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SPACE SHUTTLE MAINTENANCE PROGRAM PLANNING DOCUMENT

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(NASA-TM-X-69004) SPACE SHUTTLE MAINTENANCE PROGRAM PLANNING DOCUMENT D.V. Brown (NASA) 17 Jul. 1972 30 p CSCL 22B G3/31 Unclas 50233

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GLOSSARY

Inherent Level of Reliability and Safety	That level which is built into the unit and therefore inherent in its design. This is the highest level of reliability and safety that can be expected from a unit, system or Shuttle. To achieve higher levels of reliability generally requires modification or redesign.
Maintenance Significant Items	Those maintenance items that are judged by the manufacturer to be relatively the most important from a safety or reliability standpoint, or from an economic standpoint.
Structural Significant Items	Those local areas of primary structure which are judged by the manufacturer to be relatively the most important from a fatigue or corrosion vulnerability standpoint or from a failure effects standpoint.
Operational Reliability	The ability to perform the required functions within acceptable operational standards for the time period specified.
Effective Incipient Failure Detection	That maintenance action which will reliably detect incipient failures if they exist. That is, detect the pending failure of a unit or system before that system fails. For example, detection of turbine impeller cracks prior to impeller failure.
Real and Applicable Data	Those data about real, operating hardware that is similar enough to the hardware under discussion to be applicable to the design of maintenance programs for the current hardware.
Reduction in Failure Resistance	The deterioration of inherent (design) levels of reliability. As failure resistance reduces, failures increase; resulting in lower reliability. If reduction in failure resistance can be detected, maintenance can be performed prior to the point where reliability is adversely affected.
Does Failure Prevent Dispatch	Refers to launch and ferry operations.

Function	The characteristic actions of units, systems, and Shuttle.
Failure Modes	The ways in which units, systems and Shuttle deteriorate and can be considered to have failed.
Failure Effects	The consequence of failure.
Potential Effectiveness	Capable of being effective (maintenance action) to some degree.
Routine Operation Crew Monitoring	That monitoring that is inherent in normally operating the Orbiter. For example, the pre-flight check list, or the normal operation of the Orbiter and its components and through ground monitoring by telemetry systems.
BITE	Built in test equipment.
Minimum Equipment List (MEL)	This assumes that there can be equipment not related to the flight worthiness which could be inoperable and still dispatch the Shuttle for launch or the Orbiter for ferry flight.
Is Elapsed Time for Correction of Failure >0.5 Hr.	The figure of 0.5 hr is an arbitrary number so that time to correct the failure is a consideration.

SECTION I
GENERAL

1.1 INTRODUCTION

Airline and manufacturer experience in developing scheduled maintenance programs for new aircraft has shown that more efficient programs can be developed through the use of logical decision processes. This document ~~is an~~ adaptation of the Airline/Manufacturer Maintenance Program Planning Document, MSG-2, ~~it~~ provides a systematic tool to develop a maintenance program which will maintain inherent design levels of operating safety. Principally, the evaluations are based on the system and components functions and failures modes.

1.2 OBJECTIVE

It is the objective of this document to present a means for developing a maintenance program which will be acceptable to the Development Centers, the Operators (KSC and AF), and the Manufacturers. The maintenance program data will be developed by coordination with specialists from the operators, manufacturers and the development center. Specifically it is the objective of this document to outline the general organization and decision processes for determining the essential scheduled maintenance requirements for the Space Shuttle Orbiter.

This document is intended to facilitate the development of initial scheduled maintenance programs. The remaining maintenance, that is non-scheduled or non-routine maintenance, is directed by the findings of the scheduled maintenance program and the normal operation of the Shuttle. The remaining maintenance consists of maintenance actions to correct discrepancies noted during scheduled maintenance tasks, non-scheduled maintenance, normal operation, or condition monitoring.

1.3 SCOPE

The scope of this document shall encompass the maintenance program for the entire Orbiter and where applicable to other program elements.

1.4 ORGANIZATION

The organization to carry out the maintenance program development pertinent to the Shuttle shall be staffed by representatives of the Operators, the Prime Manufacturers of the Shuttle, and the Development Centers.

1.4.1 The management of the maintenance program development activities shall be accomplished by a Steering Group composed of members from the KSC, Air Force, MSC, MSFC and representatives of the Orbiter and Engine Manufacturers. It shall be the responsibility of this group to establish policy, direct the activities of Working Groups or other working activity, carry out liaison with the manufacturer and operators, and prepare the final program recommendations.

1.4.2 A number of Working Groups, consisting of specialist representatives from the Operators, the Prime Manufacturer, and the Development Centers may be constituted. The Steering Group, alternatively, may arrange some other means for obtaining the detailed technical information necessary to develop recommendations for maintenance programs in each area. Irrespective of the organization of the working activity, it must provide written technical data that support its recommendations to the Steering Group. After approval by the Steering Group these analyses and recommendations shall be consolidated into a final report for presentation to the Program Manager.

SECTION II
DEVELOPMENT OF MAINTENANCE PROGRAMS

2.1 PROGRAM REQUIREMENT

A maintenance program must be developed before the Space Shuttle becomes operational.

2.1.1 The primary purpose of this document is to establish an initial maintenance program. The purpose of this program is to maintain the inherent design levels of operating safety. This program becomes the basis for the first issue of Operations Specifications-Maintenance to govern initial maintenance policy. These are subject to revisions as operating experience is accumulated.

2.1.2 It is desirable, therefore, to define in some detail:

(a) The objectives of an efficient maintenance program,

(b) The content of an efficient maintenance program, and

(c) The process by which an efficient maintenance program can be developed.

2.1.3 The Objectives of an efficient maintenance program are:

(a) To prevent deterioration of the inherent design levels of reliability and operating safety of the Shuttle, and

(b) To accomplish this protection at the minimum practical costs.

2.1.4 These objectives recognize that maintenance programs, as such, cannot correct deficiencies in the inherent design levels of flight equipment reliability. The maintenance program can only prevent deterioration of such inherent levels. If the inherent levels are found to be unsatisfactory, engineering action is necessary to obtain improvement.

2.1.5 The maintenance program itself consists of two types of tasks:

(a) A group of scheduled tasks to be accomplished at specified intervals. The objective of these tasks is to prevent deterioration of the inherent design levels of Shuttle reliability, and

(b) A group of non-scheduled tasks which results from:

(1) The scheduled tasks accomplished at specified intervals,
(2) Reports of malfunctions (usually originated by the flight crew), or
(3) Condition Monitoring.

*See Glossary

The objective of these non-scheduled tasks is to restore the equipment to its inherent level of reliability

2.1.5.1 This document describes procedures for developing the scheduled maintenance program. Non-scheduled maintenance results from scheduled tasks, normal operation or condition monitoring.

2.1.6 Maintenance programs generally include one or more of the following primary maintenance processes:

(a) Hard Time Limit: A maximum interval for performing maintenance tasks. These intervals usually apply to overhaul, but also apply to total life of parts or units.

(b) On Condition: Repetitive inspections, or tests to determine the condition of units or systems or portions of structure.

(c) Condition Monitoring: For items that have neither hard time limits nor on condition maintenance as their primary maintenance process. Condition monitoring is accomplished by appropriate means available to an operator for finding and resolving problem areas. These means range from notices of unusual problems to special analysis of unit performance.

2.2 SCHEDULED MAINTENANCE PROGRAM CONTENT

The tasks in a scheduled maintenance program may include:

(a) Servicing
(b) Inspection
(c) Testing
(d) Calibration
(c) Replacement

2.2.1 An efficient program is one which schedules only those tasks necessary to meet the stated objectives. It does not schedule additional tasks which will increase maintenance costs without a corresponding increase in reliability protection.

2.2.2 The development of a scheduled maintenance program requires a very large number of decisions pertaining to:

(a) Which individual tasks are necessary,
(b) How frequently these tasks should be scheduled,
(c) What facilities are required to enable these tasks to be accomplished,
(d) Where these facilities should be located, and
(e) Which tasks should be accomplished concurrently in the interests of economy.

2.3 SHUTTLE SYSTEM/COMPONENT ANALYSIS METHOD

The method for determining the content of the scheduled maintenance program for systems and components (parts a and b of Paragraph 2.2.2) uses decision diagrams. These diagrams are the basis of an evaluatory process applied to each system and its significant items using technical data provided (Paragraph 2.7). Principally, the evaluations are based on the systems' and items' functions and failure modes. The purpose is to:

(a) Identify the systems and their significant items*.

(b) Identify their functions*, failure modes* and failure effects*.

(c) Define scheduled maintenance tasks having potential effectiveness* relative to the control of operational reliability*.

(d) Assess the desirability of scheduling those tasks having potential effectiveness.

2.3.1 It should be noted that there is a difference between "potential" effectiveness of a task versus the "desirability" of including this task in the scheduled maintenance program. The approach taken in the following procedure is to plot a path whereby a final judgment can be made as to whether those potentially effective tasks are worthy of inclusion in an initial maintenance program.

2.3.2 There are 3 decision diagrams provided (Appendix 1, Chart A, Figures 1 through 3). Figure 1 is used to determine scheduled maintenance tasks having potential effectiveness relative to the control of operational reliability. This determines tasks which can be done.

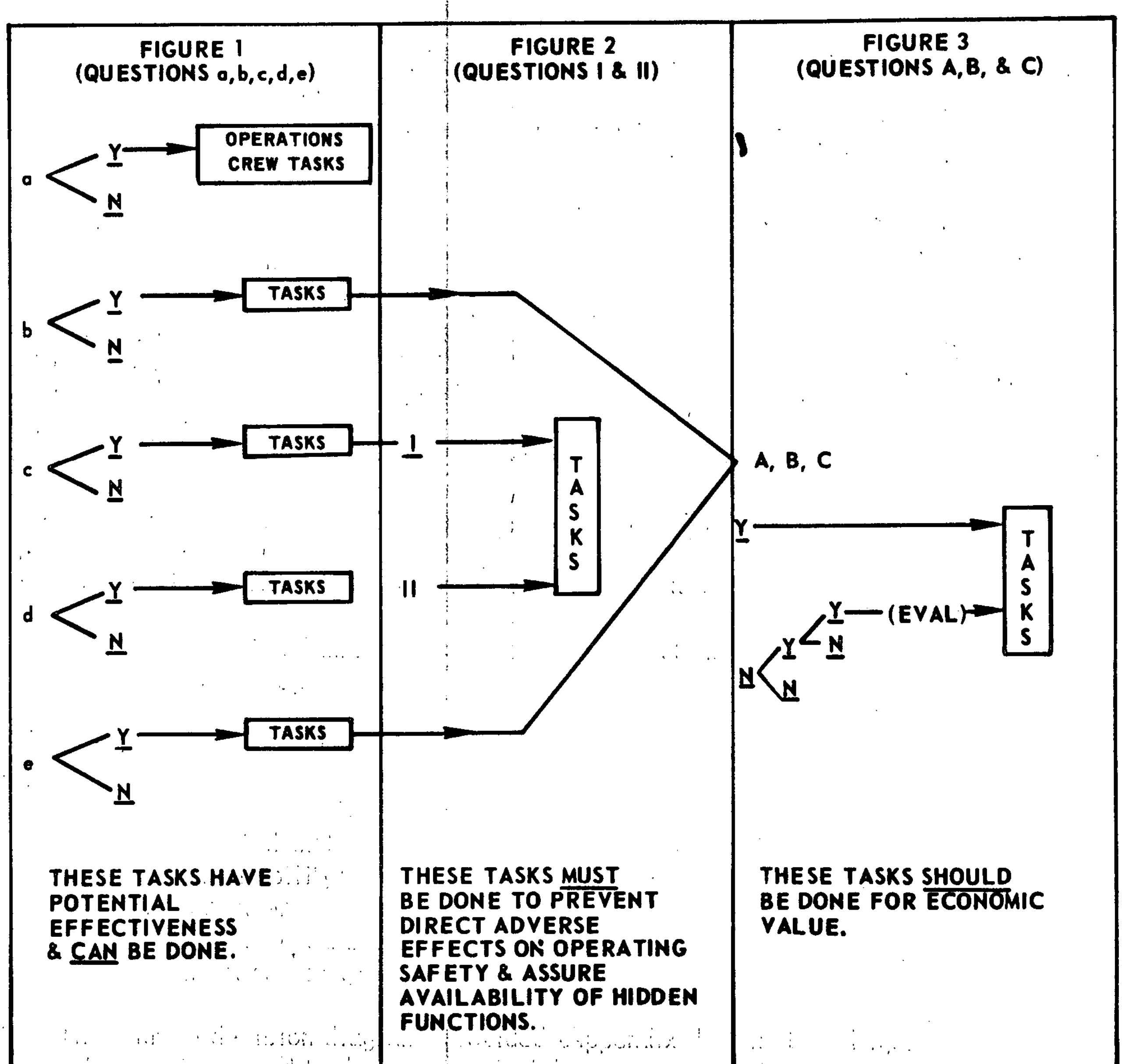
Figures 2 and 3 are used to assess the desirability of scheduling those tasks having potential effectiveness.

(a) Figure 2 tasks must be done to prevent direct adverse effects on operating safety and to assure availability of hidden functions.

(b) Figure 3 tasks should be done for economic value.

*See Glossary

2.3.3 The total analysis process is shown diagramatically below. (See Appendix 1 for details.)



2.3.4 The following guidelines encourage consideration of failure consequences and the potential effectiveness of scheduled maintenance tasks. In those cases where failure consequences are purely economic, the guidelines lead to consideration of both the cost of the scheduled maintenance and the value of the benefits which will result from the task.

2.3.5 A decision tree diagram (Appendix 1, Chart A) facilitates the definition of scheduled maintenance tasks having potential effectiveness. There are five key questions.

NOTE: Questions (a), (b), and (c) must be answered for each failure mode, question (d) for each function, and question (e) for the item as a whole.

(a) Is reduction in failure resistance* detectable by routine operations crew monitoring*?

(b) Is reduction in failure resistance detectable by in position maintenance or test (BITE or GSE)?

(c) Does failure mode have a direct adverse effect upon operating safety? (See Appendix 2.)

(d) Is the function hidden from the viewpoint of the operations crew? (See Appendix 3.)

(e) Is there an adverse relationship between age and reliability?

2.3.6 Each question should be answered in isolation, e.g. in question (c) all tasks which prevent direct adverse effects on operating safety must be listed. This may result in the same task being listed for more than one question.

2.3.7 If the answer to question (a) is Yes, this means there are methods available through monitoring of the normal in-flight instrumentation to detect incipient conditions before undesirable system effects occur. A Yes answer does not require a maintenance task. If the answer is No, there is no in-flight monitoring which can detect reduction in failure resistance. This question is meant to refer to the operations crews' ability to detect deteriorating calibration or system operation before a failure occurs. NOTE: Tasks resulting from in-flight monitoring are part of non-scheduled maintenance.

2.3.8 If the answer to question (b) is Yes, it means there is a maintenance task, not requiring item disassembly, that has potential effectiveness in detecting incipient conditions* before undesirable system effects occur. Tasks may include inspection, servicing, testing, etc. NOTE: Tasks resulting from a Yes answer to question (b) are part of the On Condition maintenance program.

*See Glossary

2.3.9 If the answer to question (c) is Yes, this failure mode has a direct, adverse effect on operating safety. It is necessary to examine the mechanism of failure and identify the single cells or simple assemblies where the failure initiates. Specific total time, total flight cycle, time since overhaul or cycle since overhaul limitations may be assigned these single cells or simple assemblies and the probability of operational failures will be minimized. Examples of these actions are turbine engine disc limits, engine gimbal actuator limits, etc. In many cases, these limits must be based upon manufacturer's development testing. Fortunately, there is only a small number of failure modes which have a direct, adverse effect on operating safety. This results from the fact that failure mode analyses are conducted throughout the process of flight equipment design. In most cases, it is possible after identification of such a failure mode to make design changes (redundancy, incorporation of protective devices, etc.) which eliminate its direct adverse effect upon operating safety. If no potentially effective task exists, then the deficiency in design must be referred back to the manufacturer. The term "direct adverse effect upon operating safety" is explained in Appendix 2. NOTE: Tasks resulting from a Yes answer to question (c) are part of either the Hard Time limitation maintenance program, or the On Condition maintenance program.

2.3.10 Refer to Appendix 3 for explanation of question (d). If the answer to question (d) is Yes, periodic ground test or shop tests may be required if there is no other way of ensuring that there is a high probability of the hidden function being available when required. The frequencies of these tests are associated with failure consequences and anticipated failure probability. A component cannot be considered to have a hidden function if failure of that function results in a system malfunction which is evident to the flight crew during normal operations. In this case, the answer must be No. NOTE: Tasks resulting from a Yes answer to question (d) may be part of either the Hard Time limitation or the On Condition maintenance program.

2.3.11 If the answer to question (c) is Yes, periodic overhaul may be an effective way of controlling reliability. Whether or nor a fixed overhaul time limit will indeed be effective can be determined only by actuarial analysis of operating experience. NOTE: Tasks resulting from a Yes answer to question (e) are part of the Hard Time limitation maintenance program.

2.3.12 It has been found that overall measures of reliability of complex components, such as the premature removal rate, usually are not functions of the age of these components. In most cases, therefore, the answer to question (e) is No. In this event, scheduled overhaul cannot improve operating reliability. Engineering action is the only means of improving reliability. These components should be operated, therefore, without scheduled overhaul. NOTE: Systems or items which require no scheduled tasks are included in Condition Monitoring.

2.3.13 The preceding paragraph is contrary to the common belief that each component has an unique requirement for scheduled maintenance in order to protect its inherent level of reliability. The validity of this belief was first challenged by actuarial analyses of the life histories of various components. More recently, the correctness of the preceding paragraph has been overwhelmingly demonstrated by the massive operational experience of many airlines with many different types of components covered by Reliability Programs complying with FAA Advisory Circular 120-17.

2.3.14 The questions in Figure 1 are intended to determine maintenance tasks having potential effectiveness for possible inclusion in a scheduled maintenance program. However, it is probable that many of these "potentially" beneficial scheduled tasks would not be "desirable" even though such tasks could improve reliability. This might be true when operating safety is not affected by failure or the cost of the scheduled maintenance task is greater than the value of such resulting benefits as reduced incidence of component premature removal, reduced incidence of departure delays, etc. Additional diagrams are used to assess the "desirability" of those scheduled maintenance actions which have potential effectiveness. This is accomplished by Figures 2 and 3, Chart A, Appendix 1.

2.3.15 Figure 2 selects those tasks which <u>must</u> be done because of operating safety or hidden function considerations. Figure 3 selects those tasks which <u>should</u> be done because of economic considerations.

2.3.16 Figure 2 assesses tasks listed against the Yes answers of questions c and d in Figure 1, and selects those tasks which must be done.

2.3.17 For the operating safety question, at least one task must be listed for each failure mode having a Yes answer to question c of Figure 1. An explanation should be given for any question c tasks not selected.

2.3.18 For the hidden function question, normally at least one task must be listed for each hidden function having a Yes answer to Figure 1, question d. If a task is not selected, as permitted by Appendix 3, an explanation must be provided.

2.3.19 Figure 3 assesses tasks listed against the Yes answers in Figure 1, questions b and c and select those tasks which should be done because of economic considerations.

2.3.20 A key question in Figure 3 is the first, "Does real and applicable data* show desirability of scheduled task?* A "Yes" answer is appropriate if there is:

(a) Prior knowledge from missile and aircraft experience that the scheduled maintenance tasks had substantial evidence of being truly effective and economically worthwhile, and

(b) The system/component configurations of previous missile or aircraft and the Shuttle are sufficiently similar to conclude that the task will be equally effective.

*See Glossary

2.3.21 The question "Does failure prevent dispatch*" refers to whether the item will be on the Minimum Equipment List (MEL)*.

2.3.22 The question "Is elapsed time for correction of failure >0.5 Hr.*" refers to whether corrective action can be accomplished with minimum delay.

2.3.23 When a task "requires evaluation" it is important that the frequency of the failure and the cost of carrying out the task are taken into consideration.

2.4 VEHICLE STRUCTURE ANALYSIS METHOD

The method for determining the content of the scheduled maintenance program for structure is:

(a) Identify the significant structural items*.

(b) Identify their failure modes and failure effects.

(c) Assess the potential effectiveness of scheduled inspections of structure.

(d) Assess the desirability of those inspections of structure which do have potential effectiveness.

2.4.1 The structure will be treated as hereafter described. This element includes the structure (fuselage, crew compartments, payload bay doors, bulkheads, thrust structure, wing, tail, etc.); and thermal protection (panels, panel support, insulation, etc.). Additionally, the mechanical assemblies of structural components, such as hatches, emergency exits, and flight control surfaces, landing gear, docking systems, separation/attachment, etc., will be treated individually by the processes described in Paragraph 2.3.

2.4.2 The decision tree diagram, Chart A, Figure 1 of Appendix 1, facilitates the definition of scheduled inspections of structure having potential effectiveness. There are five key questions.

(a) Is reduction in failure resistance detectable by routine operations crew monitoring?

(b) Is reduction in failure resistance detectable by in position maintenance or test (BITE or GSE)?

(c) Does failure mode have a direct adverse effect upon operating safety?

(d) Is the function hidden from the viewpoint of the operations crew?

(e) Is there an adverse relationship between age and reliability?

*See Glossary

2.4.3 The answer to question (a) is normally No. However, if in-flight instrumentation is developed which permits detection of incipient structural failures then the answer could be Yes.

2.4.4 If the answer to question (b) is Yes, there are methods available to detect incipient conditions before undesirable conditions occur. It would be expected that all redundant external and internal structure would be in this category. NOTE: Tasks resulting from a Yes answer to question (b) are part of the Structural Inspection program. This program is an On Condition program.

2.4.5 If the answer to question (c) is Yes, there is a failure mode which has a direct, adverse effect on operating safety for which there is no effective incipient failure detection method. It would be expected that non-redundant primary structure would be in this category. See Appendix 2 for explanation of "direct adverse effect on operating safety." NOTE: Tasks resulting from a Yes answer to question (c) are part of the Hard Time limitation (usually total time or total cycle limits) maintenance program.

2.4.6 If the answer to question (d) is Yes, there is a function required of this element of structure that is not regularly used during normal flight operations. Some inspection or test is therefore necessary to ensure that this function has a high probability of being available when required. NOTE: Tasks resulting from a Yes answer to question (d) are part of the Structural Inspection program.

2.4.7 Structures would be expected to have a Yes answer to question (e) but only in a very long total time envelope. The tasks performed as a result of Yes answers to the other questions are capable of detecting deterioration prior to failure of these items.

2.4.8 It is probable that some of these "potentially" beneficial scheduled inspections would not be desirable, even if such tasks would improve reliability. This might be true when airworthiness is not affected by failure and the cost of the scheduled inspection is greater than the value of the resulting benefits. Therefore, additional diagrams are used to assess the desirability of those scheduled tasks which have potential effectiveness. This is accomplished by Figures 2, 4 and 5 (Charts A,B,C) of Appendix 1. A No answer to all questions is unlikely for structure. If it occurs, the item is included in Condition Monitoring.

2.4.9 Figure 2 selects those tasks that must be done because of operating safety or hidden function considerations.

2.4.10 Figures 4 and 5 (Charts B and C) of Appendix 1 establish internal and external class numbers for structural items. The class numbers take into account vulnerability to failure, consequences of failure. The class numbers are to be used as guides for setting internal and external inspection frequencies.

2.4.11 The items to be evaluated by Figures 4 and 5 (Charts B and C) are those termed "structurally significant."

2.4.12 Each item is first rated for each of five characteristics per Figure 4 (fatigue resistance, corrosion resistance, crack propagation resistance, degree of redundancy and fatigue test rating).

2.4.13 Each item is then given an overall rating (R No.) per Figure 4 which considers all of the above ratings and combines them by judgment into a single overall rating (R No.) representing a relative level of structural integrity of the item. In general, the overall R No. for an item is equal to or less than the fatigue resistance or corrosion resistance rating for the item, whichever is lesser.

2.4.14 The internal and external class numbers for each item are then determined by reference to Figure 5. Note that some items have both internal and external class numbers. This occurs for those internal items which have some probability of the internal item's condition being evident by some external condition. In these cases the item as described is visible internally and the "internal" inspection specified refers to the item as described. The "external" inspection of this item refers to that portion of the external structure which is adjacent to the internal item and which may yield some indication of the internal item's condition. Therefore, when an external inspection is specified for an internal item it refers to the adjacent external structure and not the internal item itself.

2.5 PROPULSION SYSTEM ANALYSIS METHOD

The method for determining the content of the scheduled engine maintenance program is:

(a) Identify the systems and their significant items.

(b) Identify their functions, failure modes and failure effects.

(c) Define scheduled maintenance tasks having potential effectiveness relative to the control of operational reliability.

(d) Assess the desirability of scheduling those tasks having potential effectiveness.

(e) Determine initial sampling thresholds where appropriate.

2.5.1 The propulsion system as a whole and each significant engine item will be treated as described below.

2.5.2 The decision tree diagram, Chart A, Figure 1, of Appendix 1, facilitates the definition of scheduled inspections having potential effectiveness. There are five key questions.

NOTE: Questions (a), (b), and (c) must be answered for each failure mode, question (d) for each function, and question (c) for the item as a whole.

(a) Is reduction in failure resistance detectable by routine operations crew monitoring?

(b) Is reduction in failure resistance detectable by in place maintenance or test (BITE or GSE)?

(c) Does failure mode have a direct adverse effect upon operating safety?

(d) Is the function hidden from the viewpoint of the operations crew?

(e) Is there an adverse relationship between age and reliability?

2.5.3 If the answer to question (a) is Yes, there are methods available through monitoring the normal in-flight instrumentation (including maintenance recorder) to detect incipient conditions <u>before</u> undesirable system effects occur. A Yes answer does not require a maintenance task. If the answer is No, there is no in-flight monitoring which can detect reduction in failure resistance. NOTE: Tasks resulting from in-flight monitoring are part of non-scheduled maintenance.

2.5.4 If the answer to question (b) is Yes, there is a maintenance task, not requiring engine disassembly, that has potential effectiveness in detecting incipient conditions <u>before</u> undesirable system effects occur. Tasks may include inspection, servicing, testing, etc. NOTE: Tasks resulting from Yes answers to question (b) are part of the On Condition maintenance program.

2.5.5 If the answer to question (c) is Yes, this engine component has a failure mode with direct, adverse effect on operating safety. It is necessary to examine the mechanism of failure and identify the single cells or simple assemblies where the failure initiated. Specific total time, or total flight cycle, limitations may be assigned these components to minimize the probability of operational failures. NOTE: Tasks resulting from a Yes answer to question (c) are part of either the Hart Time limitation maintenance program, or the On Condition maintenance program.

2.5.6 If the answer to question (d) is Yes, there is a function required of this engine component that is not evident to the operations crew when the component fails. Some scheduled task may be necessary to assure a reasonably high probability that this function is available when required. NOTE: Tasks resulting from a Yes answer to question (d) may be part of either the Hard Time limitation or the On Condition maintenance program.

2.5.7 It is expected that the answer to question (c) is always Yes for structural engine components, but that their expected life is very long relative to the usual engine inspection periods. If tasks defined by questions (a) through (d) are inadequate to control wear or deterioration of engine components, additional tasks should be listed here.
NOTE: Tasks resulting from a Yes answer to question (c) are part of either the Hard Time limitation or the On Condition maintenance program.

2.5.8 Engine components for which no scheduled tasks are selected are included in Condition Monitoring.

2.5.9 The questions in Figure 1 are intended to determine maintenance tasks having potential effectiveness for possible inclusion in a scheduled maintenance program. However, it is probable that many of these "potentially" beneficial scheduled tasks would not be "desirable" even though such tasks could improve reliability. This might be true when operating safety is not affected by failure or the cost of the scheduled maintenance task is greater than the value of such resulting benefits as reduced incidence of component premature removal, reduced incidence of delays, etc. Additional diagrams are used to assess the "desirability" of those scheduled maintenance actions which have potential effectiveness. This is accomplished by Figures 2 and 3 (Chart A) of Appendix 1.

2.5.10 Figure 2 selects those tasks which <u>must</u> be done because of operating safety or hidden function considerations. Figure 3 selects those tasks which <u>should</u> be done because of economic considerations.

2.5.11 Figure 2 assesses tasks listed against the Yes answers of questions c and d in Figure 1, and selects those tasks which must be done.

2.5.12 For the operating safety question, at least one task must be listed for each failure mode having a Yes answer to question c of Figure 1. An explanation should be given for any question c tasks not selected.

2.5.13 For the hidden function question, normally at least one task must be listed for each hidden function having a Yes answer to Figure 1, question d. If a task is not selected, as permitted by Appendix 3, an explanation must be provided.

2.5.14 Figure 3 assesses tasks listed against the Yes answers in Figure 1, questions (b) and (e) and selects those tasks which should be done because of economic considerations.

2.5.15 A key question in Figure 3 is the first, "Does real and applicable data show desirability of scheduled task?"

A "Yes" answer is apprpriate if there is:

(a) Prior knowledge from missile and aircraft experience that the scheduled maintenance tasks had substantial evidence of being truly effective and economically worthwhile, and

(b) The system/component configurations of previous missile or aircraft and the Shuttle are sufficiently similar to conclude that the task will be equally effective.

2.5.16 The question "Does failure prevent dispatch" refers to whether the item will be on the Minimum Equipment List (MEL). The answer to question (b) is expected to always be Yes for engine components that cause engine failure.

2.5.17 The question "Is elapsed time for correction of failure >0.5 Hr.*" refers to whether corrective action can be accomplished with minimum delay.

2.5.18 When a task "requires evaluation" it is important that the frequency of the failure and the cost of carrying out the task are taken into consideration.

2.5.19 Engine tasks are included in the Threshold Sampling maintenance program. This program is described below.

2.5.20 The Threshold Sampling maintenance program is intended to recognize the On Condition design characteristics of modern rocket and turbo-jet engines, while sampling to control reliability. This program uses repetitive sampling to determine:

(a) The condition of engine components.
(b) The advisability for continued operation to the next sampling limit, and
(c) The next sampling limit, threshold, or sampling band.

2.5.21 Initial sampling thresholds are based on:

(a) The design of the engine under study, the results of developmental testing, and prior service experience,

(b) The results of previous engine programs,

(c) The fact that samples are available from engines removed for all causes at virtually all ages. This means that knowledge of the condition of engines is available over the complete continuum of time from start of operation to the highest time experienced, and

(d) The fact that most engine design problems become apparent and can be controlled well within any established limits or thresholds.

*See Glossary

2.5.22 The Threshold Sampling program establishes the initial sampling threshold. Operators are subsequently responsible for:

(a) Evaluating the samples obtained from the initial threshold,
(b) Determining the next sampling threshold, and
(c) Determining the number to be sampled at the next theshold.

2.5.23 Threshold Sampling is normally accomplished by inspecting the parts or systems of engines that are removed and accessible in the shop. These engines provide samples over a full range of ages without waiting for the threshold to be reached. The results of inspecting these samples are used to determine the future program. When samples are not available from engines that are in the shop, scheduled samples or in place inspections may be required.

2.6 PROGRAM DEVELOPMENT ADMINISTRATION

Program Office participation is encouraged as early and as thoroughly as possible in all phases of working group activity. It is recognized that the program manager will later be asked to approve the proposed program resulting from these efforts. The following activity phases will apply.

Phase I. Steering Group general familiarization training.

Phase II. (a) Working Group or Working Activity Training.

#(b) Preparation of first draft Significant Items List (Paragraph 2.7.1).

#(c) Establish functions and failure modes applicable to the Significant Items.

(d) Preparation of Figures 1 through 5 decision diagram replies and supporting data for each system and significant item.

Phase III. (a) Evaluation of manufacturer's technical data and recommended tasks by the Working Groups' operational personnel and meeting with manufacturer to make necessary revisions and prepare task recommendations.

(b) Development of task frequency recommendations. (This phase is meant to follow Phase III. (a).

NOTE: A Steering Group member should participate in all Phase III activity.

#Steering Committee audits are required for these steps before proceeding.

Phase IV. Presentation to Steering Group (meeting with each Working Group or Activity Chairman).

Phase V. Preparation and presentation of the Steering Group's proposal to the program manager.

2.7 SUPPORTING TECHNICAL DATA

The following supporting technical data will be provided in printed form, together with adequate cross-references on the records of replies to the decision diagrams.

2.7.1 Maintenance Significant Items List

This list will include by System Designator, the name, quantity per Shuttle, prime manufacturer part number, vendor name and part number for each item considered by the Working Group/Activity to require individual analysis.

2.7.2 Significant Items Data

(a) Description of each significant item and its function(s).
(b) Listing of its failure mode(s) and effects.
(c) Expected failure rate.
(d) Hidden functions.
(e) Need to be on M.E.L.
(f) Redundancy (may be unit, system or system management).
(g) Potential indications of reduced failure resistance.

2.7.3 System Data

(a) Description of each system and its function(s).
(b) Listing of any failure modes and effects not considered in item data.
(c) Hidden functions not considered in item data.

APPENDIX 1
SHUTTLE MAINTENANCE PROGRAM DEVELOPMENT CHARTS

SHUTTLE MAINTENANCE PROGRAM DEVELOPMENT

CHART A DECISION DIAGRAM

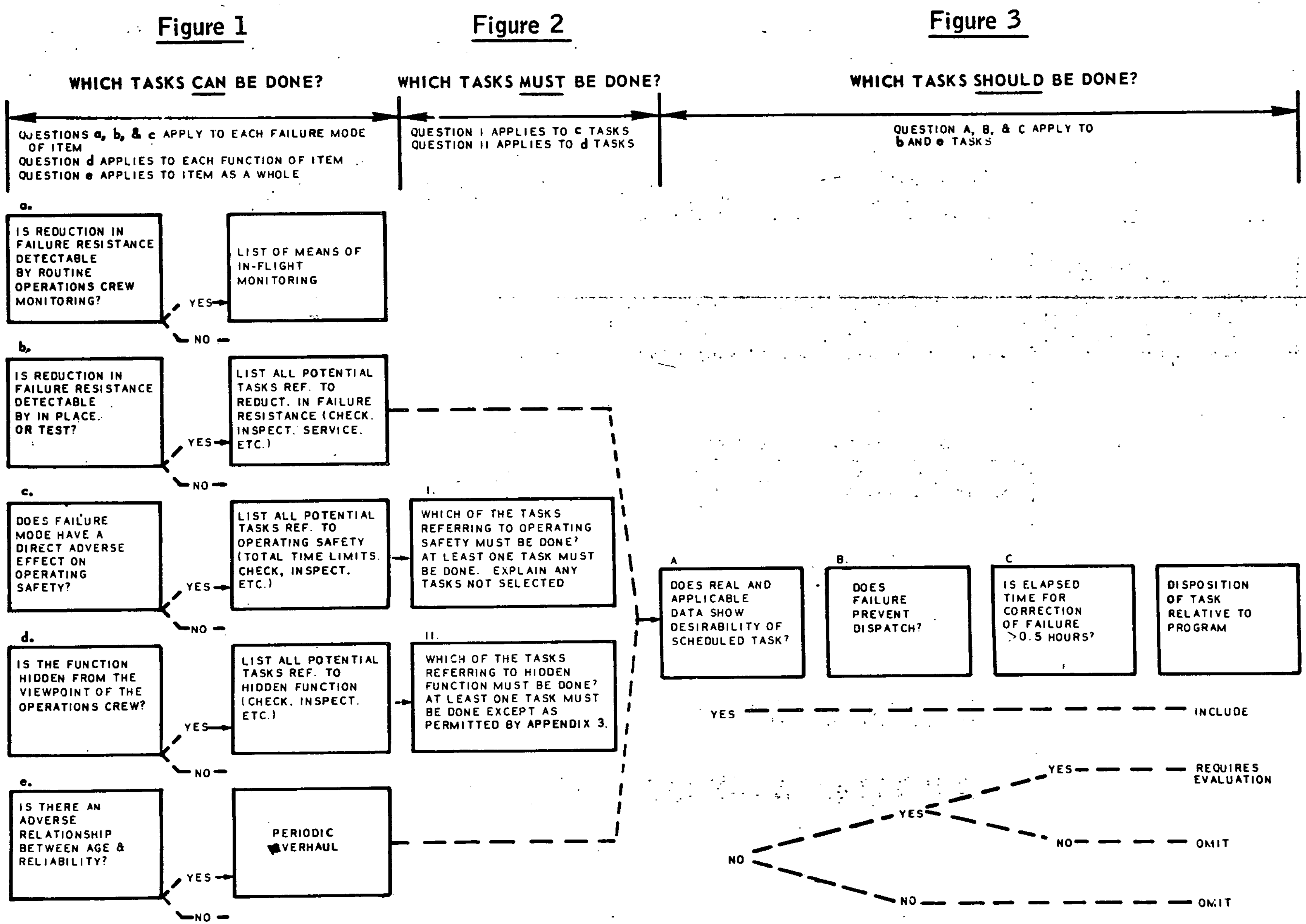


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CHART B STRUCTURE ANALYSIS METHOD

Figure 4

	1	2	3	4	
FATIGUE RESISTANCE	AN INDICATION OF THE FATIGUE RESISTANCE OF THE ITEM RELATIVE TO THE FATIGUE DESIGN GOAL FOR THE OVERALL SHUTTLE				THIS PORTION OF CHART TO BE EXECUTED FOR EACH ITEM WHICH HAS BEEN DESIGNATED AS "STRUCTURALLY SIGNIFICANT"
	SMALL MARGIN ABOVE DESIGN GOAL	FAIR MARGIN ABOVE DESIGN GOAL	CONSIDERABLE MARGIN ABOVE DESIGN GOAL	HIGH MARGIN ABOVE DESIGN GOAL	
CORROSION RESISTANCE (INCL STRESS CORROSION)	AN INDICATION OF THE RELATIVE CORROSION RESISTANCE OF THE ITEM, CONSIDERING BOTH EXPOSURE AND PROTECTION				
	LEAST MARGIN OF RESISTANCE	FAIR MARGIN OF RESISTANCE	CONSIDERABLE MARGIN OF RESISTANCE	HIGHEST MARGIN OF RESISTANCE	
CRACK PROPAGATION RESISTANCE	AN INDICATION OF THE RELATIVE ABILITY OF THE MATERIAL USED TO RESIST PROPAGATION OF CRACKS				
	LEAST MARGIN OF RESISTANCE (HI HEAT TREAT STEEL)	FAIR MARGIN OF RESISTANCE (7000 SERIES ALUM)	CONSIDERABLE MARGIN OF RESISTANCE (TITANIUM)	HIGHEST MARGIN OF RESISTANCE (2000 SERIES ALUM)	
DEGREE OF REDUNDANCY	AN INDICATION OF THE DEGREE TO WHICH THE ITEM IS BACKED UP BY REDUNDANT STRUCTURE				
	SMALL			HIGH	
FATIGUE TEST RATING	WILL THE LOADS APPLIED TO THE ITEM IN THE FULL SCALE FATIGUE TEST PROPERLY REPRESENT LOADS PREDICTED FOR SERVICE USAGE?				
	NO			YES	
OVERALL RATING NUMBER (R)	A RATING WHICH CONSIDERS ALL THE AVOVE RATINGS AND COMBINES THEM BY JUDGEMENT INTO A SINGLE OVERALL RATING WHICH REPRESENTS A RELATIVE LEVEL OF THE STRUCTURAL INTEGRITY OF THE ITEM				THIS RATING NO IS ASSIGNED TO ALL OTHER PRIMARY AND SECONDARY STRUCTURE WHICH IS NOT STRUCTURALLY SIGNIFICANT
	1	2	3	4	5

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CHART C STRUCTURE DETECTABILITY EVALUATION

THIS CHART CONVERTS OVERALL RATING (R) TO INTERNAL & EXTERNAL CLASS NUMBERS

Figure 5

	A INTERNAL CLASS NO.	B EX. CLASS NO. (IF >10 ABOVE GROUND OR IN FUEL AREA)	C EX. CLASS NO. (IF < 10 ABOVE GROUND IN NON FUEL AREA)
STRUCTURALLY SIGNIFICANT ITEMS			
(EX) EXTERNAL ITEMS	NONE	R	R+1
(IN) INTERNAL ITEMS			
• HIGH PROBABILITY OF EXTERNAL DETECTABILITY OF ITEM'S CONDITION BY FUEL LEAK ON VISUAL CONDITION OF ADJACENT EXTERNAL ITEM	R+1	R	R+1
• LOW PROBABILITY OF DITTO	R	R+1	R+1
• NO EXTERNAL DETECTABILITY OF ITEM'S CONDITION SINCE NO ADJACENT ITEMS ARE VISIBLE EXTERNALLY	R	NONE	NONE
ALL OTHER PRIMARY OR SECONDARY STRUCTURAL ITEMS WHICH ARE NOT STRUCT. SIGNIFICANT			
(EX) EXTERNAL ITEMS	NONE	5	5
(IN) INTERNAL ITEMS	5 ▷	NONE	NONE

EXTERNAL MEANS THERE IS VISUAL ACCESSIBILITY WITHOUT DETACHING ANY PARTS (INCL ACCESS PANELS) FROM THE ORBITER, AND INCLUDES CONTROL SURFACE DEFLECTION AS REQUIRED.

INTERNAL MEANS THERE IS VISUAL ACCESSIBILITY ONLY BY DETACHING REMOVABLE PARTS OR BY RADIOGRAPHIC OR OTHER MEANS.

▷ WHERE VISUAL ACCESSIBILITY EXISTS SIMPLY BY REMOVAL OF AN ACCESS PLATE AND NO ADDITIONAL DETACHMENT OF PARTS IS NECESSARY TO GAIN VISUAL ACCESS

APPENDIX 2
DIRECT AND ADVERSE EFFECT ON OPERATING SAFETY

The following eleaborates on the term "direct and adverse effect on operating safety."

During the design process considerable attention is given to system and component failure effect analysis to ensure that failures that result in loss of function do not immediately jeopardize operating safety. In many cases, redundancy can cause the consequences of a first failure to be benign. In other cases, protective devices serve this purpose. Although it may not be possible to continue to launch the Shuttle without correcting the failure and although it may indeed be desirable to make an unscheduled landing after failure, the failure cannot be considered to have an immediate adverse effect upon operating safety. The inclusion of the word direct in the phrase "direct adverse effect upon operating safety" means an effect which results from a specific failure mode occurring by itself and not in combination with other possible failure modes.

APPENDIX 3
EXPLANATION OF HIDDEN FUNCTIONS

A component is considered to have a "hidden function" if either of the following exists:

(a) The component has a function which is normally active whenever the system is used, but there is no indication to the operations crew when that function ceases to perform.

(b) The component has a function which is normally inactive and there is no prior indication to the operations crew 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.

Examples of components possessing hidden functions exist in a bleed air system. A bleed air temperature controller normally controls the bleed air temperature to a maximum of 400°F. In addition, there is a pylon shutoff valve which incorporates 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, in which event they can shut off the air supply from the engine by actuating the pylon shutoff valve switch. There is no duct temperature indication.

The bleed air temperature controller has a hidden active function of controlling the air temperature. Since there is a secondary temperature control in the pylon valve and since there is no duct temperature indicator, the flight crew has no indication of when the temperature control function ceases to be performed by the temperature controller. 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 a hidden inactive function. For a similar reason, the duct overheat warning system has a hidden inactive function. And the pylon valve has a hidden inactive function (manual shutoff) since at no time in normal use does the flight crew have to manually close the valve.

The hidden function definition includes reference to "no indications to the flight crew" of performance of that function. If there are indications to the flight crew, the function is evident (unhidden). However, to qualify as an evident function, these indications must be obvious to the flight crew during their normal duties, without special monitoring (bear in mind, however, that special monitoring is encouraged as a part of the maintenance program to make hidden functions into evident ones).

It is recognized that, in the performance of their normal duties, the flight crews operate some systems full time, others once or twice per flight, and others less frequently. All of these duties, providing they are done at some reasonable frequency, qualify as

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"normal." It means, for example, that although an anti-icing system is not used every flight it is used with sufficient frequency to qualify as a "normal" duty. Therefore, the anti-icing system can be said to have an evident (unhidden) function from a flight crew's standpoint. On the other hand, certain "emergency" operations which are done at very infrequent periods (less than once per month) such as emergency gear extension, fuel dump actuation, etc. cannot be considered to be sufficiently frequent to warrant classification as evident (unhidden) functions.

Another example is the Apollo/Saturn SIV-B APS pneumatic regulators system. A pair of series redundant regulators control the propellant ullage pressure at 196 ±3 psia. The secondary regulator is set 4 psi above the primary regulator and also has a tolerance band of ±3 psi which allows a potential 2 psi overlap. There is no pressure transducer between the regulators and no position indicator on either. The only available information is the ullage pressure measurement which cannot distinguish which regulator is in operation because of the overlapping tolerance bands.

It is therefore possible to have an undetected failure of this primary regulator and a liftoff on the backup system.

The analysis method requires that all hidden functions have some form of scheduled maintenance applied to them. However, in those cases where it may be difficult to check the operation of hidden functions, it is acceptable to assess the operating safety effects of combined failures of the hidden function with a second failure which brings the hidden function failure to the attention of the flight crew. In the event the combined failures do not produce a direct adverse effect on operating safety, then the decision whether to apply maintenance to check the pertinent hidden function becomes an economic decision to be considered by Figure 3 (Chart A, Appendix 1).

Note also, in some cases, it is acceptable to accomplish hidden function checks of removable components during unscheduled shop visits, providing the component has at least one other function which when failed is known to the flight crew and which causes the unit to be sent to the shop. Also, the hidden function failure mode should have an estimated reliability well in excess of the total reliability of the other functions that are evident to the flight crew.