically choosing the significant items carefully. Some types of equipment do not benefit greatly from preventive maintenance, therefore applying RCM may not be cost effective.

a. Aircraft systems (fuel, hydraulics, powerplants, flight control, navigation, communication, etc.) vary widely in complexity and function. Fuel, hydraulics, powerplants and other mechanical type systems should be analyzed not only at the system level, but certain items of those systems may be chosen as significant for seperate analysis. These significant items should be identified no lower than the WRA level of indenture. Avionic systems which are made up of purely "black box" type components can be analyzed at the systems level for RCM purposes. Electro-mechanical and similar types of equipment will be somewhere between these two types.

b. Structural analysis consists of identifying those airframes or components with structural function and determining which are significant to RCM analysis. A structurally significant item will require preventive maintenance or an intensive age exploration (sampling) program. Items which have both structural and nonstructural functions must be carefully considered.

c. Support equipments must also be considered for RCM analysis. The largest concern for support equipments is the selection of equipment to analyze using RCM logic. It is most important to remember that logistic resources must be provided to maintain support equipment as well as aircraft. For example, calibration requirements must be determined early enough to ensure support is in place when required. This means that SE significant items must be determined as early as possible in the acquisition cycle (D/V or FSD). Those SE significant items are then subject to RCM analysis as are other types of equipment. Tailoring RCM for SE requires ensuring that logic questions are asked of the intended operating enviroment. Effects of SE on flight safety should be considered except for those cases where the failures (of the SE item) will have a direct effect on the aircraft.

40.1.1.3 Applying RCM to Different Levels of Maintenance. The most effective method of accomplishing RCM is to exercise the logic independent from level of maintenance. That is to ask the equipment, figuratively, what is the best preventive task for each failure. To do RCM logic only to determine organizational level requirements, for example, defeats the logic behind the RCM philosophy. Certain failures (i.e., structures) however, will only be evident at intermediate or depot maintenance facilities. The level of maintenance determination when choosing tasks will influence task intervals to some extent. In tailoring RCM, then, the concept for maintenance must be kept in mind to preclude unnecessary concern over choosing the maintenance level for a task. For example, most engine and aircraft structural inspections do not occur at the organizational level.

40.1.2 Partial New System Acquisition. The RCM program also seeks to develop guidelines for use during update or modification programs to ensure a design that is compatible with existing preventive maintenance concepts. In this case, the RCM process shall be applied only to the new items of systems and equipment already fielded. This done because analysis on all other elements was completed during Full Scale Development phase of Acquisition. For the new items only, A tailored LSA process is needed. The RCM process will be similar to the Full Scale Development phase RCM accomplished as part of a complete LSA (see 40.1.1.1.3).

40.2 In-Service Applications of RCM. In-Service applications of RCM, which are not part of an LSA program, will require selection of significant items, on FMEA, and updates to the maintenance plan. Also, much of the data required for the analysis information is already available. During the in-service RCM process the reliability data is better defined by age exploration as needed to provide specific answers to RCM decision logic questions. Thus, the tasks that would ordinarily be added later to a prior-to-service program will appear from outset in a program for in-service equipment. The SI's are better defined by using historical data in the selection process. The extent of an in-service RCM logic evaluation will be governed by the amount of data considered in choosing significant items. The significant items for RCM will not be a subset of the LSA candidates, as we are not considering LSA here, but will be a unique list developed using this standard and data gathered during the prior in-service period. The FMEA for in-service RCM applications will be in the format of MIL-STD-1629, Task 103. This is necessary to have the required input data for the RCM logic evaluation. RCM tasks evaluated in-service must take into consideration the existing phase cycle, depot induction schedules and age exploration programs. RCM may be applied to isolated items of equipment to modify individual maintenance requirements. The logic may also be applied to complete systems or aircraft to modify the phase cycle or OSP. For items previously analyzed using RCM procedures, a revision to the original analysis is often more desirable than a complete new evaluation. Once the RCM analysis is complete, the maintenance plan must be updated or revised as necessary.

50. DETAILED REQUIREMENTS

Not Applicable

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U.S. GOVERNMENT PRINTING OFFICE: 1986 - 605-036/42223

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(Project ILSS-N008)

AMSC N3769 AREA-ILSS

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Wearout Characteristics - The conditional probability curve characteristics that indicate an increase in the conditional probability of failure of an item with increasing operating age.

Zero Time - To restore the operating age of a unit to zero by means of inspection, rework, or repair.

Zonal Inspections - A general inspection of a specific area of an aircraft at scheduled intervals. A zonal inspection is for obvious defects, such as leaks, frayed cables, cracks, corrosion, or physical damage.

3.2 Definition of acronyms. The acronyms listed n this standard are defined as follows:

a. AD - Accidental Damage
b. AIDS - Airborne Integrated Data System
c. AMP - Analytical Maintenance Program
d. ATA - Air Transport Association
e. CBR - Cost Benefit Ratio
f. CDS - Constant Density Sampling
g. CF - Configuration Code
h. CFA - Cognizant Field Activity
i. CILOP - Conversion in Lieu of Procurement
j. CNO - Chief of Naval Operations
k. COMB - Combination Task
l. CPL - Crack Propagation Life
m. CRA - Calibration Requirements Analysis
n. D - Depot
o. DMDS - Depot Maintenance Data System
p. DMMH - Direct Maintenance Man Hours
q. DOD - Department of Defense
r. DT - Damage Tolerant
s. ED - Environmental Damage
t. EDL - End Item Design Life
u. EMT - Elapsed Maintenance Time
v. ESSD - Engineering Specifications and Standards Department
w. FD - Fatigue Damage
x. FF - Failure Finding
y. FFMC - Functional Failure Mode Code
z. FLS - Fleet Leader Sampling
aa. FMEA - Failure Mode and Effects Analysis
ab. FMECA/MI - Failure Mode and Effects Criticality Analysis/Maintainability Information
ac. FOD - Foreign Object Damage
ad. FSCM - Federal Supply Code for Manufacturers
ae. FSI - Functional Significant Item
af.. HT - Hard Time
ag. I - Intermediate
ah. IDL - Item Design Life

ai. LDC - Life to Detectable Crack
aj. LL - Life Limit
ak. LOR - Level of Repair
al. LSA - Logistic Support Analysis
am. LSRA - Logistic Support Analysis Record
an. LCN - Logistic Support Analysis Control Number
ao. MIR - Master Index of Repairables
ap. MLG - Main Landing Gear
aq. MPA - Maintenance Planning and Analysis
ar. MESM - Mission Essential Subsystem Matrices
as. MSG-1 - Maintenance Steering Group 1
at. MSG-2 - Maintenance Steering Group 2
au. MSG-3 - Maintenance Steering Group 3
av. MTBF - Mean Time Between Failure
aw. MTBMA - Mean Time Between Maintenance Actions
ax. MTTR - Mean Time To Repair
ay. NALC - Naval Ammunition Logistic Code
az. NAMP - Naval Aviation Maintenance Program
ba. NATOPS - Naval Air Training and Operating Procedures Standardization
bb. NAVAIR - Naval Air System Command
bc. NDI - Non-Destructive Inspection
bd. NGL - Nose Landing Gear
be. O - Organizational
bf. OC - On-Condition
bg. OSD - Office of Secretary of Defense
bh. OSP - Operating Service Period
bi. PMRM - Periodic Maintenance Requirements Manual
bj. RCM - Reliability-Centered Maintenance
bk. RS - Residual Strength
bl. RW - Rework
bm. R&M - Reliability and Maintainability
bn. SE - Support Equipment
bo. SHF - Safety Hidden Failure
bp. SLEP - Service Life Extension Program
bq. SLL - Safe Life Limit
br. S,M,&R - Source, Maintenance, and Recoverability (code)
bs. SRA - Shop Replaceable Assembly
bt. SRC - Schedule Removal Component
bu. SRF - Structural Rating Factor
bv. SSI - Structural Significant Item
bw. TAMS - Test and Monitoring System
bx. TEC - Type Equipment Code
by. T/M/S - Type/ Model/ Series
bz. VAST - Versatile Avionics Shop Test
ca. WRA - Weapons Replacement Assembly
cb. WUC - Work Unit Code

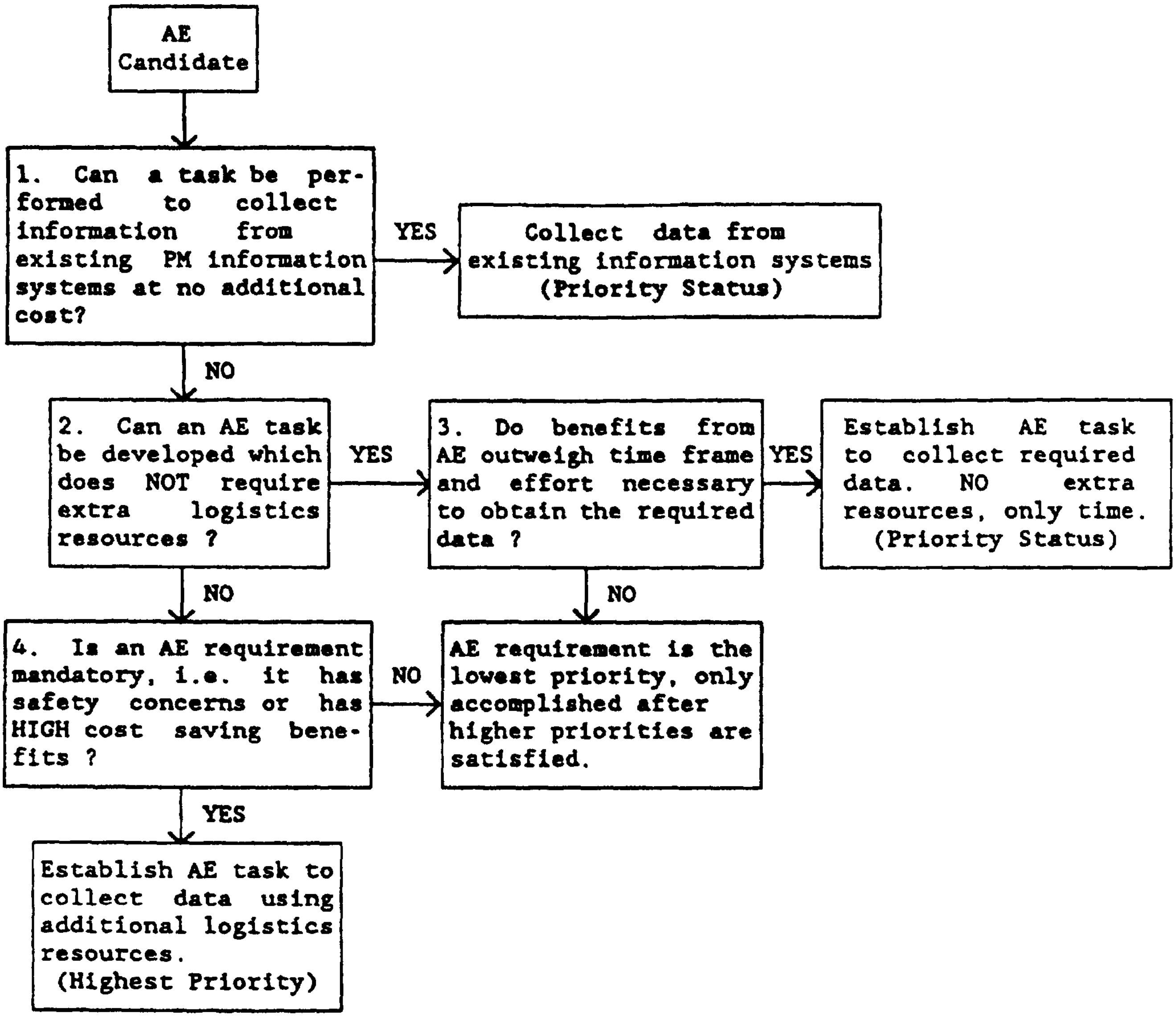


FIGURE 15 - Age Exploration Decision Logic

6c. Sample size - In this column, list the number of items or aircraft on which to perform the age exploration task described in column 6b Determine the appropriate sample size using statistical methods dependent on the required degree of precision and the assumptions which must be made regarding the expected characteristics of the data. As a result, the sample size should include adequate justification See paragraph 5.2.7.2 for SSI's subject to age exploration



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6d. Level of maintenance - In this column, list the level of maintenance (O, I, or D) responsible for performing the age exploration task. The necessary skills and equipment required to perform the age exploration task must be available at the level of maintenance selected. Also consider the types of data being collected by the age exploration task. For example, if a large amount of operational data are needed for an easily accessible item, a fleet organization should be specified to perform the task.

6e. Study period - In this column, list the time period over which the age exploration task is to be performed. The length of the study period depends on the type of information required, the hardware, and the sample size of the task. For example, if an age exploration task is performed to determine the wear rate of a brake assembly, a long study period will be needed because previous experience shows that the brake wear rate is slow. For each preliminary age exploration task proposed, the study period must be finite, allowing only enough time to gather the minimum amount of data/information to satisfy the required degree of precision and resolve the default decision.

5.2.8.1.4 Assessment of age exploration tasks. Since the application of default logic results in a potentially large workload, a screening process is needed to reduce the number of preliminary age exploration tasks and to assure that only those deemed necessary in terms of potential benefit are permitted to become accomplished age exploration tasks. FIGURE 15 depicts the logic process used to screen the preliminary age exploration tasks developed on RCM worksheet 7. The logic process depicted in FIGURE 15 assigns a three tier priority ranking to the preliminary age exploration tasks; lowest priority, priority status, or highest priority. The Age Exploration Decision Logic prioritizes the candidates so the ones with safety concerns and highest cost benefits are performed first; the lower priority candidates are performed when resources permit.

a. A highest priority ranking is directed exclusively at age exploration tasks which had default decisions made for safety items (i.e., age exploration requirement is mandatory due to safety concerns) or for the task which may have significant cost saving potential. For safety items, these tasks typically fall into two categories. (1) controlled tests performed under laboratory conditions where safety considerations prohibit the collection of operational failure data, or (2) tasks performed in the operational environment, normally existing preventive requirements, to collect data on the degradation of failure resistance with age (exclusive of actual failures) These tasks collect data up to a predetermined point at which the item is removed. An operational age exploration task assigned the highest priority must be carefully monitored with very conservative age exploration intervals to eliminate the risk of failure.

b. Priority status is assigned if a task to collect information from existing PM data sources at no additional cost can be developed In addition, if a beneficial age exploration task can be developed which requires less expenditure of logistics resources than the data collection task, the task receives priority status. These tasks are usually existing preventive requirements performed in the operational environment to collect the required data.

c. The lowest priority status is given either: 1) to an age exploration task which does require extra logistics resources but its requirement is not mandatory (i.e., not safety related or little cost savings benefit), or 2) to an age exploration task which requires extra logistics resources, but the benefits from performing the task do not outweigh the time frame and effort necessary to obtain the required data. Such low priority status AE tasks are accomplished only after all higher priority tasks are satisfactorily completed, and then only when the required funding is available.

Column 7: Age Exploration Task Assessment - Complete this column for each preliminary age exploration task listed in column 6b of this worksheet. Each of the following columns corresponds to the questions on the age exploration diagram (see FIGURE 15). Include justification for making the decisions with each answer.

7a. Question 1: Can a task be performed to collect information from existing PM information systems at no additional cost? - Answering this question "Yes" indicates that an age exploration task can be accomplished by the continuous review of operational data from existing 3M, Depot Maintenance Data System (DMDS), Fleet Reports, or other information systems. This, in turn, assumes that an applicable and effective preventive maintenance task already exists for the item. Such an age exploration task is given priority status. If the age exploration candidate in question requires the collection of more specific data not obtainable through an existing information system, answer "No" and evaluate question 2.

7b. Question 2: Can an age exploration task be developed which does <u>not</u> require extra logistics resources? - If an age exploration task can be satisfactorily accomplished by using resources which are already available, answer this question "Yes" and proceed to evaluate question 3. If the task requires additional resources (extra funding, peculiar support features, etc.), answer this question "No" and evaluate question 4. Note that if any additional resources are required to perform the age exploration task, all problems related to the acquisition of the additional resources must be resolved.

7c. Question 3: Do benefits from AE outweigh the time frame and effort necessary to obtain the required data? - This question requires careful analysis to relate the performance of maintenance to the potential failure impact on operational downtime, repair costs, and the level of effort necessary to conduct the age exploration task Answering "Yes" requires an age exploration task requiring no extra resources be established. Such a task is given priority status. A "No" answer indicates the age exploration task being considered is of low priority and should only be accomplished once all higher priority tasks are satisfactorily completed, and then only if time, effort, and funding permit.

7d. Question 4: Is an age exploration requirement mandatory? - If an age exploration task requirement is due to a safety concern (i.e., the candidate involves safety consequences of failure) or has high cost saving potential, answer this question "Yes" and establish an age exploration task which may involve additional logistics resources to collect data. Such a task is given the highest priority of accomplishment. A "No" answer indicates the age exploration requirement is of low priority and should only be accomplished once all higher priority tasks are satisfactorily completed, and then only if time, effort, and funding permit.

Since all programs have budget and time constraints, it is necessary to prioritize age exploration tasks. Tasks involving safety concerns and highest cost benefits are performed first and the lower priority tasks are performed when time and funding permit. The answers derived from the AE logic questions of column 7 make it possible to prioritize the age exploration tasks to be performed as listed in column 6 (see Table V)

TABLE V. Age Exploration task priority determination.

| Task Priority | Question 1 | Question 2 | Question 3 | Question 4 |
|---|---|---|---|---|
| Highest Priority | No | No | --- | Yes |
| Priority Status | Yes | --- | --- | --- |
| | No | Yes | Yes | --- |
| Lowest Priority | No | Yes | No | --- |
| | No | No | --- | No |

5.2.9 Determination of phase inspection and Operating Service Period (OSP) intervals. Once RCM worksheets 2 through 7 have been completed, determine the initial phased inspection intervals for organizational level maintenance activities and the initial OSP intervals for the depot activities. The preliminary intervals on worksheets 2 through 6 are recommended engineering intervals These must be analyzed to determine the most appropriate interval for the phased package and the OSP

RCM WORKSHEET NO. 7 - DETERMINATION OF AGE EXPLORATION TASKS — DATE: 12/21/88 — PAGE 1

| 1) ITEM LCN/MIN INDEX CODE | 2) ITEM NOMENCLATURE | 3) | 4) | 5) | 6) AGE EXPLORATION REQUIREMENT: a) INFORMATION REQUIRED | 6) b) PRELIMINARY TASK | 6) c) SAMPLE SIZE | 6) d) PLOM | 6) e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT: a) Q#1 ? | 7) b) QUESTION #2 ? | 7) b) JUSTIFICATION | 7) c) QUESTION #3 ? | 7) c) JUSTIFICATION | 7) d) QUESTION #4 ? | 7) d) JUSTIFICATON |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A49C | CATAPULTING SUBS. | 4A2 | RO | OC | INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | PERFORM DEGRADATION ANALYSIS. | 30 | 0 | UNTIL FAILURE | N | Y | MAINTENANCE PERSONAL CAN PERFORM INSPECTION DURING NORMAL MAINTENANCE. | Y | FAILURE CAUSES MISSION ABORT. | | |
| | | 4A3 | RO | HT | WEAROUT AGE. | PERFORM ACTUARIAL ANALYSIS. | 30 ASSEMBLIES. | 0 | UNTIL FAILURE. | N | Y | MAINTENANCE PERSONNEL CAN PERFORM TASKS DURING NORMAL DUTIES | Y | FAILURE CAUSES MISSION ABORT | | |
| | | 4A4 | RO | OC | INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE. | VISUALLY INSPECT SELECTOR VALVE TO DETERMINE POTENTIAL FAILURE AND DEGRADATION. | 30 ASSEMBLIES. | 0 | UNTIL FAILURE. | N | Y | THROUGH MAINTENANCE CREW NORMAL DUTIES. | Y | FAILURE CAUSES MISSION ABORT. | | |

FIGURE 41- RCM worksheet no.7- determination of age exploration tasks



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PAGE 2

| 1) ITEM LCN/ MIR INDEX CODE | 2) ITEM NOMEN-CLATURE | 3) FFMC | 4) | 5) | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) P L O N | e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 ? | b) QUESTION #2 ? | JUSTIFICATION | c) QUESTION #3 ? | JUSTIFICATION | d) QUESTION #4 ? | JUSTIFICATOR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A40C | CATAPULTING SUBS | 4B1 | EO | OC | INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | PERFORM DEGRADATION ANALYSIS. | 30 ASSEMBLIES | 0 | UNTIL FAILURE | N | Y | MAINTENANCE PERSONAL CAN PERFORM TASKS DURING NORMAL DUTIES | Y | FAILURES CAUSES MISSION ABORT. | | |
| | | 5A2 | EO | OC | INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE. | PERFORM DEGRADATION ANALYSIS. | 30 ASSEMBLIES. | 0 | UNTIL FAILURE | N | N | TESTING EQUIPMENT NEEDED | | | N | SAFETY OR HIGH COST SAVINGS NOT A FACTOR |
| | | 5A3 | NS | HT | WEAROUT AGE. | PERFORM ACTUARIAL ANALSIS. | 30 ASSEMBLIES. | 0 | UNTIL FAILURE | N | N | ADDITIONAL TEST EQUIPMENT NEEDED | | | N | SAFETY OR HIGH COST SAVINGS NOT A FACTOR |
| | | 5A4 | NS | OC | INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | PERFORM DEGRADATION ANALYSIS | 30 ASSEMBLIES | 0 | UNTIL FAILURE | N | N | ADDITIONAL TEST EQUIP. NEEDED | | | N | SAFETY OR HIGH COST SAVINGS NOT A FACTOR |

FIGURE 42- RCM worksheet no. 7- determination of age exploration tasks

PAGE 3

| 1) ITEM LCN/ MIR INDEX CODE | 2) ITEM NOMEN- CLATURE | 3) FFMC | 4) DEFAULT / FAIL CON | 5) TYPE / TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) PLOM | e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 ? | b) QUESTION #2 ? | JUSTIFICATION | c) QUESTION #3 ? | JUSTIFICATION | d) QUESTION #4 ? | JUSTIFICATON |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A49C | CATAPULTING SUBS | 5B1 | EO | OC | INTERVAL BETWEEN PORENTIAL AND FUNCTIONAL FAILURE | PERFORM DEGRADATION ANALYSIS | 30 ASSEMBLIES | 0 | UNTIL FAILURE | Y | | | | | | |
| | | 5C1 | EO | OC | INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE | PERFORM DEGRADATION ANALYSIS | 30 ASSEMBLIES | 0 | UNTIL FAILURE | N | N | ADDITIONAL TEST EQUIPMENT NEEDED | | | N | SAFETY OR HIGH COST SAVINGS NOT A FACTOR |
| | | 6A2 | EO | OC | INTERVAL BETWEEN POTENTIAL AND FUNCTIONAL FAILURE. | PERFORM DEGRADATION ANALYSIS. | 30 ASSEMBLIES. | 0 | UNTIL FAILURE | N | Y | DATA CAN BE COLLECTED BY O-LEVEL PERSONAL DURING NORMAL MAINTENANCE. | Y | FAILURE CAUSES MISSION ABORT | | |

FIGURE 43- RCM worksheet no.7- determination of age exploration tasks

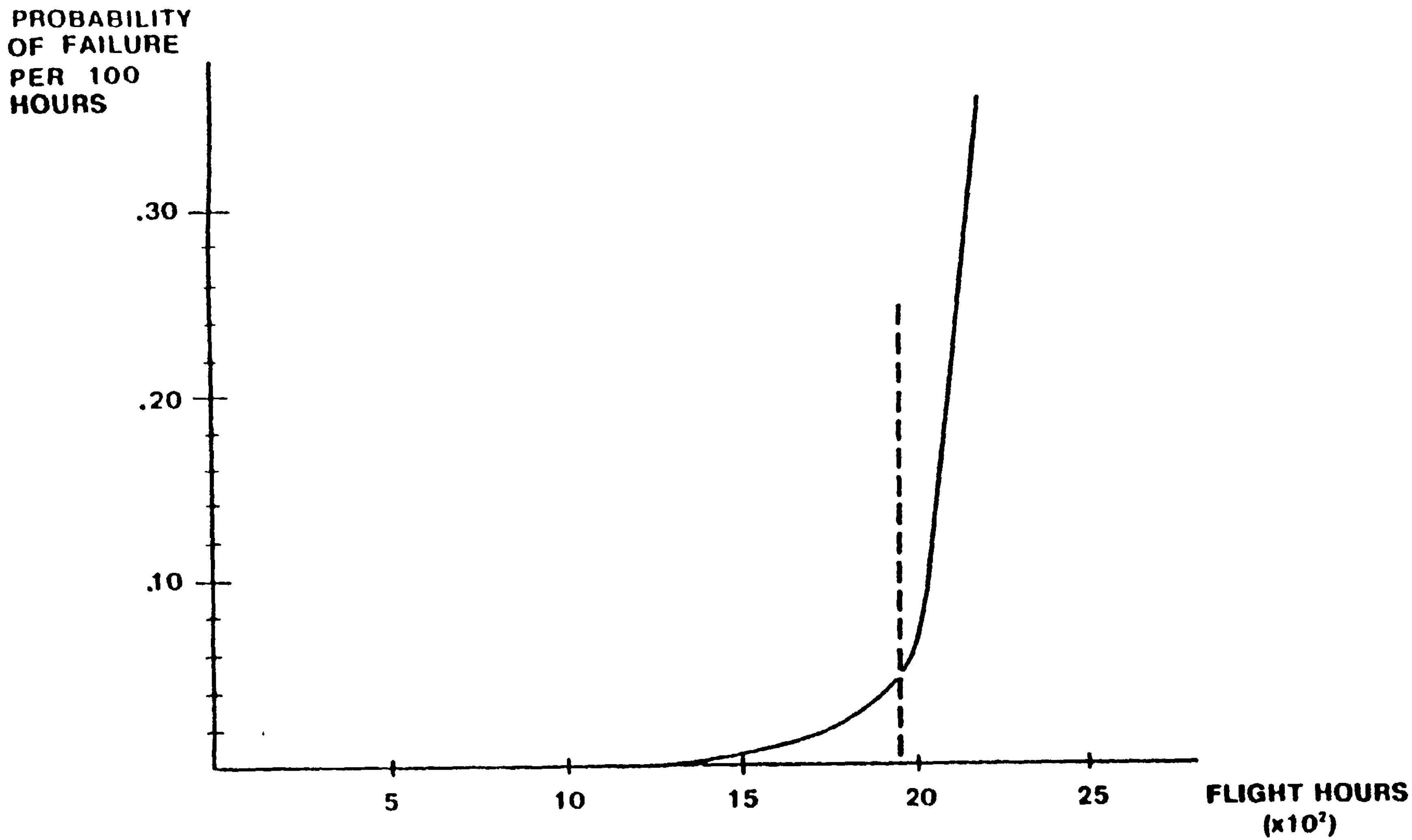


FIGURE 44- Conditional probability of failure curve for launch bar actuating cylinder

| RCM WORKSHEET NO. 7 DETERMINATION OF AGE EXPLORATION TASKS | | | | | | | | | | | | | | | | DATE: 12/21/80 PAGE 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1) ITEM LCN/ MIR INDEX CODE | 2) ITEM NOMEN-CLATURE | 3) FFMC | 4) DEFAULT / FAIL CON | 5) TYPE TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) PLON | e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 ? | b) QUESTION #2 ? | JUSTIFICATION | c) QUESTION #3 ? | JUSTIFICATION | d) QUESTION #4 ? | JUSTIFICATON |
| 13811 | WHEEL BRAKE ASSEMBL | 1A1 | S | OC | Interval between potential and functional failure | Measure valve dia. for rate of wear | 30 | 1 | Until functional failure | N | Y | Data can be collected by fleet activities | Y | Failure causes damage or loss of aircraft | | |
| | | 1A2 | S | OC | Same as 1A1 | Evaluate wear with landings to determine rate of wear | 100 | 0 | Until failure | N | Y | Data can be collected by fleet activities | Y | Failure causes damage or loss of aircraft | | |
| | | 1A3 | S | OC | Same as 1A1 | Monitor hydraulic fluid class to determine rate of contaminatio n | 50 | 0 | Until failure | N | Y | Data can be collected by fleet activities | Y | Failure causes damage or loss of aircraft | | |

FIGURE 56- Determination of age exploration tasks - RCM worksheet 7

PAGE 2

| 1) ITEM LCN/ MIN INDEX CODE | 2) ITEM NOMEN-CLATURE | 3) F F M C | 4) D E F A U L T | 5) T Y P E / A I L / T A S K / C O N | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) P L O M | e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 ? | b) QUESTION #2 ? | JUSTIFICATION | c) QUESTION #3 ? | JUSTIFICATION | d) QUESTION #4 ? | JUSTIFICATON |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13811 | WHEEL BRAKE ASSEMBL | 1B1 | EO | OC | Interval between potential and functional failure | Measure spring tension to determine rate of failure | 30 | I | Until failure | N | Y | Data can be collected by fleet activities | Y | Data will provide wearout time | | |
| | | 1B2 | EO | OC | Interval between potential and functional failure | Measure stack runout to identify rate of warping | 30 | I | Until failure | N | Y | Data can be collected by fleet activities | Y | Data will provide wearout time | | |
| | | 1B3 | EO | OC | Interval between potential and functional failure | Measure pressure plate for warping and keyslot width | 30 | I | Until failure | N | Y | Data can be collected by fleet activities | Y | Data will provide wearout time | | |

FIGURE 57- Determination of age exploration tasks - RCM worksheet 7

| 1) ITEM LCN/MIR INDEX CODE | 2) ITEM NOMEN-CLATURE | 3) FFMC | 4) DEFAULT | 5) FAIL TYPE TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) PLOM | e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 ? | b) QUESTION #2 ? | b) QUESTION #2 JUSTIFICATION | c) QUESTION #3 ? | c) QUESTION #3 JUSTIFICATION | d) QUESTION #4 ? | d) QUESTION #4 JUSTIFICATOB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13811 | WHEEL BRAKE ASSMBL | 1C1 | S | OC | Interval between potential and functional failure | Measure piston diameter for wear | 50 | I | Until failure | N | Y | Data can be collected by fleet activities | Y | Failure causes damage or loss of aircraft | | |
| | | 1C2 | S | OC | Interval between potential and functional failure | Monitor bleeder valve for cracks and damage | 30 | I | Until failure | N | Y | Data can be collected by fleet activities | Y | Failure causes damage or loss of aircraft | | |
| | | 1C3 | S | OC | Interval between potential and functional failure | Monitor housing and passageways for cracks and damage | 30 | I | Until failure | N | Y | Data can be collected by fleet activities | Y | Failure causes damage or loss of aircraft | | |

FIGURE 58- Determination of age exploration tasks - RCM worksheet 7

## ANALYSIS RATIONALE

For this analysis, the analyst calculated an acceptable probability of failure (see paragraph 5.2.3.2.1) as follows:

$$Pacc = \frac{.5}{(200)(15)(5)}$$

$$= 3.33 \times 10^{-5}$$

Calculations for FFMC 1A1:

The analyst assumed that defects are detected in one inspection 80% of the time and that the brakes are used on each mission. The analyst used the acceptable probability of failure (Pacc) to calculate the number of inspections required. The calculations are as follows:

$$P_f = (1 - \theta)^n$$

$$3.33 \times 10^{-5} = (1 - .80)^n$$

$$n = \frac{\text{Log}\ (3.33 \times 10^{-5})}{\text{Log}(1 - .80)}$$

$$n = 6.40$$

The preliminary inspection interval is:

$$\frac{1200\ FH}{6.40} = 187.5 \doteq 180\ FH$$

Actual Probability of failure is:

$$P_f = (1 - .80)^{\frac{1200}{180}} = 2.2 \times 10^{-5}$$

Calculations for FFMC 1A2:

Since damaged hydraulic lines and loose, leaking fittings are more visible and easier to detect, the analyst used $\theta = 90\%$. The calculations areas follows:

$$P_f = (1 - \theta)^n$$

$$3.33 \times 10^{-5} = (1 - .90)^n$$

$$n = \frac{\text{Log}\ (3\ 33 \times 10^{-5})}{\text{Log}\ (1 - .90)} = 4.48$$

**RCM WORKSHEET NO. 5 COMBINATION/FAILURE FINDING TASK EVALUATION** DATE 7/16/85 PAGE 7 OF 8

| 1) ITEM LSACN/ MIR INDEX CODE | 2) FFMC | 3) FAILURE CONSEQ | 4) APPLICABILITY CRITERIA a) COMBINATION TASK (COMB) DO THE TASKS MEET THEIR INDIVIDUAL APPLICABILITY CRITERIA? | 4) b) FAILURE FINDING TASK (FF) IS AN OC HT OR COMB (FOR SAFETY HIDDEN FAILURES) TASK APPLICABLE AND EFFECTIVE FOR THIS FFMC? | 5) DESCRIBE APPLICABLE TASK a) NO | 5) b) DESCRIPTION STATE IN PARENTHESIS IF TASK IS (COMB) OR (FF) | 5) c) PRELIM INTERVAL (END) | 5) d) PREVIOUS DEVELOPED (O) | LEVEL (I) | MAINTENANCE (D) | 6) EFFECTIVENESS CRITERIA a) SAFETY AND SAFETY HIDDEN FAILURE PROBILITY OF FAILURE OR MULTIPLE FAILURE | 6) b) NON SAFETY HIDDEN FAILURES (COST EFFECTIVENESS DIAGRAM) 1) IS FPR HIGH? | 2) OPERAT CONSEQ ? | 3) HIGH REPAIR OR OPER COSTS ? | 4) DOES REAL AND APPLICABLE DATA OR ECONOMIC TRADEOFF STUDY SHOW DESIRABILITY OF PROPOSED TASK? | 7) IS THE TASK APPLICABLE AND EFFECTIVE ? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3910 300 | 1A1 | Safety/ Hidden | No | No | 007P | (FF) Apply power to test chamber with door open there should be negative response If test chamber operates, switch is bad | 187 OP Hrs | | X | | Pacc = 5319 x $10^{-5}$ PF = 5 14 x $10^{-3}$ | | | | | YES |

FIGURE 69- RCM worksheet no.5 - combination/failure finding task evaluation

RCM WORKSHEET NO 7 DETERMINATION OF AGE EXPLORATION TASKS DATE. 12/22/89 PAGE 1

| 1) ITEM LCN/ MIN INDEX CODE | 2) ITEM NOMEN- CLATURE | 3) FFMC | 4) DEFAULT / FAILCON | 5) TYPE TASK | 6) AGE EXPLORATION REQUIREMENT a) INFORMATION REQUIRED | 6) b) PRELIMINARY TASK | 6) c) SAMPLE SIZE | 6) d) PLOM | 6) e) STUDY PERIOD | 7) AGE EXPLORATION TASK ASSESSMENT a) Q#1 ? | 7) b) QUESTION #2 ? | 7) b) JUSTIFICATION | 7) c) QUESTION #3 ? | 7) c) JUSTIFICATION | 7) d) QUESTION #4 ? | 7) d) JUSTIFICATON |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30ED300 | TEST CHAMBER | 2A1 | EO | OC | Interval between potential and functional failure | Inspect inservice motors every 10 hrs. for cracks in shaft and track to find times between pot. and functional failure | 20 Units | I | Sample until functional failure of all 20 units | N | Y | Information can be collected by fleet personnel | Y | Data is easily accessed | | |
| | | 2A2 | EO | OC | Interval between potential and functional failure | Inspect inservice motors every 10 hrs. for evidence of leakage and pump pressure | 20 Units | I | Sample until functional failure of all 20 units | N | Y | Information can be collected by fleet personnel | Y | Data is easily accessed | | |

FIGURE 70- RCM worksheet no.7 - determination of age exploration tasks

**RCM WORKSHEET NO. 7 DETERMINATION OF AGE EXPLORATION TASKS** | DATE | PAGE ___ OF ___

| 1) ITEM LSACN/MIR INDEX CODE | 2) ITEM NOMENCLATURE | 3) FFMC | 4) DEFAULT FAILURE CONSEQ (W/S-2) | 5) DEFAULT TASK EVALUATION | 6) AGE EXPLORATION REQUIREMENT | | | | | | | 7) AGE EXPLORATION TASK ASSESSMENT | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | TYPE TASK | a) INFORMATION REQUIRED | b) PRELIMINARY TASK | c) SAMPLE SIZE | d) PROPOSED LEVEL OF MAINTENANCE | | | e) STUDY PERIOD | a) Q#1 | b) QUESTION #2 | | c) QUESTION #3 | | d) QUESTION #4 | |
| | | | | | | | | O | I | D | | Y/N | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION | Y/N | JUSTIFICATION |
| | | | | | | | | | | | | | | | | | | |

FIGURE 91

Determination of age exploration task - RCM worksheet 7



Supersedes page 209 of MIL-STD-2173(AS)

APPENDIX E

AUDITING RCM ANALYSIS

10. GENERAL

10.1 Scope. This appendix provides the means to review the RCM analysis process to ensure the RCM program goals are met.

20. REFERENCED DOCUMENTS

Not applicable.

30. DEFINITIONS

30.1 MESM - Mission Essential Subsystem Matrices.

30.2 FMEA - Failure Mode and Effects Analysis.

40. GENERAL REQUIREMENTS

40.1 Auditing the RCM analysis. Although an RCM analysis is conducted by highly experienced analysts, objective judgments of the RCM logic decisions may become biased during the analysis process. Therefore, an independent review of the analysis decisions ensures that logic is properly applied and identifies any errors in the decision process. This independent review shall be accomplished externally from the organization which performs the analysis. The review or audit process should include the following areas:

a. Significant item selection.

b. Determination of item functions, failure modes and effects.

c. Classification of failure consequences.

d. Evaluation of applicability and effectiveness criteria for task selection.

e. Overall RCM Program.

The following section discusses in detail the specific areas to be reviewed during an audit of the RCM analysis.

50. DETAILED REQUIREMENTS

50.1 Significant item selection. The chief prerequisite for auditing the RCM analysis is a clear understanding of RCM principles. As a preliminary step, the auditor screens out all obviously nonsignificant items and ensures that