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A Study of Programs for Evaluation of Component Life

Final Report

August 1969

prepared for

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MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

prepared by

MARTIN MARIETTA CORPORATION DENVER DIVISION

MCR-69-366

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A STUDY OF PROGRAMS FOR EVALUATION OF COMPONENT LIFE

Final Report

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ABSTRACT

This report presents the findings and recommendations resulting from a study of limited life components of the types used in the Saturn booster stages. Management methods and techniques for extending component life or recertifying limited life components for flight are discussed.

FOREWORD

This final report is submitted by the Martin Marietta Corporation in accordance with the Data Requirements of Contract NAS8-21296. The results of Phase II of the study of Space Vehicle Storage Requirements are presented.

This study was performed for the NASA Marshall Space Flight Center Storage Committee. The Contracting Officer Representative is the chairman of the Storage Committee, Mr. Kenneth Riggs, S&E-ASTN-XPS. Much valuable assistance was provided by Mr. Riggs and other members of the committee who accompanied us on interview trips, including:

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CONTENTS

ACRONYMS AND ABBREVIATIONS

AAP	Apollo Applications Program
ABRES	Advanced Ballistic Reentry System
ACS	attitude control system
AF	Air Force
AFB	Air Force Base
AFTO	Air Force Technical Order
AGE	aerospace ground equipment
AMA	Air Materiel Area
AMEA	aging modes effects analysis
AVE	airborne vehicle equipment
°C	degrees Celsius
CDF	confined detonating fuse
CSM	Command and Service Module
DDC	Defense Documentation Center
DOD	Department of Defense
DRB	Design Review Board
EBW	exploding bridge wire
ECS	environmental control system
°F	degrees Fahrenheit
GFAE	Government-furnished aircraft equipment
GFP	Government-furnished procurement
GG	gas generator
GSE	ground support equipment
ICBM	intercontinental ballistic missile
IMP	improved maintenance program
IMU	inertial measurement unit
IRP	inertial reference platform
IU	Instrument Unit
KSC	Kennedy Space Center

LASS	lateral acceleration sensing system
LM	lunar module
lox	liquid oxygen
max	maximum
MDF	mild detonating fuse
min	minimum
MRB	Material Review Board
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
OCAMA	Oklahoma City Air Materiel Area (Tinker AFB, Oklahoma)
OOAMA	Ogden Air Materiel Area (Hill AFB, Utah)
OGE	operational ground equipment
P/N	part number
PPM	parts per million
psi	pounds per square inch
PVC	polyvinyl chloride
RCS	reaction control system
RF	radio frequency
RH	relative humidity
rpm	revolutions per minute
SAAMA	San Antonio Air Materiel Area (Kelly AFB, Texas)
SMAMA	Sacramento Air Materiel Area (McClellan AFB, California)
SCID	Special Considerations Items Drawing
SLV	space launch vehicle
SPGG	solid propellant gas generator
SPS	service propulsion system
T. O.	Technical Order

I. INTRODUCTION

A. PURPOSE OF STUDY

The purpose of phase II of the Storage Requirements Study was to recommend to NASA/MFSC a management program including suggested techniques to define, monitor, and control life limited items. The scope and responsibilities of the suggested management program are defined.

To provide the necessary background information and depth of study, comprehensive surveys of literature, government agencies, aerospace contractors, and component manufacturers were conducted. The depth of the surveys assured salient recommendations for a technically feasible and efficient program for the evaluation and/or recertification of space system hardware life.

No specific conclusions or recommendations are presented concerning life limits for specific categories of hardware or individual components.

B. BACKGROUND

The Apollo/Saturn program was originally conceived and scheduled to follow a pattern of build-test-launch. No major periods of storage were anticipated and storage requirements were only an incidental part of the various systems and components.

As a result of several factors, it became apparent that some completed stages of the Saturn launch vehicle would have to be placed in storage for as long as 3 to 5 years.

Phase I of this study was performed to provide information to support development of storage requirements for the Saturn launch vehicle stages. The report covering phase I, <u>A Study of Storage Technology for Various Launch Vehicle Systems</u>, MCR-68-329, was issued during October 1968. The problem of limited life hardware exceeding limits because of storage or storage related activity was discussed only in general terms in that report. However, two problem areas plus one potential problem were evident:

1) Hardware included on existing lists as "life limited" would in some cases, exceed the stated limits during storage. The validity of the stated limits was questioned in certain cases;
2) No general program had been developed for reclaiming or recertifying, for flight, components that had exceeded life limits;
3) Storage of assembled stages for periods of 3 to 5 years might degrade performance in components not presently included on the limited life lists.

Phase II of the space vehicle storage study was defined to investigate these problems.

At NASA/MSFC a committee was formed to serve as a central source for developing and administering the program to determine and extend component life. This committee, entitled MSFC Component Life Committee, consists of 20 members, and includes representatives of all of the S&E laboratories and cognizant program management groups. Mr. J. E. Kingsbury (S&E-ASTN-DIR) is chairman and Mr. K. E. Riggs (S&E-ASTN-XPS) is the executive secretary of the committee.

C. STUDY METHODS

1. General Approach

The methods used to accomplish the limited life component study were the same as those used during the vehicle storage technology study performed as Phase I of this contract. Information and data were gathered from the document library accumulated during Phase I, from documents obtained as the result of additional data searches, from a survey of government agencies and aerospace contractors and suppliers, and from additional documents obtained during the course of the survey.

The information was reviewed, correlated, and evaluated to:

1) Develop a proposed management approach based on the better features of systems currently in use;

2) Evaluate techniques of determining and extending component life;
3) Compare life limits imposed on Saturn components with those imposed on similar components of other vehicle systems;
4) Provide general information on component life for all categories of hardware used on a booster vehicle.

2. Document Library

During Phase I approximately 150 documents were accumulated relating to storage of space vehicles. Many of these documents also contained information relating to component life. The additional data searches and survey contacts produced over 130 documents which have been added to our library. Appendix A lists the reference documents used during preparation of this report and provides a selected bibliography of other pertinent documents obtained during the study.

3. Survey

The survey portion of the study included a wide variety of contacts with Army ordnance, Air Force logistic, and Navy aviation agencies; system contractors for several active launch vehicle or missile systems; NASA contractors (both Saturn and Apollo); manufacturers in several categories of vehicle subsystems and components; and an airline maintenance facility. A total of 40 survey visits was made over a 4-month period. As in Phase I, a questionnaire was prepared and distributed in advance to identify the specific areas of interest to each organization being surveyed. A copy of the questionnaire may be found in Appendix B.

Each organization was visited by a team consisting of two members of the Martin Marietta study group, and one or more members of the NASA/MSFC Component Life Committee. Within one week after each interview a report was prepared and submitted to the committee. Appendix C includes copies of these reports.

II. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a summary of the conclusions reached and the recommendations made as a result of the study. The stated objectives of the study were:

1) Define as many different systems for component life evaluation as can be identified. Methods, effectiveness and cost of each system shall be evaluated;
2) Develop and define practical and efficient techniques for utilization of existing data to accurately estimate extended shelf life of spare components and assembled flight or space systems;
3) Investigate and define practical methods for determining the minimal testing or other methods required to recertify components and systems that exceed their designated shelf life;
4) Identify specific types of hardware or physical parameters that prevent a valid determination of shelf life.

The conclusions and recommendations presented here satisfy the objectives and answer related questions which arose during the course of the study. All details and supporting information may be found in subsequent chapters or appendices of this report.

A. CONCLUSIONS

Component life control has been a way of life in military and supporting aerospace organizations for many years. Because military hardware usually requires storability and long life, various systems have evolved to assure and monitor these factors. NASA has had little reason for concern about component life and until recently no apparent effort has been made to coordinate contractor efforts in this area. The Saturn-stage contractors are not consistent in their treatment of controlled life components. It appears that the principal factor is the different systems used. Each contractor has used his own approach to the few situations which have arisen resulting in inconsistent treatment of controlled life components.

All organizations surveyed employed systems for monitoring limited life items and extending component life. These systems are defined in Chapter IV. The systems use one or more of the following methods to evaluate and extend component life:

1) Testing - (the most widely accepted technique);
2) Surveillance - (generally used with medium to large component populations);
3) Refurbishment - (generally used when capability exists and cost criteria are met);
4) Inspection - (accepted, usually in combination with other concepts);
5) Analysis - (accepted by many organizations, but often only in combination with 1) above);
6) Similarity - (accepted by some organizations surveyed, definition of concept varied);
7) Waiver - (often used for short-term extensions of installed hardware to meet test or launch schedules).

These methods are defined in Chapter V.

Surveillance, analysis, similarity, and waiver methods often utilize inspection records, test data, failure analysis records and other existing data to estimate and extend component life.

A lack of consistent terminology caused some difficulty in evaluating the various approaches used.

An evaluation of the cost of the systems defined was not possible because cost data was not available from those surveyed. The only cost information provided had to do with refurbishment costs.

Contractor component life control systems are sometimes active as early as the design phase. No formal design guidelines or aids were found during the survey. Rather the control system was an approval of the design or request for change to improve life characteristics.

Military component control is usually concerned with a large population. Surveillance programs and testing of aged samples are often used to support life extension decisions, and overhaul or refurbishment is used whenever practical to maintain a stock of usable components.

Initial component life assignments tend to be conservative because they often reflect specification or program requirements rather than actual hardware capability.

During the study interviews, no specific type of hardware or physical parameters that prevent a valid determination of life were identified.

Although there are a few inconsistencies between stages, most of the life limits specified for Saturn components appear to be in line with aerospace industry practice. It is possible to extend the limits in some instances using the techniques described in this report. In many cases, recertification techniques can reestablish flight worthiness.

The NASA/MSFC standard for age limits of elastomers (MSFC-STD-105) is more liberal than the handbooks and standards used for military programs and some other NASA installations. However, the survey indicated that most components manufacturers, contractors, and using agencies feel that a more liberal approach is justified and preferred.

B. RECOMMENDATIONS

An organization for single point control should be established by NASA/MSFC to coordinate and control programs involving calendar life and operating life of components. The Component Life Committee, recently organized, satisfies this recommendation. The committee should be given the necessary authority to:

1) Obtain a consistent approach to limited life components program;
2) Obtain support as required to accomplish programs to establish extension of limits or recertification requirements;
3) Require compliance with decisions concerning life extension or recertification;
4) Obtain data required to monitor life limited components;
5) Assure that future MSFC programs include adequate systems of component life control including aging modes and effects analysis (AMEA) at the design stage.

A suggested sequence of committee activity is presented in Chapter IV of this report.

Some logical sequence of terms and definitions should be established and required for use by MSFC contractors. A suggested sequence of terminology and definitions is presented in Chapter III.

A mechanized system should be established for handling component life data, and controlling required replacement, refurbishment, retesting, or other actions.

Component recertification requirements should be established to relate to the action taken on the component:

1) If the component is refurbished, acceptance level test is usually required;
2) If adjusted or calibrated, the parameters involved should be certified and a component functional test run;
3) Minimum recertification should include a functional test of the item.

Over-age items that cannot be recertified, or cannot be refurbished should be retained for test programs to extend or verify the imposed age limit. Cost guidelines should be established concerning disposition of components whose life has expired. The suggested limit for refurbish and recertification is 65% of replacement cost. The guideline must be flexible to take care of availability or other problems. It is also suggested that components to be refurbished have a minimum value of $500.

Cost effectiveness reviews should be made for all components capable of being refurbished and recertified.

III. TERMINOLOGY

A. DISCUSSION

The contract statement of work covering this study calls for a study of "...hardware shelf life." The statement of work goes on to say "In the context of this study, the term, 'Shelf Life', is applied to the status of items stored in place, on vehicles, or on components, or in subsystems, etc; not just to items 'on the shelf'."

It was apparent at the outset that additional terminology was needed to cover the various aspects of hardware life to be studied. In addition, during the survey interviews it was discovered that there is very little consistency between organizations concerning the definitions of the terminology, and, in fact, at least two cases were observed where the definitions were not consistent within organizations.

Written definitions were extracted from documents obtained from 17 organizations. Common usage definitions were obtained from two other sources. Over 30 different terms relating to component life were defined in these sources. Fifteen terms were encountered in two or more sources, although the definitions were not always similar. Thirteen terms relating to test and recertification activities were defined.

Two examples of the difficulty in assuring ourselves that we understood the terms used during the survey interviews are presented below.

1. Component Life

The following terms were used by various organizations to define component life. The number indicates the number of organizations which used each term.

Shelf Life (12)	Installed Life, Operating (1)
Calendar Life (4)	Installed Life, Nonoperating (1)
Assembly Life (2)	Useful Life (2)
Service Life (2)	Design Life (1)
Storage Life (2)	Use Life (1)
Installation Life (3)	Operational Life (1)
Installed Life (3)	

2. Shelf Life

The following definitions are those encountered for the term "shelf life":

1) Two organizations stated that "shelf life" was used to describe materials or components in shelf-type storage.

2) "Shelf life shall be the time span ... that item is actually stored at a ... facility. This span of time shall begin with either Date of Manufacture (DOM) of a material at the vendor's facility or Date of Receipt of a material at a ... facility. In all cases, shelf life shall end with date of assembly of a material into deliverable engineering hardware. For all rubber or elastomeric materials, cure date shall be regarded as DOM.

   "If the shelf-life period of an item expires while being stored at a ... facility, the item shall be either scrapped or further dispositioned in accordance with ...." (Ref 1). (Several additional organizations indicated that shelf life was only applied to material or piece parts prior to assembly into components.)

3) "Shelf Life - the maximum period of time from date of cure, manufacture, or assembly that an item can remain unused in storage before being reconditioned or condemned." (Ref 2).

4) "The shelf life is defined as that period of time the item is stored from cure date to installation date or to expiration of the expected shelf life whichever occurs first." (Ref 3).

5) "'Shelf Life' specifies the minimum period of (component) storage life, during which it remains in a ready-for-installation status. Shelf life is specified separately from storage life in order that a distinction can be made between levels of maintenance.

   "Generally speaking, maintenance intervals associated with shelf life represent the maximum time an item can remain in storage prior to installation as a flightworthy component without first undergoing a revalidation test. The Shelf Life maintenance requirement is not mandatory if the item is not to be maintained in the ready-for-installation status." (Ref 4).

6) "Shelf Life - the time that an item or material can be stored without degradation of performance. This definition applies only to items containing calendar-age sensitive material." (Ref 5).

7) "Shelf life limit is defined as the maximum calendar time which an equipment can accrue without risk of degradation of performance beyond acceptable limits." (Ref 6).

B. RECOMMENDED DEFINITIONS

A review was made of all of the terms and definitions and of the sequences of terminology used by several organizations. The definitions presented in this section provide a logical sequence of terms for a component life program. These definitions will apply to the terminology used in the following chapters of this report.

Throughout the following definitions the word ITEM is used and should be understood to also mean PART, COMPONENT, or ASSEMBLY as appropriate.

1. Limited Life Item

A limited life item falls within one or more of the following categories:

1) An item whose performance or reliability deteriorates below acceptable limits due to aging after a specified period of time following the date of manufacture, delivery, acceptance or activation;

2) An item whose estimated prelaunch and mission usage is a significant percentage of its service life;

3) An item that must be calibrated or adjusted periodically;

4) An item for which operating time or cycle history must be maintained.

2. Shelf Life

Shelf life is the allowable period of time a material or detail part may be stored following cure date, date of manufacture, or date of receipt as applicable, before assembly of the material or part into a component or higher level assembly.

3. Storage Life

Storage life is the allowable period of time a component or higher level assembly may be stored without requiring recertification upon removal from storage.

4. Calendar Life

Calendar life is the period of time from date of manufacture or assembly that an item can retain its desired performance and reliability characteristics while in storage or installed, operating or nonoperating before being recertified or condemned.

5. Service Life

Service life is the amount of functional or operating time or cycles that may be accumulated on an item before the probability of failure exceeds acceptable limits, requiring that the item be refurbished and recertified, or condemned.

6. Operating Limits

Operating limits are the designated limits of functional or operational time or cycles imposed on an item because of the criticality of the application or mission. Usually operating limits will be less than service life to provide the desired safety factor.

7. Milestone Limits

Milestone limits are portions of the operating limits allocated to each phase of operation (acceptance test, production test, static test, prelaunch test, etc).

8. Cycle

The cycle is usually defined uniquely for each item. It generally implies a complete operation from the normal, deenergized, or disconnected state to the operated, energized, or connected state and return to the normal state. Pressure vessels often have a special formula for defining cycles of pressurization.

9. Refurbishment

Refurbishment is a maintenance operation performed on an item, consisting of disassembly, cleaning, inspection, replacement or repair of subassemblies, components, or parts and reassembly. Refurbishment and recertification restores all or part of the calendar life and/or service life as specified for the item.

10. Recertification

Recertification restores all or part of the operating limits for the item as specified. Recertification is accomplished by adjustment, calibration, or test or combination of these, to the level required for the item.

11. System Level Test

A test performed on installed equipment to verify that the system meets operational requirements is a system level test.

12. Functional Test

A functional test is performed on a component or subassembly to verify operational integrity. Usually an item is removed or isolated from the system during functional testing.

13. Acceptance Test

Acceptance tests are used to verify that an item meets the required procurement specifications. In most cases, acceptance level testing is required for recertification following refurbishment.

14. Qualification Test

Qualification tests are a complete series of tests required for an item to be qualified for its flight mission.

IV. MANAGEMENT OF A COMPONENT LIFE EXTENSION PROGRAM

With the advent of the Saturn vehicle storage program, it has become apparent that a secondary program is required to handle the problem of the limited life component. Many of the component parts will exceed their presently stated calendar age limits during the storage program. In addition many components in storage as spares will exceed calendar age limits during the stage storage program.

The principal goal of a program of component life evaluation and control is to assure availability of qualified flight hardware, including spares support, to meet launch date requirements. Additional goals involve holding down costs involved in replacing, reworking, or retesting hardware whose life limits have expired, and assuring that all flight hardware has been properly categorized as to: (1) age sensitivity, (2) wearout sensitivity, or (3) life limits not required.

The organizational functions involved in such a program are many and varied, including design engineering, system engineering, reliability, logistics, quality control, maintainability engineering, and test operations. During the course of the survey, a variety of management approaches to component life control were observed, however, most of the effective, comprehensive programs were administered by a single controlling agency. That agency sometimes took the form of a committee and other times was an organizational unit. In either case the authority was provided to direct the necessary actions in support of the component life program.

A. METHODS USED BY THOSE SURVEYED

All of the companies and agencies surveyed have experienced some effects as a result of aging materials or components and all have developed a method or technique for dealing with those problems.

The following paragraphs describe the management methods used by a few of those surveyed. These appear to be the best systems for controlling equipment that possess aging characteristics.

1. Grumman Program

The salient features of the Grumman program for control of life-sensitive components are as follows.

Grumman controls life-sensitive components through two systems. The "shelf life" program monitors items susceptible to calendar aging. The "limited life" program monitors components susceptible to wearout degradation due to operation.

Both programs are administered by a single point of contact (a group within the Reliability and Maintainability Control Section of the Engineering Department).

Data sheets are prepared for each component to the deliverable part level. A sample data sheet is presented in Appendix D. Determination of the life limit, and the action to be taken when the limit is reached is based on vendor recommendation and engineering analysis, including experience, data, and mission considerations. Design and Reliability Sections and NASA sign off the data sheet. Purchased parts also require a data submittal that is reviewed by Materials and Reliability engineers to assure proper inclusion in the component life programs. The single agency administration assures consistency among the various types of components.

No specific testing is conducted to obtain or verify life-limit data at the component level.

Operating life limit milestones are established to control operating times at the various test locations. The document listing the equipment life and milestones has released engineering status. Changes may be made that affect only one vehicle effectivity at one milestone, or any combination of equipment effectivity and milestones as appropriate to the situation.

Analysis and test data are the principal tools in changing life limits. The test data involved are usually from routine test procedures. Inspection data may be useful where contamination or corrosion are of concern.

The shelf life program terminates for some components at installation in a system. Other components are monitored to launch.

Operating times are monitored by manually entering event clock time in the procedure. Quality Control is responsible for maintaining component time logs and summary sheets. Some events are recorded on tape, however, these data are only used to back up the manual entry system. Quality Control monitors items against the milestone limits.

The administrative group monitors component shelf life by an automated system. This group notifies Quality Control on a special form when an action is necessary for a specific item. This form is returned to the administrative group on compliance to close out the item. Examples of the automated shelf life logs are presented in Appendix D. Excerpts from Report ARP 255-015, AAP/LM-A Time/Cycle Sensitive Items Summary, are also presented in Appendix D to better illustrate the Grumman documentation.

2. McDonnell Douglas Program

Component age and operating life for the Gemini and Gemini B programs were controlled by the Product Support or logistics organization of the McDonnell Douglas Corporation through the use of Preventative Maintenance Requirements Summary Documents. These documents established life limits for all spacecraft systems equipment. The equipment was analyzed from the standpoint of access and removal, repair location and description, periodic maintenance, special storage, and handling requirements. The information was coordinated with systems engineers and test personnel and represented the total program repair and maintenance policy. Component life is established by program requirements and is extended only by testing. Some changes to component life have been made based on past history experience. A Material Review Board system is used for handling components that have passed their life limits.

Samples of the Gemini and Gemini B maintenance summary documents and a description of the columns for each are provided in Appendix D.

3. Screening Committee

Lockheed Missiles and Space Company's Space Systems Division has been faced with extending the calendar life of components in the Agena system. A screening committee was set up to direct and monitor this function. In addition, the committee monitors other parameters that affect the reliability of the system, such as failures and excessive rework. The screening committee is composed of the following members:

1) Product Assurance Program Representative (Chairman);

2) Program Chief Systems Engineer;

3) Program Reliability Engineer;

4) Responsible Equipment Engineer;

5) Customer Representative, if required.

On occasion, the reliability of equipment that has passed acceptance test and meets its specified contract requirements may become suspect. The following criteria were established for mission-critical flight hardware to help define those circumstances that may result in equipment reliability degradation:

"1. UNVERIFIED FAILURES: When a failure cannot be reproduced in subsequent testing and detailed investigation indicates that replacement of all components that could cause the problem is not practicable or would result in excessive rework.

"2. RELATED FAILURES: When a verified failure appears to be related to a prior failure (verified or unverified) but exact cause cannot be determined and detailed failure analysis indicates that replacement of all components that could cause the failure is not practicable or would result in excessive rework.

"3. EXCESSIVE OR UNKNOWN STRESS LEVELS: When there is reasonable evidence of a component having been subjected to stress levels in excess of allowable normal ground operating specification limits or when a component failure is known to produce excessive stress levels elsewhere within the component and replacement of all overstressed parts is not practicable or would result in excessive rework.

"4. EXCESSIVE REWORK: When a component has or will have a history of excessive rework, repair or modification of a functional nature.

"5. INCOMPLETE PEDIGREE DATA: When a component lacks adequate repair, rework, or corrective action documentation.

"6. INADEQUATE OPERATING TIME TO ALLOW RECYCLING: When any nonrefurbishable limited-operating-life component cannot be recycled so that its remaining ground operating life limits will not be exceeded prior to launch.

"7. <u>EXCESSIVE CALENDAR LIFE</u>: Unless otherwise defined by governing equipment specifications or contract documentation, all nonrefurbishable components for which effects of extended storage are unknown shall be reviewed after 36 months." (Ref 7)

Equipment to be screened is determined by the Reliability Group or the Program Office. The task of preparing a plan for extending life is assigned to the responsible equipment engineer by the screening committee. The plan is reviewed and approved by the committee and a decision is made on life extension based on the results of the actions involved.

The following information concerning life extension of the horizon sensor system will illustrate the above process. This system has a specification calendar life of 36 months. Of 33 units, 26 have accrued 28 months or more of calendar life. It is expected that 14 units will exceed 36 months at their predicted use date. To extend calendar life the following functions will be performed on one system that is over 40 months old (oldest available):

1) Open mixer box for visual inspection;

2) Measure head pressure;

3) Perform evaluation test to the original qualification level which includes -

    a) Thermal vacuum, both high and low temperature,

    b) Vibration,

    c) Shock;

4) Parameter verification and visual inspection;

5) Complete tear down and destructive inspection.

Upon successful completion of this evaluation a functional test requirement for the rest of the systems will be established and the calendar life will be extended to 60 months. The calendar life of the velocity meters has recently been extended from 36 to 60 months using a similar technique.

4. Material Review Board (MRB)

Martin Marietta Corporation, McDonnell Douglas Corporation, and Lockheed Missiles and Space Company are among those that use a Material Review Board system. An MRB is used to determine the disposition of material or hardware that does not conform to specifications or exceeds its operating limitation or calendar life. An MRB is usually composed of authorized members of the Quality and Engineering departments and a customer representative with acceptance authority. The MRB has the authority to order an item scrapped, use as is, or rework the item in accordance with MRB's prescribed instructions. The MRB has no authority to approve the use of a nonconforming item when a deviation will exist in the final hardware. Authority for use of nonconforming material which exceeds the operating limitation or calendar life must be approved by the customer.

5. Aging Modes and Effects Analysis

An Aging Modes and Effects Analysis (AMEA) is a systematic study of the effects of aging on each element of an item and whether these effects could degrade or negate the function of the item. The AMEA can go one step further and determine what effect either degradation or loss of the function of the item would have on mission success. An AMEA could also consider the effects of interface aging. A sophisticated AMEA might include estimates of the probability of occurrence of each aging effect. Experienced chemists, physicists, or material engineers should perform the AMEA since the AMEA is performed essentially at the materials level.

An AMEA should be required before design release to determine what elements of an item are age critical and the life limitations of the item. Modification of the design is required if calendar or cyclic life does not meet minimum specifications. It is suggested that design engineers should include a life analysis, including the AMEA, in their design reports submitted to the design review board (DRB). Part of the DRB function should be to ensure that life/cycle requirements have been met.

Although many of those interviewed employed an informal AMEA, General Electric Company, Missile and Space Division, apparently was the only company using a formal AMEA (Trip Report II-22).*

*Trip reports are reprinted in Appendix C.

6. Service Life Evaluation Program

The Service Life Evaluation Program is a method used by the military to evaluate the capability of equipment to survive its environment and successfully perform its assigned function within existing requirements and ultimately to determine the maximum service life that can be established consistent with reliability requirements.

It has been used successfully on programs such as the Atlas, Thor, Titan, Minuteman, and Polaris to evaluate the capability and extend the life of those weapon systems. It is most effective when the quantity of equipment within the program is great enough to provide meaningful degradation data.

Evaluation missiles are removed from operational deployment at programed ages. These units are given a series of analytical tests or an analytical overhaul to determine aging degradation or wearout characteristics.

7. Technical Orders 00-20K Series

The 00-20K series of technical orders are used by the Air Force to establish allowable time limits for the storage, issue, and shipment of specific categories of property and to prescribe the action to be taken at the end of such time limits. This series of T.O.s was established by Headquarters, Air Force Logistics Command Regulation No. 65-23, which prescribes responsibilities and guidance for the establishment of age controls on AF property, surveillance of items so designated while in storage, and for reexamination and analysis of such property for possible extension of shelf life.

> "The commander at each Air Force activity is responsible to insure that qualified personnel are assigned as required to:
>
> "a. Establish and maintain identification, condition, and status of all property.

"b. Make systematic inspection of all property being received, shipped and in storage, to determine if rust, corrosion, fungus, loss, or drying out of lubrication, obvious or suspected damage or other action has occurred or is about to occur which may render the material or equipment unfit for issue, shipment or continued storage.

"c. Make regular examinations of humidity indicators in desiccant packaged items to insure that the moisture content of such package does not exceed the allowable limits.

"d. Inspect pressurized containers to insure pressure is maintained within limits established in applicable technical orders.

"e. Insure that appropriate maintenance action is accomplished on property requiring such action.

"f. Insure that Government Furnished Property (GFP) and Government Furnished Aircraft Equipment (GFAE) stored at contractors' plants is subject to the required inspections and functional tests." (Ref 8)

The following criteria are used by the Air Force as justification for applying age control:

"1. End assemblies or components which have direct effect on safety of flight (missile safety) and life sustaining equipment will be subject to age controls, if documented failure or factual data indicate that premature failure has occurred as a result of deterioration while in storage.

"2. On a new item entering the inventory, experience gained on a like item should be used. If no experience data is available, the item should not be subjected to age control until experience dictates.

"3. All other items on which documented failure or factual data indicates that the useful life of the item will be degraded as a result of shelf life deterioration will be considered for age control.

"4. Age controls are not to be applied to items containing Silicone, Neoprene or Teflon merely because of the presence of these materials in the part or assembly.

"5. Age controls are not to be applied when deterioration can be prevented by proper packaging or preservation." (Ref 8)

Each Air Materiel Area is responsible for administration and control of the age control program on the property for which it is designated as Maintenance Engineering Manager.

8. Improved Maintenance Program (IMP)

The extension of shelf and operating lives of components in the Thor system is part of the responsibility of the Improved Maintenance Program (IMP). This program is implemented by a series of annual review meetings attended by representatives from the cognizant Air Materiel Areas (AMA) and the using agencies. It is chaired by the technical services group from the AMA.

This meeting is controlled by an agenda prepared in advance from inputs of the AMAs and using agencies. The agenda is prepared early enough to allow each responsible agency to prepare tentative solutions to its particular problem areas. The IMP group acts on each problem taking into consideration the suggested solutions. The results of these actions are recorded in the IMP review minutes which, after being signed by representatives of all agencies, become binding. Decisions to change the lives of items are based on the methods discussed in Chapter V.C. These decisions are implemented by changes to the applicable -6 inspection manual.

Manual AF-LCM-66-2, a general responsibility document, requires the IMP or a similar program to define life limitations. For example, a similar program at the Ogden AMA is the Maintenance Service Review, which was formerly the IMP program. The Maintenance Materiel Division (MCMT) of the Air Force Logistics Command at Wright-Patterson AFB monitors all Technical Orders for uniformity of content and form. MCMT recommended that each life limitation request or change be accompanied by a statement that delineates why the request or change is required (Trip Report II-31).

Three examples of Thor components whose lives have been extended by IMP are presented in Trip Report II-16. At SMAMA, it is the responsibility of the service engineering group to plan and implement cases involving the extension of lives and to sell the results to the IMP review.

9. Open Ended Life

The open ended life method is used by the Navy on the Polaris weapon system, which is now considered to be completely open ended with no age limitations imposed. The open ended life method is an extension of the service life evaluation program.

The Polaris system was originally designed for a 5-year life. After it had been deployed for about 4 years, it became obvious that steps would have to be taken to maintain confidence in the system. For this reason, a Service Life Evaluation Program was established consisting of the following steps:

1) Approximately 50% of the entire fleet of missiles are removed from the submarines every year. These missiles receive a functional check before removal and are then taken to a Naval depot facility where the functional test is repeated. After this, the missiles are broken down into their major components and these components are tested to assure that they are still operating within specification limits. All components that satisfactorily pass these tests are held in stock until required to build up a new missile. Results of this testing are sent to Lockheed. Where appropriate, components that are out of specification are sent to Lockheed for failure analysis.

2) Twelve missiles per year are removed from the active fleet and returned to Lockheed for more complete testing to the component level.

3) Two to four missiles per year from the active fleet are returned to Lockheed for complete analytical tear down and where necessary, destructive testing.

4) One shot items, e.g., ordnance and batteries are sampled every year and results of their tests are compared to the acceptance test data. All of these data are collected and evaluated at Lockheed and become the basis for identifying any action required to maintain confidence in mission success.

Due to fund reduction, it is becomming necessary to change the Service Life Evaluation Program. The new program will continue the testing of 50% of the fleet by Naval depots, but the test equipment at the locations is being modified to record the measured parameters on magnetic tape that is compatible with Lockheed computers so that the data can be monitored mechanically for discrepancies and trends. The program of sampling and expending one shot items will be continued and Lockheed intends to run tests to measure degradation on all components that are returned to them for repair.

10. Special Considerations Items Drawing

The Special Considerations Items Drawing (SCID) is used by the Martin Marietta Corporation to define the requirements and special considerations applicable to specific hardware of the Titan III family necessary to achieve flight reliability. All airborne and ground items that have special requirements or limitations are covered. The criteria for component selection for inclusion are as follows:

"a. AGE/AVE items that must function properly from the final countdown through flight for mission success.

"b. AVE instrumentation and tracking and flight safety items required to obtain significant data for evaluation of mission objectives.

"c. Operational control levels, end items, subsystems, and components that require AFTO and DD 829-1 Forms in accordance with SSD Exhibit 66-1.

"d. Items requiring contamination control.

"e. Items having special packaging, handling or storage requirements to prevent degradation of reliability.

"f. Items having one or more of the following time/cycle limitations:

1) Calendar Life

2) Shelf Life

3) Operation Life/Cycle

4) Environmental Acceptance Test Vibration Limitation.

"The following criteria are used in addition to the above criteria for the selection of critical items:

"a. Safety Critical (SC) - AVE items for which a single failure will result in an abort with warning time less than 2 seconds. SC is applicable only on the Titan IIIM Program.

"b. Mission Critical (MC) - AVE items for which a single failure, or double failure of the same failure mode in a redundant circuit, will result in a mission abort.

"c. Launch Critical (LC) - AVE/AGE items for which a single failure will result in a launch hold during final countdown and the expected occurrence is greater than one hold per 10,000 launches.

"d. Time/Cycle Sensitive (TC) - Items having one or more of the following time/cycle limitations:

1) Calendar Life

2) Shelf Life

3) Operational Life/Cycle

4) Environmental Acceptance Test Vibration.

"e. Mission Instrumentation (MI) - AVE/AGE instrumentation and tracking and flight safety items required to obtain significant data for evaluation of mission objectives. Items classified as MI which fail prior to launch shall not be flown, but shall be replaced/repaired prior to launch.

"f. Items that are classified as bulk items, soft consumables and operating materials and supplies shall not be included." (Ref 2)

The SCID is prepared and maintained by the Logistics Section of the Engineering Operations and Logistics Department with inputs as required from the engineering departments, and is implemented by all affected company organizations as directed by operations directives and standard procedures. The organizations use the specified requirements/limitations when ordering, receiving, handling, storing, repairing, testing, and approving hardware as well as during preparation of data products required to support any of the above functions. Affected departments prepare or revise internal operating practices, procedures, process plans, shop folders, log books, and related instructions to ensure that the requirements/limitations are implemented. Sample SCID pages and an explanation of the entries are presented in Appendix D.

B. PROPOSED FUNCTIONAL SEQUENCE

The flow chart in Fig. IV-1 presents a proposed sequence of management and support functions for the control of components subject to aging degradation. The sequence is a composite of features of several of the systems encountered during the survey, and is not used in this specific format by any of the organizations surveyed.

The following paragraphs discuss each segment of the chart, describing the proposed function, the reasoning behind the function, alternative approaches, and other factors taken into consideration. Methods of accomplishment are mentioned where appropriate, but the detailed discussion of these methods is located in subsequent sections of this report.

Various alternatives to the functions and sequence shown may be found in Chapter IV.A, which describes systems in use by some of the organizations surveyed.

1. Establish Control Organization

Most of the system contractors surveyed had an organizational unit responsible for component life control. However, the committee approach seems more practical for the MSFC Saturn organization. Committee membership can include the stage program organizations as well as the various engineering, quality, and reliability organizations. The committee approach should simplify the establishment of lines of authority to assure a consistent approach to component life and control throughout the stages and subsystems.

It is important that authority be established to allow the control organization to request and receive inputs, and to establish actions to be accomplished by the functions required to support a component life control program.

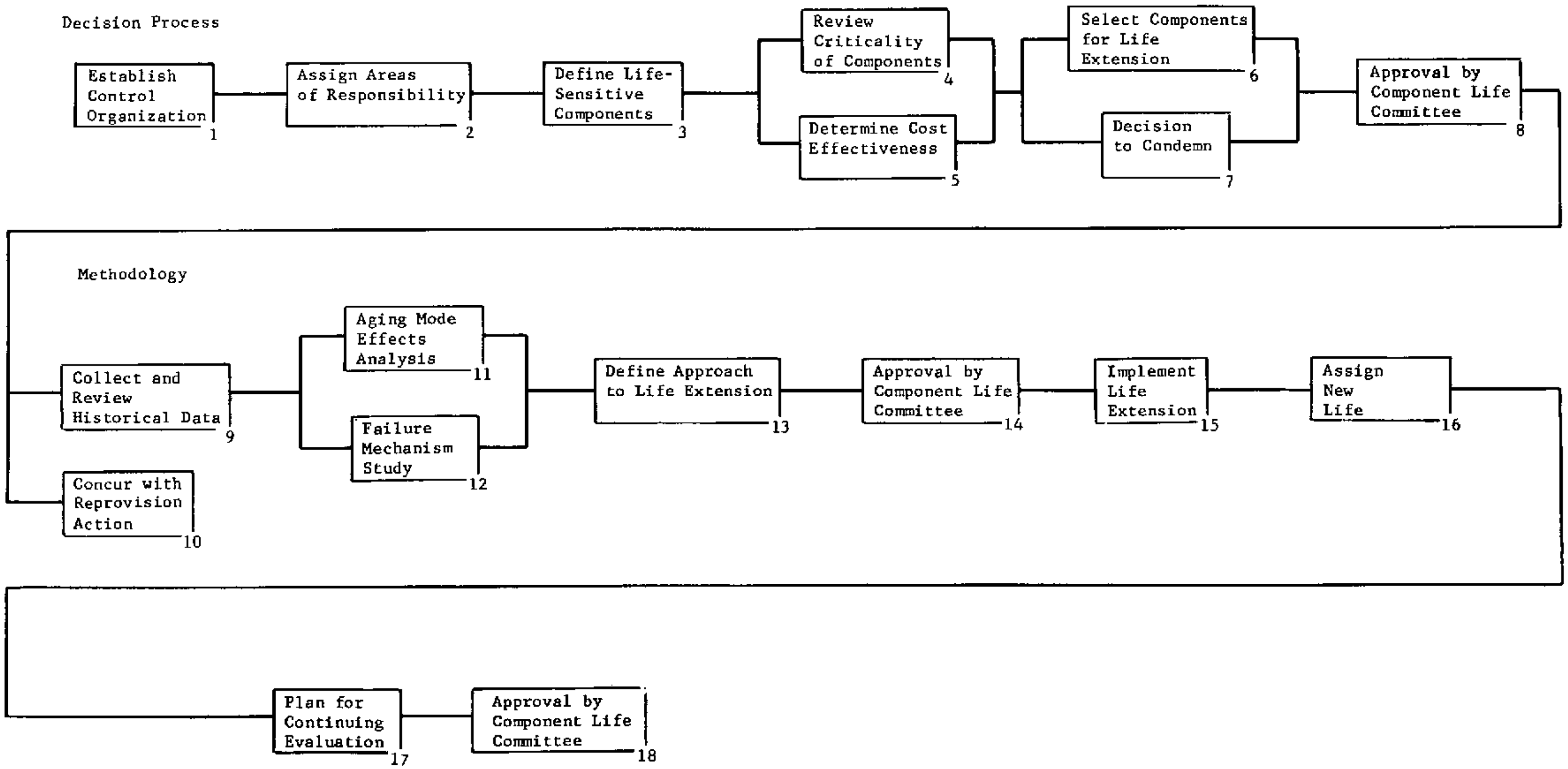

Fig. IV-1 Management Flow Chart

MCR-69-366

2. Assign Areas of Responsibility

This function is self-explanatory. It is suggested that the basic alignment of component responsibility be by subsystem to assure similar treatment across the five stages. Other responsibilities may be arranged in the most convenient manner.

3. Define Life Sensitive Components

Committee members review all components of assigned subsystems. Existing lists of component life limits should be reviewed to assure that limits are reasonable and consistent. All other components should be reviewed to assure that all age sensitive items that may be affected by extended stage storage are placed on the component life control list. Government-furnished equipment as well as contractor-furnished hardware should be covered by these reviews. Support should be obtained, as required, from design engineers, materials engineers, and reliability engineers.

It is suggested that data sheets be prepared for each component (by P/N) to document the decisions, justifications, and approvals through the flow of committee activity. Examples of data sheets in use are provided in Appendix D.

4. Review Criticality of Components

All components should be rated for criticality. The rating system should be standard across all stages. Where the same part is used in more than one application or location, the criticality should be established for each usage and the number of parts at each criticality level indicated, either by stage or by complete vehicle. Support may be required from design engineering and systems engineering.

5. Determine Cost Effectiveness

Cost data should be accumulated on components that might require replacement before launch because of calendar life or operating life expiration. Support may be required from logistics and maintainability engineers. Replacement costs, availability, refurbishment cost estimates, retest cost estimates, and similar information are required to assist in decisions concerning disposition of the expired part.

6. Select Components for Life Extension
and
7. Decision to Condemn

With the information accumulated during the preceding activities, the limited life components are divided into categories for life extension programs or condemnation. Factors affecting the decisions include cost, availability, and imposed limits.

Cost - Military organizations and defense contractors usually use a guideline of 65% maximum for cost of refurbishment and recertification versus cost of replacement. The minimum cost of a component considered for life extension varied rather widely, with an average in the $100 to $500 range.

Availability - Long procurement lead time items, items no longer available, or new procurement items that might require requalification are usually considered for life extension with the cost factor secondary.

Imposed Limits - If the limits imposed on a component seem unreasonable, or are "program limits" (calendar life limits that are the same as contract limits for the system or program), a change of the limits may be considered. Components that must be condemned upon expiration of life limits should be considered for a change of limits.

Components condemned as flight hardware are often used for test purposes as "hangar queens," or held for aging surveillance testing.

8. Approval by Component Life Committee

The full committee should review and approve decisions made during the activity of blocks 3 thru 7.

9. Collect and Review Historical Data

After a component is selected and approved for a life extension program, a file should be prepared containing available data concerning the component. A summary of age and operating times for each serial number should be developed for this file. Failure data and failure analysis reports should be accumulated. Maintenance and maintainability information may be included if available.

Any data relative to performance of the component through production, test, and mission should be summarized in this file. The information accumulated will be useful in developing the specific life extension program for each component (by part number), whether the proposed extension is a change in limits or a maintenance or recertification action.

10. Concur with Reprovision Action

If the previous evaluations resulted in a decision to condemn a component on expiration of its life limits, the quantity and life status of spares must be reviewed. The logistics support function should advise the committee whether the supply of spares is adequate or additional procurement is required. If it is determined that an additional number of the components must be procured, the Component Life Committee should assure itself that component life factors and procurement schedules have been coordinated with program requirements.

11. Aging Modes Effects Analysis

The aging modes effects analysis is described in Section A.5 of this chapter. It is suggested for use in this sequence as a tool to aid in determining the appropriate techniques for extending component life.

12. Failure Mechanism Study

Failure mechanisms and related reliability information should be known and understood for each component before determining the approach and techniques to be used for extending its life. Much of this information should already be available from design and reliability groups.

13. Define Approach to Life Extension

Using the results of the aging modes effects analysis, the failure mechanism study, and any other applicable information from the component data file, determine the approach to be used in extending the life of each component.

The two basic approaches are (1) to change the existing limits and (2) to recertify the component for an additional life period. The recommended techniques for implementing life extension should also be defined at this time. If the second approach is used it should be determined if the additional life period will be the same as or different from the original period.

14. Approval by Component Life Committee

The committee should review decisions reached and techniques recommended for the life extension program for each component at this time.

Approval of the committee should be required before the program is implemented.

15. Implement Life Extension

Following the approach and techniques defined in block 13 and approved in block 14, proceed with the life extension program. Assign the work effort to the appropriate function and monitor schedules to assure timely action. Available techniques are discussed in Section C of Chapter V.

16. Assign New Life

In the case of a program aimed at changing the life limits of a component, the new limits are assigned at the completion of the program and after the necessary approvals.

If the program is one that recertifies the component, the approved additional life is assigned on completion of the recertification procedure and verification by the cognizant Quality organization. The additional life period may be the same as the original, or different as determined during preceding committee action.

17. Plan for Continuing Evaluation

A system should be established for receiving periodic summaries of data generated during recertification, refurbishment, and other activity of the component life extension programs.

The data files established in block 9 should be continued and kept current. A plan should be developed for a continuing or periodic review to add components to or delete them from the limited-life lists or to update the life extensions programs as appropriate.

18. Approval by Component Life Committee

The plan for continuing action should be reviewed by the committee and approved for implementation.

C. MANAGEMENT TECHNIQUES

Much of the effort involved in a component life control program consists of accumulating data, monitoring for compliance with decisions, and assigning work items when required. Several mechanized systems for accomplishing these efforts were observed during the survey. The systems varied in complexity with the simpler systems providing only monitoring and scheduling capability.

The control organization must have the authority to obtain all of the documents, reports, and records needed to make a mechanized system perform its function.

All of the Saturn contractors and MSFC groups that have undertaken programs or tasks relating to storage or component life from the material level on up to the system level should be required to notify the Component Life Committee of the nature of the program and to justify any results or conclusions reached. Contractors on future projects should be required to interface with this committee on a periodic basis starting with the design phase.

Summaries of hardware Unsatisfactory Condition Reports should be available to the committee on a regular basis. The committee should be authorized to recommend or require failure analysis of nonconformance hardware if aging or wearout is suspected as a cause.

V. LIFE LIMITED HARDWARE

A. FACTORS AFFECTING COMPONENT LIFE

The principal factors of component degradation are calendar aging, and operation (wearout). Contributing factors are environment, design limitations, and handling. These factors operate or exist continually during the programed life of the component.

1. Environment

Environment cannot be avoided and is one factor that receives the most attention.

Two of the best publicized environmental studies in recent years concern equipment removed from "My Gal Sal", a B-17 down on the Arctic icecap for 23 years, and "Lady Be Good", a B-24 that had lain in the North African desert for 17 years.

The Arctic environment was estimated to range from -78°F to +35°F and from 55% to 95% relative humidity.

> "The instruments and material samples were sent to the Materials Laboratory at Wright Field. Preliminary inspections of these instruments showed them to be in excellent condition with them meeting the calibration requirements of new pieces of equipment.
>
> "The four pieces of hydraulic equipment were returned to Vickers for examination and inspection. It was found that this accumulator still contained all of its normal air precharge of 325 psi. A similar accumulator recovered from the "Lady Be Good" B-24 aircraft after 17 years in the North African Desert did not contain an air precharge, even though the accumulator and diaphragm were in excellent condition. It would appear from this that the higher humidity was beneficial in providing a continuous seal.
>
> "The disassembled accumulator showed the rubber diaphragm to be in excellent condition -- still soft and pliable, with no bubbles on the rubber surface evident. There was no external leakage with this accumulator under a cycling pressure condition.

"The AA-16801 Vickers Ball Turret Transmission bore no external signs of deterioration or corrosion. The unit was operated in the Laboratory and found to meet the requirements of a new unit.

"One of the performance operational requirements of this transmission is that under a no-load condition, the maximum output speed of the transmission shall be from 28.5 percent to 31.5 percent of the input speed. On test, this unit was slightly better than average for a new unit condition, producing 30.8 percent of the input speed. Another requirement is that under the maximum load condition of 1100 psi, the output speed shall decrease no more than 200 rpm. Under these conditions, the speed drop was 200 rpm. The rubber lip type shaft seal appeared to have a slight sweating, but insufficient to form a drop. This condition would have passed the production test.

"Upon disassembly, the transmission appeared to be in excellent condition. The bearings all appeared to be bright and shiny and showed no signs of deterioration. All the parts appeared to be in a new condition. The external surface of the seal retainer showed some minor corrosion conditions.

"The engine-driven pump tested satisfactorily and pumped 4.4 gallons per minute at 4000 rpm at 1000 psi. At the beginning of the test run there was some external shaft seal leakage, but this then reduced to zero shaft seal leakage after approximately five to ten minutes of operation.

"From the preliminary results of these investigations, it can be concluded that hydraulic systems can withstand many years of normal earth environments.

"It appears that seals in tactical military vehicles such as ICBM missiles might be changed over a 5-10 year period of time instead of the present 2 year period of time. It is believed that this and other similar accumulated data will further provide the aerospace industry with much additional information for the continuing development of aerospace aircraft and space vehicles." (Ref 9).

The desert environment of "Lady Be Good" ranged from a possible winter night temperature of 26°F to a summer day temperature of 120°F and from 5 to 10% relative humidity in the daytime and possibly as high as 36% relative humidity at night.

"The temperatures previously mentioned were a few feet off the ground, and during the middle of the day the actual desert sand temperature on the surface of the sand may reach a maximum of 185°F. In the case of dark color, thin, insulated material, temperatures up to 215°F in the sun have been attained. However, aluminum, with its excellent conductivity, would likely have a slightly lower figure, so that temperatures of the bottom surface of structural components, such as wings and engines, probably reached maximum values of 150°F to 200°F, depending upon the amount of conduction taking place. Solar radiation at approximately mid-day in summer desert weather has been found to be approximately 94 langleys per hour.

"The inspection and analysis of the 16 mechanical items removed from this aircraft was done in conjunction with the Wright Air Development Division, at Wright Field. Since there was a duplication of many types of equipment, that is, we had two piston units, several small cylinders, two large cylinders, two check valves, etc; it was decided to divide the equipment into two sections and test one group as is, and deassemble and inspect one group as-is.

"Prior to test, a visual inspection of the Vickers PF-713 main system pump showed it to be in excellent condition. Externally there was some sand clinging to the unit, but it showed no evidences of corrosion or pitting of the external surfaces. The pump drive shaft turned very freely by hand.

"Prior to disassembly this pump was given a standard production type test with this unit meeting the delivery requirements of a new unit. There was zero shaft seal leakage. As an example, a new pump is required to have a .497 to .507 cubic inches per revolution displacement at 1000 psi. This unit, upon test, was found to have a .502 cubic inches per revolution displacement, which is the exact median of the displacement limit. An examination of the coupling shaft showed the external grease coating to be soft and pliable.

"Disassembly of the pump showed it to be in excellent condition. The bearings, as well as all other metal surfaces, were in bright shiny condition; the shaft seal rubber sealing element was in good soft pliable condition, as were the two housing gaskets.

"The MF-713 Vickers bottom turret retraction motor was disassembled in an as-is condition. Due to the position of this motor at the time of the crash, all three hydraulic lines, inlet, outlet, and case drain, were sheared off at the unit fittings.

"Externally the motor was quite caked with sand, which accounted for some discoloration on the housing. However, the drive shaft turned freely by hand. The shearing of these hydraulic lines then permitted all three ports to be open during this 17 year period. Upon disassembly of this motor, all parts were found to be in excellent mechanical condition. There was an excellent coating of red hydraulic fluid, in very good condition, on all parts. Due to the open ports, a fair amount of sand had drifted into the internal parts of the unit.

"The motor was in very good mechanical condition, with all metal parts bright and shiny, and the shaft seal soft and pliable. The unit was then reassembled in an as-is condition, with no attempt to lap the valving surfaces or replace the shaft seal. This unit also met the efficiency requirements of a new unit. However, the shaft seal leakage was above the one drop per 10 minute specification, which was due to a scratch previously noted in the drive shaft.

"The 5-inch diameter Vickers accumulator had some discoloration on the housing due to fluid leaking down on top of it as a result of the crash, and then being dried in that condition. This may have been acid from a battery. A preliminary check of the accumulator showed that a full air charge could not be maintained for a period of time, due to air leakage at the rim threads. The accumulator was disassembled, and the internal two shell and rubber diaphragm appeared to be in very serviceable condition. The diaphragm was soft and pliable. Upon replacing the original diaphragm, the unit met complete operational and functional test requirements.

"An inspection of the left flap actuating cylinder showed the piston to move freely, with a very excellent coating of hydraulic fluid found to be in it. There was no corrosion on any of the external or internal parts. The "O" rings were soft and pliable and showed a durometer reading of 75 to 80. The condition of this cylinder was typical of that of the other cylinders, as all of them were found to be in excellent condition. In other cylinders the piston rod rings and packings were all found to be in soft pliable working condition.

"While we have made rapid advances in our aircraft and missile hydraulic control activity during the past years, many of these components did have basic designs that could permit excellent comparison with today's equipment. The results of these tests and inspections indicate that in present missile hydraulic equipment, if humidity and temperature are controlled in the presently planned manner, that long term silo storage would offer no foreseeable problems." (Ref 10).

"Similar examination and analysis has been performed on equipment removed from aircraft downed in the jungles of the Panama area. Temperature averages 85°F with an 87% average relative humidity and 148 inches average yearly rainfall.

"The equipment removed from 6 to 24 years storage in a jungle environment showed heavy deterioration on assemblies that were not sealed, such as electrical motors, radio panel and thin gauge sections. The fungus growth on much of this equipment was heavy and damaging. On the sealed components such as hydraulic pumps, deterioration was only partial with some of the units still operable. The "O" rings were in good condition and still functional in most cases.

"As a result of these environmental studies, it is believed that the present military specifications for shelf life of hydraulic "O" rings can be changed from its present 24 to 36 months period to 5 years, and perhaps with further information even to 7 years duration. In designing equipment for the more severe environments around the world, it appears that if the equipment can be sealed or semi-sealed, its chances of surviving long term storage will be excellent." (Ref 11).

Tropical environments have caused some polyurethane and polyacrylate encapsulants to revert to a liquid state. Test performed at the U. S. Naval Avionics Facility subjected material to an environment of 100°C and 95% relative humidity. "The results of this extended testing indicated that the reversion problem was much more severe than had been anticipated." (Ref 12). Six of the eleven compounds tested reverted to the liquid state.

High temperature and humidity produce degradation, but other environmental factors (atmospheric pollutants, ozone, microbes, insects, and animals) can also produce severe degradation. Much information concerning environment is contained in the Phase I report and all of the information obtained during this phase reaffirms the conclusions reported.

2. Design Limitations

At the start of Phase II it was assumed that there were many materials that would adversely influence component life. As the study progressed it became evident that this impression was not entirely correct. The materials that affect component life have been determined to be relatively few and fit into one or more of the following categories: elastomers, ordnance, batteries, lubricants, stress corrosion sensitive materials, and radio active components. The study has also indicated that elastomerics (seals, gaskets, O-rings, etc) aging has been overemphasized, and in fact has been excessively conservative.

The major factors influencing component life are the environment and operation/handling modes to which the component is subjected and not the materials used in the component.

Problems do arise when materials are used in unusual or new combinations without adequate testing or when little background data are available for the new materials used. Probably the best example is the grounding of the F-4 aircraft in Vietnam to rework the electrical systems at a cost of approximately $9 million because of the degradation of the potting compound due to high temperature and humidity.

Elastomers - Most people think immediately of rubber goods at the first mention of age limited or limiting materials. Our survey indicated that there is a wide diversity of opinion and practice concerning life limits for rubber goods depending on compounds used, application, and the contractor involved. Life limits ranged from as low as two years to a high of 13 years. Most uniformity was found where companies followed the limits established by ANA Bulletin 438. It was generally concluded that Military Specification and AMS compounded rubbers possess longer and more consistent life limits than those produced to commercial specifications.

Ordnance - Ordnance component life is related to the processes and changes caused by environmental and operating conditions. Chemical changes continue during storage. The changes usually become evident first by a reduction in performance at the extremes of the temperature limits. Ordnance life can be extended by maintaining a controlled environment.

Batteries - Silver-zinc batteries are assigned limited life due to the material used in their construction. Voltage decays during a dry storage period. The degradation rate is increased by high temperatures and is caused by the relative instability of the silver peroxide.

Lubricants - Lubricants tend to lose their lubricity with storage due to evaporation or drying. Lubricant seapage past seals also may cause limited component life.

Stress Corrosion - Use of stress corrosion susceptible materials can limit component life and should be avoided. "Materials that are stress corrodable in a specific environment tend to fail under tensile stress which is often below nominal design loading. The corrosion function takes place in relatively mild environments, very often with little evidence." (Ref 13).

Radioactive Components - Radioactive and luminescent components have limited life because of degradation of the materials. The life limits of some switch tips and docking targets, either installed or in storage are established as 900 days and 360 days, respectively.

B. LIFE LIMIT COMPARISON

During the course of the survey, information and documentation was requested from each organization listing the life limits applied to the components or systems under discussion.

The information has been accumulated in a matrix form (Table V-1) to facilitate comparison. Two comparisons were made: (1) the component life assignments for similar components of the Saturn booster vehicle stages were compared to determine if inconsistencies existed, and (2) the Saturn component life limits were compared to life limits of similar components of other vehicles to determine if the limits were consistent with aerospace industry practices.

Caution must be exercised when attempting to draw conclusions from these comparative data. One must bear in mind the mission objectives of each vehicle or program. The difference in approach between unmanned and manned vehicle programs varies from component to component. Differences in approach were also seen where missions or payloads of differing criticality used the same basic vehicle (especially the Atlas programs). An understanding of the definitions in use for each program is also necessary. In spite of the difficulty in arriving at specific conclusions, general conclusions can be drawn that may be of some benefit.

The following paragraphs describe the programs and systems compared and provide background relating to the approach used to develop component life limits. Where possible, terminology defined in Chapter III of this report has been used. The documents defining the limits are also referenced.

1. Titan III

The Titan III program includes a family of space booster vehicles. No manned missions have been flown although the Titan IIIM version is man-rated. Other versions can be man-rated with little difficulty.

Components common to Titan IIIM and other versions carry the same life limitations and handling requirements. Martin Marietta Corporation Drawing 80801Y90000, Special Consideration Items - Titan III Family, defines all component life limits, handling requirements, criticality, and other special considerations. An extract from this drawing can be found in Appendix D. Assembled stages have been stored as long as 30 months between production acceptance test and start of prelaunch preparation.

2. Atlas

For comparison of component life, the Atlas must be considered in two sections. The SLV-3 booster vehicle is in current production with prelaunch storage seldom exceeding 12 months. The Atlas E and F military vehicles were produced in the period of 1961 thru

TABLE V-1 COMPONENT LIFE LIMIT COMPARISON

Component	S-IB			S-IC			S-II			S-IVB			IU			Titan III			Atlas SLV-3		Atlas E, F Series	Thor Delta		Scout	Gemini B			Apollo CSM		LM/A		
	Quantity	Calendar Life	Operating Life	Quantity	Calendar Life	Operating Life	Quantity	Calendar Life	Operating Life	Quantity	Calendar Life	Operating Life	Quantity	Calendar Life	Operating Life	Calendar Life	Operating Life	Storage Life	Calendar Life	Operating Life	Calendar Life	Calendar Life	Operating Life	Storage Life	Calendar Life	Operating Life	Storage Life	Calendar Life	Operating Life	Calendar Life	Operating Life	Storage Life
HYDRAULIC SYSTEM																																
General	4	72M					8	72M		23	72M					60M			78M*		144M*			24M								
Actuators	1	72M	100H	6	48M																			18M								
Main Pump	1	72M	100H																													
Auxiliary Pump	2	72M	50H														18H															
Auxiliary Pump Motor	4		30H/250C							1		60H/50C																				
										1		120H/1000C																				
Swivel Fittings																								36M								
ORDNANCE																																
General	6	60M		17	36M		8	36M		78	36M					36M			24M		24M	36M		36M†				36M‡				
EBW Detonator	1	60M		2	60M		1	60M		2	60M																					
EBW Firing Unit	3	36M	1,000C	2	36M	1,000C	4		1,000C	1	36M	1,000C																				
Safe Arm Device	1	60M		1	60M		1	60M		3	60M											24M										
Retro Motor				1	48M					2	24M										60M				60M							
Destruct Controller	1	60M		1	60M					1	60M																					
Rocket Motor Initiator										1	24M											60M			60M							
Components with O-Rings										15	72M																					
Gas Cartridges																48M																
High Explosive Burster																			60M													
Hypergolic Igniters																						24M										
Gas Generator Igniters																						24M										
SPGG and Igniter																					60M											
Solid Motor Pyrogen Unit																						60M										
Conical Charge																						60M										
Interconnect MDF, etc																									120M							
Shape Charges																									72M							
Detonators																									72M							
VALVES/REGULATORS																																
General	24	72M		16	72M		5	72M		40	72M		3	24M					78M*		144M*				120M	2,000H	30M					
	1		500C	17		1,000C							1		500H																	
	1		750C										1		1,000H																	
	11		1,000C										1		2,000H																	
	2		1,500C																													
	3		7,000C																													
Regulator				1	48M	1,000H	1		3,000C									60M							120M	28D	24M			60M		
																		48M														
Valve				2	48M													60M						24M								
				1		500S												48M						18M						24M		17M
																		36M														
Solenoid Valve							1		40H Accum									60M														
									18H Cont																							
Prevalve							1		250C Amb																120M	1 mission	12M					
									300C Cyro																							
Check Valve																	40 min															36M
Bipropellant Valve																													400C			
Isolation Valve																									40M	1C/28D	12M					
GUIDANCE AND CONTROL SYSTEM																																
Inertial Platform													1	60M	1,000H									24M	57M	5,000H	3M					
Displacement Gyro																72M	4000H			1000H		36M	2,000H									
Rate Gyro													1	60M	1,000H	72M	4000H			1000H		36M	2,000H	24M	60M	670H	30M				2000H	12M
Control Signal Processor													1	60M	2,000H																	
Programer																				2000H		36M	1,000H	24M							1000H	
Timer																						60M	500C/50H									
LASS																36M																
Pulse & Rate Beacons																				300H												
Rate Beacon																				500H												
Filter Servo Pkg																								24M								
Attitude Control Electronics																									60M	100,000C	30M			60M		12M
Attitude Director Indicator																									90M	1,000H	60M					
Flight Director Controller																									90M	2,000H	60M					
Guid. Comparator Indicator																									120M	2,000H	30M					
Digital Computer																									55M	15,000H	55M					
Gimbal Control Ejector																									57M	5,000H						
Guid. Interface Adapter																									60M	5,000H	30M					
ELECTRICAL AND ELECTRONICS																																
General	20		5,000H							58	72M					60M																
Battery**	1	36M	120H	1	24M	120H	1	24M	7D	7	24M	7D				36M	30D		36M						12M	45D		12M	36D	12M	30D	
Static Inverter																12M									60M		30M				108AH	6M
Rotary Inverter																						36M	34H/100C									
Power Transfer Switch				1	42M	10,000C														500C				12M								
						10,000H																										
Pressure Switch	3		1,000C															12M						12M								
	1		750C																					24M								
Digital Receiver	1	48M	2,000H	1	48M	2,000H				1	48M	2,000H								500H				24M	60M	500H	12M					
Range Safety Decoder	1	48M	2,000H	1	48M	2,000H				1	48M	2,000H																				
Transponder	1		5,000H	1	60M	1,000H											400H	12M													800H	
RF Power Ampl.				1		500H	1		500H				2		2,000H		300H	12M							48M	500H	12M					
Selector Switch	1		250,000C	1		250,000C	1		250,000C	1		250,000C	1		250,000C																	
Rotary Switch																									36M	10,000C	36M					
Propellant Cutoff Sensors	3		3,000H	3		10,000H				1	72M	2,000C								300H												
												or 5,000C																				
Measurement Voltage Supply	2		3,000H																													
Lox Vent Switch	1		1,000C																													
Power Supply	1		3,000H																													
Tape Recorder-Transport							1		10H	1		50H																				
Tape							1		20H	1		50C																				
Control Relay Package										1	36M	100,000C																				
Multiplexer																		60M							48M	2,000H	18M					
Converter Unit																		24M						12M	60M	2,000H	18M					
Radar Beacon																								6M	60M	800H	3M			12M	800H	
VHF Beacon																									60M	500H	12M					
Diode Unit																								36M			12M					
Beacon Light Power Supply																												12M	2H			
Power System Monitor																									36M	2,000H	18M					
Junction Box																								36M								
Lanyard Switch																								36M								
Limit Switch																													60C			
MISCELLANEOUS																																
Items for Rubber Goods	17	72M		3	72M					Many	72M							78M				60M							48M			
Fuel Tank				1		Special	1		Low P								30C Hydrostat															
									245C																							
									35C Hi P																							
Oxidizer Tank				1		Special											30C/Hydro															
Umbilical Disconnect				10		25C	2		100C																							
							1		15C Amb																							
									5C Cryo																							
Seat Assembly				1		25C																										
Aux. Prop. Drain Disc																72M																
Torroidal Accum. Fuel																12M																
Fluid Pressure Dampener																48M																
Hi Pressure Sphere	1		500C							1		50C						60M														100C
Nitrogen Tank																									120M	28D	24M		10,000C			
Bladder Propellant Tank										1	36M																					
APS										1		20C																				
Fuel																	13C								38M	7C/28D	12M		3,000C			100C
Oxidizer																	18C								32M	7C/28D	12M					
Bladder																													20C Wet			6C
Positive Expulsion										1		3000 in.																	40C Dry			
Bellows												travel																				
LH_2 Childown Pump							1		100H	1		100H																				
									24 Dry			40 min Dry																				
									Starts																							
												10 Dry																				
												Starts																				
LO_2 Childown Pump										1		20H																				
Burner Assy										1		100H																				
Pumping Unit										1		1,500H																				
Cold Plate Assy										1		200H																				
Feed Lines (static firing)							2	30 min																								
Coolant Pump													1	24M	1,000 H																	
Flow Meters														24M	400H																	
Container	1		2,500C																													
Gimbal Assy	1	24M																														
Turbo Pump	6	24M																														
Gimbal Cycling									Special			Special																				
Engine																					48M								750S			
Att. Control Sys. Modules																	60S 215S/1230 pulses	90D							33M	100S	6M					
Reaction Control System																								18M								
H_2O_2 Tank																								12M								
H_2O_2 Bypass Resistor																								36M								
Thrust Reduction Valve																								24M								
Burst Diaphragm																													40C			

*From assembly date to launch.

†Except two of four motors are 12M.

‡Except five items controlled at 48M for rubber goods.

**Operating time is activated stand time.

Legend:

M = months
D = days
H = hours
S = seconds
C = cycles
Min = minutes

1963, and deployed at several launch sites. A storage program began during 1965 as the launch sites were deactivated and over 100 E and F vehicles were put into storage. These vehicles are still being refurbished and launched for various programs such as ABRES (Advanced Ballistic Re-Entry Systems). Atlas E and F missions are not considered to be as critical as the SLV-3 missions. Present missions are unmanned although SLV-3 was used for the Mercury launch program. Life limit information was obtained from Convair Drawings 27-00767, Replacement Time Requirements E/F Missiles, ABRES, and 69-00721, Replacement Time Requirements, SLV-3 Follow-On.

3. Thor/Delta

Thor/Delta is still in production and is used for Air Force and NASA missions. These missions are all unmanned. Many of the old military Thors have been rebuilt and flown following long-term storage; about 20 are still in storage. When these vehicles are rebuilt, components are either replaced or refurbished.

Vehicles in recent production have always been flown at less than 36 months calendar age. Life limits shown are for current production vehicles and were obtained from McDonnell Douglas Specification No. ST-DES 0010, Limited Life Items Specifications for DSV-2L-1A Space Boosters (SLV-2H). Milestone age limits are also listed in this document.

4. Scout

Data shown for the Scout missile were obtained from a NASA report, CR-66321, Feasibility Study of Storage Concepts for Scout and Other NASA Solid Propellant Vehicles. This report was prepared by LTV Aerospace. The proposed plan provides for "ready-to-launch" vehicle storage. This requires that storage limits be stricter than those imposed on a system which can be refurbished and tested after storage. Component operating limits were not available for the Scout vehicle.

5. Gemini B

Gemini B is the manned spacecraft for use in the Air Force Manned Orbital Laboratory program. Data shown were obtained from McDonnell Douglas report P.S. 338, MOL Program Gemini B System Segment, AVE Preventive Maintenance Requirements Summary.

6. LM/A

The Lunar Module of the Apollo program has perhaps the most critical mission of the entire Apollo system. Not all of the systems are comparable to the booster stage systems, but there are several areas of interest. The limits given are those for the LM to be used on AAP missions. The document is Grumman Report ARP 255-015, AAP/LM-A Time/Cycle Sensitive Items Summary. Portions of this document may be found in Appendix D.

7. Apollo CSM

Portions of the Command Service Module limited life component list are also shown in the comparison charts. This information was taken from NAR Space Division Specifications MA0201-077, Apollo Time/Cycle Significant Item List and Requirements, and MA0201-5695 Apollo CSM Age Controlled/Time Action List and Requirements.

8. Saturn S-IB Stage

Information was obtained from Chrysler S-IB Serialized Component List dated 11 October 1968.

9. Saturn S-IC Stage

Information was obtained from Boeing Drawing MSFC 60B03007, Summary of Time, Cycle, and AGE Recording Requirements and Life Apportionment for S-IC Stage Components.

10. Saturn S-II Stage

Information was obtained from NAR Space Division Specifications MA0201-1021, Airborne and GSE Equipment Saturn S-II Operating Time/Cycle Measurement and Recording Requirements, and MA0506-1003, List of Age Sensitive Components - S-II Stage and GSE.

11. Saturn S-IVB Stage

Information was obtained from McDonnell Douglas Drawings 1B55423, Government Furnished Property Time/Cycle Significant Items, 1B55424, Limited Data Collection Time/Cycle Significant Items, 1B55425, Reliability Time/Cycle Significant Items - Calendar, and 1B66667 List, Master, Age Control Items, DSV-4B/IB/V Flight Stages, GSE, and GSE Repair Kits.

12. Saturn Instrument Unit

Information was obtained from IBM Report MSFC No. III-6-602-61 Operating Time Cycle Critical Components, and Drawing 7915953, Storage, Instrument Unit, Long Term Procedure for SI-B/V.

A review of Table V-1 leads to two primary conclusions:

1) There is no basic difference apparent between the Saturn limits and other program limits. The individual cases of differing limits are the result of differences in mission objectives or storage objectives;
2) There are inconsistencies in the approach taken by the Saturn stage contractors -
    a) Hardware installed in all stages does not appear on all of the life limit lists. (For instance, the range safety receiver and decoder);
    b) One contractor took a much more literal approach to listing component life because of inclusion of elastomeric parts. (Ordnance items in one list at 24, 36, and 60 months are duplicated in the rubber goods list with a 72-month limit, and a large quantity of electronic components are listed for rubber goods while the other stages have none listed for rubber goods.)

C. METHODS FOR EXTENDING LIFE

The objective of this section is to present currently accepted methods that can be employed to justify extending and recertifying either the calendar or operational life of an item. The methods will be discussed under seven general categories. The methods may be used singly or in combination. In order of discussion these categories are similarity, analysis, surveillance, inspection, testing, refurbishment, and waiver.

1. Similarity

The life of an item can be based on the life of a similar item. The two items must be very similar in terms of design, materials, and function. Thus the life of an item might be extended if the life of a similar item has a longer demonstrated life.

Normally, the life of the similar item must have been demonstrated by either test or satisfactory service life; a life estimated from analysis alone would not be acceptable.

Considerable care must be exercised in determining that two items are, in fact, similar and directly comparable. Subtle differences can invalidate the comparison. Many of the persons interviewed did not accept similarity as a valid method to extend life because of the uncertainties of attempting direct correlation.

Some items may be composed of portions of other items. Attempts to correlate life data relative to these portions into a life estimate for the subject items could result in inaccurate estimates. Cross coupling effects and nonlinear relationships may prevent accurate life estimates.

Despite some of the uncertainties, prudent use of the similarity method can be successfully employed to extend the lives of some items. Grumman Aircraft Engineering Corporation reported that they use the similarity method to establish and extend component lives.

Thiokol has recommended extending the service life of the S-II retromotor (Recruit-TEM-294) based partially on similarity to the M-18 and M-46 USAF rocket motors that have demonstrated lives of 7 and 10 years, respectively. In addition, testing at the Redstone Division of Thiokol indicates that there should be no degradation in polysulphide propellants, such as used in Recruit Motors, for at least 6 years. NASA/MSFC feels that additional testing and analysis of the S-II retromotor is necessary before the recommendation can be accepted.

2. Analysis

Item life can sometimes be determined or extended by analysis. The analysis, usually a "paper study," separates the item into its elements and determines the life of each element. Obviously, the life of an item is limited by the minimum element life whose failure could negate the function of the item. The element could be a basic material such as an elastomer, lubricant, structural metal, etc.

The analysis method is generally employed during the preliminary design phases to determine if a design will provide the necessary life. However, it can also be used to estimate and extend the life of an existing item whose life has been only roughly estimated as meeting the then current program life requirements.

The Aging Modes and Effects Analysis (AMEA) is one of the systematic analysis methods employed to varying degree by some of the companies visited. The AMEA has been described previously in Chapter IV.D.

3. Surveillance

The surveillance method is used to verify, establish, or extend component life by continuously or periodically monitoring the functional parameters of the item and comparing these measured parameters to specification. If the parameters are within specification, the life of the item is, in general, at least as great as the life duration when the parameters were measured. Assuming a statistically adequate sample size, the lives of identical (or very similar) items manufactured after the surveillance samples should be at least equal to those surveyed. It is good technique to set aside early or preproduction samples for a surveillance program; failure of these samples will provide a warning of impending failure of those in service. Similarly, failures of early lots in service will indicate impending problems of later lots. For maximum effectiveness, a surveillance program plan should be initiated during the design phase.

The life of an item can be extended based on analysis of the parameter trends. If a parameter is drifting toward a specification limit at a known rate (linear or exponential), the time at which it will exceed specification limits can be estimated and the item life extended to that time.

The surveillance program may monitor all the functional parameters of an item or just the parameters determined to be age sensitive. The AMEA is helpful in determining which parameters to monitor. Only age-sensitive parameters need be measured if the AMEA was complete and accurate.

4. Inspection

The lives of some items may be extended by inspection. Inspection in this case refers to a visual check of the item or component for evidence of some condition that would render it unserviceable for future or continued use, e.g., leaking fluids, corrosion, or wear. Generally inspection is used in conjunction with or as a part of one or more of the other methods such as testing. These tests are normally performed by Quality Control personnel, as opposed to tests performed by engineering laboratories. When the inspection test is satisfactorily completed, the item's life is extended until the next scheduled inspection.

The duration between inspections may be equal or decrease with each subsequent life extension. In a proposed spares shelf-life implementation program for a guidance system, the AC Electronics Division of General Motors Corporation decreased each subsequent life extension period and limited the number of extensions. Honeywell Inc. indicated during the survey visit that each life extension period should be shorter than the previous one. (Trip Report II-18). The Polaris weapon system extends the lives of items by use of the inspection method; the Polaris approach has been discussed previously in Chapter IV.D.

5. Testing

The information received from testing an item may be used to justify extension (or reduction) of its life limit. Depending on what portion of the item is age critical, the tests may be conducted on either the entire item or a component or an element, or a material employed. The lower the confidence in the knowledge of what is critical, the greater the probability the entire item will be tested. From a cost view point, only the minimum amount of testing required to recertify should be performed.

The effects of aging/cycling can be determined by either real time or accelerated testing. Real-time aging/cycling data are taken mostly from laboratory and flight tests, and service and overhaul records. Accelerated aging usually involves specialized techniques such as functional tests at elevated temperatures, application of Arrhenius's life-temperature relationships, etc. The test methods will be discussed briefly in the following paragraphs.

Real-Time Tests - Laboratory testing normally subjects the test item to its measured or predicted critical environments for prolonged periods of time to ascertain life limitations. Critical parameters are monitored during the tests to determine how long the item can successfully survive its environment. The test may last until the desired extended life is exceeded, until failure occurs, or until a trend is established from which the life of the item can be estimated. If the tests demonstrate that the life of an item exceeds its current certified life, the item's life can be recertified for the additional time/cycles indicated by the tests. The real-time laboratory test is probably the most readily accepted method for extending the life of an item.

Material testing usually involves measuring engineering characteristics such as tensile strength, hardness, resistance, etc, at various times. However, one interesting innovation under study at OOAMA involves measuring changes in the molecular and crystalline structure of nonmetallic materials with time. Changes in crystalline symmetry of polyurethane with age and when exposed to high temperature and humidity environments were measured using an X-ray diffraction technique. It was possible to correlate changes in lattice with degradation; in fact, changes in crystalline structure could be measured before gross physical degradation was apparent. This and similar techniques are now being applied to other materials (Trip Report II-33).

Differential thermal analysis (DTA) and thermogravimetric analysis (TGA) are specialized techniques under development that may be used to detect and determine changes in material properties due to aging. Most of the effort in this area has been with pyrotechnics. These techniques have not yet received general acceptance for life extension.

Prelaunch and flight data can also be employed to extend the life of an item if its cumulative life exceeds that certified. Normally an item is replaced or refurbished before its certified life is exceeded; however sometimes due to either program delays or lack of replacement parts an "over-age" item is employed (by waiver). Depending on circumstances, the life of an item might be extended to that demonstrated satisfactorily by prelaunch or flight data.

Data obtained from service or overhaul records can sometimes be useful in establishing a basis for life extension. If the maintenance record of an item reveals an acceptable low maintenance level, then the item's life might be extended. The same is true of overhaul. If the item is satisfactory and shows negligible age/cycle effects at overhaul, the life may be extended. Usually the service and overhaul data are used with other life extension methods in arriving at a decision. For example, HIG-4 gyro lives have been extended from 18 to 36 months based on Thor field experience, according to the Missiles and Space Systems Group of McDonnell Douglas Corporation (Trip Report II-29). Initially, times were established by engineering rule of thumb and by customer direction based on program requirements.

In another case, as a result of a J-2 engine overhaul study performed about 1967 by North American Rockwell, the lives of some components were increased from 5000 to 5700 seconds (Trip Report II-27). Component life extensions were based on test results and experience.

Accelerated Aging Tests - It is not always feasible to wait for the results of real-time testing, especially if the lead time for test is less than the required life for an item. Accelerated aging tests attempt to produce in a shorter period of time the same changes in critical parameters that occur during an item's normal real-time aging/cycling. On accelerated aging the test item is usually subjected to an environment, or combination of environments, more severe than that encountered during normal storage or service.

The environments employed for accelerated testing must have energy levels high enough to have effect. The results of the accelerated testing in terms of rate of parameter change are correlated to the rate of change expected under normal storage and service environments.

Accelerated testing is not a generally accepted method for estimating the life of an item according to most of the persons interviewed during the survey trips. General acceptance of accelerated testing is prevented by lack of confidence in either (1) the correlation of accelerated test data with real-time aging effects, or (2) the correct selection of the test environments and their energy levels. Nevertheless, some of those interviewed believed accelerated testing has some value (Trip Report II-33).

Accelerated testing at the material level is usually easiest. Elastomers are one of the more popular subjects for accelerated testing; accelerated aging is accomplished by subjecting the elastomers to elevated temperatures. Attempts to correlate the property changes at elevated temperature with real-time changes at normal temperature were only partially successful. A study of O-ring aging techniques by Rocketdyne resulted in the statement: "One general conclusion is that no rapid aging method can be expected to do more than approximate the reaction of an elastomer to its service environment. The principal reason for this is that more than one reaction occurs during aging, and one reaction may be more dependent on temperature, oxygen, pressure, or some other aging factor, than another." (Ref 14).

According to B. F. Goodrich Rubber Company accelerated aging tests of elastomers are not generally acceptable (Trip Report II-32). However accelerated aging data of elastomers exposed to steam could be correlated with natural weather aging data. Accelerated aging data of elastomers exposed to hot air could not be correlated. A computer program to correlate aging parameters using test data was not too successful.

Arrhenius plots are sometimes employed for accelerated aging data. For example, data provided by ESB shows that silver-zinc battery capacity decreases with age and increasing temperature. An Arrhenius plot of capacity loss rate ($\log_{10}$) versus the reciprocal of storage absolute temperature is a straight line. The line can be extrapolated to provide a life estimate for the battery at a given storage temperature.

6. Refurbishment

Replacing the life-limited elements in an item is a generally accepted method for extending an item's life. The replacement elements may be either identical to or superior to the refurbished elements. Depending on the nature of the refurbishment, the life of the item may be extended for a duration of time less than, equal to, or more than the original certified life. Elastomers are the most commonly refurbished item.

Costs must be considered in any decision to refurbish or to scrap an item reaching the end of its certified life. The Air Force Logistics Command has established guide lines (Trip Report II-31). If the line item (not per unit) cost exceeds $15.00, tests must be conducted to determine if the line item life can be extended. However, the cost of extending a line item life cannot exceed 65% of the original cost unless the item is in critical demand. A DOD study to review the entire age control program should be completed during 1969 by the Camden Station at Alexandria, Virginia. The study results may be of interest to NASA.

7. Waiver

An item that has exceeded its age or operating limits by a small factor may be used if the item is in critical supply and if the probability of failure during its mission is sufficiently low. This is not a recommended technique; however, program requirements sometimes require this approach. Customer approval is always required.

D. INDETERMINATE LIFE HARDWARE

During the study interviews, no specific types of hardware or physical parameters that prevent a valid determination of life were identified. The only components that would seem to fit in this category are those using new technology material such as the boron or carbon filament materials. These materials are undergoing tests to determine their applications and limits. Materials subjected to unknown or undefined environments may also preclude a valid life determination.

VI. DESIGN CONSIDERATIONS

A. DESIGN FACTORS

One of the main factors influencing component life is program or contractual limitations. Many life limits have been imposed on equipment by application of contractual or program limits. These limits once established become accepted standards whose origin may be impossible to trace though there is no actual experience or test data to support their accuracy.

The S-IC stage life was based on a 5-year program life. Qualification testing was performed to satisfy that requirement. In addition there is a contractual requirement that 50% of specified component life must remain on the life-limited components when the stage is shipped to KSC. These requirements pose problems with life extension. First, there is justifiable reluctance to extend beyond the 5-year program limitation without extensive testing, and second, unnecessary replacement and refurbishment of otherwise good components may be required. Component size presents additional limitations concerning life. Increasing the size of a component does not always result in the same long life and reliability of the original component. The stresses imposed on or by the larger component may alter its reliability and life.

Equipment guarantees may be extremely conservative. IBM successfully actuated one relay 1 million times although the vendor guaranteed only 25,000 cycles. Generally AC Electronics uses 10 years normal life (including recertification periods) with 12 years absolute maximum, for their electronic components. They feel that state-of-the-art advances within this time period would make equipment extended beyond this time obsolete.

It is recommended that realistic life limits be established at program inception. Provisions must also be made for validating life limits throughout the program by testing and surveillance of the affected equipment. The following paragraphs discuss additional considerations for long life design.

B. DESIGN POLICIES AND GUIDELINES

None of the companies surveyed had detailed formal procedures, standards, or policies established for use by designers to assist in the design of long life components. All companies rely on the ability of their engineers to achieve long life design by using the latest state-of-the-art components and design practices. Quality and reliability are stressed. The designers try to minimize stress and avoid incompatible materials. Critical hardware is designed for high reliability, which is then proved through qualification and reliability testing. Screened parts are often used in electronic equipment and derating techniques are applied. Conformal and other coatings are used to minimize environmental stresses. These and the following general guidelines are applied to equipment design for maximum life:

1) Minimize use of cold flow susceptible materials;
2) Maintain adequate structural strength on prestressed parts, e.g., springs and diaphragms;
3) Select material not subject to corrosion.

Military handbooks and specifications are widely used by designers when selecting materials and establishing life limits, particularly with respect to rubber products. MIL-HDBK-695 is the Military Standardization Handbook covering rubber products shelf storage life. "This handbook provides guidance as to the time periods during which rubber products may be stored without deterioration. The handbook covers rubber products of Military, Federal, and recognized industry specifications. The handbook is not intended to be referenced in purchase specifications except for informational purposes, nor shall it supersede any specification requirements." (Ref 15).

In addition to military handbooks and specifications, other documents are available that provide guidelines for material selection, such as <u>Corrosion Prevention/Deterioration Control in Electronic Components and Assemblies</u>, by R. H. Sparling. "The purpose of this document is to focus the attention of designers on corrosion and the consequent degradation of reliability of electronic items. The report points out dangerous combinations of materials and processes, emphasizes the importance of proper selection of materials, and provides the designer with modern techniques for prevention of deterioration. The aim of the report is not to dictate design, but to help the designer meet environmental requirements." (Ref 16).

A proposal by AC Electronics Division of General Motors Corporation contained a Shelf Life Guidance Summary which would provide guidelines concerning materials and components life limits. Selected entries from this guide (Ref 17) are shown in Table VI-1. "This shelf Life Guidance Summary is presented as a condensed guide covering the known "STATE-OF-ART" material pertaining to degradation of parts and assemblies during non-operating storage. The material presented herein is the result of literature searches and past experience. The recommendations for initial shelf life assignment may be to the conservative side, but this approach is justified by the fact that these recommendations are presented primarily for "Man Rated" missile programs." (Ref 17)

The General Electric Company, Missile and Space Division, uses a three-step approach to extend allowable age or operational limits or ensure reliability under existing limits.

First, an Aging Modes and Effects Analysis as described in Chapter IV.A is performed to determine what items in a component are age critical and to determine their life limitations. Modification of the design is accomplished if calendar or cyclic life does not meet specifications. Experienced chemists, physicists, or material engineers perform the AMEA because it is essentially performed at the materials level. Secondly, the designer includes a life analysis, including the AMEA, in his design report submitted to the design review board. Part of the design review board's function is to ensure that life requirements are met. Finally, a properly constituted surveillance program is implemented to ensure that estimated life limits are being obtained in actual storage or service.

At General Electric, Missile and Space Division, an Integrated Test Program Board (ITPB) determines whether equipment has met the requirements of any level of qualification. The board concerns itself with technical evaluation of the test specifications and results and decides whether they formulate a valid basis for qualification and/or requalification. Life is considered a performance parameter. Thus the ITPB is responsible to ensure that life requirements are met.

The ITPB is chaired by a representative from the Reliability and Technical Requirements Section and members from the Program Office, Engineering Section, Quality Control and Test Section Systems and Technologies Section, Manufacturing Section, and necessary specialists. Each program has its own ITPB.

Table VI-1 Excerpts from Shelf Life Guidance Summary

ITEM	STORAGE LIMITS	DETERIORATION MODES	COMMENTS
1. Batteries			
a. Lead Acid - Dry Charged	00		
b. Lead Acid - Wet Charged	100 Cycles	Poor charge retention: In general, the activated charge retention when stored at specific temperatures (to 1/2 initial capacity) will be: Temperature 80°F 125°F 165°F Retention Time 1-2Mo. 1Week 1/2 Day	Replace after 100 cycles of complete charge and discharge. A specific gravity check should be made every 30 days except when exposed to elevated temperatures.
c. Nickel Cadmium	60 R		
2. Bearing, Anti-Friction			
a. Oil. Lubricated	24 R	Corrosion; Particle contamination; Lubricant degradation in prelubricated bearings.	Packaged bearings and bearings in assembly should be inspected, refurbished, relubricated or replaced when storage limits are reached. Except where torque restrictions are imposed, bearings stored in required usage lubricant may be assembled in equipment if used within the allowed storage period. Where torque limits are specified, applicable bearings should be requalified before assembly into equipment, or prior to end item deployment, after a 12-month period in storage. NOTE: 1A8 package is minimum allowable for storage.

Table VI-1 (cont)

6. Circuit Breakers Magnetic Thermal	 36 R 24 R	 Drift (Set point change)	 Minimum protection, of 1A8 package. It is imperative that these items be stored with contacts in the closed position (this is the rule and the condition of shipment from the manufacturers). Calibration before use is mandatory.
7. Coils	00		
8. Connectors	12 R	Silver migration through gold flash on pins - subsequent tarnish formation develops high contact resistance.	Corrective action underway. Estimated shelf life on new procurement connectors that do not employ silver plating - 60 R.
9. Crystals Sealed Non-Sealed	 48 R 12 R	 Drift Not used in T-III M	 Minimum protection, at least 1A8 package.
10. Coupling Fluid	 36 R	 "O" Ring sealing degradation	
11. Diodes	48 R	Leakage current increases; Saturation and Zener voltage decreases; Forward voltage drop increases; Dynamic Impedance changes.	Minimum packaging protection. Type 1A8. and Preferably Type 2 (with desiccant). These items are sensitive to damage during handling and when exposed to moisture. Protection is required to eliminate bending or flexing of the leads, particularly at the case junction. Packaging should be done in a clean, low humidity atmosphere (Preferably less than 50% relative humidity)
12. Elapsed Time Indicator	36 R		
13. Filters Electrical	60 R		

Table VI-1 (concl)

The use of these recommendations is based on the following concepts:

1. Each item stored in a non-operating mode must be packaged in accordance with the "Preferred Packaging Instructions" of MIL-P-116*. Packaging must be adequate to protect each item from corrosion, excess humidity, etc., and to provide proper physical protection during handling and storage.

2. Under the column "Storage Limits" the basic shelf life (non-operating storage) period is specified as follows:

   a. <u>00</u>: The designation 00 indicates that for all practical purposes no appreciable degradation of the item will occur during a shelf life period of 10 to 12 years. However, no item can be considered to have an unlimited non-operating storage capability. Therefore, it is recommended that no part over 10 years old be used, either as a spare or in production of new equipment.

   When a spare part with this designation reaches the age of 10 years a decision should be made to either replace the part or to delete it from inventory. If the program has less than two years to completion, the item could be left in inventory with no action but the 12-year point should never be exceeded.

   b. <u>XXR</u>: A two-digit number with the suffix R indicates the basic shelf-life in months before a retest, repair, replace, or other maintenance action should be performed. The maintenance action may range from cleaning and relubricating bearings to full functional retest including vibration. The maintenance action when accomplished would insure basic operational adequacy of the item and would requalify the item for another period of non-operating storage. The ultimate extension of the shelf life period may range from two to three times the original assigned period by properly spaced maintenance actions.

*MIL-P-116 should be supplemented as noted under comment section of attached shelf life guide.

It is the consensus of those surveyed that a company's design engineers through coordination with all of the other engineering disciplines, materials, reliability, maintainability, etc, can design components that will meet the specification requirements imposed. The company's policies and procedures governing coordination of the efforts of the various engineering departments makes establishment of specific policies covering long life design unnecessary.

C. SELECTION OF MATERIAL AND PIECE PARTS

Items should be selected where possible on the basis of proved capability of each part and material for its application, including demonstrated life limits. The selection should be from sources employing effective reliability and quality programs in their manufacture.

To ensure long item life, the materials should be as compatible as possible with their environment. Selection of the longest life material is not always possible because of design parameter trade-offs. Similarly extension of item life via material changes is not always possible- although acceptable new materials may become available. Information on material lives is available and a partial list may be extracted from the bibliography (App A).

Piece parts should be chosen among items already qualified to pertinent specifications. Use only the minimum practical number of styles of each generic type. When selecting items previously qualified, particular attention should be devoted to how current the data are, applicability of basis for qualification, and adequacy of specifications. The results of the selection will determine the requirements, if any, for additional qualification (and life) testing.

D. DERATING

Derating of components or parts is one technique used to increase reliability of assemblies or systems. Derating may be used in mechanical or structural systems as well as electronic and electrical systems. The usual technique is to apply the part at power, exitation, or stress levels below the normal or rated application levels. The derating factor or percentage is often a compromise between weight considerations and desired reliability factors.

Derating has little or no effect on storage failure rates of electronic equipment, but may have some effect on mechanical items. The effect of derating on operating limits will vary with each case and depends on a variety of factors, such as criticality, specification requirements, and extent of derating.

VII. COMPONENT CONSIDERATIONS

The purpose of this chapter is to orient and inform the reader about some of the life limited aspects of selected materials and items by functional categories. This chapter will discuss how the lives of selected materials and items were determined, and in some cases extended, by the methods outlined in chapter V.C. The life limits imposed by various government agencies and manufacturers will be discussed and compared.

Each of the materials or categories covered was chosen because of the limitations they imposed upon the lives of components or the launch vehicle. Not all life limited materials or categories are covered; however, those presented are considered to be involved in the major problem areas concerning life limitations. The presentations on each of the following materials or categories are essentially self explanatory.

A. MATERIALS

1. Soft Goods

Soft goods are the most frequently mentioned life limited items. Soft goods include seals, gaskets, O-rings, hoses, etc. Various polymers are usually employed in aerospace soft goods. Either elastomers (synthetic rubbers) or plastics are used. Dynamic applications of seals, O-rings, and hoses were of particular concern. Soft goods in static applications were, in general, considered to have open-ended lives subject to periodic inspection or leak test. Dust seal and similar applications are often not checked at all.

MSFC controls the age of synthetic rubbers with MSFC-STD-105. This standard limits the lives of synthetic rubbers to 12 quarters from cure date to installation (shelf life) and to 32 quarters installed. The age control specification for synthetic rubbers at Kennedy Space Center is Drawing 79K0030. It limits the shelf life to 8 quarters and the maximum installed life to 16 quarters. Thus, the KSC life limits are more restrictive on installed life than MSFC.

With ANA Bulletin 438c, the Air Force and Navy delineate age limitations for specified synthetic rubbers during various phases before delivery (DD250) to the procuring activity. After delivery, USAF age limited items are controlled by the T.O. 20K series of documents (R&D items excepted). ANA 438c limits shelf life to 8 quarters and the installed life prior to DD250 to 12 quarters. The shelf life limits of KSC and MSFC are 8 quarters, and 12 quarters respectively. The assembled life limits of the KSC, MSFC, and ANA 438c specifications are not comparable because of application definition differences.

The life of an uninstalled elastomer on the shelf is not affected by its future application; however, the installed life of an elastomer can vary according to its application. For example, the life of an elastomer installed in a hydraulic ground unit might be different from that of an elastomer in an airborne pneumatic unit. The three life control documents state the installed life limits without regard to the different applications and environments encountered. The Air Force can (and does) vary the "in-service" installed lives via the T.O. 20K documents to account for application and environment differences after delivery. The two NASA documents do not provide for modification to synthetic rubber life limits to reflect application and environment effects.

It is assumed that the age limits specified in MSFC-STD-105 were defined to provide adequate lives under the most severe combinations of application and environment. Hence the lives of synthetic rubbers used under less than worst-case conditions could be safely extended. MSFC-STD-105 could be revised to specify the lives of installed synthetic rubbers by application and environment, viz, airborne or ground and either pneumatic, hydraulic, fuel, etc. The specified maximum lives could be further categorized into high temperature, low temperature, criticality, etc. However, this much detailed life definition may not be worth the required effort. An optimization tradeoff study is required between the cost of determining the lives of elastomers for various applications and environments and the cost saving from extending the lives of the items.

Only one organization believes that presently accepted preflight limits are too liberal, and this was for the special case of the spacecraft intended for extended space missions. The majority of those interviewed during the survey trips believed that the life limits imposed on elastomers were too conservative. Several bibliography entries and trip reports verify this conclusion. The following facts illustrate this conclusion:

1) Elastomeric O-rings are never changed in Polaris components unless the rings fail or are exposed during a disassembly operation (Trip Report II-15);

2) Vickers Incorporated feels that current life limits on hydraulic system O-rings are too restrictive. Vickers investigated hydraulic equipment recovered from crashed planes (see Chapter V) and reported that nitrile rubber compounds were very long lived when protected from ozone and sunlight. Vickers believes that systems or components should not be disassembled for O-ring replacement following storage unless leakage is found during retest;

3) The Convair Division of General Dynamics in their age control document for synthetic rubber (Dwg. 1-02737) sets the cure date to installation limit at 42 quarters and the installation limit after DD250 at 48 quarters for the ABRES E/F missile. These limits were based on data and experience. The Oklahoma City AMA has extended O-ring shelf lives up to 40 quarters in one year increments after analyses of test and surveillance data. These limits are considerably above those specified by MSFC-STD-105. These are only two examples of life limits greater than those defined in the MSFC and KSC specifications.

Many of those interviewed believe that dynamic seals, especially O-rings, should not be disturbed after installation unless tests indicate leakage. It was felt that the probability of component damage during refurbishment was greater than the probability of leakage due to aging. It is not recommended that seals have open-ended lives; however, the refurbishment period might be extended to long durations, perhaps on the order of the 90 quarters total life used on the Atlas ABRES E/F.

2. Potting Compounds

Service experience indicates that some encapsulants have poor hydrolytic stability and tend to revert to liquids. Some rubber encapsulants, such as polyurethane and polyacrylate, can revert to a liquid state under environmental stress, usually involving high humidity and accelerated by high temperatures.

Difficulty has been experienced after about 18 months with the polyurethane potting in USAF airplanes located in humid environments. This problem has been particularly acute in South Vietnam where high temperatures accelerate the deterioration. The USAF is currently replacing all polyurethane potting (Trip Report II-23). A 3- to 5-year maximum life has been estimated from accelerated aging tests using Arrhenius plots. Complete degradation occurred at test temperatures of 150°F. Because of hydrolitic instability, failure has occurred at a test temperature of 75°F and 50% relative humidity.

McDonnell Douglas reported epoxy potting compound failures after about 5 years; the potting flowed out of the connectors (Trip Report II-10). The OCAMA reported potting compounds 3M, EC 20273, and Pro Seal 777 have been a problem, degrading with time, temperature, and humidity. The compounds also revert to a liquid and run out of the connector. The 3M and Pro Seal compounds are no longer used (Trip Report II-12).

It is recommended that all encapsulants that are unstable be deleted from future use, and unstable encapsulants, such as polyurethane and polyacrylate that have been employed be monitored for any indication of degradation. A low humidity and temperature environment will prolong the encapsulant lives. The degradation tests should include material samples from below the surface of the potting because some of the potting failures do not appear on the surface. Hypodermic syringes have been employed to obtain samples of the potting materials for test.

3. Protective Coatings

Paints, finishes, and coatings have calendar age limits. The corrosion protection, reflectivity, and conductivity, or emissivity may degrade with age. It is necessary to determine the life limits of protective coatings and establish age controls, if required.

McDonnell Douglas Corporation stated that thermal coatings on orbiting stages were the biggest problems since the coatings degrade prior to launch and must be replaced. Kapton was substituted for Mylar because of higher temperature resistance and nonburning characteristics (Trip Report II-4).

The OCAMA extends the lives of protective coatings if tests indicate the characteristics of the coatings are still satisfactory. Acceptance tests are usually conducted if cost, quantity involved, and application warrant such tests (Trip Report II-12).

The heat shield of MK 6 had a life set at 5 years, 3 years of which can be operational. The 5-year life has been extended based on accelerated aging test (Trip Report II-22). NASA-KSC found that the shelf life of ablative coatings increases below 75°F (Trip Report II-7).

4. Wire Insulation

No general problem with wire insulation degradation with age was found. The Convair Division of General Dynamics Corporation reported MIL-5086 wire insulation became brittle and cracked after 4 years of storage. The appearance was bad but megger tests revealed no failures (Trip Report II-26).

SMAMA had a similar experience with engine wiring harnesses on Thor. There were visible cracks in the cable outer sheath, but there were no reductions in insulation resistances (Trip Report II-16).

The AC Electronics Division of General Motors reported that nylon insulation on wiring experienced accelerated aging when subjected to the 140 ± 5°F storage temperature. Out of 26 five-year old IMUs, two electrical harnesses required replacement because of insulation degradation from the required storage temperature (Trip Report II-19).

Convair reported Teflon insulated wire exhibited "cold flow" phenomenon in areas where bundles were doubled back and tied with a short radius. Copper was visible in the bend area. It is recommended that bundles not connected to equipment be supported in approximately normal position rather than be tied back.

NASA-KSC stated that electrical cables should have a useful life of at least 5 years and should be checked at this time. Critical cables in the Saturn GSE are continuity and megger tested before each launch operation. There has been some degradation of O-rings in connectors; they are inspected every time a connector is mated (Trip Report II-7).

5. Lubrication

Items requiring a lubricant may be age or cycle limited because of loss of lubricant (migration) or change of physical properties with time or operation. "There are three major parameters that affect the life of a lubricated item, viz, the lubricant, the material being lubricated, and the environment" (p. C-27, Ref 18). Hence, three factors must be considered in setting the life of a lubricated item.

The physical properties of a lubricant may degrade with time, primarily because the additives evaporate away with the lower molecular weight additives evaporating first. In addition, the surrounding environment may promote chemical changes or act as a catalyst. Organic lubricants do not wear out but become contaminated with usage from wear or foreign particles. Solid film lubricants such as graphite or molybdenum disulfide do have finite wear lives and must have cyclic limits imposed.

Fluorocarbon greases are stable with age (Trip Report II-13). Ordinary greases tend to separate during storage, especially with higher temperature cycling. SMAMA had no record of lubricants imposing a time limit on components. However, some of those interviewed did impose life limitations on lubricated items; life extension usually consisted of replacing the lubricant. For example, the Commercial Aircraft Division of Boeing Company limits the shelf life of bearings to 2 years and the operating time to 10,000 hours.

The AC Electronics Division of General Motors has experienced very few corrosion problems with lubricants because of the materials used, e.g., gold plated IMU housing and passivated steels. Bearings lubricated with grease are stored 3 years and 2 years if lubricated with oil, before being relubricated. Gyros are operated until they fail. Use of TCP (tri-cresyl-phosphate) on bearings improves bearing performance. Stratification of fluid in floated instruments does occur and can result in degradation of performance (Trip Report II-19).

Honeywell Inc. stated that for their guidance equipment, the principal storage degradation factor is bearing lubrication. Refurbishment is considered a valid concept. Upon removal from storage, a run-in period is recommended before acceptance testing.

Dry lubricants are used by Honeywell Inc. in some sliding metal-to-metal situations. No degradation or corrosion has been identified as a result of using this type of lubricant (Trip Report II-18). SAAMA, on the other hand, found Molycoat L (gimbal bearing lubricant) tends to become corrosive after 12 months and must be flushed out and replaced (Trip Report II-13). These differing results illustrate the need to analyze the relationship between the environment and material being lubricated before setting a life limit.

The U.S. Navy's analyses of lubricants are employed extensively to ascertain if the item being lubricated is deteriorating as indicated by metal chips, etc (Trip Report II-23). The lubricated item is withdrawn from service for inspection if the lubricant analysis is negative. This technique has saved many aircraft engines. Analysis of lubricants from turbines, pumps, etc, could be used as a basis for extending the lives of either the lubricant or the item.

6. Stress Corrosion

Stress corrosion cracks can appear in castings over an extended period of time. Tests conducted on various casting materials over a 20-year period showed stress corrosion cracks in castings stored on the floor (Trip Report II-6). North American Rockwell is changing materials within the SII stage and components to eliminate stress corrosion susceptible materials (Trip Report II-5). SMAMA found stress corrosion cracks in cast liquid oxygen regulator caps (7075-T6) after eight years of life (Trip Report II-16). These were redesigned to increase fillet radii. In addition the surfaces were shot peened to relieve surface stresses. With these changes incorporated, the caps survived 34,000 pressure cycles under ambient conditions. One thousand additional cycles in a salt spray caused surface cracking. Obviously some consideration must be given life limits for castings. The Phase I summary report for this study presented a thorough discussion of stress corrosion.

B. COMPONENT CATEGORIES

1. Ordnance

The life of ordance components can be related to the processes and changes caused by environmental and operating conditions. "Explosives are complex compounds and mixtures and may tend to react with each other or their container to form other compounds which will change the performance characteristics of the explosive unit." (Ref 19) Storage usually produces longer time between ignition and maximum pressure or a partial loss of pressure. Stabilizers are added to the explosive mixture to lessen spontaneous deterioration and increase the life of the explosive unit considerably.

In a recent report prepared by North American Rockwell Corporation concerning Saturn V common ordnance it was concluded that, "Although a three year shelf life requirement was specified at the time of design for each of the four CDF (confined detonating fuse) ordnance components, it appears that all materials employed are capable of withstanding the proposed five year shelf life period under existing storage conditions without suffering significant degradation of functional performance characteristics." (Ref 20) "Five Thiokol Chemical Corporation TE-344 Titan II retromotors having ages from 64 to 72 months were subjected to prefire temperature cycling and then tested at simulated altitudes ranging from 114,000 to 134,000 ft. to determine if the present shelf/service life of 72 months can be extended." (Ref 20) The retromotors fired successfully, well within model specification requirements and have now been extended to a shelf/service life of 84 months. The life of these retromotors when originally procured for the Titan II was established at 36 months. These same motors are used on the Titan III and have a 36-month life established for that program.

Thiokol Chemical Corporation has also recommended that the storage life of the Recruit retromotor be extended from 2 to 4 years based on Recruit history, life capability of polysulfide propellant systems, and other experience with motor age life of from 4 to 5 years.

Controlled environment storage is beneficial in extending the life of ordnance components. Chemical changes continue during storage which usually result in a reduction of performance at the temperature extremes (-65°F to 180°F). Most ordnance life extensions are based on the results of surveillance and testing programs which may include visual inspection, X-ray inspection, vibration, electrical checks, and firing.

2. Hydraulic Components

The main life limiting factor for hydraulic components is the seals. Vickers has conducted several investigations involving hydraulic equipment recovered from crashed airplanes (see Chapter V).

> "The hydraulic and electric equipment removed after 17 years in the desert environment was in excellent condition, with the majority of it -- the Vickers pumps and motors -- meeting the requirements of new units. To a certain extent, the desert's low humidity had a detrimental effect on some large seals such as the accumulator diaphragm, causing them to harden slightly.

> "The hydraulic and electrical equipment removed from the B-17 aircraft after 23 years in an Arctic environment was in excellent condition; with it also meeting the requirements, in most cases, of new equipment. This included the Vickers turret transmission, engine-driven pump, and an accumulator which still could meet its 1942 test specifications. The accumulator diaphragm was in 'like-new' condition having retained its air charge since 1942. It appears that the somewhat higher Arctic humidity assures good seal life over extended storage periods, without being high enough to cause excessive corrosion." (Ref 11)

On sealed components such as hydraulic pumps, deterioration after 6 to 24 years in a jungle environment was only partial with some of the units still operable. The O-rings were in good condition and still functional in most cases. As a result of these investigations Vickers feels that current O-ring life limits are too restrictive and that systems or components should not be disassembled for O-ring replacement following storage unless leakage is found during retest.

Vickers has experienced no significant degradation as a result of:

1) Relaxation of springs during storage;
2) Stress corrosion (although some susceptible materials have been used);
3) Aging of the lubricant in shaft couplings although a check of the couplings is recommended upon removal from storage.

Vickers engineers expressed the opinion during the survey meeting that periodic exercise of hydraulic equipment during storage is beneficial even though their amount of exercise recommended was only that required to change relative positions of parts in mechanical components (Trip Report II-20). It was recognized that the human activity in accomplishing the exercise could cause equipment damage or degradation.

The following design practices contribute to long life equipment:

1) Use O-rings only in compression (some rubber chemists believe that rubber under compression may last up to 100 times longer than in its ambient state);
2) Use backup rings to prevent O-ring extrusion at high pressures;
3) Use military specification practices.

Moog has experienced very few problems with O-rings in hydraulic fluid except under high temperature conditions and can foresee no problem with O-rings installed and stored at 90°F upper limit. Moog's experience has indicated that components in storage should be left alone. Servo valves unoperated and stored in an uncontrolled environment for 4½ years performed as well as valves operated every 30 days. The servo valves are designed so that they have no limited life cycle. Valve life is determined by fluid erosion, not wear or sliding wear of parts. Torque motor operation changes occur with time, cycle, and temperature, resulting in null shift. Temperature has the most effect on null band shift. It is Moog's opinion that refurbishment to replace O-rings only results in more damage than leaving O-rings alone, especially in press fit parts.

3. Electrical System Components

Components to be discussed in this paragraph include power sources, wiring, distribution panels, connectors, relays, and switches. Batteries and inverters were the only power sources for which information was obtained during the study.

Degradation in batteries of the type used in the Saturn vehicle (silver-zinc, primary, dry plate storage) is almost entirely chemical in nature. A fully charged battery plate contains silver peroxide ($AG_2\ O_2$). The degradation mechanism is migration of the AG_2O_2 and deterioration to silver oxide (AG_2O). All design factors, which include initial load, initial voltage, discharge rates, voltage limits, and wet stand time requirements, affect the rate at which this deterioration takes place. The two principal effects are (1) degradation of the initial voltage and the voltage curve during initial load application, and (2) decreased total load capacity. Storage at low temperature (30° to 40°F) will reduce the rate of degradation.

The only extension technique applicable to batteries is a test program on aged samples. Batteries are usually designed with 25% to 35% excess capacity beyond the specification and often the specification has an additional margin over mission load requirements. The Titan II batteries had a 36-month life limit. Over-age batteries tested at ages up to 66 months frequently did not meet the specification load voltage curve, however they were capable of supplying mission load requirements with adequate margin. They were extended to 48 months on this basis. Preloading the battery (application of an artificial load either manually or automatically for a short period of time) is the usual technique for alleviating effects of age on the initial voltage curve, however this also reduces the power available for the mission.

Inverters may be of the static or rotary type. The primary deterioration factors of the rotary-type inverter are the bearings and their lubrication. In some cases, start transient stresses cause deterioration which requires that a cycle limiation be imposed. Electronic piece part considerations, both aging and operating, govern the limits that are imposed on static inverters. Some programs surveyed do not apply operating or calendar life limits on static inverters.

Wiring systems and distribution panels have successfully survived long-term storage, even in uncontrolled environments. The only case of storage degradation known involved improper application of materials (hysol and butyl) intended to protect terminal boards from corrosion.

Degradation modes in disconnects include (1) pin (or socket) wear and tear due to operation; (2) corrosion; and (3) aging of rubber inserts or O-rings. Corrosion in gold-plated pins has been a problem. Careful handling, careful prestorage preparation, and a dry storage environment will prevent most storage degradation. Life limits are not recommended for most connector applications. Only those connectors in highly critical locations or applications involving many repeated operations should be considered for life limits.

Relay and switch operating limits are relatively easy to define thru test programs. Nearly all relay applications in booster vehicles involve a fairly small percentage of the available cycle life, therefore, limits usually are not specified. Storage degradation is occasionally seen in the form of increased contact resistance. This can usually be corrected by operating the relay five or ten times. A storage life limit of from 3 to 5 years may be imposed to assure detection and correction of increased contact resistance.

4. Electronic Equipment

A considerable amount of research and study concerning the reliability of electronic equipment has been accomplished by others. Much of this effort, however, has been concerned with special situations such as tropical service and similar harsh environments, or with specific hardware in specific applications. One study of interest to any storage program is <u>Dormant Operating and Storage Effects on Electronic Equipment and Part Reliability</u>, performed for Rome Air Development Center, Air Force Systems Command by the Martin Marietta Corporation, Orlando Division. The following excerpts are from the Conclusions section of the report:

> "It has been established that electronic part failure rates in the nonoperating mode are essentially the same over many different systems and programs. This finding has resulted in the concept that the nonoperating failure rates for electronic parts represent a baseline and that changes from this baseline failure rate due to such factors as electrical stresses, application tolerance margins, mission environments, and parts screening programs can now be established with an accuracy previously unattainable...
>
> "A comparison of recent observed data showed that operating to nonoperating failure rate ratios average about 15 to 1...
>
> "Present day prediction methods for electronic systems incorporate electrical stress, temperature stress, and use environment. This program has shown, however, that such factors as parts screening techniques, tolerance margins in application of parts, and the design of test and checkout equipment have a greater influence over part failure rates in operational use...
>
> "The frequency of electronic part failures can be correlated with nonoperating as well as operating time periods. This does not imply that either is the cause of failures, but rather that time and the operating stresses may be viewed as accelerating or precipitating factors in the basic failure mechanisms...
>
> "The acceleration factor for basic failure mechanisms is recognized as being the lowest for conditions of controlled storage because in controlled storage many of the operating stresses are either eliminated or reduced. This is proved by actual field experience as shown in the report...

"Most nonoperating failures are traceable to latent manufacturing defects rather than specific aging mechanisms. These defects will pass initial functional tests but finally become evident after nonoperating periods....

"The type of failure detected in this study strongly supports the practice that reliability can be improved by part screening. It is believed that a sizeable percentage of the failures could have been eliminated by burn-in and production environmental testing that included temperature, shock, and vibration exposure." (Ref 22)

The actual failure rates developed and the interpretation of data can be obtained by studying Reference 22.

Additional data of interest may be found in Corrosion Prevention/Deterioration Control in Electronic Components and Assemblies, by R. H. Sparling, U.S. Army Missile Command, Redstone Arsenal, Report CR6-347-958-001.

To recertify electronic equipment many of the organizations surveyed performed a complete functional test when the equipment was removed from storage. Refurbishment is used whenever practical to correct nonconformance operation detected during testing.

5. Guidance

Calendar or operating limits of guidance systems may relate either to electronic or electro-mechanical equipment. Electronic elements were discussed in the preceding section. The gyroscope is usually the component that is the ruling factor in guidance package life.

Several mechanical variations affect the storage survivability of gyros. These variations include:

1) Ball bearing spinmotor;
2) Air bearing or gas hydrodynamic spinmotor;
3) Fluid floated gimbal;
4) Air floated gimbal.

Storage characteristics of the various configurations are indicated below.

Ball Bearing Lubrication Retention - Lubrication may migrate or collect in one area of the bearing, or the lubricant may deteriorate with age. The various gyro vendors contacted used differing approaches to the problem. Packages from various programs have been flown at 3 or more years of age, and several packages over 5 years of age have demonstrated successful operation. Rate gyros from the military Atlas missiles demonstrated less than 10% reject rate after extended storage (this reject rate was based on the requirements of the new mission). A "run-in" period on removal from storage usually redistributes the lubrication. Oils in current use have not exhibited significant deterioration during storage up to 5 years.

Air Bearing Spinmotor Start Up Torque. This has been a problem on at least one missile program. The problem has been attributed to metal migration (at the molecular level) while the unit is at rest. However, vendors surveyed stated that this factor had not been a cause of nonconforming operation in their units.

Fluid Floated Gimbal - Fluid stratification has been a problem in the past and can cause mass unbalance. Also fluid reaction with internal parts of the gyro has caused failures. These problems have been resolved with development of better fluids. Fluid contamination has also been encountered. Many fluid floated gyros must be kept at +140°F at all times. This heat has caused degradation of other materials in the package over a 5-year period.

Air Floated Systems - The only concern for storage is that the quality of the gas in the gyro is sufficient to avoid corrosion or contamination.

The gyros used in the Saturn guidance system have ball bearing spin motors and air floated gimbals. This gyro should survive storage adequately.

An additional factor in gyro storage is the oxidation film that develops on the slipring contacts. Slip rings must be wiped (by gyro operation) before testing for performance after storage.

If storage degradation does occur in a gyro, it usually shows up in the parameters of run-up time and drift. Capability of refurbishing a nonconforming gyro varies according to the vendor and the specific design of the gyro.

6. Valves and Associated Hardware

The lives of valves are generally limited by age, not cycles of operation. The cyclic lives of aerospace quality valves usually greatly exceed the actual service requirements. Material compatibility with its environment, not cyclic life, usually limits valve life (Section IV of Ref 18). The seals are normally the life limiting factor. Polymer seals have been discussed previously in Chapter VII.A.1.

Some valve manufacturers believe that the installed lives of hydraulic valves are greater than their shelf lives because the hydraulic oil keeps the seals lubricated when the valve is installed in a system. By similar rationale, the installed lives of hydraulic valves may be longer than the installed lives of pneumatic valves since the pneumatic elastomers are not continuously exposed to a lubricant. North American Rockwell apparently recognizes the life limit differences between wet and dry operation. In their Apollo Time/Cycle Requirements Specification MA0201-0077, the cyclic lives of rocket engine injector valves are 600 cycles dry and 10,000 cycles wet. It is suggested that consideration be given to specifying valve lives based on the application and environments encountered.

Differences of opinion exist as to the need for periodically exercising valves to prevent polymer seals from adhering to metallic seats during prolonged storage. Isolated occurrences of this phenomenon have been reported. The Titan II engine valves are operated once a year to prevent sticking (Trip Report II-17). Conversely, Moog Incorporated reported that their experience indicates components in storage should be left alone. Moog servo valves unoperated and stored in an uncontrolled environment for 18 quarters performed as well as valves operated every 30 days (Trip Report II-21). The divergence of opinions needs to be resolved to ensure maximum reliability.

The general consensus was that valves in service should not be disassembled to replace over-age seals. (See the elastomer discussion in Chapter VII.A.1.)

Care should be exercised to ensure that all of the test medium used during testing is removed before extended storage. Also, any fluids used to clean or flush valves should be compatible with the valve material. For example, Aerojet-General Corporation experienced difficulty actuating valves after cleaning them with alcohol;

a residue remained that supported corrosion (Trip Report II-17). Unless the valve materials and environments, including test mediums and cleaning agents, are completely compatible, the valve materials can deteriorate during long-duration storage. Valves should be flushed with a compatible preservative before storage.

Valve Springs - Aerojet-General Corporation reported that valve springs have not failed (Trip Report II-17). The old springs are reused when the valves are rebuilt. Some cadmium plate has come off the springs. Vickers Incorporated reported there were no instances of spring relaxation during storage. The Rocketdyne Division of North American Rockwell also reported no spring relaxation problems (Trip Report II-27). Of those interviewed, only OCAMA reported spring problems; carbon seal wave springs supplied by one vendor degraded after 3 to 4 years on the shelf, resulting in seal leakage (Trip Report II-12). No general age limiting problems were noted for valve springs.

Pressure Switches - Absolute pressure transducers will drift depending on leakage rate. A welded case unit, tested to 10^{-11} microns, will shift about 1% in ten years according to Conrac Corporation (Trip Report II-28). Units using organic sealing would leak more rapidly and also the sealing material would deteriorate with age. Pressure switch units have a cyclic life dependent on the pressure involved, the type of operation, and the contact arrangement. Higher operating pressures result in lower cycle limits because of the mechanics of the bourdon tube. Pressure switches may need recalibration before installation after storage.

7. Pressure Vessels

Pressure vessels are included in the life limited category because of cyclic life limitations. Boeing and Grumman are among those who use the technique of fracture mechanics to determine pressure vessel life.

> "A classical example of fracture-mechanics application concerns the design of high-strength pressure vessels. Since it is now realized that all vessels are likely to contain cracks or crack-like flaws (either incorporated in the material or generated in the fabrication process), it is essential that the design include consideration of the crack tolerance of the material....

"If existing cracks or flaws in the structure do not exceed the critical size for the operating stress level, the structure can be expected to sustain the first load application. With repeated load application, however, a flaw would be expected to grow in size and could eventually attain critical size and cause structural failure. To ensure structural integrity under repeated loading, subcritical flaw growth must be considered. This facet of design can also be interpreted in terms of fracture mechanics.

"It has been established that the maximum possible flaw size that could be present at the operating stress level is the critical size that was tolerated at the proof-pressure stress level. Additionally, it is known that this flaw size is less than the critical flaw size at the operating stress level and that the difference between the two flaw sizes represents the slow growth potential of the vessel material. It is now merely required that the cycles to failure be established to estimate the vessel's usable life.

"A hypothetical plot illustrating the procedure for estimating the minimum cyclic vessel life is shown in Fig. VII-1. Here it is assumed that the proof pressurization was 40% above the operating stress level of the vessel. Tests are conducted to determine the rate of crack growth with load repetition, and a family of growth curves are plotted representing the remaining cycles of failure.

"The single-cycle curve shows that a successful proof test indicates the presence of no flaws greater than about 50% of the critical flaw size at the operating stress level. Additionally, the family of growth curves shows that at the operating stress level this flaw will not grow to critical size in less than about 150 cycles; this then becomes the operating life of the vessel at the assigned stress level. The cyclic life span of the vessel would, of course, be greater than the predicted life if the retained initial flaws after proof test were actually smaller than 50% of the critical size." (Ref 23)

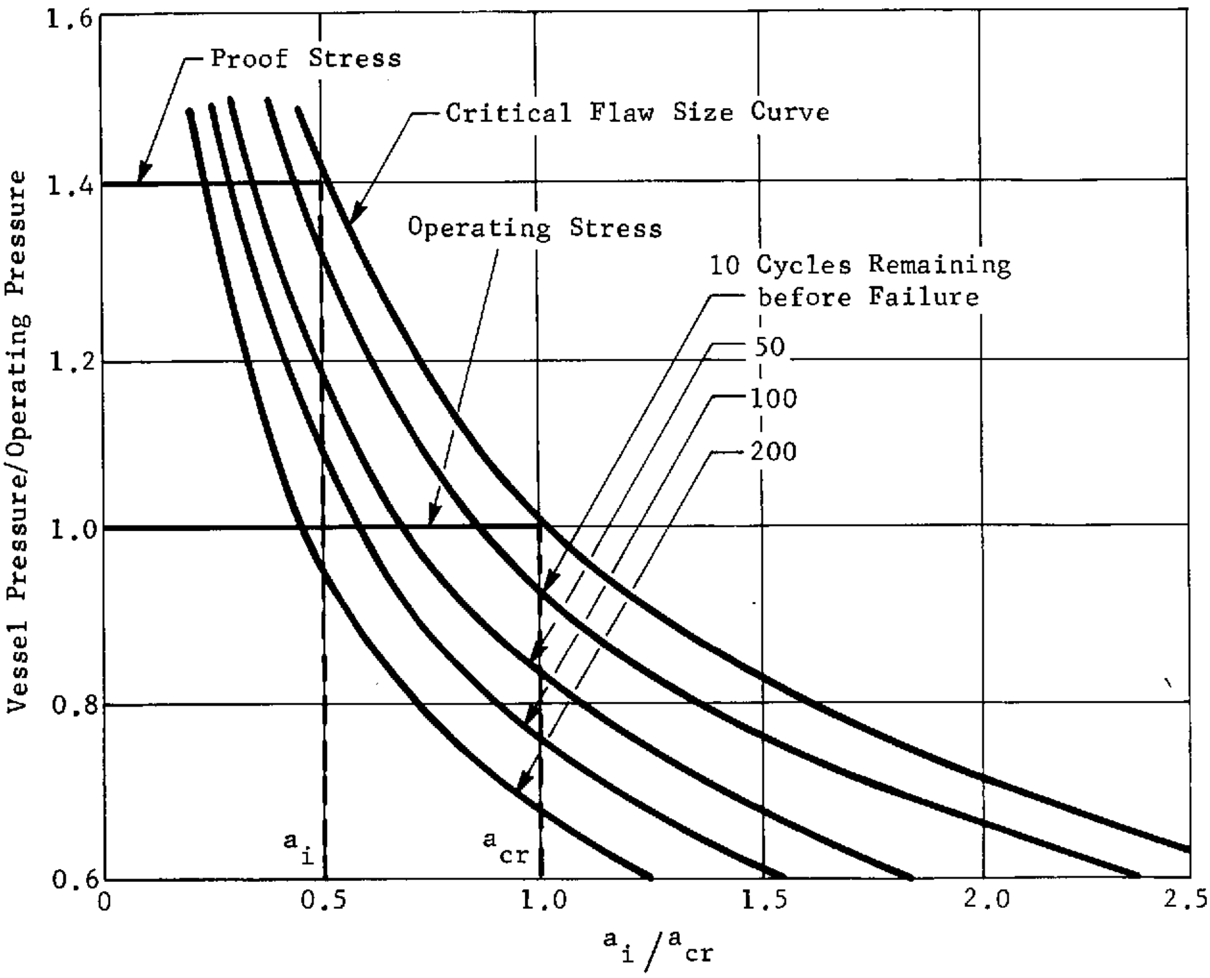

Fig. VII-1 Family of Critical Crack-Size Curves Used in Estimating Service Life.

APPENDIX A

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APPENDIX B

SURVEY QUESTIONNAIRE

MARTIN MARIETTA DENVER DIVISION

QUESTIONNAIRE

A. AREA OF INTEREST

Martin Marietta Corporation is conducting a study for NASA of Government and Aerospace Industry techniques and engineering systems used for determining and recertifying the shelf life of spare components and assembled flight or space systems. In the context of this study, the term "Shelf Life", is applied to the status of items stored in place, on vehicles, or on components, or in subsystems, etc; not just to items "on the shelf". All categories of airborne equipment which are age controlled are of interest to this study.

B. STUDY OBJECTIVES

1. Define and evaluate the different systems used for shelf life evaluations.

2. Define techniques for using existing data to estimate extended shelf life.

3. Investigate and define methods for determining minimal testing or methods used to recertify components and systems that exceed their designated shelf life.

4. Identify specific types of hardware or physical parameters that preclude a valid determination of shelf life.

C. QUESTIONS

1. What components are considered time sensitive? Why? What life is assigned?

2. What components are considered cycle sensitive? Why? What life is assigned?

3. What procedure is used to determine limiting age and or shelf life? Cycle life?

4. We have established the following categories of time sensitive components. Do you agree or have any to add?

Category	Reason
Components Containing Elastomers	Aging of Elastomers

QUESTIONNAIRE (Cont'd)

C. 4. Continued

Category	Reason
Ordnance Items	Aging of Propellants/ Explosives
Batteries	Oxidation and Increasing Resistance
Miscellaneous Electronic Components	Whisker/Crystal Growth and Corrosion
Lubricated Components	Drying of Lubricants
Components Requiring Calibration	Shifting Limits

5. We have established the following categories of cycle sensitive components. Do you agree or have any to add?

Category	Reason
Pressure Vessels	Fatigue
Bladders	Fatigue
Valves	Wear

6. The following techniques have been suggested for extending shelf or cycle life. Please discuss any experience you have had in these areas. Do you have any to add?

   a. Similarity - In cases where an article can be demonstrated to be similar to an article which has proven to have a significantly longer shelf life, the life of the first article can be extended on the basis above.

   b. Analysis - A study of the materials involved, the storage environment, activities and testing performed, expected degradation, intended use and failure history could lead to the extension of shelf life by analysis.

   c. Inspection - In some cases, visual and/or radiographic inspection will provide sufficient data to extend shelf or cycle life.

   d. Testing - In many ways, it will be necessary to retest the components or subsystems to justify the extension of shelf life. If testing is required, methods and levels of testing must be determined, for instance can a representative sample be tested or is it necessary to test the complete population and is it possible to test to the acceptance level or is a repeat of qualification testing required.

QUESTIONNAIRE (Cont'd)

C. 6. Continued

e. Refurbishment - In many cases refurbishment such as the replacement of deteriorated piece parts or relubrication will extend shelf or cycle life.

f. Combination - In most cases, a combination of the above five approaches will be required.

7. What has been the effect of storage on shelf life?

a. Method of storage, that is stored when assembled into a complete system or stored as a separate component.

b. Effect of storage environment including humidity, temperature, atmospheric contaminants, etc.

c. Effect of packaging, preservatives, protective films, encapsulation, etc.

d. Personnel access during storage.

8. What has been the effect of storage on operational reliability?

9. What do you consider good design practices for maximum shelf life? Cycle life?

10. What procedure do you use to monitor shelf life of components assembled into systems? Stored as spares?

11. Have there been any changes to the list of time or cycle sensitive components (additions, deletions or age extensions) during the life of the program? Why were these changes made?

12. Do you have any test data on components that have been stored that verifies the shelf or cycle life imposed?

13. What materials impose a shelf life on components?

a. What is the basis for this finite life?

b. Has there been any history of change to the allowable life of these materials due to testing, experience, etc.

c. Are there any particular combinations of materials that are age sensitive or will reduce the allowable age of either material.

14. How has cost affected the decision to extend shelf life of a component? Please discuss the impact of the following factors:

Cost per unit

QUESTIONNAIRE (Cont'd)

C. 14. Continued

Number of units involved

Cost of an analysis program including cost of retrieving data

Cost of refurbishment

Cost of testing

Cost of inspection

Cost of cleaning

15. Do you have any specific data on costs involved in extending shelf life or cycle life of a component?

16. We would like copies of any documents pertinent to this subject. If copies are not available, we would like references.

APPENDIX C

SURVEY TRIP REPORTS

All of the survey trip reports generated during the course of this study are presented in this appendix. The reader is cautioned to keep in mind that the information was raw data at the time the report was written. Many instances of conflicting information were resolved during later evaluation and analysis.

SURVEY TRIP REPORT II-1
THE BOEING COMPANY
SPACE DIVISION
MICHOUD, LOUISIANA

6 January 1969

1. Persons Making Trip

M. G. Mueller, Jr.	Martin Marietta Corporation - Systems Engrg.
W. B. Gizzie	Martin Marietta Corporation - Logistics
K. E. Riggs	NASA-R-TEST-ST
J. A. Greer	NASA-I-V-SIC/SIB
R. W. McCoy	NASA-I-V-E
T. W. Ogletree	NASA-I-I/IB-E

2. Persons Visited

H. L. Collins	Boeing - Systems Integration
H. B. Gibbs	Boeing - Systems Integration
H. Farner	Boeing - Materials & Processes
D. L. Wilkerson	Boeing - Elect. Materials & Processes
T. J. Jerson	Boeing - Stage Design
J. P. Ringler	Boeing - Stage Design
T. B. Barbee	Boeing - Systems Integration
H. C. Tucker	Boeing - Systems Integration
M. T. Monson	Boeing - Logistics
J. N. Dexter	Boeing - Materials & Processes
C. A. Vogtner	NASA I-MICH-OA
H. R. Bencaz	NASA I-MICH-OB

3. Purpose of Visit

The purpose of the visit was to discuss the various components of the S-IC stage which have limited life due to calendar aging or operation and to explore ways and means of extending that life.

4. Discussion

Any S-IC stage part that may reach the end of its operational life before the end of the stage mission when subjected to the normal operational requirements of manufacturing, testing, and launch checkout is considered a limited life part.

Included in the list of limited life items are ordnance items, valves and regulators, electronic units, switches, relays, propellant tanks, filters, servo-actuators, umbilical couplings, batteries, and liquid sensors. Criteria for inclusion on the list include MSFC specification requirements, GFP requirements, vendor recommendation, industry standards, and test data.

4. Discussion - Continued

Boeing has a contractual requirement that 50% of specified component life must remain when the stage is shipped to KSC. It is felt that this requirement is too restrictive and could result in unnecessary replacement and refurbishment of otherwise useful components.

S-IC design was based on a five-year program. A storage requirement which results in a stage age of greater than five-years may result in additional items of limited life components. Boeing feels that testing to re-verify aged components is the only valid approach to extending life, except for those items which are regularly refurbished.

Some electronic components are periodically tested for function and dielectric strength. These are go-no-go tests and do not indicate trend toward malfunction.

Monitoring of component life is by standard methods. Q&RA keeps serialized component logs. Logistics keeps part number component records. Much of the operating time and cycle monitoring is automated in the ground test equipment.

The only additional life limit categories suggested were metallics (for corrosion), relays and switches (wear and tear).

5. Documents Obtained

a. Summary of Time, Cycle and Age Life Recording Requirements and Life Apportionment for S-IC Stage Components, Boeing 60B03007, Change A.

6. Action Items

None

7. Summary

A list of S-IC life-limited component was obtained. Discussion revealed no unusual items or situations with respect to that list. Boeing feels that refurbishment and/or retest are the only valid bases for extending component life.

SURVEY TRIP REPORT II-1
ADDENDUM 1 - 3 FEBRUARY 1969

THE BOEING COMPANY
SPACE DIVISION
MICHOUD, LOUISIANA

6 January 1969

Add to Paragraph 4 - Discussion

The Boeing Company made the following comments in response to our Question Number 9, "What do you consider good design practices for maximum cycle life?"

> Fracture mechanics and proof testing are applied to verify static strength or fatigue critical structures or components. Fracture mechanics is used to establish cycle life and would be used as an aid in determining storage life limits.

SURVEY TRIP REPORT II-2
CHRYSLER CORPORATION
SPACE DIVISION
MICHOUD, LOUISIANA

7 January 1969

1. Persons Making Trip

M. G. Mueller, Jr.	Martin Marietta Corporation - Systems Engrg.
W. B. Gizzie	Martin Marietta Corporation - Logistics
J. A. Greer	NASA - I-V-SIC Project
C. R. Fitts	NASA - I-I/IB-SI/IB
R. D. McCoy	NASA - I-V-E
T. W. Ogletree	NASA - I-I/IB-E

2. Persons Visited

G. E. Moore	CCSD - Mgr. - Logistics Eng.
R. M. Ament	CCSD - Mgr. - Maintenance Eng.
J. W. Peart	CCSD - Materials Eng.
W. H. Juengling	CCSD - Chief, Eng. E&EE
R. J. Bork	CCSD - Mgr. - Electro-Mech. Des.
J. F. Patrick	CCSD - Mgr. - Quality Control
W. A. Potrafke	CCSD - Managing Eng Material Eng.
M. Ambruzy	CCSD - Q.C. Engineering
G. T. Rounis	CCSD - Mgr. - Quality Engineering
H. R. Stamm	CCSD - Sys. Engr.
L. A. White	CCSD - Reliability Engineering
G. H. Goble	CCSD - Reliability Engineering
B. D. Emeric	CCSD - Prop & Mech Engineering
J. L. Dietz	CCSD - Logistics
E. J. Dofter	CCSD - Reliability Eng.
C. A. Vogtner	NASA - I-MICH-OA

3. Purpose of Visit

The purpose of the visit was to discuss the various components of the S-IB stage which have limited life due to calendar aging or operation and to explore ways and means of extending that life.

4. Discussion

It was agreed that the categories of time sensitive components identified in Question (4) of the Questionnaire are those that are also recognized by CCSD. Stress corrosion susceptible materials, miscellaneous organic materials, and materials that cold flow should be added to the list. Reliability publishes data for all age control items. As a general rule operating life is set the same as qualification test requirements. Electronic equipment life is established by decree. Cycle sensitive hardware life is based on wear out of the equipment rather than deterioration due

4. Discussion - Continued

to storage. CCSD is watching the following areas for signs of degradation: PVC coated electrical wiring, Teflon coated wire, Asbestos insulation where a sodium silicate bonder creates an alkaline condition and electrical connector pins that are gold plated over silver and unprotected silver plate. The following items should be added to the list of cycle sensitive components contained in Question (5). Regulators due to lubrication, switches due to fatigue, motor pump due to wear and auxiliary pump motor due to insulation breakdown and explosive bridge wire firing unit due to spark gap. A glass filament wound pressure vessel with a butyl bladder is being watched for degradation of the adhesive scarf joint.

The techniques that are used to extend component life are refurbish and testing. Soft goods change and lubrication are accomplished during refurbish. When time or cycle life expires, components are reviewed on an individual basis for corrective action. The similarity method of extending life is disliked because requalification of modified parts has to be considered.

Designing for maximum life should consider use of high reliability components, Military Specifications, screened parts, 50% derated electrical parts, avoid use of stress corrosion and cold flow susceptible materials.

Component life control is monitored through use of part number and serial number control system. Quality Control monitors all life items. Control is mostly computerized.

Materials which impose shelf life restriction are: elastomers and polymers affected by ultra violet radiation, ozone, and plasticsizer migration, plating combinations sensitive to corrosion, materials with appreciable vapor pressures, and materials susceptible to creep, fatigue or stress corrosion.

No specific data is available on costs involved in extending shelf life or cycle life of a component.

5. Documents Obtained

a. S-IB Serialized Components Life, dated 11 October 1968.

b. Logistic Engineering Spares Specification List, dated 1 October 1968.

c. Space Division Procedure SD-99, Control of Serialization for Traceability, Operating Time, Operating Cycles and/or Age and Deterioration.

d. General Specification for Packaging and Packing of Parts, Repair Parts, and Components for Space Vehicles, Specification 60C06020 Revision F, dated 19 June 1964.

6. Action Items

Martin Marietta Corporation to discuss Butyl lined glass wound pressure vessel adhesive problems with AGC.

7. Summary

Lists of S-IB life limited components were obtained. Extending life has not been a practice and little storage experience exists at CCSD because of the nature of the program. Refurbish and testing techniques are used. Several materials were added to our list of categories of materials affecting component life.

SURVEY TRIP REPORT II-3

North American Rockwell Corporation
Space Division
Downey, California

January 8, 1969

1. Persons Making Trip

M. G. Mueller, Jr.	MMC Systems Engineering
W. B. Gizzie	MMC Logistics
K. E. Riggs	NASA R-TEST-ST

2. Persons Visited

A. L. Varneau	NAR, Apollo Reliability Certification & Data
M. B. Pierce	NAR, Apollo Reliability Certification & Data
F. A. Hill, Jr.	NAR, Apollo Reliability Certification & Data
R. V. Scott	NAR, Design Assurance
L. E. Love	NAR, Apollo Plans & Programs

3. Purpose of Visit

The purpose of the visit was to discuss limited life components utilized in the Apollo Command & Service Modules and to explore ways and means of extending component life.

4. Discussion

Limited life components of the Apollo CSM are controlled with respect to calendar life, age at installation, installed life, periodic operation, periodic servicing, operating time and/or cycle life. Categories of controlled life components not mentioned in our questionnaire include folded fabrics (parachutes, for instance) which require periodic repacking, chemicals which may deteriorate with time, photographic film, radiation detectors, switches and relays. Pressure vessels are controlled with respect to operating time at specified pressures as well as cycles.

Most operating life limits were determined from development and qualification test results. Other limits are established by MSC specification requirements, GFP requirements, and vendor data.

Operating time and cycle records for most components are kept by factoring from assembly or key component operating times. By this method specific recordings are only required for about 5% to 10% of the components for which time records are kept.

Most of the spacecraft components have a three year life requirement, however this requirement has not been proven. Many of these items are not on the limited-life component lists. As the storage program is developed for the AAP spacecraft new problems may arise.

Extension of the life limit might include all the concepts listed in the questionnaire. Design groups and design assurance groups have the basic responsibility for the requirements.

The milestone review system is used to assure adequate life of each component for remaining scheduled operations.

Components are added to or deleted from list for various reasons including modification to eliminate age or wear sensitive piece parts, experience and test data, or vendor information.

Apollo has accumulated very little data on the effects of storage on operating life.

No data was available on costs of extending component life.

5. Documents Obtained

   a. Controlled Deliverable Limited Useful Life Items, NAR Policy C-09, 11-15-68.

   b. Control of CSM Age Controlled and Time Action Items/Assemblies, Implementing Instruction AII-C16, 9-24-68.

   c. Apollo Time/Cycle Significant Item List and Requirements, NAR Spec. MA0201-0077, Rev. K, 10-1-68.

   d. Apollo CSM Age Controlled/Time Action List and Requirements, NAR Spec. MA0201-5695, 9-19-68.

   e. Age Control Standard for Age-Sensitive Rubber Items, NAR Spec. MA0116-029, Rev. E, 9-27-68.

   f. Block II Assessment Operating Time Tree, Revised 3-5-68.

   g. Sample Copies of Estimated Operating Time Report.

   h. Apollo Operating Time/Cycle System.

6. Action Items

   a. MMC to check with Honeywell Corporation regarding study to extend the operating life and age limit on the Apollo Stabilization and Control System.

7. Summary

Many of the spacecraft components have life limits. Limits have been determined by test data, analysis, MSC requirements and vendor data. Little data has been accumulated on the effects of storage on limited life items. Extension of operating or cycle life has been based on test data or refurbishment. Analysis would also be an acceptable approach.

SURVEY TRIP REPORT II-3
ADDENDUM 1 - 3 FEBRUARY 1969

NORTH AMERICAN ROCKWELL
SPACE DIVISION
DOWNEY, CALIFORNIA

8 January 1969

Add to Paragraph 4 - Discussion

A study was conducted for the Earth Landing Sequence Controller which resulted in extending its life from three years to six years. Qualification and other test data was utilized to justify the extension. The CSM Apollo Project at MSC - Houston authorized the life extension.

Add to Paragraph 6 - Action Items

b. Contact R. C. Hood, Project Officer, CSM Apollo, JC211 concerning information relative to extension of Earth Landing Sequence Controller life.

SURVEY TRIP REPORT II-4
McDONNELL DOUGLAS CORPORATION
MISSILE & SPACE SYSTEM DIVISION
SPACE SYSTEM CENTER
5301 BOLSA AVENUE
HUNTINGTON BEACH, CALIFORNIA 92646

9 January 1969

1. Persons Making Trip

M. G. Mueller, Jr.	Martin Marietta Corporation - Systems Eng.
W. B. Gizzie	Martin Marietta Corporation - Logistics
K. E. Riggs	NASA - R-TEST-ST

2. Persons Visited

J. P. Arroyo	MDAC - Program Office
R. F. Finney	NASA/MSFC - Huntington Beach
R. C. Lindberg	MDAC - Program Office
R. E. Crandall	MDAC - Program Office
J. B. Vanaman	MDAC - MM-RE
R. A. Welbourn	MDAC - MM-RE
J. E. Green	MDAC - MM-RE
T. A. Burley	MDAC - Dev. Eng.

3. Purpose of Trip

The purpose of the visit was to discuss the various components of the S-IVB stage which have limited life due to calendar aging or operation and to explore ways and means of extending that life.

4. Discussion

Test requirements to establish age or cycle life are generated by the designer and components are subjected to qualification test or life cycle test. No company guide or checklist exists to help designers establish cycle life or age. Customer direction, Marshall Change Order 1715, establishes guide lines along with experience and documented data. Cycle life of components is identified on Drawings 1B55423, 24 and 25. Cycle life is established by the designer based on his conditions or considerations for the component except for pressure vessels which are designed using fracture mechanics. It is generally felt that if a failure does not occur within one year a failure will not occur within five years.

Paints, finishes and coatings should be added to list of categories of time sensitive components. Reflectivity and emissivity of finishes may degrade with age. Kapton was substituted for Mylar because of higher temperature resistance and non-burning characteristics. Thermal coatings on orbiting stages are the biggest problem. The coatings degrade and may have to be replaced.

4. Discussion - Continued

Redesign or modification of components may require or impose changes on cycle life or age limits. MDAC does not anticipate any changes to life or age lists as a result of storage for three years. There is no requirement to reserve a percentage of life after delivery of equipment for launch. The life of every critical component has been established based on test data and technical analysis. No limits have been arbitrarily established.

The reliability assurance organization, quality control, monitors and records time and cycle data. A purely manual accounting system is used. Spares are bench checked before installation on the stage. Spares are maintained in controlled storage area. The test procedures define time recording requirements. Cost is influenced by the availability of parts. Generally vendor parts are returned to the vendor for refurbishment. Parts would be refurbished unless cost would exceed 60-65% of new item.

5. Documents Obtained

a. 1B66667 List, Master Age Control Items, DSV-4B/1B/V Flight Stages, GSE, and GSE Repair Kits.

b. 1B59360 Time Significant Items - Calendar

c. 1B55423 Government Furnished Property (GFP) Time/Cycle Significant Items

d. 1B55424 Limited Data Collection Time/Cycle Significant Items.

e. 1B55425 Reliability Time/Cycle Significant Items.

6. Action Items

R. E. Crandall, MDAC - Program Office agreed to send a copy of the time and cycle log and recording sheet used by MDAC.

7. Summary

Age and cycle life drawings were obtained. There were no major problem areas disclosed. Paints, finishes and coatings degrade and may have to be replaced. MDAC does not anticipate any changes to component cycle life or age lists as a result of storage for three years.

SURVEY TRIP REPORT II-5
NORTH AMERICAN ROCKWELL CORPORATION
SPACE DIVISION
SEAL BEACH, CALIFORNIA

9 January 1969

1. Persons Making Trip

M. G. Mueller, Jr.	Martin Marietta Corporation, Systems Engrg.
W. B. Gizzie	Martin Marietta Corporation, Logistics
K. E. Riggs	NASA/MSFC - (R-TEST-ST)
W. H. Johnson	NASA/MSFC - S-II Engr.

2. Persons Visited

E. E. Phillips	NR-D507 Contracts
G. H. Tifft	NR-D/099 S-II M&P
J. S. Mullen	NR-D/595 Engrg.
O. R. Bird	NR-D/595 Proj. Engrg.
S. Mochidome	NR-Contracts & Pricing
D. L. Roelands	NR-595.300 Reliability
V. P. Ostrander	NR-595.310 Reliability
R. B. Burton	NR-D/574 Logistics
A. F. Weissenberger	NR-D595/220 Proj. Engr.
E. J. Earl	NR-D/148 S-II Q&RA

3. Purpose of Visit

The purpose of the visit was to discuss the various components of the SII Stage which have limited life due to calendar aging or operation and to explore ways and means of extending that life.

4. Discussion

Every component procurement specification has a design limit and a test program to verify the limit specified. Components are qualification tested to the design limits. Some limits are established by limited life item specifications. Other components have no limit specified because life would not be exceeded during program. Method of accounting for component life was changed from installation in stage to starting with acceptance test. With present margins it is felt that life cycles will never be exceeded with extended storage.

Materials within stage and components are being changed to eliminate stress corrosion susceptible materials. Teflon seals were indicated as having a limited cycle life. Materials that are pre-stressed under normal condition, e.g., compressed springs or seals, should be added to categories of time sensitive components. Gimbal seals and duct bellows should be added to cycle sensitive components. Insulation panels are being subjected to continuing tests with no problems showing up with one year of natural environment exposure and 3-5 years of accelerated aging.

4. Discussion - Continued

It is felt that tests would be required after storage to verify operational capability and that a learning curve for training new people would consume some hardware. There is no requirement as to life remaining prior to delivery. There are requirements for vendors on life remaining prior to delivery to NAR. An evaluation of the time remaining is made at various phases in the program. Time and cycles are recorded against serialized part numbered components and are provided in the acceptance data package.

No specific data is available on components that verifies the shelf life or cycle life imposed. There is no pre-installation test performed on spare components. Materials that were identified as affecting life of components are elastomerics, batteries and ordnance.

5. Documents Obtained

a. Information: Limited Life, Age Sensitive, Operational Time/Cycle (A collection of NAR policies, specifications and procedures defining S-II stage component life limits).

6. Action Items

A. NAR will provide a sample document demonstrating the control date recording system (Document received - item closed)

7. Summary

Limited life, age sensitive and cycle life documents were obtained along with NAR policies, specifications and procedures. Some additional components were added to our list of cycle sensitive hardware. No major problem areas were identified and it was stated that with present margins it is felt that the operation life cycle will never be exceeded with extended storage.

SURVEY TRIP REPORT II-6
THE IBM CORPORATION
SPACE SYSTEMS CENTER
HUNTSVILLE, ALABAMA

14 January 1969

1. Persons Making Trip

L. W. Tipton	MMC - Systems Engr.
J. C. DuBuisson	MMC - Systems Engr.
R. McCooper	NASA - I-U-IU
D. J. Forsythe	NASA - R-TEST-ST

2. Persons Visited

G. Case	IBM - Material Engineer
J. E. Lundberg	IBM - Equipment Engineer
C. J. Napolitano	IBM - Reliability Engineer
E. S. Hastings	IBM - Program Office

3. Purpose of Visit

The purpose of the visit was to discuss the sundry components of the Saturn 1B/V Instrument Unit which have limited life due to calendar aging or operation and to explore ways and means of extending their lives.

4. Discussion

Instrumentation unit components that are operating time/cycle sensitive are replaced, refurbished or reviewed before flight if the accumulative time/cycles exceeds that specified in MSFC No. III-6-602-61 ("Operating Time/Cycle Critical Components) Synthetic rubber and elastomeric items are age controlled per MSFC-STD-105A and ANA-438 respectively. Other documents used as guides are:

IBM#	MSFC#	Title
67-386-0003A	III-6-602-774	Report on Age of Rubber Parts in 1U 204.
67-296-0006	III-5-502-7	Maintenance Analysis Summary Report
67-296-0004	III-6-602-57	Time Sensitive Components
7915953	- -	Storage, Instrument Unit, Long Term Procedure For

IBM#	MSFC#	Title
386-SL-003C	--	Storage of Perishable Parts
386-SL-004	--	Age Control and Storage Life of Elastomerics

The standard compression of gaskets and seals in ANA-438 is 30%. The standard compression used by IBM is 50%; therefore, the military specifications is not completely applicable. Also elastomer life is a function of whether the elastomer is in tension or compression, the amount of ozone present, etc.

The following suggestions and comments were made on the general subject of design:

1. Vendor guarantees tend to be conservative. For example, IBM successfully actuated one relay one million times although the vendor guaranteed only 25,000 cycles.

2. Don't store bearings pre-loaded if avoidable. (G. E., Cincinnati, Ohio, is studying the dimensional changes of ball bearings with age.)

3. An electronic piece part failure is usually traceable to a fault in manufacturing or design.

4. Wipe-off slip rings after storage.

5. Periodically add power to magnetrons to remove formed gases.

6. Presently, no one accepts the results of accelerated testing.

7. Cast materials age. Tests conducted over a twenty year period found stress corrosion cracks in castings stored on the floor. Materials tend to become homogeneous.

8. The Martin Marietta Corporation, Orlando Division, report on solder joints was deemed excellent. Success with the crimp design has been obtained by IBM.

9. The strength of 7075 and 2014 decrease with age.

10. Also suggested were (a) use solid state devices, (b) design for minimum residual stresses, (c) derate, stress relief parts, (d) use minimum number of moving parts, (e) match parameters, (f) etc.

The following suggestions and comments were made on the general subject of storage:

1. The IMU is stored in a controlled 32% R. H. environment. (Iron rusts at 40% R. H., ref.) The IMU is stored either as a complete system or as separate components. PVC covers and desicant are employed. The storage areas are behind limited access, locked doors.

2. Shelf life is monitored via log books.

3. Cost data concerning storage, refurbishment, and replacement are not available.

5. Documents Obtained

Operating Time Cycle Critical Components, Revision A, MSFC No. III-6-602-61, 16 March 1968, IBM, (U)

6. Action Items

Obtain the remaining documents listed in the discussion section.

7. Summary

A list of Saturn Instrument Unit life limited components was obtained. The discussions of design and storage parameters as they affect life limiting components agreed with the general concepts expressed elsewhere during this study.

SURVEY TRIP REPORT II-7
NASA
KENNEDY SPACE CENTER, FLORIDA
15 January 1969

1. Persons Making Trip

H. R. Gangl	NASA/MSFC - R-QUAL-AT
D. J. Forsythe	NASA/MSFC - R-TEST-ST
J. T. Bull	NASAA/MSFC - I-V-1U
J. C. DuBuisson	MMC - Reliability
L. W. Tipton	MMC - Systems Engr.

2. Persons Visited

J. B. Downs	NASA/KSC	- DE-MSD-2
W. E. Radford	NASA/KSC	- LV-MEC-1
J. E. Sullivan	NASA/KSC	- DE-KEM-2
J. R. McBee	NASA/KSC	- DE-MSD-2
W. Stamples	NASA/KSC	
K. Jenkins	NASA/KSC	

3. Purpose of Trip

The purpose of this trip was to identify and discuss various components in the Saturn GSE which have a limited life due to calendar aging or operation and explore methods of extending this life.

4. Discussion

The components and materials discussed during this meeting were primarily those used in the Launch Umbilical Tower (LUT) since this was the area of responsibility for the attendees.

Components with an operating time or cycle limit are listed in a "Saturn V Msle Time/Cycle Data Printout" No. D5-16309-1 prepared by the Boeing Company which mentions

Pneumatic separators
Valves
Transducers
Compressors
Pumps

In addition to this there is an age control requirement imposed on synthetic rubber by KSC spec 79K00030 which allows a shelf life of eight quarters prior to installation of the rubber piece part into its next assembly and sixteen quarters after installation. It is interesting to note that a similar spec from MSFC allows 24 quarters after installation. At the expiration of this 16 quarter life, the component is disassembled and the synthetic rubber parts are replaced. Several of the attendees disagreed with this approach for the following reasons:

1. Many of the components have been damaged during disassembly.

2. Often, when a component is removed for disassembly it is necessary to rerun tests to verify the operation of the replacement part.

3. There has never been a failure or malfunction that could definitely be attributed to age degraded synthetic rubber.

No distinction is made in this spec between synthetic rubber parts used in hydraulic and pneumatic systems.

It was pointed out that the P&VE Lab at MSFC has been doing considerable test work on the aging of synthetic rubber piece parts. Mr. Gleason Williams of that organization was mentioned as a source for this data.

Synthetic rubber piece parts are controlled from their cure date. This date is stamped on the part. When a piece is installed in a serialized component, the fact is so noted in the component's log book by quality control. Kits containing synthetic rubber parts are recorded by cure date.

Components requiring calibration are normally calibrated every six months. Calibration is maintained on critical spares.

Several opinions were expressed by attendees at this meeting.

1. Glass fuses become erratic after two or three years and should be replaced.

2. Nickel-Cadmium batteries used as a back up power source have been a continuous source of trouble apparently due to whisker growth during charging.

3. Electrical cables should have a useful life of at least five years and should be checked at this time. Critical cables in the Saturn GSE are continuity and megger checked before each launch operation. There has been some experience with degradation of "O" rings in electrical connectors. These rings are inspected every time a connector is made up.

4. Large motors should be rotated periodically during storage to prevent imbalance.

5. The shelf life of ablative coatings increases below 75°F.

6. Synthetic rubber parts should be stored in light proof, sealed containers. The present storage procedure does not require light proof containers but it should be changed.

It was felt that a test program should be started to determine the condition of synthetic rubber goods that has been removed due to age in order to extend the useful life and measure the difference of affect of hydraulic and pneumatic environment.

5. Documents Obtained

1. KSC Spec 79K00030, Age Control of Synthetic Rubber, Specification for

2. Saturn V MLSE Time/Cycle Data Printout No. D5-16309-1

6. Action Items

1. Mr. H. Gangl NASA/MSFC will provide file of Intercenter Alerts for review.

2. Mr. D. Forsythe NASA/MSFC will contact Mr. Gleason Williams and get the results of age testing on synthetic rubber that is being done by the MSFC P&VE lab.

7. Summary

Several problem areas and data sources were discussed.

SURVEY TRIP REPORT NO. II-8
MARTIN MARIETTA CORPORATION
ORLANDO DIVISION
ORLANDO, FLORIDA
1-16-69

1. Persons Making Trip

D. J. Forsythe	NASA/MSFC - R-TEST-ST
H. R. Gangl	NASA/MSFC - R-QUAL-AT
J. C. DuBuisson	MMC - Reliability
L. W. Tipton	MMC - Systems Engr.
J. T. Bull	NASA/MSFC - I-V-IU

2. Persons Visited

W. Wood	MMC - Reliability
W. Smalley	MMC - Pershing Logistics
L. Schaidt	MMC - Bull Pup Program Manager
A. Donelan	MMC - Pershing Logistics
J. Meritt	MMC - Pershing Logistics

3. Purpose of Visit

The purpose of this visit was to gether shelf life, operating life and cycle life data from weapon systems that are manufactured at MMC, Orlando.

4. Discussion

There was a general discussion on the shape of failure rate curves for electronic and electro-mechanical components. In both cases the failure rate peaks at about one hundred hours of operating life. From this point there is a drop off of failure rate to a knee at eight to twelve hundred hours. For pure electronic, solid state components, the failure rate remains constant until obsolescense. For electro-mechanical components or components containing tubes, there is an increase in failure rate due to wear out at three to four thousand hours.

The Bull Pup project has been monitoring a program for the evaluation of aging degradation on one shot items in this weapon system including ordnance, batteries and spring wound gyros. Twenty one missiles worth of these components, three, four and five years old making a total of sixty three sets have been expended under controlled conditions. The results of this testing were not immediately available but report references were supplied.

The Pershing project is monitoring a Storage Quality Evaluation program which is being run by Pueblo Army Depot. In this program, certain critical components are tested periodically in an effort to identify degradation trends. Results of this program will be made available by Mr. Dave Ray of the Pershing quality organization.

The following statements were made about the condition of the Pershing system:

1. The self contained hydraulic units are cycled every six months. There has been some precharge leakage noted.

2. The silver zinc, one shot batteries used in the Pershing missile were originally assigned a five year service life. These batteries are four to five years old and there has been no evidence of degradation.

3. Pershing solid motors are inspected periodically using a boroscope. No radiographic inspection is performed. There has been no detectable degradation in these motors.

During this visit, the documents available in the Orlando reliability group were reviewed and it was requested that about thirty documents be provided for review

5. <u>Documents Obtained</u>

1. First Year Failure Rates for Improved Pershing System Spares.

6. <u>Action Items</u>

1. MMC to get reports on the Bullpup one shot item test program.

2. MMC to get results of Pershing Storage Quality Evaluation Program.

3. MMC to follow up on borrowing documents from Orlando reliability group

7. <u>Summary</u>

Several documents were identified that should provide useable data for this study.

SURVEY TRIP REPORT II-9
ESB INCORPORATED
EXIDE MISSILE AND ELECTRONICS DIVISION
RALEIGH, NORTH CAROLINA

17 January 1969

1. Persons Making Trip

L. W. Tipton	Martin Marietta Corp. - Systems Engr.
J. C. DuBuisson	Martin Marietta Corp. - Systems Engr.
D. J. Forsythe	NASA/MSFC, R-TEST-ST
H. R. Gangl, Jr.	NASA/MSFC, R-QUAL-AT

2. Persons Visited

L. M. Hayes	ESB, General Sales Mgr.
A. M. Chreitzberg	ESB, Assistant Director of Engr.
J. F. Szabo	ESB, Senior Project Engr.
H. C. Williams	ESB, Section Leader, Primary Batteries
W. D. Bulla	ESB, Project Engr.

3. Purpose of Visit

The purpose of the visit was to discuss the sundry types of aerospace batteries and their components which have limited life due to calendar aging or operation and to explore ways and means of extending that life. Silver-zinc batteries were of particular interest.

4. Discussion

Data is available to estimate the shelf life of aerospace batteries. Data was provided by ESB that shows the decrease in battery capacity with age and increasing storage temperature. With the storage temperatures as parameters, plots of log capacity versus time results in essentially linear relationships. If a certain battery capacity is required for a mission after n months @ a known storage temperature, the required mission capacity can be insured by increasing the specified as-manufactured rating by the amount of the storage degradation (weight limitations permitting).

The adverse storage effects can be reduced by maintaining a battery at lower temperatures. For example; batteries supplied to JPL for Mariner applications showed little degradation after three years storage (1964-1967) at 30°F. The batteries were activated, charged, and sealed when flown to JPL under controlled temperature conditions.

Martin Marietta Corp., Denver Division, has Titan II battery data that supports the general trend of the storage degradation figures.

The U.S. Navy should have considerable data on battery storage. Two data sources recommended were the Key Point Naval Station in Washington and the Naval Ordnance Laboratory at White Oaks, Maryland. (Mr. Fritz Bower).

Mr. Don Elliot at SAAMA, San Antonio, Texas was also suggested as a possible source of data information.

The following storage conditions were recommended:

a. storage temperature below 80°F

b. low relative humidity

c. sealed batteries

d. keep battery in polyethelene bag with a desicant

e. fume free storage area

f. bring battery to 50% R. H. before activating to prevent cellophane stress (thermal)

g. store not charged.

The material suppliers provide ESB with life estimates of their products every six months on a batch basis (epoxies, resins, adhesives, o-rings, etc.). The stock is rotated on an age basis.

The shelf life of a material may be extended if tests indicate the material is still within specification (customer approving). The tests for life extension decisions are specified by the vendor. Lives are extended by three month periods and are retested before use. They employ the mix date of pyrotechnics for control purposes; a 4 to 5 year life is normal.

The following techniques are employed by ESB for extending shelf life (question #6).

a. By simulating whenever possible. They use standard drawings whenever possible.

b. By chemical analysis and projection of life properties.

c. By radiographic inspection. In addition to determining faulty batteries, technique is used to determine which batteries are superior for airborne usage.

d. By refurbishment of squibs as applicable. Also refurbish with improved longer life components if applicable.

The thermostat settings on heated Saturn batteries changed with storage time. The problem is under consideration.

It was not known how to perform an accelerated life test for batteries. Accelerated testing changes the failure modes.

ESB conducted tests to determine the effect of a battery being charged during storage. One battery, not charged, was stored for one year; it lost 20% of capacity. Another battery, charged, lost 40 to 50% of its capacity in six months.

5. Documents Obtained

a. A bound collection of shelf life storage test data prepared by ESB for Martin Marietta. Dated 17 January 1969.

6. Action Items

Contact suggested sources of data.

7. Summary

Useful data was obtained upon which shelf life decisions can be made.

SURVEY TRIP REPORT II-10
McDONNELL DOUGLAS CORPORATION
P.O. BOX 516
ST. LOUIS, MO. 63166

21 January 1969

1. Persons Making Trip

M. G. Mueller, Jr.	Martin Marietta Corporation - Systems Engr.
W. B. Gizzie	Martin Marietta Corporation - Logistics
W. H. Johnson	NASA S-II Stage Office
R. L. Graham	NASA R-QUAL-QR

2. Persons Visited

L. F. Fry	Chief of Maintenance, Aircraft
J. H. Bleiler	Section Chief, Aircraft Maintainability
R. A. Brink	Supervisor, Maintenance Engineering
D. J. Arbuthnot	Manager, Astronautics Division, Maintenance Engr.
R. E. Moon	Supervisor, Maintainability Gemini B

3. Purpose of Visit

The purpose of the visit was to identify and discuss various aircraft and spacecraft components which have a limited life due to calendar aging or operation and explore methods of extending this life.

4. Discussion

Little aircraft components shelf life data exists at McDonnell Douglas, because the components are procured and delivered according to production schedules. Major aircraft problem area encountered concerned epoxy potting-coumpound used on electrical connectors. The potting-compound failed after approximately five years by flowing out of the connectors. Identification of the potting-compound was not immediately available.

In our discussion on the spacecraft components, it was learned that McDonnell Douglas has no contract to maintain or store equipment from past programs. From their past experience, problems have been encountered with the following components:

clocks - accuracy degrades without proper winding frequency

heat sinks - coolant fluid has caused corrosion

transducers - go out of tolerance, but would return with cycling

4. Discussion - continued

parachutes - repacked every 120 days and 30 days prior to launch

relays - increased resistance and out-of-spec performance within four year period

meters - fatigue

ordnance actuators - extend and hold 10 duty cycle operating limit on compressed air due to peening of stops

batteries - experienced people/procedure problems bring out of storage

"O" rings - use 6 year life but believe it is not conservative enough for seals used in space environment

The following definitions were obtained from the Air Lock System Maintenance Summary document.

Equipment installed life is the calculated time interval that equipment installed in the spacecraft will still meet specified requirements of performance. This is subdivided into two categories:

a. Installed life operating - The period of time or number of cycles an item may sustain before it must be removed from flight status or requalified in accordance with the maintenance requirements column. A life limit time in this column denotes that the item must be removed when the life limit has been reached or exceeded.

b. Installed life non-operating - The period of time in calendar time only that an item may remain inactive before it must be tested or maintained to prevent degradation. This figure assumes specified precautionary measures have been taken for protection from extreme environments and contamination.

Storage life - the shortest time period a component may remain in storage before refurbishment is required. Refurbishment and retest returns the storage age to zero.

Useful life - the total life span of the component including extensions following retest and refurbishment (usually to program limit including contract extensions)

Shelf life of a component is that time period during which the component may be removed from storage and used directly without a pre-installation test.

A moisture barrier compound, CRS.27, has been evaluated with results available in a NASA-MSC study.

4. Discussion - continued

Component life is established by program requirements. The testing method is the only method that has been used to extend life. Similarity methods could be used only if components are used in similar mission applications. Inspection method was felt to be good for pyrotechnics and heat sinks, but not for valves. Changes have been made to component life based on past history and experience.

A Material Review Board system is used for handling components which have passed life limits.

5. Documents Obtained

A. SEDR 306, Gemini Spacecraft Systems Maintenance Summary

6. Action Items

A. Obtain from McDonnell Douglas PS338 Gemini B AVE Preventative Maintenance Requirements Summary, dated July 1967

B. Obtain copy of NASA-MSC Report on CRS-27

7. Summary

Little useful aircraft component data was obtained. Spacecraft component data and definitions discussed revealed no major problem areas. Documents obtained contain useful information for comparison with other programs.

SURVEY TRIP REPORT II-11
EAGLE PICHER INDUSTRIES, INC.
JOPLIN, MISSOURI

22 January 1969

1. Persons Making Trip

W. B. Gizzie	Martin Marietta Corporation - Logistics
M. G. Mueller, Jr.	Martin Marietta Corporation - Systems Engr.
R. L. Graham	NASA R-QUAL-QR
W. H. Johnson	NASA S-II Stage Office

2. Persons Visited

George Babb	EP Contracts
Curtis Brown	EP Engineering

3. Purpose of Visit

The purpose of the visit was to discuss the modes of degradation in silver-zinc batteries and to explore ways and means of extending storage life limits of batteries.

4. Discussion

Battery shelf life (dry storage life) cannot be inferred from a comparison of results of life tests of similar batteries. Analysis is not a reliable basis for establishing life limits.

Many factors affect the storage life of a primary silver-zinc battery. These factors include:

1. Open circuit initial voltage limit
2. Pre-discharge procedures
3. Initial discharge rate
4. Discharge rate vs. time requirements
5. Load voltage limits
6. Voltage recovery requirements (following peak load pulses)
7. Wet stand time requirements
8. Dry storage environment
9. Production techniques utilized to meet specification requirements including vibration.

Batteries of the type utilized on the Saturn stages are usually designed to provide 30% to 35% more capacity (when new) than the specifications require. Aging effects are most noticeable during the first portion of the load voltage curve causing the voltage to droop toward the minimum limit. As the discharge continues the voltage usually recovers to normal levels. The pre-discharge procedure (application of a specified load for a specified period of time after activation but before installation)

4. Discussion - continued

will usually carry the battery through most of the drooped portion of the curve.

Energy is stored in the silver plates of the battery in the form of silver oxide and silver peroxide. Part of the aging effect is the result of migration or breakdown of the silver peroxide molecules.

Aging can also occur in the plate separator materials; however, a battery stored in the dry state does not experience crystal growth or separator puncture.

The degradation is not significantly related to the use of either air or nitrogen in the cells during storage.

The total load capacity of the battery is reduced by the effects of aging. Testing of an aged battery utilizing the specified load curve is the only established method of determining if a storage life limit can be extended. The SIV-B battery storage limit was extended from one year to two years utilizing the test concept. Accelerated aging has not been an effective tool in identifying age failure rates.

Optimum battery storage temperature is $20^{\circ}F$ to $30^{\circ}F$. Degradation is minimal at storage temperatures up to $60^{\circ}F$. Batteries should be kept in their shipping containers which include desiccant and humidity indicators.

Eagle Picher has performed a study for NASA/MSFC regarding extension of the stand time limits of Saturn batteries after activation.

5. Documents Obtained

A. Manually Activated Primary Silver Zinc Batteries

B. Automatically Activated Silver Zinc Batteries

C. Secondary Silver Zinc Batteries

D. New Developments in Primary Batteries

All above are brochures published by Eagle Picher Industries, Inc.

6. Action Items

Contact R-ASTR-EPE, William Britz or Walter Goodhue for data from a study of wet (activated) stand time limit extension (MAS8-30023).

7. Summary

Battery aging modes involve chemical changes within the battery plates and can only be retarded by controlling the storage environment. Testing of an aged battery is the only way to determine possible storage life extension. Accelerated aging has not been a satisfactory tool.

SURVEY TRIP REPORT II-12
OCAMA
TINKER AIR FORCE BASE

OKLAHOMA

23 January 1969

1. Persons Making Trip

M. G. Mueller, Jr.	MMC - Systems Engr.
W. B. Gizzie	MMC - Logistics
W. H. Johnson	NASA - S-II Stage Office
R. L. Graham	NASA - R-QUAL-QR

2. Persons Visited

J. M. Blake	OCAMA (OCVP) Plans & Programs
R. W. Wright	OCAMA (OCVP) Plans & Programs
E. R. Spillman	OCAMA (OCNET) Materials & Testing
B. W. Campbell	OCAMA (OCNMM) Policy/Systems
Maj. H. G. McElroy	OCNES Service Engineering
F. C. Boardman	OCNEM Service Engineering
J. W. Mullins	OCNER Service Engineering
C. R. Inmon	OCNEMH Service Engineering
H. E. Orr	OCMQQLT Materials Testing Unit

3. Purpose of Visit

The purpose of the visit was to gather shelf life, operating life and cycle life data from weapon systems and components for which OCAMA is the prime AMA.

4. Discussion

A brief presentation was made to acquaint us with the mission of OCAMA and to identify the equipment for which OCAMA has responsibility. The AMA is divided into four directorates. Materials, Maintenance, Supply and Transportation and Procurement with responsibility for the following equipment: B-52, A7D, ADM-20 Quail, AGM-28 Hound Dog, AGM69A SCRAM, Ground Communications Equipment, Jet Engines, Accessories, Hydraulics, Pneumatics, and Instruments.

Procedures exist at each AMA covering control of age controlled items. .

Procedures are defined and established by AF Regulations and Technical Orders.

A copy of the regulations and T. O. were obtained along with several copies of AF Forms 160 which is the age control recording form.

Paints, sealers and adheasives are tested by OCAMA depending upon such factors as cost, quantity involved, application, etc. and are extended only after passing test requirements. Service engineering looks at the material sample. The chemistry laboratory tests the sample based on experience, specifications and material. The tests performed are generally acceptance type tests. If the material passes the test, the life is extended. "O" rings and gaskets have been extended up to 10 years, one year at a time with no problems. Communications and electronics equipment have had no failures related to age. The equipment is refurbished due only to operating time, not age.

Potting compound, 3M, EC20273 and Pro Seal 777 have been a problem. These compounds degrade with time, temperature, and humidity and are no longer used. The compounds revert to a liquid form and run out of the connector.

Subassembly installed "O" rings take a set and some scoring and nicking has been noticed on some assemblies produced by a particular vendor. It was felt that virgin teflon seals are generally superior to reclaimed teflon seals. Viton "O" ring seals have stuck to teflon coated parts on the shelf. Carbon seal wave springs have degraded after 3 to 4 years on shelf resulting in seal leakage. Service tests on landing gear has indicated that static leakage is greatest at cold temperatures. Vapor phase inhibitor (VPI) has been used as an engine preservative successfully preventing corrosion.

5. <u>Documents Obtained</u>

A. AFLCR65-23 Age Controls For Property In Storage

B. OCAMAR65-5 Maintenance-Engineering and Supply Control of Shelf-Life Items.

C. T. O. 00-20K-1 Inspection and Age Control USAF Equipment.

D. Report of Investigation of Accelerated Aging of Nitrile Rubber.

E. Aging of Cure Dated Items and Various Elastomeric Compounds.

F. AF Form 160 Stock or Price Change Voucher.

6. Action Items

A. H. E. Orr, OCMQQLT, to send copy of Report of Investigation of Accelerated Aging of Nitrile Rubber. (Closed copy of report received 1-28-69).

B. MMC to obtain copies of AFLC Reg 65-2, AFLC Manual 65-3 and AFM67-1 ERRC coding dollar criteria on throw away items during visit to Dayton, Ohio.

7. Summary

The data and documents obtained will provide information useful for this study. Identification was made of the potting compounds that degrade with age, temperature and humidity. "O" rings have been extended in 1 year increments up to 10 years shelf life. An active testing program is utilized to extend shelf life.

SURVEY TRIP REPORT II-13
SAN ANTONIO AIR MATERIEL AREA
KELLY AIR FORCE BASE, TEXAS
24 January 1969

1. Persons Making Trip

W. B. Gizzie	MMC Logistics
M. G. Mueller, Jr.	MMC Systems Engineering
A. C. Banning	MMC Omaha District Office
R. L. Graham	NASA R-QUAL-QR
W. H. Johnson	NASA S-II Stage Office
A. F. Kluever	NASA LVGSE Logistics

2. Persons Visited

Charles Mosely	SANEW Deputy Chief
John Taylor	SANEAD Aero Engr.
Monte Autry	SANEPR Propulsion
1/Lt. B. Motonaga	SANEMB Mechanical
Ray S. Martinez	SAMQQC Chemist
Charles D. Elliott	SANEEE Batteries
1/Lt. Wm. S. Files, Jr.	SANEEM Electronics
John Pruett	SANEEM Electrical
Eddie J. French	SAOQT Chemist
Oscar H. Martinez	SANEMS Mechanical
Lt. Robert P. Oates	SANETP Materials
Raul S. Saenz	SANEMM Mechanical
M. H. Steiner, Sr.	SANVTA Equipment Specialist

3. Purpose of Visit

The purpose of this visit was to discuss component age limits and aging surveillance testing of systems under SAAMA jurisdiction including aircraft components, re-entry vehicle components, and batteries.

4. Discussion

A. Batteries

Thermal batteries have had storage life extended from three years to as much as seven years.

Titan II batteries (silver zinc, automatic activation, Yardney Electric) have been extended from three years to four years. Test data has revealed no failures, based on the load profile used, on batteries to 66 months old.

Falcon batteries (silver zinc) have been extended from three years to four years for batteries from two suppliers and 3-1/2 years for those from a third supplier.

Degradation is due to chemical change in plates. It is affected by time and temperature. Maximum storage temperature is 70°F.

Degradation rates are not significantly different between automatically activated (sealed) batteries and manually activated batteries.

Effects of degradation can only be determined by test of aged battery to specific load profile.

B. Fluids and Lubricants

In 5606 type hydraulic fluids the viscosity improver additive begins to precipitate out after about two years in storage. This is easily identified by a viscosity check of a sample of the fluid. For fluid stored in a closed system, remixing is possible by exercise of the system, except in areas of low fluid velocity such as reservoirs and accumulators.

Flourocarbon greases are very stable with age. Ordinary greases tend to separate during storage, especially with higher temperature cycling.

Molycoat L (gimbal bearing lubricant) tends to become corrosive after more than twelve months and must be flushed out and replaced.

C. Electrical/Electronic Equipment

A basic go-no go functional test is used to extend life of electrical/electronic subassemblies. Storage is in a warehouse environment in sealed containers.

Deterioration of a silastic potting compound (Dow Corning S651) caused malfunction of an altitude pressure switch. Aging of the silastic was the cause of deterioration. Average time to operation outside specified limit was 20 months. Substitution on S6505 provided longer life up to about 60 months. A copy of the test report was obtained from SAAMA.

SAAMA personnel also mentioned the connector potting compound problem reported at McDonnell and OCAMA meetings.

A magnetic latching relay anomaly was reported, however they feel that a manufacturing defect is responsible rather than age.

No data has been gathered on change of relay contact resistance with storage age.

Solenoids to about seven years old have been tested with no failures attributed to aging. Insulation resistance was still good with no serious downtrend noted.

D. Bonding Materials

Epoxy bonding materials used at SAAMA usually have a one year shelf life. After fabrication Shell Epon 931 and Epoxylite 5403 have shown tendencies to crack or debond after 3 to 4 years in dormant mode. Ablative materials have shown similar trends.

Honeycomb bonding problems nearly always relate to temperature cycling, high humidity, or fabrication problems.

E. Mechanical Equipment

Mechanical component experience is principally with fuel systems (JP and RP fuels, and aromatic fuels). Principal cause of age degradation is rubber goods. Components including O-rings and diaphragms installed in 1200 fuel pumps have been in storage as long as 13 years, then put in service after a spot check of rubber goods. No failure due to rubber goods has been reported after four to five years in operation.

O-ring shelf life ranges from 5 to 9 years depending on the compound and vendor. All O-rings are sealed in opaque packages. Light is a detrimental factor in aging process.

No limit is applied to storage of components or use of components based on the age of the installed rubber goods.

Component operating time limits are often converted to calendar age limits by estimating average use per day. A study of Air Force Technical Orders defining overhaul, refurbish, or retest time period must be accomplished with this factor in mind.

Teflon lined flexible hoses have a 48 to 60 month storage life, with no limit imposed after installation. Working pressure is usually 3000 psi.

Operating life limits of various components have been extended as the result of inspections or test programs.

5. Documents Obtained

A. Report of Aging surveillance test of Pressure Lockout Switch, 1-1688, Avco.

6. Action Items

A. Obtain copy of report AFML-TR-67-235: Literature Survey of the Effects of Long-Term Shelf Aging on Elastomeric Materials.

B. Obtain copy of Report 92-20, Rubber Laboratory, San Francisco Bay Naval Shipyard: Effects of Shelf Aging on MIL-P-5516 O-rings.

7. Summary

Useful data was obtained in several component categories of interest to this study.

SURVEY TRIP REPORT II-14
THE BOEING COMPANY
MISSILE & INFORMATION SYSTEMS DIVISION
SEATTLE, WASHINGTON

28 January 1969

1. Persons Making Trip

L. W. Tipton	Martin Marietta Corporation, Systems Engineering
J. C. DuBuisson	Martin Marietta Corporation, Reliability
K. E. Riggs	NASA-R-TEST-ST

2. Persons Visited

D. Martin	Ordnance
R. Beebe	Ordnance
O. Bennett	Reliability
F. Robert	Reliability
R. Frank	Reliability

3. Purpose of Visit

The purpose of the visit was to discuss sundry aerospace components which have limited life due to calendar aging or operation and to explore ways and means of extending their lives. Propellants and ordnance devices were of particular interest.

4. Discussion

The separation ordnance of Minuteman has a demonstrated combined storage and service life of nine years. It is composed of a RDX-Lead Azide mix. Boeing and North American Rockwell data indicates an eight year life for battery squibs.

It is believed that the solid propellant motor of the Minuteman's first stage may never achieve the nine year life of the separation ordnance since the propellant is failing in tension and internal cracks are appearing. However, 25 or 26 cracked first stage motors on the "A" program were test fired satisfactorily at the Ogden Air Materiel Area. The first stage propellant used a star grain configuration. The second stage motor may be more susceptible to cracks since it doesn't use the star grain configuration. The motors are packaged under Class C of standard USAF ordnance packing specifications. Mr. Joe Barrett at Ogden AMA should have more Minuteman life and failure data. (Mr. Barrett will be contacted during the visit to OOAMA.

4. Discussion - Continued

A data survey indicates that linear charges of RDX-Lead Azide have a 15 year life. Boeing uses metal-to-glass seals and performs 100% leak tests. Epoxy is not considered very satisfactory. Soldering creates problems requiring special handling and process control. Aluminum is recommended as the tamper material for linear shaped charges; lead tends to change shape with temperature and load variations.

Ordnance circuits are automatically checked prior to sending to the field and after a field test shows a missile malfunction. Those components out of specification are refurbished. No evidence exists that age has been a cause of failure. The failure rate has been a random 4% per recycle. No deterioration of O-rings used in static applications was found.

The operational characteristics of 1000 electronic components five years old were compared to those measured when the identical components were new. Based upon extrapolation of drift parameters, the lives of the parts were estimated to be from 15 to 20 years, assuming a linear relationship. The drawer from which these parts were taken was in continual use at 50% of rated power, 50-55°F and a RH of 60% maximum. They were subjected to very little ON and OFF cycling. Components included transistors, diodes, resistors and capacitors.

In addition, other experience indicates that (1) relay contacts degrade with time, (2) brush resistance varies with age, (3) timing controls change with age, and (4) the integrity of a hermatic seal is an indication of the condition of the parts encased.

The Boeing packaging requirements are established piece by piece by contractual specifications. The levels A, B and C of MIL-P-116 are defined in Boeing Specification SC-25-27621-101. Class A is dry pack in cans. Boeing relies on packaging rather than environmental storage controls for product protection. However, the motors are stored at 45% maximum RH and temperature controlled.

The general answers to Question 6 of the questionnaire were:

a. Lives of similar components considered the same only if exactly similar.

b. Life of a material can be estimated by analysis.

c. Radiographic inspection not useful for providing life extension data for linear shaped charges. It is better to buy extra ordnance devices for destructive testing.

4. Discussion - Continued

   d. Retest is used to justify life extension.

   e. Refurbishment is used to extend life.

5. Documents Obtained

   None

6. Action Items

   Obtain a copy of "Age/Wearout Evaluation of Electronics Equipment", SR-2-6522-001, dated 10 January 1969, from Mr. L. D. Alford, Minuteman Program Manager, P. O. Box 3985, Seattle, Washington, 19824.

7. Summary

   Useful data was obtained upon which shelf life decisions can be made.

SURVEY TRIP REPORT II-15
LOCKHEED MISSILE AND SPACE COMPANY
P. O. BOX 504
SUNNYVALE, CALIFORNIA 94088
28 January 1969

1. Persons Making Trip

K. E. Riggs	NASA/MSFC R-TEST-ST
R. McCoy	NASA/MSFC I-Y-E
J. C. DuBuisson	MMC - Reliability
L. W. Tipton	MMC - Systems Engineering

2. Persons Visited

W. L. Hurd	LMSC SSD Product Assurance Manager
L. Finch	LMSC SSD Reliability
D. Mazenko	LMSC SSD Reliability
C. Leake	LMSC SSD Reliability
J. H. Teske	LMSC SSD Product Assurance
A. S. Fallon	LMSC Polaris Reliability Manager
E. G. Bentley	LMSC Polaris Operational Reliability
L. H. Britton	LMSC Polaris Reliability
H. C. Custer	LMSC Electronic Reliability
W. Malaun	NPRO SPL443

3. Purpose of Visit

The purpose of this visit was to identify and discuss various missile and spacecraft components which have a limited life due to calendar aging or operation and explore methods of extending this life.

4. Discussion

Lockheed Process Specification No. LAC 3900B, Limited Calendar Life Materials, Control of, lists the calendar life of material used at LMSC. In addition to the specification number and title, it lists the following acceptable time spans:

a. Date of manufacture to date of receipt by LMSC.
b. Date of manufacture to date of assembly.
c. Date of receipt to date of assembly.
d. Date of assembly to date of assembly life expiration.

This document also lists the storage temperature for each material. In the event that the calendar life of the material is exceeded, there are provisions in this specification for extending life. Generally this is done by retesting the overage lot, and if it passes the test, the life is extended by 25% of the original spec life. There is no limit placed on the number of retests.

The Space Systems Division (SSD) of LMSC has been faced with extending the calendar life of components in the Agena system. A screening committee has been set up to direct and monitor this function by LMSC SSD Policy Directive No. P-47. In addition to the age and operating time function, this committee monitors other parameters that impact the reliability of the system, e.g., failures, excessive rework. The screening committee has the following members:

a. Product Assurance Program Representative (Chairman)
b. Program Chief Systems Engineer
c. Program Reliability
d. Responsible Equipment Engineer
e. Customer Representative, if required

Equipment to be screened is determined by SSD reliability or the program office. This committee then assigns to the responsible equipment engineer the task of preparing a plan for extending shelf life. This plan is reviewed and approved by the screening committee and based on the results of the actions involved, a decision is made on shelf life extension.

In order to better understand this process an ongoing action to extend the shelf life of the Horizon Sensor System was discussed. This system has a spec shelf life of 36 months. At present there are on hand 33 of these units, 26 of which have accrued 28 months or more of calendar life. It is expected that 14 units will be over 36 months old at their predicted use date. In order to extend calendar life, the following function will be performed on one system which is at present over 40 months old (oldest available).

a. Open mixer box for visual inspection.
b. Measure head pressure.
c. Perform evaluation test to the original qualification level to include:

    1) Thermal vacuum, both high and low temperature
    2) Vibration
    3) Shock

d. Parameter verification and visual inspection
e. Complete tear down and destructive inspection

Based on the successful completion of this evaluation, a functional test requirement for the rest of the systems will be established and the shelf life will be extended to 60 months.

The shelf life of the velocity meters has recently been extended from 36 to 60 months using a similar technique.

The Polaris weapon system life is considered to be completely open ended with no age limitations imposed at present. This system was originally designed for a five year life. After it had been deployed for about four years, it became obvious that steps would have to be taken to maintain confidence in the system. For this reason, a Service Life Evaluation Program was established consisting of the following steps.

a. Approximately 50% of the entire fleet of missiles are removed from the submarines every year. These missiles receive a functional check prior to removal and are then taken to a Naval depot facility where the functional test is repeated. After this, the missiles are broken down into their major components and these components are tested to assure that they are still operating within spec limits. All components that satisfactorily pass these tests are held in stock until required to build up a new missile. Results of this testing are sent to LMSC. Where appropriate, components that are out of spec are sent to LMSC for failure analysis.

b. Twelve missiles per year are removed from the active fleet and returned to LMSC for more complete testing to the component level.

c. Two to four missiles per year from the active fleet are returned to LMSC for complete analytical tear down and where necessary, destructive testing.

d. One shot items, e.g., ordnance and batteries are sampled every year and results of their tests are compared to the acceptance test data.

All of these data are collected and evaluated at LMSC and become the basis for identifying any action required to maintain confidence in mission success.

Due to fund reduction, it is becoming necessary to change the Service Life Evaluation Program. The new program will continue the testing of 50% of the fleet by Naval depots, but the test equipment at the locations is being modified to record the parameters measured on magnetic tape that is compatible with LMSC computers so that the data can be monitored mechanically for discrepancies and trends. The program of sampling and expending one shot items will be continued and LMSC intends to run tests on all components that are returned to them for repair to measure degradation.

It is interesting to note that elastomeric O-rings are never changed in Polaris components unless the rings fail or are exposed during a disassembly operation.

5. Documents Obtained

a. Shelf Life Evaluation Plan, Horizon Sensor System

b. SSD Policy Directive No. P-47, Special Screening Action - SSD Mission Critical Flight Hardware

6. Action Items - None

7. Summary

Techniques used to extend shelf life on SSD hardware and maintain confidence with time in the Polaris system were discussed.

SURVEY TRIP REPORT II-16
SACRAMENTO AIR MATERIEL AREA
MC CLELLAND AIR FORCE BASE
CALIFORNIA
30 January 1969

1. Persons Making Trip

K. E. Riggs	NASA/MSFC R-TEST-ST
R. D. McCoy	NASA/MSFC I-V-E
W. H. Johnson	NASA/MSFC
J. C. DuBuisson	MMC Reliability
L. W. Tipton	MMC Systems Engineering

2. Persons Visited

E. H. Dodge	SMNEMP
Capt. H. E. Webster III	SMNEMP
M. Alonso	SMNCTB
R. K. Donohoo	SMNCTB
G. W. Hostetler	SMNCTB-1
T. Goodman	SMNCTV
L. McCurdy	SMNCTB

3. Purpose of Trip

The purpose of this visit was to discuss various missile components which have a limited life due to calendar aging or operation and explore methods of extending this life.

4. Discussion

The discussion at Sacramento Air Materiel Area (SCAMA) primarily concerned the Thor system which is the responsibility of this Air Materiel Area (AMA).

A Service Life Analysis Program (SLAP) has been run on these engines in an effort to extend the period between overhauls. Three vernier engines and four main engines were involved in this program with the following ages:

Engine Serial No.	Built	Overhauled
Main		
4221	1958	1962
4304	1959	No
4104	1958	1962
4292	1959	No
Vernier		
4232	1959	No
4406	1959	No
4334	1959	1962

Main engines 4221 and 4304 and vernier engines 4406 and 4334 were sent to Rocketdyne, instrumented and hot fired. After the hot firings, they were disassembled and major components were tested. Then there was a complete tear down and all parts were examined for degradation. There was no significant change in the parameters measured during hot firing from those measured in the hot firing after original build or overhaul.

Main engines 4104 and 4292 and vernier engine 4232 were leak and functional checked then disassembled to the component level. Components were tested then completely torn down and inspected.

Based on this program, the overhaul period on these engines has been extended from 48 to 96 months. Complete results of this program are in a report entitled "Thor MB3 Missile Propulsion System, Service Life Analysis" prepared by and available at SCAMA.

The soft goods removed from the engines that were not overhauled have been sent to Mr. R. Thornton, NASA/MSFC I-E-H for analysis. It is important that the results of this analysis be included in this study.

SCAMA does not have responsibility for the Atlas engines. Mr. Dodge believes that Space and Missile Systems Organization (SAMSO) is running a program which will include firing and tear down of these engines with a goal of increasing their overhaul period from 52 to 72 months.

Several other significant statements were made about life of the Thor engines.

a. Based on results of the service life analysis and review of other data, the representation period for the Thor engine gear boxes has been extended from two to four years.

b. Pump turbine wheels have a running life of 1200 seconds.

c. It is felt that turbine pumps should be green run after overhaul primarily to catch any errors made in buildup.

d. There is no cycle life imposed on flex lines.

e. Gimbal bearings showed some wear due to excessive operation.

f. Engine wiring harnesses showed no reduction in insulation resistance although there were visible cracks in the cable outer sheath.

g. After eight years of life, some stress corrosion cracking was found in lox regulator caps which are cast from 7075-T6. These were redesigned to increase fillet radii from 0.030" to 0.090" and the surfaces were shot peened to remove surface stresses. With this change incorporated, the units survived 34,000 pressure cycles at ambient. One thousand additional cycles in a salt spray caused surface cracking.

The extension of shelf and operating life of components in the Thor system is part of the responsibility of the "Improved Maintenance Program " (IMP). This program is implemented by a series of annual review meetings attended by representatives from the cognizant AMA and the using agencies and is chaired by the Technical Services group from the AMA. This meeting is controlled by an agenda prepared in advance from inputs from the AMA and using agencies. It is expected that the agenda will be prepared early enough for the responsible agency to prepare an approach for solving each problem on the agenda to present at the IMP meeting. This group acts on each problem. The results of these actions are recorded in the IMP review minutes which, after being signed by representatives of all agencies, become binding.

Three cases of components whose life had been extended were mentioned.

a. The fuel tank vent valve life was extended from 24 to 48 months. In this case, failure history was reviewed and one valve was disassembled and analyzed by the service engineering group at SCAMA.

b. The life of the linear actuators was extended from 36 to 48 months installed in the missile based on review of failure history alone. This actuator also has a shelf life of 36 months prior to installation.

c. The flight controller had a time change requirement at 42 months at which time it was disassembled, refurbished and reacceptance tested. Based on a review of failure history, it was decided to remove the time change requirement but recertify, by test, these units every 30 months.

In every case involving the extension of life it has been the assigned responsibility of the service engineering group at SCAMA to plan and implement this task and sell the results to the IMP review.

Several other items of interest were mentioned.

a. Rate gyros are overhauled by the vendor every 60 months.

b. Shelf life of O-rings is held to 60 months before installation.

c. Shelf life of tantalum capacitors varies from 12 to 36 months. This is based on recommendations by Western Electric.

d. The missile storage warehouses at San Barnardino AFB now have conditioning equipment installed that holds the humidity below 40%. This has made it possible to extend the interval between corrosion inspections on the Thor from 30 to 90 days.

e. There is no record of lubricants time limiting components.

5. <u>Documents Obtained</u> - None

6. <u>Action Items</u>

a. Mr. Riggs will get the results of test on O-rings removed from a nine year old Thor engine from Mr. R. Thornton, NASA/MSFC I-E-H.

b. MMC will follow up on obtaining a copy of the service life report on Thor engines from Capt. H. E. Webster, SMNEMP.

7. <u>Summary</u>

Data were obtained on service life, problems in the Thor systems and techniques used to solve these problems.

SURVEY TRIP REPORT II-17
AEROJET-GENERAL CORPORATION
SACRAMENTO, CALIFORNIA

31 January 1969

1. Persons Making Trip

L. W. Tipton	Martin Marietta Corporation - Systems Engineering
J. C. DuBuisson	Martin Marietta Corporation - Reliability
K. E. Riggs	NASA-R-TEST-ST
R. W. McCoy	NASA-I-V-E

2. Persons Visited

H. K. Fong	Aerojet-General - Engr. Mgr., Titan Weapon Systems
G. Miller	Aerojet-General - Engineering
R. M. Lydon	Aerojet-General - Materials Engineering
D. Mayfield	Aerojet-General - Engineering

3. Purpose of Visit

The purpose of the visit was to discuss propulsion system components which have limited life due to calendar aging or operation and to explore ways and means of extending their lives.

4. Discussion

Although there is no scheduled overhaul of Titan II engines, two engines are torn down and analyzed each year. The disassembly is usually after an engine run. Some random overhaul data is also available. The only age limiting components are soft goods. No cyclic limits have been encountered; firing and running times are always recorded.

A few non-critical discrepancies have been found such as:

a. Some corrosion of the shaft and bearings of the turbine pump plus foreign matter in the gear box. Aerojet-General doesn't run preservative through the gear box, but relies upon the wet sump lubricating during engine run.

b. Turbine cracks.

c. A little corrosion of the needle bearing race of the gimbal assembly. No problem.

The Titan II engine valves are functioned once a year to prevent sticking seats. Difficulty has been experienced with cleaning the valves with alcohol after actuation; a residue remains that supports corrosion.

4. Discussion - Continued

Kel-F and Nylon seals are used in the oxidizer and fuel systems respectively. The polymer seal lives are limited to 48 months in the fuel system and to 36 months in the oxidizer system. The 48 month limit is slightly conservative to allow for stress corrosion effects. No springs have failed; the old springs are used during rebuilding. Some cadmium plate has come off of the springs.

In 1957, Aerojet-General tested 1500 elastomers by immersing in fuel for one year. The more promising elastomers were immersed for three years. Thirty-four seal characteristics were recorded.

During the R&D stage, the selected O-ring materials were tested before and after exposure to 75 ± 5°F for 365 days and 160 ± 5°F for 90 days. Extrapolation of age limiting parameters indicated a five year or more life. The R&D data has been compared to that of 2315 O-rings removed from engines that have been in service. Some O-rings were approaching 72 months service. Total assembled time, time on engine, and silo age were known for these O-rings. Reports are available concerning the O-ring tests.

5. Documents Obtained

None

6. Action Items

a. Obtain through Ogden AMA; "Titan II Augmented Long Term Readiness Evaluation Program, Soft Goods Analysis Report", IR-TA-2575-I/M, Parts I and II, Vol. II, Aerojet-General, July 1968

b. Obtain Reliability Presentation Viewgraphs from Mr. Fong.

7. Summary

The data on O-ring aging may be beneficial in setting age limits.

SURVEY TRIP REPORT II-18

Honeywell Inc.
Aeronautical Division
Minneapolis Minnesota

10 February 1969

1. Persons Making Trip

William B. Gizzie	MMC	Logistics
Mark G. Mueller, Jr.	MMC	Systems Engineering
Heinz W. Kampmeier	NASA/MSFC	R-ASTR-BV
Joe A. Moore	NASA/MSFC	I-V-SIVB

2. Persons Visited

J. C. Sindt	Honeywell	Reliability & Maintainability
R. E. Myers	Honeywell	Reliability
D. J. Behun	Honeywell	Reliability
C. B. Hodge	Honeywell	Reliability
E. L. Lippo	Honeywell	Design
T. E. Scarlett	Honeywell	Reliability
E. W. Soronen	Honeywell	CA&S
T. P. Young	Honeywell	Reliability

3. Purpose of Visit

To discuss shelf life and life limitations imposed on guidance type components and to review the program currently in progress to extend the life limits for the Apollo Stabilization Control System.

4. Discussion

During this meeting discussions covered components in the electromechanical and electronic categories as utilized in guidance equipment.

A. Gyros - Gyro spin motors utilizing ball bearings have an operating life limit of 4000 hours. This limit is based on test data (94 units tested to failure) which demonstrates an increasing failure rate for units operated beyond 4000 hours. The only item of concern is the ball bearings. Units in storage longer than two years would require relubrication (by the manufacturer). Relubrication was recommended at 2 year intervals, however, it was admitted that with an optimum storage environment lubrication only upon removal from storage would probably be satisfactory. Versalube F-50 is utilized. Gyro float fluid involving bromine or chlorine has been found to degrade and cause contamination or corrosion. Flourinated fluids are recommended for best storage life. Gyro drift is the parameter which is most often out of tolerance following storage. Minor non-conformances can often be corrected by a run-in period (15 to 30 minutes) following storage.

Hermetically sealed units have a better shelf life capability than other types.

For units which require that the float fluid be maintained at 140°, heater runaway is a hazard which can cause high internal pressure and resultant case leakage.

In air bearing gyros, high starting torque may cause failure or non-conforming operation following storage. This phenomenon may be the result of metal migration because of dry metal to metal contact during storage.

Slip ring contact has not been a significant problem, especially when a run-in time is utilized after storage.

B. Electronics - Capacitors and batteries are the only piece parts of significant concern to Honeywell. Wet slug capacitors are not utilized. Data from a series of 2000 hour operating life tests of capacitors was not received in time for our meeting. A copy of the data will be forwarded to us when received by Honeywell.

The battery utilized for the guidance system on the Athena vehicle has a one year storage life. With proper pre-conditioning after activation, a two year storage life is available. The average age of batteries as launched is approximately fifteen months.

C. Apollo SCS Life Extension Program - This study program is intended to provide data for proposed extensions of (1) shelf life from three years to five years and (2) operating life from 1500 hours to 5000 hours for specified components of the Stabilization Control System. Included are gyros, synchros, resolvers, gear trains, displays, stepper switches, and similar components. Operating life studies will include maintenance recommendations to obtain the desired life.

Because the shelf life study results have not been reported to NAR Space Division, and the operating time tests are still in progress, specific data was not discussed. Honeywell agreed to supply us with a copy of the interim report on shelf life results after submittal to NAR - Space Division.

The original shelf life limit of three years was a program limit and not a limit imposed by hardware requirements. The only area of real concern to Honeywell for extending shelf life to five years is bearing lubrication. Other items reviewed and tested have not indicated significant storage degradation.

Analysis was the basic approach used for the shelf life extension with test data support in some areas.

Material basic stability was reviewed and the five year requirement was met in all cases.

D. Miscellaneous - Honeywell opinion is that storage results in reduced operating capability, however, they cannot identify this in terms of reliability degradation. Refurbishment was felt to be a valid concept for extending life, but has not been required for Apollo hardware.

Dry lubricants are used by Honeywell in some sliding metal to metal situations. No degradation or corrosion has been identified as a result of using this type of lubricant.

Magnetic fields are not a degrading factor in any of the hardware discussed.

5. Documents Obtained

A. Advanced Orbiting Solar Observatory - Fine Wedge Test History; C. B. Hodge, Honeywell, Inc. 15 December 1965.

B. Summary Sheets - Five Year Life Test Program on Charged Capacitors; E. L. Ford, Sandia, 12 August 1968, IDEP 153.00.00.00-60-01.

C. Notes and miscellaneous data on guidance equipment life tests.

6. Action Items

A. MMC to obtain a copy of the Interim Report from Honeywell to NAR Space Division concerning shelf life extension of Apollo SCS components when available (approximately April 1969).

B. Honeywell to furnish additional information on capacitor life limitations.

C. Honeywell to furnish a copy of Hughes Aircraft Co. report on lubrication.

7. Summary

In guidance type equipment supplied by Honeywell the principle storage degradation factor is bearing lubrication. Programs to extend hardware life are based on analysis and supported by test data. Refurbishment is also considered to be a valid concept. Upon removal from storage, a run-in period is recommended prior to taking required test data.

SURVEY TRIP REPORT II-19
AC ELECTRONICS DIVISION
GENERAL MOTORS CORPORATION
MILWAUKEE, WISCONSIN

11 February 1969

1. Persons Making Trip

M. G. Mueller, Jr.	Martin Marietta Corporation - Systems Engrg.
W. B. Gizzie	Martin Marietta Corporation - Logistics
H. W. Kampmeier	NASA/MSFC R-ASTR-BV
J. A. Moore	NASA/MSFC I-V-SIV-B

2. Persons Visited

M. Alexander	AC Electronics - Systems Engineering
J. H. Hall	AC Electronics - Maintenance Engineering

3. Purpose of Visit

To identify and discuss various components which have a limited life due to calendar aging or operation and explore methods of extending this life.

4. Discussion

Terminology was discussed and AC Electronics' definitions for the following terms were obtained:

Calendar Life - The maximum period of time from date of acceptance at the contractor's facility that an item can retain its desired performance characteristics, before being reconditioned or condemned - whether the item is installed, either operating or not operating, or in storage. On the form, the specific limit is to be recorded under "Limit". The conditions under which the limit applies are to be given under "Remarks". These specific limits are engineering estimates based on the operating life and shelf life data in the CIL.

Shelf Life - The maximum period of time from date of acceptance at the contractor's facility, during which the item remains unused in storage, that the item can retain its desired performance characteristics before being reconditioned or condemned. The values recorded on the forms are engineering estimates based on Technical Report No. RADC-TR-66-348 (RADC-TR-66-348, October 1966, "Dormant Operating and Storage Effects on Electronic Equipment and Part Reliability") and AC experience.

4. Discussion - Continued

Time/Cycle Sensitive (TC) - An item which has a significant degradation mode or demonstrated failure rate such that the event (performance outside the maximum acceptable degradation limits) can be predicted as a function of operating life or calendar life.

All of ACE's T-III parts are stored in bonded storage areas within the plant. SAMSO has removed all shelf life requirements from these components.

Some factors influencing and improving shelf life are a screening process for electrical components, use of high quality lubricants, de-rating the design, and preferred packaging (sealed moisture proof containers and desiccants).

Wet capacitors have been eliminated from T-III components. Generally ACE uses 10 years normal life and 12 years absolute maximum recertification for their electronic components. They have experienced no problems identified as the result of very low humidity on electronic components during storage. Contamination introduced during process- and manufacturing of components is known to have resulted in reduced life. Bubbles in rubber shock mounts were cited as an example as well as solvents and cleaners on electronic equipment. Nylon insulation on wiring experienced accelerated aging when subjected to $140 \pm 5°$ F toast temperature. Out of 26 IMU 2 electrical harnesses required replacement due to insulation degradation.

Very few corrosion problems have been experienced by AC due to materials used, e.g., gold plated IMU housing and passivated steels. Bearings lubricated with grease are stored 3 years, 2 years if lubricated with oil, before being relubricated. Gyros are operated until they go bad. Use of TCP on bearings increases bearing performance and results in higher yield rates. Stratification of fluid in floated instruments does occur and can result in degradation of performance. The light source in IMU is good for 6600 hours minimum and was extended by de-rating and changing design. It is no problem and storage has no effect. Storing of FC-75 presented the problem of rusted containers returned from England but the fluid stored within a plastic liner in the containers met all specifications upon testing. The fluid is hygroscopic and is reclaimed by distillation but presents no problem when stored in sealed containers.

The AFTO system is used to control and track operating time and spares information. Elapsed time indicators on the equipment are used to record operating time. The people who operate the equipment record the time and are monitored by Quality Control. Spares information is maintained by serial number on the stock record sheet and automated tracking control by computer. Manual tracking would be used for a small quantity of spares.

5. Documents Obtained

   a. A Proposed Spares Shelf Life Implementation Program for T-III Mol Booster Inertial Guidance System, 12 December 1967.

   b. Copy of Terminology Definitions

6. Action Items

   Consider contacting NAR Autonetics concerning gas bearings.

7. Summary

   The discussion provided useful information concerning ACE's experiences with their components and equipment. The documents obtained contain useful information for comparison with other programs.

SURVEY TRIP REPORT II-20
VICKERS, INCORPORATED
DIVISION OF SPERRY RAND CORPORATION
TROY, MICHIGAN

11 FEBRUARY 1969

1. Persons Making Trip

William B. Gizzie	Martin Marietta Corporation - Logistics
Mark G. Mueller, Jr.	Martin Marietta Corporation - Systems Engrg.
Heinz W. Kampmeier	NASA/MSFC R-ASTR-BV
Joe A. Moore	NASA/MSFC I-V-SIV-B

2. Persons Visited

Bob Murray	Vickers - Aerospace Service Dept.
Bob Egge	Engineering Manager
Joe Jaskolski	Military Support Manager
Art Lang	Engineering Standards
Dick Leslie	Manager, R&D Chem. Lab.
Pete Mandalis	Quality Assurance
Ted Zajac	Quality Assurance

3. Purpose of Visit

To discuss shelf life and operating life limitations and recertification methods for hydraulic system components.

4. Discussion

The principle factor in assignment of life limits to hydraulic pumps and related components of a hydraulic system is O-ring life limits. Usually the life limit assigned to synthetic rubber goods of the types compatible with MIL-H-5606 and MIL-H-6083 is in accordance with requirements stated by the ultimate user or buyer of the component.

Vickers has conducted several investigations involving hydraulic equipment which has lain unused for many years. These include recovered components from B-24 "Lady Be Good" after 17 years in the African desert, B-17 "My Gal Sal" after 24 years on the Greenland ice cap, and two aircraft after 6 and 24 years respectively in the Panamanian jungle.

4. Discussion (Continued)

As one result of these investigations Vickers feels that current O-ring life limits are too restrictive. Nitrile rubber compounds have been very long lived when protected from ozone and sunlight. Vickers also feels that systems or compounds should not be disassembled for O-ring replacement following storage unless leakage is found during retest.

Components and systems should be stored filled with 6083 oil. 5606 oil may be used in systems in storage providing that the moisture content is in the lower portion of the allowable range, and that the system is tight. It was suggested that we obtain O-ring life data from one of the commercial airlines using the Electra aircraft which uses MIL-H-5606 type fluid.

No significant degradation has occurred in Vickers equipment as a result of:

(a) Relaxation of springs during storage.

(b) Stress corrosion (although some susceptible materials have been used).

(c) Aging of the lubricant in shaft couplings, although a check of the coupling is recommended upon removal from storage.

The electric motors used with hydraulic pumps for space applications have operating limits to avoid excess temperature in the insulating materials. One storage problem has been encountered in Saturn motor pumps - the motor housings have exhibited minor corrosion due to moisture accumulation and retention. The housing has been modified to provide purge fittings for drying the inside of the housing prior to storage. Units should be purged prior to storage and inspected following storage.

Vickers engineers were of the opinion that periodic exercise of hydraulic equipment during storage is beneficial. The amount of exercise recommended was only that required to change relative positions of parts in mechanical components. They did recognize, however, that human activity in accomplishing the exercise could cause equipment damage or degradation.

Among their design practices, the following were cited as contributing to long life equipment:

4. Discussion (Continued)

a. Use O-rings only in compression. (Some rubber chemists believe that rubber under compression may last up to 100 times longer than in its ambient state)

b. Use back-up rings to prevent O-ring extrusion at high pressures.

c. Use MIL specification practices.

Vickers does not feel that operating time capability is reduced by storage.

5. Documents Obtained

A. Aircraft Component Longevity (A Study of B-24 "Lady Be Good" Aircraft Hydraulic Equipment After 17 Years in the African Desert); A. B. Billet

B. First Progress Report on Investigation of Hydraulic Equipment Removed from B-24-D "Lady Be Good" Aircraft; G. R. Blaske and D. J. Burkhavdt, 9-7-60

C. Tale of a Frozen Lady (Hydraulic System Studies of B-17 "My Gal Sal" After 23 Years in Arctic Environment) A. B. Billet

D. Jungle Explorations of World War II Aircraft; A. B. Billet

E. Excerpts from Unconfirmed Minutes Combined Meeting No. 60 of SAE Committee A-6, Aerospace Fluid Power Technologies of the SAE Aerospace Equipment Division with Hydraulic Engineers of Industry and Government, Mar. 28-31, 1966.

6. Action Items

A. Martin Marietta Corporation to contact Mr. Ben Mettee during visit to Navy Aviation Command Offices for pneumatic/hydraulic system information.

B. Martin Marietta Corporation to consider contact with American Airlines maintenance base to discuss experience with hydraulic system of Electra aircraft (which uses MIL-H-5606 hydraulic fluid).

C. Martin Marietta Corporation to obtain copy of AFML-TR-66-275. Report covering equipment recovered from B-17 "My Gal Sal".

7. Summary

In hydraulic pumps and related equipment, O-ring life limits are the principle factor in component calendar life limits. For booster vehicle equipment the principle operating time or cycle limit is related to the electric motor and not the mechanical equipment. Vickers test programs indicate that O-ring life limits are still very conservative. They feel that O-rings should not be arbitrarily changed if the life limit is exceeded during storage; replacement should be made only to correct leakage found during retest.

SURVEY TRIP REPORT II-21

Moog, Incorporated
East Aurora, New York

13 February 1969

1. Persons Making Trip

Mark G. Mueller, Jr.	MMC	Systems Engineering
William B. Gizzie	MMC	Logistics
Heinz W. Kampmeier	NASA/MSFC	R-ASTR-BV
Joe A. Moore	NASA/MSFC	I-V-S IV B

2. Persons Visited

R. J. Newhard	Moog	Quality
H. L. Steck	Moog	Program Manager
L. J. Williams	Moog	Engineering
D. R. Zook	MMC	Quality (Moog Rep.)
D. C. Dillon	MMC	Engineering (Moog Rep.)

3. Purpose of Visit

To discuss storability and life limits of hydraulic servo-actuators of the types used on the Saturn vehicle.

4. Discussion

Moog has experienced very few problems with "O" rings in hydraulic fluid except under high temperature conditions. Buna N seals are used with 5606 and 6083 fluids. Valves for Martin are flushed and filled with 6083 before leaving the plant. Saturn actuators are filled with oil prior to delivery and shipment. Moog can foresee no problem with O rings installed and stored at 90^{o}F upper limit. Their experience has indicated that components in storage should be left alone. Servo valves unoperated and stored in an uncontrolled environment for 4-1/2 years performed as well as valves operated every 30 days. Servo valves are designed such that they have no limited life cycle. Valve life is determined by fluid errosion not wear or sliding wear of parts. Torque motor operation changes occur with time, cycle and temperature resulting in a null shift. Servo valves should not be stored in high EMI areas. Temperature has the most effect on null band shift. Actuators are qualification tested for 2 million cycles at 1/3 stroke. Seal leakage is the biggest problem. The Gemini program is the only known program where cycle life was recorded for actuators.

Stress corrosion is a problem to cope with and is being controlled or eliminated by proper design, selection of basic material and by paying particular attention to exposed areas and plug areas. It is Moog's opinion that refurbish to replace O rings only results in more damage than leaving O-rings alone, especially to press fit parts. Problems encountered with electrical components have not been related to age.

Rubber goods age is monitored and controlled by Production Control. On military programs rubber not installed by the 7th quarter is thrown away. On NASA equipment rubber up to 8 quarters old can be installed.

5. Documents Obtained

a. Moog Procedure 812-003-100, Control for Synthetic Rubber Components, Rev. A, 10/23/68 and Supplement #1, Rev. A, 10/20/68.

6. Action Items

None

7. Summary

Moog's experience indicates that installed O ring life is no problem and that many unnecessary O ring changes are made because of unrealistic specification requirements resulting in more handling damage. Servo valves are not cycle life limited. The problems encountered with electrical components have not been related to age.

SURVEY TRIP REPORT 11-22
THE GENERAL ELECTRIC COMPANY
MISSILE & SPACE DIVISION
VALLEY FORGE, PENNSYLVANIA

17 February 1969

1. Persons Making Trip

L. W. Tipton	MMC, Systems Engineering
J. C. DuBuisson	MMC, Reliability

2. Persons Visited

C. A. Locurto	G. E., Mgr., Aging & Surveyance Dept.
T. D. Price	G. E., Mk 6 Program Office
R. I. Swan	G. E., Mk 12 Program Office

3. Purpose of Trip

The purpose of the visit was to discuss sundry aerospace components which have limited life due to calendar aging or operation and to explore ways and means of extending their lives.

4. Discussion

Essentially a three step approach to either extending allowable age/operational limits or insuring reliability under present limits was suggested. First, an Aging Modes and Effects Analysis (AMEA) should be performed to ascertain what is age (or cycle) critical. An AMEA should be required prior to design release to determine what items in a component are age critical and their life limitations. Modification of the design is required if calendar or cyclic life does not meet minimum specifications. Experienced chemists, physicists or material engineers should perform the AMEA since the AMEA is performed essentially at the materials level.

Secondly, the designer should include a life analysis, including the AMEA, in his design report submitted to the design review board (DRB). Part of the DRB function should be to insure that life/cycle requirements have been met.

Finally, a properly constituted surveillance program should be implemented to insure that estimated life or cycle limits are being obtained in actual storage or service. Only age sensitive components and their indicative parameters need be monitored if either the AMEA was complete and accurate and/or test/field data backs up the age critical items list. If an AMEA wasn't performed prior to design release, one should be performed sometime to help establigh the age critical list and to determine what parameters to monitor. It is feasible to monitor degradation if one fully knows the component. (It was suggested that NASA might consider an age review board to perform AMEA's.)

In conjunction with the three preceding steps, overall management control of calendar/cylic life may be required. At General Electric's Missile and Space Division, an Integrated Test Program Board (ITPB) is employed to pass on any specification changes including those that affect component/system life. Life is considered a performance parameter. The ITPB is chaired by the program reliability engineer and has members from quality control, engineering, manufacturing, projects, and the customer. The ITPB operates under a written charter; a copy of which will be obtained.

It was stated that accelerated testing has been unduly condemned. The energy level must be high enough to have effect. However, one must thoroughly understand the physics of the material. Accelerated testing at the material level is easiest.

Age limits should not be determined or extended by similarity unless they are almost identical. Concerning ordnance items, calendar lives have been extended using manufacturer's bulk data. Ordnance life extension based on X-raying is not recommended; destructive testing is the only acceptable technique.

The Mk 6 life was set at five calendar years, three years of which can be operational. Refurbishment of timers and batteries is used; however, the test shield life cannot be extended by refurbishment. The five year heat shield life has been extended based on accelerated aging tests and a TRW study. G. E. was not involved in the life extension decision.

Batteries are stored dry until prior to use. A ten-year storage life is under evaluation. USAF will be periodically testing batteries in addition to the "How Now" program.

Electrical disconnects can wear out from remating too many times. Life can be limited by design wearout. Any high voltage switching gear can be cycle sensitive.

5. Document Obtained

None

6. Action Items

Obtain a copy of the ITPB charter.

7. Summary

It was suggested that NASA might set up an aging review board to perform an AMEA to determine age critical items and to integrate aging controls as indicated in the discussion. The cognizant component, system, and stage contractors could supply the necessary data.

SURVEY TRIP REPORT II-23

U.S. NAVAL AVIATION COMMAND
WASHINGTON, D.C.

18 February 1969

1. Persons Making Trip

L. W. Tipton	MMC - Systems Engineering
J. C. Du Buisson	MMC - Reliability
R. Eilerman	NASA -R-P&VE

2. Persons Visited

R. B. Bussler	USNAC - System Effectiveness
F. S. Kirk	USNAC - Quality Assurance
J. Gurtowski	USNAC - Materials Engineering

3. Purpose of Visit

The purpose of the visit was to identify and discuss sundry aircraft components which have a limited life due to calendar aging or operation and to explore methods of extending this life.

4. Discussion

The Naval Aviation Command employes an "open ended" life policy; components/systems are stored or used until surveillance tests indicate that degredation is impending or has occurred. The testing is accomplished by U.S. Navy quality evaluation laboratories. There is no specific management directive on how to establish shelf or operational life. Calendar age or operational lives are established on an individual basis. A component/system may not be loaded aboard ship unless its remaining life exceeds the duration of the ship's mission.

Refurbishment is employed to extend equipment lives. Life limited equipment is refurbished with improved components if possible. No cost effective refurbishment studies have been conducted; their philosophy is "fix-it-now" because they do not know where (what environment) the aircraft will be sent next.

Life saving devices are tested each year and their lives extended for a one year period. Guidance and control equipment have open ended lives; they are tested whenever off loaded. After a service life of about five years, the lives of ordnance devices are usually extended by two or three year periods after passing lot performance tests. Marginal testing is not employed to estimate equipment life. Eighteen (18) months is the longest time allowed between major aircraft overhaul and inspection.

A material accelerated aging program is conducted in parallel with the surveillance program to better estimate age limits of critical materials. The August 1968 issue of Installation Magazine presents a paper on their accelerated aging techniques on polymers.

Data indicates that vibration isolators deteriorate in a relatively short time if constantly loaded and under vibration. The load should be removed from vibration isolators during storage.

It was stated that it is best to leave hydraulic systems alone as long as they function satisfactorily. The USN facility at Seal Beach tests hydraulic fluid samples for specification compliance; contamination is the primary problem area. Tests indicate that Viton B seals do not swell more than 3 to 4% and the maximum compression set is 10%. Buna N has a 6 to 8 year shelf life; they are spot checked at eighteen (18) month intervals. Neoprene presently has not an apparent shelf life limit.

Analyses of lubricants is employed extensively to ascertain if the item being lubricated is deterioriating as indicated by metal chips, etc. The lubricated item is withdrawn from service for inspection if the lubricant analysis is negative. This technique has saved many aircraft engines.

Difficulty has been experienced with polyurethane potting running after about 18 months due to temperature and humidity conditions. A three to five year maximum life has been estimated from accelerated aging tests. Complete degredation accurred at test temperatures of 150°F. Because of hydrolitic instability, degredation has occurred at controlled 75°F and 50% R.H. The USAF is currently replacing all polyurethane potting. This problem area first occurred about 1962. Because some of the potting failures do not appear externally, hypodermic needles are employed to obtain internal samples of the potting material for test.

Additional suggested data sources are:

a. Naval Weapons Center (NWC), China Lake, California, Contact Mr. Crill Maples at 375-1411 extension 9252. NWC is studying the actual environments throughout the world and attempting to correlate the environmental effects upon weapons at one location with those at another.

b. Navy facility at Indian Head. Propellant age limits by components are available from their Solid Propellant Information Analysis (SPIA). Contacts are Dr. Bartoca and Dr. Tuono.

c. Fleet Missile Life Group (FMLG) of the Fleet Missile System Analyses and Evaluation (FMSAE) Unit at Corona, California. They have computerized data for all Navy Missile firings.

5. Documents Obtained

Howard C. Schafer Environmental Criteria Determination For Air-Launched Tactical Propulsion Systems, Part 2. Technical Support for Stockpile- To - Target Sequence, NWC TP 4464, July 1968.

6. Action Items

Obtain a copy of paper on accelerated aging techniques on polymers in Installation Magazine, August 1968.

7. Summary

The U.S. Naval Aviation Command employs surveillance techniques to determine and control age limited equipment.

SURVEY TRIP REPORT II-24
BALLISTIC RESEARCH LABORATORY
U. S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
ABERDEEN, MARYLAND 21105

19 February 1969

1. Persons Making Trip

R. N. Eilerman	NASA/MSFC - R-P&VE
J. C. DuBuisson	Martin Marietta Corporation - Systems Engr.
L. W. Tipton	Martin Marietta Corporation - Systems Engr.

2. Persons Visited

O. D. Bruno	BRL - Surveillance Reliability
P. DeAngelus	BRL - Chemist

3. Purpose of Trip

The purpose of this visit was to discuss methods of measuring the degradation of ordnance components and extending the life of these components.

4. Discussion

The surveillance reliability group at the Ballistics Research Lab (BRL) has the primary responsibility within the Army Ordnance Command for setting up and monitoring surveillance programs for ordnance items. Generally, the life of these items is considered to be open ended and the condition, including any degradation, is monitored by periodically testing representative samples of the total population. No attempt is made to track individual lots or batches. This approach has been used by BRL for twenty-five years and it is felt that it fulfills their needs.

When a system becomes operational a surveillance program is set up

a. Based on specification and supplier's information, an initial life is established. This also establishes the time to start surveillance testing.

b. Provisions are made for a continuing physical properties test program to be run by BRL chemistry lab.

c. The BRL engineering group defines the test program which includes:

sample size
test interval
source of test samples
method of testing
allowable degradation

d. This program is assigned to an arsenal for implementation.

e. Data are gathered from all training firings to include age, range, miss distance, and environment.

f. Electrical and electronic components are tested in the aresenal labs.

g. Results of all of this testing is returned to BRL for evaluation and action as required.

A program of this type is being run on the Honest John missile. This missile started with a projected life of five years. This life has now been extended to twelve years but degradation in ballistic parameters during this time has made it necessary to revise the ballistic firing tables.

Double base propellants have shown no apparent degradation for ten years but at times there seems to be a decrease in specific impulse and heat of explosion and an increase in tensile strength.

Composite propellants (polysulphides) showed no apparent change for ten years but Sargeant rockets twelve years old have shown some changes in ballistic parameters.

Some accelerated aging testing has been done on propellant samples. On polysulphides, it is felt that this will show chemical changes but will provide little information on physical composition. It is felt that it is not possible to meaningfully correlate accelerated aging test results with actual aging.

There has been some work done with Differential Thermal Analysis (DTA) and it is believed that this could be developed into a useful tool for detecting changes in organic compounds. Some DTA testing has been done on synthetic rubber 'O' rings twelve years old. No changes were detected, however, this testing was not followed up by other testing on these 'O' rings.

There has been some degradation to explosive bridge wire units. This was traced to corrosion at the welds due to moisture that leaked in.

5. <u>Documents Obtained</u>

None

6. <u>Action Items</u>

MMC to get from BRL a bibliography of their reports and review for usable data.

7. <u>Summary</u>

The primary effort of this organization has been surveillance testing to identify and evaluate degradation. This technique has proven satisfactory for their requirements.

SURVEY TRIP REPORT II-25
THIOKOL CHEMICAL CORPORATION
ELKTON DIVISION
P. O. BOX 241
ELKTON, MARYLAND 21921

20 February 1969

1. Persons Making Trip

R. N. Eilerman	NASA/MSFC R-P&VE
J. C. DuBuisson	Martin Marietta Corp. - Systems Engr.
L. W. Tipton	Martin Marietta Corp. - Systems Engr.

2. Persons Visited

T. B. Wilson	Thiokol-Program Manager
R. M. Brownell	Thiokol-Chemist
W. G. Andrews	Thiokol-Engineering
R. P. Gallant	Thiokol-Engineering
E. Oostrem	Thiokol-Program Office

3. Purpose of Visit

The purpose of this visit was to discuss the problems encountered with degradation due to aging of small rocket motors, methods of measuring this degradation and methods used to extend shelf life.

4. Discussion

Thiokol-Elkton provides three motors used on the Saturn Vehicle.

A. SIC retro motor (TEM-424) which is supplied to Boeing. Eight are used per launch vehicle.

B. SII retro motor (TEM-294) which is supplied to McDonnell-Douglas. Four are used per launch vehicle. This particular motor has been produced at Elkton for several years for the Air Force and is known as the Recruit.

C. Tower jettison motor (TEM-380) which is supplied to North American Rockwell. One motor is used for each flight operation. Each of these motors was supplied with a two year shelf life.

Since original purchase the shelf life of the SIC retro motor has been extended to four years and the shelf life of the tower jettison motor has been extended to five years. In both cases, the basis for this extension has been a review of the results of firing tests of similar motors in this age bracket.

Negotiation is proceeding at present to extend the service life of the SII retro motor (Recruit). Thiokol has recommended that this life be extended to four years based on the following data.

A. The M18 rocket motor which has a similar propellant composition was supplied to the Air Force, originally had an assigned five year life. At the end of this period, ten motors were returned to OOAMA. They were inspected, X-rayed, temperature conditioned and static fired at either + 170°F, + 70°F, or - 40°F. There were no indications of unserviceability by visual inspection or X-ray. The ballistic performance data were well within specification. Based on this testing, the service life was extended to seven years.

B. The M-46 motor which has similar propellant composition was supplied to the Air Force for use in an air to air missile. Two years after original procurement, a surveillance program was originated at OOAMA. Every year, a sample from the total inventory is returned to OOAMA, inspected and fired. Based on the results of these firings, the life of these motors has been extended to ten years.

C. Extensive testing has been done at the Redstone Division of Thiokol. These tests indicate that there should be no degradation in polysulphide propellants for at least six or seven years. Useful life can be extended by protecting these propellants against detrimental effects of atmospheric oxygen and moisture.

D. Flight and test history has been accumulated on 54 Recruit motors aged from 30 to 74 months which were fired successfully.

No decision has been reached at this time on this life extension.

The surveillance program for the tower jettison was discussed. This motor is poured in batches of six. At the same time, twelve five-inch center perforate (5" Cp) scale motors are poured and tensile and peel specimens are prepared. One motor is fired for batch acceptance and two 5"Cp motors are fired to provide baseline data. If the batch acceptance test is satisfactory, this leaves a lot of five motors available for operational use. When one of these motors is selected for use on an Apollo mission, two 5"Cp motors from the same batch are fired and tensile and peel tests are run on specimens from this batch. Based on these tests, the motor is approved for flight. In discussing the validity of this program, it was pointed out by Thiokol that there is some doubt about the correlation of rate of degradation between the 5"Cp motors and the full scale motors. They would like to include some full scale motor firings in this surveillance program. Also, there is some doubt about the validity of the data from the tensile and peel specimens.

Surveillance programs of this type are not being conducted on the SIC retro motors or the SII retro motors.

Several techniques for identifying and measuring degradation were discussed.

A. Peel and shear tests should be used to measure interface degradation, e.g., propellant to case.

B. Radiographic inspection is being used but is not completely satisfactory on these motors since the case is changing rapidly in cross section in the critical areas.

C. Cross link density testing which is a measure of the increase of polymeric cross links with time should identify changes in propellant properties.

D. In a sealed motor, the degradation of polysulphides should give off measurable quantities of gas, e.g., ammonia and deplete the available oxygen. Analysis of this gas could be a measure of degradation.

E. Little work has been done at Thiokol with micro tensile testing. It is felt that it would be difficult to correlate the results.

The tower jettison motors are purged with nitrogen and shipped in a sealed container with a nitrogen atmosphere. After receipt at KSC they are stored in a temperature and humidity controlled bunker.

5. <u>Documents Obtained</u>

Thiokol letter No. SP/6230, dated 12 September 1968, subject: Saturn/Recruit Retro Motor-Storage Life

6. <u>Action Status</u> - None

7. <u>Summary</u>

Shelf life of the Thiokol motors discussed has been extended by similarity, that is, by a review of firing data from similar, not necessarily the same, motors. The emphasis at this facility is on firing of full-scale motors.

SURVEY TRIP REPORT II-26
CONVAIR DIVISION
GENERAL DYNAMICS CORPORATION
SAN DIEGO, CALIFORNIA
24 February 1969

1. Persons Making Trip

W. B. Gizzie	MMC	Logistics
M. G. Mueller, Jr.	MMC	Systems Engineering
R. L. Graham	NASA/MSFC	R-QUAL-QRR
J. T. Bull	NASA/MSFC	PM-V-IU
A. O. Boyanton, Jr.	NASA/MSFC	PM-V-E

2. Persons Visited

R. Romero	GD/C	Atlas E/F Program Office
W. D. Donnelly	GD/C	Atlas E/F Program Office
R. M. Williams	GD/C	Atlas E/F Systems Engineering
S. Chamberlain	GD/C	LVP Systems Engineering
R. W. Eichman	GD/C	Reliability Engineering
R. D. Stoneburner	DG/C	Contracts

3. Purpose of Visit

To discuss Atlas program experience with limited life components and component recertification.

4. Discussion

Atlas vehicle component life limits are established by engineering judgment and based on the critical nature of the specific component. Vendor recommendations are usually followed. Requirements of ANA-BUL-438 are used for rubber goods.

O-ring life limits are defined only for dynamic seals.

The first portion of Atlas missiles (D model) refurbished for use as space boosters had all components refurbished as a matter of course. On recent programs (E & F models) no components are automatically refurbished and three components are automatically recertified: gyros, inverters (rotary), and umbilicals. Many components are modified to meet new mission requirements and are refurbished along with the modification work. Components are refurbished or replaced only as a corrective action for non-conforming operation identified during system or component recertification testing. MIL 5086 wire insulation became brittle and cracked. The appearance was bad but megger tests revealed no failures. Teflon insulated wire exhibited "cold flow" phenomenon in areas where bundles were doubled back and tied with a short radius bend. Copper was visible in the bend area. It was recommended that bundles not connected to equipment be supported in approximately normal position rather than be tied back.

4. Discussion (Continued)

Electrical umbilicals have been relatively clean, with occasional residue successfully removed by cleaning. Handling damage to the outer shell has occurred. Bendix bayonet type connectors have become loose in the shell as a result of many disconnect cycles, however no discontinuities or other failures have been attributed to this problem.

No electronic equipment failures have been attributed to age or storage. No contact resistance problems have been encountered in the motor driven power changeover switches.

Retro-rocket motors originally had a 2 year life. This has been extended to 5 years as a result of a test program on 5 rockets. The units are all X-rayed upon removal from storage. For a Conax pyrotechnic valve, it was found to be more economical to replace the pyrotechnic device than to conduct a test to extend its storage life.

Life limits are not established for pressure vessels, since logical limits (1000 cycles or more) are not approached.

Gyro retest requirements were originally based on acceptance specifications. The reject rate was about 60% for run-up time and drift. Analysis of the hardware and the mission indicated that the run-up time could be doubled (to 125 seconds) and drift allowance increased. The reject rate dropped to 10% and no system problems have resulted from the increased tolerances. Ball bearing lubrication (in the spin motors) was the factor which affected the run-up time.

Trimpots obtained during 1963 through 1965 had a silicone based shaft lubricant. The lubricant migrates throughout the inside of the trimpot insulating the wiper from the resistor. The lubricant was changed (by the manufacturer) on units after 1965.

All concepts stated in our questionnaire have been utilized for extending component life.

GD/C engineering opinion is that storage does not affect remaining operational life.

No cost factors were available.

Data has not been accumulated on the condition of components which were modified or refurbished.

No stated policies or guidelines exist for aid in determining component life. Determination considers mission requirements, specification requirements, contract incentives, etc.

5. Documents Obtained

   a. Written answers to Shelf Life Questionnaire.

6. Action Items

   a. MMC to ask GD/C for identification number of Rocketdyne elastomer report mentioned during discussions.

7. Summary

Many of the Atlas limited life components are modified to meet new mission requirements. No components are refurbished except as a result of non-conformance during post-storage retest. Life limits are sometimes based on arbitrary or judgment factors, rather than test or usage experience

8. Special Note

Convair provided comments on the Phase I report. The principal effect of their comments was to reflect an increase in the time span of periodic inspections of the Atlas missiles at Norton AFB from 120 days to 180 days. Details of the comments will be provided to K. E. Riggs, R-TEST-ST.

SURVEY TRIP REPORT II-27
NORTH AMERICAN ROCKWELL CORPORATION
ROCKETDYNE DIVISION
CANOGA PARK, CALIFORNIA 91304
25 February 1969

1. Persons Making Trip

M. G. Mueller, Jr.	MMC	Systems Engineering
W. B. Gizzie	MMC	Logistics
A. O. Boyanton, Jr.	NASA/MSFC	PM-V-E
J. T. Bull	NASA/MSFC	PM-V-IU
R. L. Graham	NASA/MSFC	R-QUAL-QRR

2. Persons Visited

M. Bensky	NAR Rocketdyne	Advance Projects
E. A. Lamont	NAR Rocketdyne	Marketing
C. A. Hauenstein	NAR Rocketdyne	LM Ascent Engineer
J. L. Rosengard	NAR Rocketdyne	Materials & Processes
A. D. Lucci	NAR Rocketdyne	H-1 Systems
S. C. Nethery, Jr.	NAR Rocketdyne	F-1 Projects
E. J. Frey	NAR Rocketdyne	Reliability
N. D. Sensenbaugh	NAR Rocketdyne	Thor Engine Systems
J. F. Robinson	NAR Rocketdyne	Thor Engine Systems
J. R. Costello	NAR Rocketdyne	J-2 Engine Systems
L. E. Tomlinson	NAR Rocketdyne	Control
F. L. Fletcher	NAR Rocketdyne	Electrican & Instrumentation

3. Purpose of Visit

To discuss shelf life and life limitations imposed on rocket engines and components and to investigate methods employed to establish and extend life.

4. Discussion

Time remaining on engines is not affected by storage. Before flight, engines are subjected to a functional checkout. Lox/RP thrust chambers develop pin hole leaks. Thor thrust chambers have a guaranteed life of one flight (approximately 180 seconds) and a calendar life of 54 months. No pin holes or rust have been detected during this period even with a functional test. Engine life starts after engine acceptance on a DD250 by the customer. Thor engines are not static fired after delivery. Turbine life is controlled by blade fatigue and is established based on test experience. Thor turbine life is 2000 seconds including powered flight.

As a result of a J-2 engine overhaul study performed about two years ago, the life on some components was increased from 5000 to 5700 seconds.

4. Discussion (Continued)

Component life extensions are based on test results and experience. The air force (SBAMA) has extended the life of Thor block 1 engines to nine years before overhaul. Block 3 space launch vehicle engines' life is 4½ years. Rocketdyne does not concur with the nine year limit.

Instrumentation calibration drift does occur during storage but no time period correlation has been established. Rocketdyne does not recommend instrumentation transducer recalibration but recommends only a normal system checkout be performed after storage.

H-1 engines have experienced no deterioration after 4-5 years storage. Frequent checkout can cause wearout of the equipment. The main propellant valve had a 1000 cycle life limit but because this is well in excess of what the valve would see in actual service the life limit was abandoned.

ANA-BUL-438 and MSFC-105 documents are followed concerning elastomers. Rocketdyne does not agree with limiting the life of Viton A as per MSFC 105. They feel that it should have unlimited life.

Moly disulfide dry lube history has indicated no corrosion problems. MIL-G-7118 grease is used in addition to the dry lube on gimbal bearings. Gimbal bearings do not require relubrication for 54 months. Gear box preservation has been extended to 54 months on the space launch Thor engines. H-1 engine gear box preservation has been proposed to be extended to 5 years and it was indicated that the F-1 will rely on the H-1 data and experience.

FS 1281 O-ring lube has dried out or rubbed off in the FABU with repeated checkout and after storage has caused problems with FABU.

Electrical harnesses have posed no storage problems. Spring relaxation has not been a problem. Rocketdyne has no specific guide for designers to follow as far as designing for long life. Materials selection control exercised during design and experience are the major factors influencing the design. Hardware is not designed to run beyond qualification life. Improper storage would affect the life remaining on the engine. Pressure vessels have posed no life problems because cycle life is well beyond what ever would be experienced in service.

Hypergol igniters have a 2 year life which can be extended 1 year by weighing the igniter. The air force (OOAMA) has established a 5 year life on pyrotechnic igniters. The auto igniting gas generator for H-1 is good for 1 year. F-1 is investigating 5 year life for igniters. Rocketdyne has no age vs. reliability study data available but indicated that with 200 Thor launches with 1-2-year-old vehicles with 40 to 45-month-old engines there were no failures.

4. Discussion (Continued)

Time is recorded and maintained using the AFTO system and record book logs. The logs are maintained by Field Engineering.

Cost of a complete engine overhaul is almost 100% of cost of new engine. Definitions used at Rocketdyne depended upon program and project.

5. Documents Obtained

None

6. Action Items

None

7. Summary

The time remaining on engines is not affected by proper storage. No major problems were uncovered relative to storing engines and components for extended periods.

SURVEY TRIP REPORT II-27
ADDENDUM 1 - 28 MAY 1969
NORTH AMERICAN ROCKWELL CORPORATION
ROCKETDYNE DIVISION

At the end of Paragraph 4, Discussion (Page 3) the statement was made that a complete engine overhaul cost almost 100% of new engine cost. Rocketdyne has advised us that this was a special case involving overhaul and conversion of Thor Block 1 engines to Block 3 engines. At the time of the survey meeting we were also told that overhaul to the usual level would cost in the neighborhood of 30% of new engine cost. We are also advised that this figure is somewhat high, and that 25% is more accurate.

SURVEY TRIP REPORT II - 28
CONRAC CORPORATION
Instrument/Controls Division
Duarte, California

26 February 1969

1. Persons Making Trip

W. B. Gizzie	MMC	Logistics
M. G. Mueller, Jr.	MMC	Systems Engineering
R. L. Graham	NASA/MSFC	R-QUAL-QRR
J. T. Bull	NASA/MSFC	PM-V-IU
A. O. Boyanton, Jr.	NASA/MSFC	PM-V-E

2. Persons Visited

D. C. Baker	Conrac	Process Engineering
J. E. Mueller	Conrac	Process Engineering
J. Nevins	Conrac	Gyro Engineering

3. Purpose of Visit

To discuss limited life aspect of gyros, accelerometer, pressure transducers, and pressure switches.

4. Discussion

Conrac has not conducted any specific investigations or test programs concerning storage or aging characteristics of the components discussed. These included gyros, pressure switches, pressure transducers, and accelerometers. The principle concern has been to verify operating life limits and design to meet age limits as specified by the buyer.

The design approach is not stated in any policy or guideline documents, but includes concern for compatible materials, the stated environment, protection against contamination, etc.

Gyro spin motors are ball bearing type. The operating life limit is 1000 hours. This has been successfully accomplished after as much as 5 to 6 years of storage. The limit is based on spin motor reliability. Storage may cause the bearing lube to migrate, but operation following storage will usually redistribute the lubrication adequately.

No gyro float fluid problems have been encountered. No calendar life is imposed on gyros.

Absolute pressure transducers will shift depending on the leakage rate. A welded case unit, tested to 10^{-11} micron, will shift about 1% in ten years. Units utilizing organic sealing would leak more rapidly and also the sealing material would deteriorate with age.

Pressure switch units have a cycle life dependent on the pressure involved, the type of operation, and the contact arrangement. Higher pressures result in lower cycle limits because of the mechanics of the bourdon tube.

Slip ring and switch contact contamination which may occur during storage can often be removed by operation following storage. Operation during storage would reduce the magnitude of the problem.

The opinion was expressed that components should be operated periodically during storage, however the discussion indicated that the operation was desirable more for gathering aging trend data than to benefit the components.

The types of components supplied by Conrac can usually be refurbished. The cost of refurbishment was estimated at approximately 50% of new cost (as an average).

No significant problems have been observed concerning aging characteristic of wire insulation, conformal coatings, and plastic materials.

The opinion was expressed that three years of storage would not affect operating time limits, and five years storage would probably not affect operating time limits to a significant degree.

5. Documents Obtained

None

6. Action Items

None

7. Summary

Very little aging or storage information has been accumulated by Conrac. Operating limits are usually based on customer requirements and qualification tests. No significant storage or aging problems have been encountered.

SURVEY TRIP REPORT II-29
MC DONNELL DOUGLAS CORPORATION
MISSILES AND SPACE SYSTEMS GROUP
SANTA MONICA, CALIFORNIA

26 February 1969

1. Persons Making Trip

M. G. Mueller, Jr.	MMC	Systems Engineering
W. B. Gizzie	MMC	Logistics
A. O. Boyanton, Jr.	NASA/MSFC	PM-V-E
R. L. Graham	NASA/MSFC	R-QUAL
J. T. Bull	NASA/MSFC	PM-V-IU

2. Persons Visited

C. D. Haynes	MDAC	Booster Requirements
F. C. McJunkin	MDAC	System Effectiveness
R. A. Dixon	MDAC	Logistics

3. Purpose of Visit

To investigate and define Thor booster components that have shelf life and to determine how life was established and extended.

4. Discussion

Copies of two Limited Life Items Specifications for Space Boosters were presented and discussed. The lists contain items like the Flight Controller, H I G - 4 Gyro, Timer, Rate Gyro and Inverter which have operating time and calendar life limits and numerous other components whose life is limited due to rubber goods. Initially times were established by the engineering rule of thumb method and over the years have been revised and verified by experience in field. Times have also been established by Customer direction and based on program requirements. Calendar times have been increased eg. gyros increased from 18 months to 36 months based on field experience. No additions or deletions have been made to these lists. It is felt that column C, Useful Life (Replacement Schedule) times are very conservative in some cases, eg. the timer is listed as 36 months, RCA who builds the timer maintains that it is good for 5 years.

Over 400 Thor vehicles have been built and rebuilt. Vehicles stored for up to 2 years at Norton A. F. B. have been reconditioned and flown. Many components on these vehicles were rebuilt and inspection and rework documentation exists covering the discrepancies found and the amount of rework required. These records, however, are not readily available and would require much effort to extract any useful information.

Bulletin 438A is used for life determination of rubber goods used on the Thor. It was felt that relief valves and high pressure hoses should be added to our categories of time sensitive components, question C 4, for safety reasons.

In the past Air Force control of life limited hardware was more stringent than NASA controls on the Thor program but now a limited life list also exists for the Delta vehicles.

The 65% cost factor is used for determination of scrap or refurbish requirements.

A vibration testing program has been started to detect failures. A process to fill Bendix electrical connectors with epoxy material has been developed which is said to improve connector reliability. No epoxy bonds or sealant problems have been experienced on the Thor program.

5. Documents Obtained

   a. Specification No. St-Des 0011 Limited Life Items Specification for DSV-2L-1B Space Boosters dated 1 November 1967.

   b. Specification No. St-Des 0010 Limited Life Items Specification for DSV-2L-1A Space Boosters dated 1 November 1967.

   c. 2L-1A Reliability, Overall Rankings.

6. Action Items

   None

7. Summary

   Documents and information obtained will be useful for comparison with other programs. There have been no unusual problems concerned with Thor storage or component life.

SURVEY TRIP REPORT II-30
TALLEY INDUSTRIES
MESA, ARIZONA
28 February 1969

1. Persons Making Trip

W. B. Gizzie	MMC	Logistics
M. G. Mueller, Jr.	MMC	Systems Engineering
J. T. Bull	NASA/MSFC	PM-V-IU
A. O. Boyanton, Jr.	NASA/MSFC	PM-V-E

2. Persons Visited

A. L. Pittinger	Talley	Director of Research
J. Pietz	Talley	Head, Propellant Research
C. Haff	Talley	Head, Applied Research Division
E. F. Garner	Talley	Staff Chemist
T. Ryan	Talley	Engineering

3. Purpose of Visit

To discuss life limits and aging characteristics of ordnance devices.

4. Discussion

Talley Industries produces a variety of ordnance activated devices including rocket catapult escape systems for aircraft, latching and unlatching devices, rotating devices, arming devices, and valve actuation devices. They use the term "ballistic devices" to describe the product line. They have supplied components or systems to the Mercury, Gemini, and Titan systems to name a few. Talley produces the propellant and many of the mechanical devices involved, however they purchase most of the initiator or ignition components.

Storage time limits are usually controlled by the extremes of the operating environmental requirements. That is, the degradation is usually a reduction in performance at the extreme temperature requirements (usually - 65°F to +180°F.)

Storage surveillance programs supply the bulk of the statistical data which is used in setting storage time limits. Overall reliability of the system or component is the principle concern, rather than reliability of the individual parts. Accelerated aging tests are used to aid in confirming life limits.

Most of the devices have a three-year life, however some have been extended to five years. Talley feels that propellant compounds generally are more age stable than the igniter elements. They use hot wire or percussion igniters usually. They do not furnish EBW igniters, however some devices are furnished without the igniter.

X-ray is performed on all items returned for aging tests, however few problems have been revealed by this method. Aging degradation may not show up on X-ray. They feel that X-ray is more important for examining rocket motors.

No storage problems have been encountered with the mechanical devices.

Talley feels that optimum storage conditions for ordnance devices are +10°C to +20°C at 30% relative humidity. Storage in an inert atmosphere is helpful (argon or nitrogen). Operational life is affected by storage, since chemical changes continue during storage. As stated previously, the effect on operational life appears first at the extremes of the required operational environment. Degradation after three years exposure to service environment (aircraft applications) has averaged about 10% based on performance during aging tests. This performance is usually within qualification test limits.

Many of the devices can be renewed by replacing the igniter element and/or propellant. Average cost was estimated at 25% to 50% of cost of new device.

5. Documents Obtained

None

6. Action Items

None

7. Summary

Controlled storage is beneficial in extending life of ordnance components, however testing or refurbishment are the only valid methods of extending stated limits. Most devices have a three or five-year life limit.

SURVEY TRIP REPORT II-31
AIR FORCE LOGISTICS COMMAND
WRIGHT PATTERSON A. F. B.
DAYTON, OHIO

4 March 1969

1. Persons Making Trip

L. W. Tipton	MMC	Systems Engineering
J. C. DuBuisson	MMC	Reliability

2. Persons Visited

Harold E. Seewer	AFLC	Aeronautical Equipment
John S. Bauer	AFLC	Fluid & Hydraulic Components
Ralph Corwin	AFLC	Transportation

3. Purpose of Trip

The purpose of the trip was to discuss sundry aircraft components which have limited life due to calendar aging or operation and to explore ways and means of extending their lives.

4. Discussion

The five Air Material Areas (AMA) of USAF use the technical order (TO) 20K series for inspection and age control of about 9000 line items. DOD controls about 40,000 line items. AMA monitors all the TO's affecting the line items for which they are responsible. Type I TO's define and limit the shelf lives in years or cycles. Type 2 TO's allow life extension by test or analysis.

A tabulation of the sundry AMA's respondibilities follows:

T.O.	AMA	NO. LINE ITEMS	RESPONSIBILITIES
00-20K-4	WRAMA	2200	Guns, Fire Control
00-20K-6	OCAMA	300	Hyd. Units, Filters
00-20K-7	OOAMA	2500	Missile Parts
00-20K-8	SAAMA	3000	O-rings, Parachutes
00-20K-9	SMAMA	500	Missile Parts

Similarity is sometimes used as a basis for establishing the lives of new items. Also failure rate data is used to determine if an age limit is required. Inspection is sometimes used to extend item lives. Age controlled items are stored separately for better management control.

Cost guides have been established to help determine disposition of over age items. If the line item (not per unit) cost exceeds $15.00, tests must be conducted to determine if the line item life can be extended. However, the cost of extending a line item life cannot exceed 65% of the original cost unless the item is in critical demand. If a line item costs more than $9.99 ($24.99 overseas) and has reached its age limit, a disposition must be determined - i.e., the item is not automatically discarded.

The following documents were recommended as possible references:

1. DOD Instruction 4140.27, Identification, Control and Utilization of Shelf Life Items, September 12, 1968.

2. AFLCM 66-2, Time Replacement Program

In addition, a report on a DOD study to review the entire age control program should be completed by July 1969 by the Camden Station at Alexandria, Virginia.

Experience at AFLC suggests that:

1. One person (or committee) control all age limits.

2. A "why" statement should accompany each age limitation.

3. Avoid setting item lives by broad categories.

5. Documents Obtained

a. AFLC Regulation No. 65-23, Age Controls for Property in Storage.

b. ANA Bulletin 438c, Age Controls of Age - Sensitive Elastomeric Items

6. Action Items

Obtain a copy of AFML-TR-67-235, Literature Survey on the Effects of Long Term Shelf Aging on Elastomeric Materials, WPAFB, R. H. House (MAAE) and R. T. Hedrick (MANE).

7. Summary

See discussion paragraph.

SURVEY TRIP REPORT II-32
B. F. GOODRICH RUBBER COMPANY
AEROSPACE & DEFENSE PRODUCTS DIVISION
AKRON, OHIO
5 March 1969

1. Persons Making Trip

L. W. Tipton	MMC	Systems Engineering
J. C. DuBuisson	MMC	Reliability

2. Persons Visited

W. E. Schlag	Goodrich	Sales Engineer
K. Paige	Goodrich	Chemist, Compounder

3. Purpose of Trip

The purpose of the trip was to discuss sundry rubber products which have limited life due to calendar aging or operation and to explore ways and means of extending lives.

4. Discussion

Since all polymer seal materials cold flow to some extent, it was recommended that seals not be tightened-up until just prior to service. Adverse environments such as ozone and ultra-violet have less effect if the elastomer is relaxed during storage. Elastomers will cold flow even after retorquing the seal. Springs have been placed behind bolts to ensure a constant pre-stress as the elastomer cold flows.

In general, accelerated aging tests are not acceptable. However, accelerated aging data of elastomers exposed to steam has been correlated with natural weather aging data. Accelerated aging data of elastomers exposed to hot air is not correlateable with natural age data. A computer program to correlate aging parameters using test data has not been too successful.

Some batches receive 100% inspection. A batch usually weighs 200 to 300 pounds. There is a tendancy for the distribution of ingredients to level out; however, it is impossible to be certain that the last of a batch is the same as the first of the batch. There is little data available to compare elastomer characteristics after service aging with those of the original batch.

It was suggested that a quantity of a batch be set aside for periodic age testing. The lives of F-111 elastomers have been extended after tests of overage components indicated they were still satisfactory. Differential thermal analysis is used primarily in tire compounding at Goodrich, not for seals. Goodrich manufactures the bulk material for O-rings, not the O-rings.

Keep O-rings lubricated or let the O-rings see the lubricant when installed. Be careful of changing the environment to which a seal has been qualified. For example, one seal deteriorated rapidly when a cooling lubricant on one side of the seal was changed to air.

In specifying cures, the following should be considered:

a. A 10°F variation in the cure temperature of a fast cure (10 minutes) could change material characteristics substantually, however.

b. A 10°F variation in the cure temperature on a long cure (hours) doesn't affect material characteristics materially.

c. Viton A&B and silicones properties are sensitive to post curing treatment. Volatiles are driven off changing properties.

Source inspection at the factory was recommended to eliminate damage from receiving inspection at the customer's facility. Store in a cool (40°F), dry, dark environment. Keep silicone components separated because they adhere to themselves.

5. Documents Obtained

None

6. Action Items

None

7. Summary

See discussion paragraph.

SURVEY TRIP REPORT NO. II-33

OGDEN AIR MATERIEL AREA
HILL AIR FORCE BASE, UTAH
6 March 1969
7 March 1969

1. Persons Making Trip

H. Smyly	NASA/MSFC	R-P&VE
J. C. DuBuisson	MMC	Systems Engineering
L. W. Tipton	MMC	Systems Engineering

2. Persons Visited

D. F. Woods	OOAMA	OOYEGL
K. Barney	OOAMA	OOYECP
H. Matticks	OOAMA	OONER-T
R. Dulle	TRW	OONER
Lt. D. Roberts	OOAMA	OONERM
Capt. J. A. Levitsky	OOAMA	OONERM
C. Barnes	OOAMA	
J. Muhl	MMC	
E. Barker	OOAMA	OONERM

3. Discussion

The surveillance program for the small rocket motors used on the Titan II weapons system was discussed in detail. Every six months, five units of each motor are picked at random for test. The following inspections and tests are run on each article.

1. Visual inspection
2. X-ray inspection
3. Vibration equivalent to the vibration run during original qualification
4. Electrical check of igniters
5. Instrumented firing at simulated altitude

The altitude firing is done at Arnold Space Center. All other tests are performed at Hill A. F. B. Data from these tests are compared, by lot, with the original acceptance data and with data acquired from earlier surveillance testing. Regression analysis is being used to predict future life. Comparisons between lots have been made. There is apparently little difference in aging characteristics from lot to lot.

Based on this testing the Titan II vernier rocket motor, which is loaded with 67 lbs. of TP-G-3129 propellant, has been assigned a service life of 93 months and the Titan II retro motor, which is loaded with 4.6 lb. of TP-H-8009 propellant, has been assigned a service life of 78 months. It is expected that future testing will make it possible to further extend the service life of both of these units.

In addition to this program, a Differential Thermal Analysis (DTA) study has recently been started at MMC on contract to OOAMA. Results of this study are not available at present.

Pressure cartridges are normally assigned a three year life. At the expiration of this period a surveillance program is started. Thirty-three samples are tested each year. There has been some apparent change in pressure in bomb tests but not sufficient to make the cartridge unusable.

This agency is responsible for two large polysulphide boosters, the Mace booster and the Bomarc B motor. Based on surveillance programs similar to those discussed earlier in this report, the Mace booster has been extended to 120 months and the Bomarc B booster has been assigned an indefinite service life.

A study is in progress to investigate the possibility of reloading Bomarc booster cases if it becomes necessary to reprovision this item. Propellant was removed from several cases and they have been reloaded. Tests run on the reloaded booster have been satisfactory. It is felt that significant savings can be obtained in this manner.

Tests on two silver oxide-zinc ordnance actuated batteries used on the Minute Man indicates that there is a constant battery voltage drop of 0.25 volts per year. Sixty-five month old batteries have been tested and a service life of 120 months has been assigned these batteries contingent upon continuation of the surveillance program.

An extensive program is in progress at this facility to measure aging of non-metallic materials using change in molecular and crystalline structure as the criteria. Changes in crystalline symmetry of polyurethane with age and when exposed to a high temperature and humidity environment were measured using X-ray diffraction technique. It was found that it was possible to correlate changes in lattice spacing with degradation, in fact changes in crystalline structure could be measured before gross physical degradation was apparent. This and similar techniques are now being applied to other materials. Results of these studies will be supplied as they become available.

The reliability organization responsible for the Minute Man system suggests that an aging study should include the following steps:

1. The system should be reviewed to select those items that affect the success of the mission and warrant study.

2. An aging sensitivity analysis should be performed to determine age sensitive materials, high loading within the component and interfaces that can accelerate degradation.

3. Techniques for measuring the aging of materials, etc. should be reviewed and used where appropriate. When possible, accelerated aging tests should be designed. Examples of techniques presently available are:

   X-ray diffraction
   Electronic microscopy
   Differential thermal analysis
   Cross link density

4. Provisions should be made for a surveillance program that can measure the change in performance with time of a specific serial number component or lot, making it possible to perform a meaningful regression and trend analysis.

5. Environmental affects should be simulated in the aging and testing where appropriate.

5. <u>Documents Obtained</u>

A. An Approach to Explosive Component Surveillance, OOAMA, Airmunitions Plan OOY-P-68-1001 dated September 1968.

B. Altitude Performance of Five Thiokol Chemical Corporation TE-345 Titan Vernier Solid-Propellant Rocket Motors Having Ages Ranging from 73 to 75 Months, AEDC-TR-69-16 dated February 1969.

C. Simulated Altitude Performance of Five Thiokol Chemical Corp. TE-344 Titan II Retromotors Having Ages from 68 to 72 Months, AEDC-TR-69-43 dated February 1969.

D. Crystal Structure Changes in Elastomeric Polymers. I Polyurethane, Joseph A. Levisky and Clair W. Rogers.

E. Curves Showing Effects of Aging on Delco Batteries and Bomarc Boosters.

6. <u>Action Items</u>

A. MMC to get from Capt. Levisky results of additional crystalline structure tests now in progress.

6. Action Items (Continued)

B. MMC to get from D. F. Woods additional data on aging of Bomarc and Mace Motors.

7. Summary

Several surveillance programs are being conducted at this facilities on components of the Titan II and Minute Man systems. In addition, attempts are being made to measure aging by examining changes in molecular structure.

SURVEY TRIP REPORT NO. II-34
GRUMMAN AIRCRAFT ENGINEERING CORPORATION
BETHPAGE, L.I., N.Y.

15 April 1969

1. Persons Making Trip

William B. Gizzie	Martin Marietta - Logistics
Mark G. Mueller, Jr.	Martin Marietta - Systems Engineering
Eugene H. Fikes	NASA/MSFC S&E-ASTR-GC
Douglas J. Forsythe	NASA/MSFC S&E-TEST-ST

2. Persons Visited

Stuart Weisberg	GAEC - Reliability/Maintainability Asst. Section Chief
John C. Gaglione	GAEC - APP Reliability
Walter F. Frahm	GAEC - LM Reliability - Limited Life/Shelf Life
Joe Mule	GAEC - LM Reliability
William Doyle	GAEC - Advanced Systems - Space
John W. Fletcher	GAEC - AAP Reliability

3. Purpose of Visit

The purpose of this visit was to discuss the Limited Life/Shelf Life Programs conducted by Grumman for the LM and AAP programs and other programs.

4. Discussion

Grumman controls life sensitive components through two systems. "Shelf Life" control monitors items susceptible to calendar aging. The "Limited Life" program monitors components susceptible to wear-out degradation due to operation.

Both programs are administered by a single point of contact (a group within the Reliability and Maintainability Control Section of the Engineering Department).

Data sheets are prepared for each component to the deliverable part level. Determination of the life limit, and the action to be taken when the limit is reached is based on vendor recommendation and engineering analysis, including experience data and mission considerations. Design, reliability, and NASA sign off on the data sheet. Purchased parts also require a data submittal which is reviewed by Materials and Reliability Engineers to assure proper inclusion in the component life programs. The single agency administration assures consistency among the various types of components.

No specific testing is conducted to obtain or verify life limit data at the component level.

4. Discussion

Operating life limit milestones are established to control operating times at the various test locations. The document listing the equipment life and milestones has released engineering status. Changes may be made which affect only one vehicle effectivity at one milestone, or any combination of equipment effectivity and milestones as appropriate to the situation.

Analysis and test data are the principle tools in changing life limits. The test data involved are usually from routine test procedures. Inspection data may be useful where contamination or corrosion are of concern.

The shelf life program terminates for some components at installation in a system. Other components are monitored to launch.

Operating times are monitored by manually entering event clock time in the procedure. Quality Control is responsible for maintaining component time logs and summary sheets. Some events are recorded on tape, however, these data are only used to back up the manual entry system. Quality Control monitors items against the milestone limits.

The administrative group monitors component shelf life by an automated system. This group notifies Quality Control by a special form when an action is necessary for a specific item. This form is returned to the administrative group upon compliance to close out the item.

The techniques of fracture mechanics are used for pressure vessels to determine, at specified intervals, the remaining cycles and pressure levels, or to require a proof test before additional use.

No cost data was available. Cost has not been a factor determining life limits. No specific programs have been conducted to extend component life.

5. Documents Obtained

A. Miscellaneous documents relating to operation of the Limited Life/ Shelf Life Programs.

6. Action Items

A. Martin Marietta Corporation to get a copy of SR-QUAL-67-31, MSFC Requirements for Age and Time/Cycle Control (Action Item completed).

7. Summary

The meeting with Grumman discussed the philosoply, procedures, and controls applied to limited life components as used in the Apollo LM and AAP Programs.

SURVEY TRIP REPORT NO. II-35
KEARFOTT SYSTEMS DIVISION
SINGER-GENERAL PRECISION, INC.
LITTLE FALLS, NEW JERSEY
16 APRIL 1969

1. Persons Making Trip

William B. Gizzie	MMC	Logistics
Mark G. Mueller, Jr.	MMC	Systems Engineering
Eugene H. Fikes	NASA/MSFC	S&E-ASTR-GC
Douglas J. Forsythe	NASA/MSFC	S&E-TEST-ST

2. Persons Visited

William Henrich	Kearfott	Marketing
Paul Sondhoff	Kearfott	E/D
Sam Wong	Kearfott	E/D

3. Purpose of Visit

The purpose of this visit was to discuss life limitations of gyros, especially gas bearing gyros.

4. Discussion

The meeting began with a summary of the types of gyros manufactured by Kearfott. In the course of the discussion it was determined that the Martin Marietta personnel were under a misapprehension as to the type of construction used in the IV stabilization platform gyros. The terminology "gas bearing" applied by MSFC refers to the float medium. The spin motors utilize ball bearings rather than gas, or hydrodynamic, bearings.

Kearfott supplies liquid floated gyros with either ball bearing or gas bearing spin motors. The units with ball bearing spin motors are recommended for 1000 hours (one type), 2000 hours (seven types), 3000 hours (one type), or 5000 hours (two types). Ball bearing units have been stored for periods up to 5 years with little or no effect on operation.

KG80 or V78 oil is used for lubrication, impregnated in a phenolic retainer. No aging problems have been observed with the lubricant.

4. <u>Discussion</u> (Continued)

Storage temperature is an important factor in the manner in which it affects bearing preload and the various stresses in the balls and races.

Magnetic properties of permanent magnets may change with time. This factor can be determined and taken into account in assembly operations.

Depending on assembly techniques, refurbishment is practical for some modes of degradation or failure.

The usual degradation mode which limits ball bearing gyros is an increase in the noise level on the output signal. This is caused by mechanical factors in the ball bearing itself and usually manifests itself gradually.

Long term dimensional stability of metals is an important factor in calendar aging of units with moving clearances on the order of 50 microns or less. Research into this area has been conducted on Contract NASA-ERC-1965-66 and reported in NAS12-90.

5. <u>Documents Obtained</u>

   a. Data and discussion concerning operating and storage life of various Kearfott gyros.

   b. Kearfott gyros, Catalog D65-0169

6. <u>Action Items</u>

None

7. <u>Summary</u>

Ball bearing gyros can successfully be stored for periods up to five years without significant effect on operation.

SURVEY TRIP REPORT II-36
BENDIX CORPORATION
NAVIGATION & CONTROL DIVISION
TETERBORO, NEW JERSEY

17 April 1969

1. Persons Making Trip

M. G. Mueller, Jr.	MMC Systems Engineering
W. B. Gizzie	MMC Logistics Engineering
E. H. Fikes	NASA/MSFC S&E-ASTR-GC
D. J. Forsythe	NASA/MSFC S&E-TEST-ST

2. Persons Visited

R. Abramowitz	Bendix - Sr. Proj. Engr. Components
P. Imbeniwato	Bendix - Asst. Chief Engr. Mechanical
S. Haddad	Bendix - Asst. Chief Engr. Electronics
W. Ficken	Bendix - Sr. Engr. Components

3. Purpose of Visit

The purpose of the visit was to discuss life limits of the Saturn IU stage inertial platform and components supplied by Bendix.

4. Discussion

Components used in the Saturn inertial platform are very similar to those used in the Pershing missile which has been in the field for eight years. Bendix has experienced no failures of the Saturn platform components after two years in bonded storage. Units are stored at room temperature. It was stated that an inert nitrogen atmosphere would be beneficial. No life limit tests have been run on flight hardware and there are no established operating time or calendar life limits other than a five-year storage life program limit. A 1,000 hour operating time limit preference is in effect. Bendix was not aware of the existence of the IBM Instrument Unit, Long Term Storage Procedure for SIB/V#7915953 or MSFC No. III-6-602-61 Operating Time Cycle Critical Components Documents.

Materials used in the platform have exhibited good storage capability. Bendix has no long-term experience concerning potting materials or conformal coatings but have experienced no problems with these materials. Wiring is TFE teflon coated. "O" rings are Viton. Anodized Beryllium is used in gyro components. Beryllium whiskers did grow when parts were not anodized. V-78 or KG-80 oil is used for bearing lubrication. Pivot bearings are lubricated with Bendix No. Piny #10 oil. Noise problems, possibly related to aging, have been noted with zener diodes. A study is being performed to determine the cause of the noise. A study is in process on ball bearing life and tests are being

4. Discussion - Continued

run to establish life limitations. Slip rings are rotated every 100 hours to prevent increasing resistance. Periodic calibration is performed to insure operability of equipment when required as dictated by program requirements. There is no reason to perform a checkout except at the end of the storage period. Similarity method is used for establishing life limitations. It was felt that the Inspection method would be of little value except for detection of peeling of the infared filters from the prisms.

5. Documents Obtained

None

6. Action Items

None

7. Summary

Little platform storage data is available. No storage problems have been encountered with up to two years of bonded area storage. According to persons interviewed, no operating time or calendar life limits have been established.

SURVEY TRIP REPORT II-37
SPERRY GYROSCOPE DIVISION
SPERRY RAND CORPORATION
GREAT NECK, NEW YORK

17 April 1969

1. Persons Making Trip

M. G. Mueller, Jr.	Martin Marietta - Systems Engineering
W. B. Gizzie	Martin Marietta - Logistics Engineering

2. Persons Visited

A. J. Squillante	Sperry Gyroscope Inertial Components

3. Purpose of Visit

The purpose of the visit was to discuss gyro life limitations.

4. Discussion

After a brief introduction as to the purpose of our study, it was determined that little pertinent information would be obtained. The discussion concerned gas bearing liquid float gyros. No recommendations were made as to operating time limits. Three to five-year spin motor life is consistently achieved. Sperry has experienced no problem with the fluid used. Hustler gyros have been stored 3-4 years before use with no problems.

5. Documents Obtained

Gyroscopes for Space Missions by Robert G. Domini, John R. Mott, and Alphonse J. Squillante.

6. Action Items

None

7. Summary

No applicable data was obtained.

SURVEY TRIP REPORT NO. II-38
PUEBLO ARMY DEPOT
PUEBLO, COLORADO
6 MAY 1969

1. Persons Making Trip

Mark G. Mueller, Jr.	Martin Marietta - Systems Engineering
William B. Gizzie	Martin Marietta - Logistics

2. Persons Visited

Ron Mueller	Martin Marietta - Depot Representative
William M. Ringnalda	Bendix - Service Engineer

3. Purpose of Visit

The purpose of this visit was to discuss calendar and operational life limits of the Pershing missile guidance and control section with particular emphasis on the gyro platform.

4. Discussion

The Pueblo Army Depot is the maintenance depot for the Pershing missile system. Spare missiles are stored, along with spare components. Repair and overhaul activities are also performed.

Depot personnel are not required to keep statistical records of failures or of the repairs required or probable cause of failure. Contractor personnel (Martin, Bendix, etc.) attempt to keep records, but these records are dependent on personal contact and conversations with repair activity personnel.

It was the opinion of the persons interviewed that, in spite of the similarity of the Pershing guidance platform (ST-120) and the Saturn platform (ST-124), little correlation would be possible between the units for operational life and storage. The ST-120 platform is subjected to a much harsher environment and to considerable physical abuse. In spite of this, the platform seems to survive satisfactorily. It is felt that the platform is the most reliable component in the G&C (Guidance and Control) section of the missile. MTBF figures were not available. A listing of repaired units over several recent months showed an average of 150 to 175 operating hours per unit. However most of the problems were the result of physical abuse.

G&C sections in storage are tested every six months to assure readiness. Over the past eighteen months 268 functional checks have been performed at the depot. Seven platform non-conformances were found. Problem areas were caging switch (2), temperature sensor (1), roll gyro (1), CR accelerometer (1), air pendulum (2). No further information was available to analyze these failures.

No information was available concerning gyros in spare parts storage, except concerning the storage/shipping container. The protection provided seems much in excess of the real requirement.

There are no specific limits of calendar life or service life imposed on the G&C section or its components, except the requirement for the six-month functional test.

A Pershing missile assigned to a storage life test is nearing the end of this ten year requirement. The platform was still operating properly during the most recent functional test.

Hysol epoxy was used during early production to encapsulate or coat electronic assemblies in the guidance package. Use of this material was discontinued in 1965 or 1966 after it was found that aging stresses in the Hysol caused cracking of glass diodes and ceramic resistors.

5. <u>Documents Obtained</u>

A. Bendix Packaging Data Sheet for AB-5 Gyro Stabilizer, 2 September 1965.

6. <u>Action Items</u>

None

7. <u>Summary</u>

Because there is no requirement imposed for maintaining records concerning the reasons for failure of the gyro platform, little statistical data was obtained that can be applied to this study. It was the consensus of opinion that the gyro platform withstands the rigors of its service life very well and is in fact the least likely component to fail within the system. The packaging of the gyro for shipment and storage appears to be overdone and may be more than is actually required.

SURVEY TRIP REPORT NO. 39
SPACE AND MISSILE SYSTEMS ORGANIZATION
NORTON AFB, CALIFORNIA

13 & 14 May 1969

1. Persons Making Trip

L. W. Tipton	MMC - Systems Engr.
J. C. DuBuisson	MMC - Reliability
K. E. Riggs	NASA - S & E - TEST - ST
R. L. Graham	NASA - S & E - QUAL - QRR
A. O. Boyanton, Jr.	NASA - PM - SAT - E

2. Persons Visited

Lt. Col. Robert Lerner	USAF - SMYND
Lt. Col. Jack Hilden	USAF - SMQNP
Major James Pursell	USAF - SMVMF
Lt. Russell	USAF - MKI R/V

3. Purpose of Visit

To discuss sundry missile components which have limited life due to calandar aging or operation and to explore ways and means of extending their lives.

4. Discussion

The Minuteman Configuration Control Board (MCCB) has the final responsibility for changes including extending the lives of components. General Schultz is the chairman. Board membership depends upon the problem under consideration; members are from projects, reliability, corrosion control, SAC, air training, OOAMA, etc.

It is basically the responsibility of the project groups to define possible problem areas for the MCCB. Lt. Col. Hilden has the propulsion responsibility. There are seven project areas; hence, there are seven surveillance programs in existance. No one individual or group coordinates these surveillance programs into a homogeneous program.

Minuteman surveillance programs commenced in 1958, with emphasis on propulsion. During the first production run, motors from all three stages were saved for age surveillance. A failure criteria program was completed in 1964 in which the minimum (or maximum) values of critical parameters were established. Critical parameter values are plotted against time to develop trends. Data is collected from laboratory, component and system tests to obtain trend data. A full-scale motor program fires one or two motors per year; the data helps bring component data into perspective. SAMSO attempts to test items that are at least six months older than the items in service to anticipate any future problem areas. Their programs are coordinated with OOAMA programs. Inspection tests are developed as required. A three-year life was contractually imposed upon minuteman vendors; a ten-year life was a goal. Some component lives are now at seven years.

Some accelerated aging of solid motors via elevated temperatures has been attempted; but, in general, most laboratory aging tests have paralleled field environments. Minor grain cracks are now accepted as not affecting performance. Also minor cracks are accepted in the buna-n gasket on the end of the first stage nozzle.

TRW has a contract to assist and advise SAMSO concerning age/cycle limited items. TRW developed a decision matrix for age out - whether to refurbish, modify, or scrap. The only major weakness of this technically oriented matrix is the lack of political impact parameters, especially concerning scrap decisions.

An age sampling program for the Mk I re-entry vehicle (R/V) was started five years after production started. A sample size of one to six is tested each year. It was stated that vendor data was the best source of information for R/V's. The life of a pressure switch was extended after age-trend data was fitted to an exponential curve rather than considered a linear function.

5. Documents Obtained

None

6. Action Items

a. Request a classified SAMSO report on propulsion surveillance from Major Pursell.

7. Summary

See discussion paragraph.

SURVEY TRIP REPORT NO. 40
CONTINENTAL AIRLINES
LOS ANGELES, CALIFORNIA

15 May 1969

1. Persons Making Trip

L. W. Tipton	MMC - Systems Engr.
J. C. DuBuisson	MMC - Reliability
K. E. Riggs	NASA - S & E - TEST - ST
R. L. Graham	NASA - S & E - QUAL - QRR
A. O. Boyanton, Jr.	NASA - PM - SAT - E

2. Persons Visited

Dale W. Rausch	CAL - Director of Planning and Controls

3. Purpose of Visit

To discuss sundry commercial aircraft components which have limited life due to calandar aging or operation and to explore ways and means of extending their lives.

4. Discussion

A manufacturing review board (MRB) of FAA decides component by component upon their time or cycle lives. The FAA is primarily concerned with safety in setting lives, whereas the airlines are more cost effective oriented. The prime aircraft manufacturers write the original manuals for maintenance and operation. The FAA must approve all initial specifications including the minimum equipment list (MEL) that lists all items that must be functioning all the time.

Continental Airlines (CAL) develops its own maintenance procedure consistant with FAA of approved procedures. CAL can perform more maintenance than required. The CAL specifications are sometimes tailored to specific geographic areas. Based upon experience the reliability engineers at CAL can extend item lives within reasonable limits; large extensions require FAA approval. Mr. Rausch felt that the reliability engineers of the prime manufacturers should work closer with CAL in setting lives.

Airlines used to deal with subcontractors directly, but now deal through the major contractor (on tri-jets and later aircraft). Minimum reliability is now part of the subcontracts; if the actual MTBF falls below specification, the subcontractor provides free spares to the airline. Once the MTBF guarantee is exceeded, the airlines are responsible for the item.

The quality control group at CAL assembles all item data and notifies engineering if a problem area is developing. An IBM setup is used for time control of age limited components. The repair and overhaul records are kept in the cognizant shop per FAA requirement. The FAA maintains part lists denoting maximum periods between overhauls. For a sample list contact Chief of Maintenance and Inspection, Air Carrier.

Per FAA, the maximum life of any unit is six years; it must be overhauled at this point. As a minimum, a visual inspection is required every two years. Units are inspected every year during far east service.

The shelf life of uninstalled rubber goods is three years from date of cure. The life can be extended two years by a shop inspection. Six years is the maximum total life allowed. It is best to operate rubber goods occasionally since O-rings get tacky and sticky if inoperative. CAL is extending the shelf life of O-rings three years after WEMCOR, Inc. of Miami Springs recertifies each O-ring by test.

Pan American Airlines has the most environmental data of any airline. CAL is going to encapsulate engines in NAVAN bags of PVC next month.

5. <u>Documents Obtained</u>

None

6. <u>Action Items</u>

a. Obtain a sample copy of a FAA document listing maximum over-haul periods for aircraft equipment.

b. Contact WEMCOR, Inc. for further details concerning their recertification of O-rings.

7. <u>Summary</u>

See discussion paragraph.

APPENDIX D

LIMITED LIFE HARDWARE CONTROL PROGRAMS

A. MARTIN MARIETTA CORPORATION

The following sheets are excerpts from Martin Marietta Corporation, Denver Division's Special Consideration Items - Titan III Family, Drawing 80801Y90000 (SCID).

3.3.1.3 Section III contains the special consideration item sheets which define the special requirements/limitations applicable to each item. The individual sheets are arranged in alpha-numeric order by part number. To prevent an excessive number of items appearing in this section, the dash numbers have been omitted unless the special requirements/limitations are affected by the dash number. When dash numbers are omitted, the requirements/limitations apply only to that item identified by the nomenclature in block 3 and does not apply to items with the same basic part number but different nomenclature.

3.4 DATA ELEMENTS - The data elements contained on the special consideration item sheets and the indices are as follows:

3.4.1 Block 1 - PART NUMBER - The number assigned by the contractor or supplier to identify the item. Operation Control Levels (OCL) is the highest level of control for operation and maintenance records. The OCL(s) will be entered in this block only in Section I. The OCL(s) presently assigned to T IIIC will be used on STC and the OCL(s) presently assigned to T IIIB will be used on STB.

3.4.2 Block 2 - PROGRAM EFFECTIVITY - A designator indicating the program using the item. The designators are:

B - Titan IIIB	STB - Titan IIIB Follow On
C - Titan IIIC	STC - Titan IIIC Follow On
M - Titan IIIM	STD - Titan IIID
	STK - Common Core

3.4.3 Block 3 - NOMENCLATURE - The noun and necessary modifiers on the engineering drawing that describes the item.

3.4.4 Block 4 - CRITICALITY - Entries for this data element shall be in accordance with the criteria of paragraph 3.2.2 above. The criticality classifications identified below are applicable to all Titan III family programs with the exception of SC-Safety Critical which is applicable only to the Titan IIIM program. Only highest criticality classification shall be assigned to any item.
Entries are:

a. SC - Safety Critical;
b. LC - Launch Critical;
c. MC - Mission Critical;
d. TC - Time/Cycle Sensitive;
e. MI - Mission Instrumentation;
f. NA - Not Applicable.

3.4.5 Block 5 - <u>CREW SAFETY REVIEW</u> - A review of crew safety aspects for each critical and major failure, in accordance with the Systems Effectiveness Plan. This element of data is applicable only to the T IIIM Program.
Entries are:

a. YES - Affirmative;
b. NA - Not Applicable.
c. NO - Negative

3.4.6 Block 6 - <u>FLOW CHART</u> - Indicates a requirement for establishing and maintaining production flow charts in accordance with applicable System Effectiveness Plans.
Entries are:

a. YES - Affirmative;
b. NO - Negative.

3.4.7 Block 7 - <u>AUTOMATIC FAILURE ANALYSIS</u> - Items that require automatic failure analysis are those items that must function properly in the countdown through payload separation to accomplish mission success or degrades Planned Launch On Time (PLOT). The contractor shall conduct and document failure analysis for all critical and major failures. The documentation may take the following forms:

a. System Martin Automatic Reporting System (S/MARS);
b. Failed Parts Analysis Report;
c. Annotation on the MARS. In those cases where previous knowledge is available to properly define cause or where cause is self evident by the MARS statement.

Entries are:

a. YES - Affirmative;
b. NO - Negative.

3.4.8 Block 8 - <u>CUSTOMER FAILURE REPORTING REQUIRED</u> - The point of contractor initial acceptance used to determine requirement for reporting critical and major failures to the customer. These failures will be documented in MCR-67-60.
Entries are:

a. Applicable Point of Initial Acceptance;
b. NA - Not Applicable;
c. M - Index only, during Acceptance Test at Martin Marietta;
d. V - Index only, during Acceptance Test at Vendor.

3.4.9 Block 9 - SUBCONTRACTOR/VENDOR CONTROL - The additional controls and requirements such as Reliability Program Plan or M-64-119 that are imposed on the Subcontractor/Vendor.
Entries are:

a. Document Numbers or Titles;
b. NA - Not Applicable.

3.4.10 Block 10 - TRACEABILITY - The control that is used for traceability of parts, i.e., lot control, serialization.
Entries are:

a. LOT - Lot Control;
b. SERIAL - Serialization;
c. NA - Not Applicable.

3.4.11 Block 11 - DATA REVIEW REQUIRED - Airborne traceable components that are considered critical to mission success as a result of a review of failure history. These components are approved for flight usage by Quality and the Product Integrity Engineer after a review of the build, test and failure data of each component by serial number. SAMSO/Aerospace Data Review and approval prior to vehicle acceptance and prior to launch is also required.
Entries are:

a. YES - Affirmative and the types of data required;
b. NO - Negative.

3.4.12 Block 12 - CRITICAL SPARE - Spares that have special requirements/limitations that can be removed and replaced after propellant loading without causing an abort of the mission. All critical spares will be stored in the critical spares storage area.
Entries are:

a. YES - Affirmative;
b. NO - Negative.

3.4.13 Block 13 - DATA TO BE SHIPPED WITH SPARE - The AFTO Forms, Equipment Logs, Test Data, Calibration Data, Historical Records, Inspection and Acceptance Records, etc., that must be shipped with the spare.
Entries are:

a. Type of Data;
b. NA - Not Applicable.

3.4.14 Block 14 - <u>AFTO FORMS REQUIRED</u> - This entry shall identify the applicable Operational Control Level (OCL) and the individual Air Force Technical Order (AFTO) and DD 829-1 Forms that will be initiated and maintained. The Operational Code (OC) shall be included.
Entries are:

a. AFTO/DD 829-1 Forms, OCL(s) and OC;
b. NA - Not Applicable.

3.4.15 Block 15 - <u>CLEAN LEVEL</u> - The cleaning requirements for all items which are contamination controlled. The cleaning level will be reflected as identified in Engineering Process Specification (EPS) 50405 latest revision/amendment. Exceptions will be documented in this drawing. Items cleaned to Level J or commercial clean level will not be reflected in this drawing.
Entries are:

a. Applicable Clean Level;
b. NA - Not Applicable.

NOTE: Items presently in stock that are secondary spares and require cleaning need not be cleaned until prior to installation in the applicable component or system.

3.4.16 Block 16 - <u>OPERATING LIMITATION</u> - The time or cycle limitation of an item under operating conditions.

a. Limitation - the time or cycle limitation.
Entries are:

(1) Time or Cycle Limitation;
(2) NONE - No Limitation;
(3) (R) - indicates that the item will be reconditioned after expiration of the limitation;
(4) (D) - indicates that the item will be disposed of after expiration of the limitation.

b. Where two limitations are provided, "AFVA" - indicates limitation at the beginning of Combined Systems Test for Air Force Vehicle Acceptance; "LAUNCH" - indicates limitation at launch.

3.4.16 Block 16 - OPERATING LIMITATION - Continued

c. Remarks - applicable narrative information to explain the condition of the limitation. The operational code will be included when applicable. Operational Codes (OC) are codes assigned to items requiring AFTO 2E Forms which describe the methods, variance and conditions for recording time or cycles.

3.4.17 Block 17 - CALENDAR LIFE - The maximum period of time from date of assembly or manufacture that an item can retain its desired conformance characteristics, before being reconditioned or condemned, whether the item is installed or in storage.

a. Limitation - time limitation. Entries are:

(1) Time Limitation;
(2) NONE - No Limitation;
(3) (R) - indicates that the item will be reconditioned after expiration of limitation;
(4) (D) - indicates that the item will be disposed of after expiration of limitation.

b. Where two limitations are provided, "AFVA" indicates limitation at the beginning of Combined Systems Test for Air Force Vehicle Acceptance; "LAUNCH" indicates limitation at launch.

c. Remarks - applicable narrative information to explain the conditions of the limitation.

3.4.18 Block 18 - SHELF LIFE - The maximum period of time from date of cure, manufacture or assembly that an item can remain unused in storage before being reconditioned or condemned.
Entries are:

a. Time Limitation;
b. NONE - No Limitation;
c. (R) - indicates that the item will be reconditioned after expiration of the limitation;
d. (D) - indicates that the item will be disposed of after expiration of the limitation.

3.4.18.1 Storage - Rubber items, products, and assemblies that contain age - sensitive polymers shall be protected from circulating air, sunlight, fuel, oil, water, dust, and ozone (which is generated by electric arcs, fluorescent lamps, and similar electrical equipment). The storage temperature should not exceed 100°F and shall not exceed 125° F.

3.4.18.2 Example where an item has both a Calendar Life and a Shelf Life Limitation:

Assume an item has a calendar life limitation of 36 months and a shelf life limitation of 24 months. The item remains in storage for 23 months and is then installed in a system. The remaining life of the item is the difference between the total calendar life and the accrued time spent in storage. In this example the remaining time would be 13 months (36-23=13). If an item is reconditioned after the expiration of either the calendar life or shelf life the accrued time reverts to zero.

3.4.18.3 Items with a calendar or shelf life limitation identified in months will be controlled to the calendar month and year and not to the day, month and year.

3.4.19 Block 19 - ENVIRONMENTAL ACCEPTANCE TEST (EAT) VIBRATION LIMITATION - The maximum time an item may be subjected to vibration and still be considered for flight usage without being reconditioned or overhauled.
Entries are:

a. Time Limitation;
b. NONE - No Limitation;
c. (R) - indicates Random Vibration;
d. (S) - indicates Sine Vibration.

3.4.20 Block 20 - DISPOSITION INSTRUCTIONS - The disposition action to be taken if the item has exceeded any of the limitations contained in blocks 16, 17, 18 and 19 of this drawing.
Entries are:

a. Applicable Instructions or a Reference Thereto;
b. NA - Not Applicable.

3.4.21 Block 21 - RETEST INSTRUCTIONS - The test requirements or a reference to the test requirements that the item must meet in order to verify that the item has been returned to its original operating condition as a result of instructions in Block 20.
Entries are:

a. Applicable Instructions or a Reference Thereto;
b. NA - Not Applicable.

3.4.22 Block 22 - QUALIFICATION TEST - The testing required to qualify an item for usage.
Entries are:

a. FULL - Full Qualification Test;
b. SIMILARITY - Qualified by Similarity;
c. PARTIAL - Partial Qualification Test;
d. NA - Not Applicable.

3.4.23 Block 23 - EXTENDED ACCEPTANCE TEST - The additional testing required to insure that an item is acceptable for usage on the Titan IIIM Program and will be conducted in accordance with the requirements established in Volume VI and VIII of SSD-CR-65-275. This element of data is applicable only to the Titan IIIM Program.
Entries are:

a. Applicable Volumes of SSD-CR-65-275;
b. NA - Not Applicable.

3.4.24 Block 24 - CRITICAL LAUNCH SITE REPLACEABLE ITEM - STB, STC, STD and Titan IIIM Critical Items which can be replaced at the launch complex.
Entries are:

a. YES - Affirmative;
b. NO - Negative;
c. NA - Not Applicable.

3.4.25 Block 25 - PACKAGING REQUIREMENTS - The special or unusual packaging requirements peculiar to the item. For normal packaging requirements refer to the applicable Package Data Card. (Martin Marietta Corporation only).
Entries are:

a. Special Packaging Requirements or a reference to the requirements;
b. NA - Not Applicable.

3.4.26 Block 26 - HANDLING REQUIREMENTS - The special or unusual handling requirements peculiar to the item. (Martin Marietta Corporation only).
Entries are:

a. Special Handling Requirements or a reference to the requirements.
b. NA - Not Applicable.

3.4.27 Block 27 - STORAGE REQUIREMENTS - The special or unusual storage requirements peculiar to the item. (Martin Marietta Corporation only).
Entries are:

a. Special Storage Requirements or a reference to the requirements;
b. NA - Not Applicable.

3.5 IMPLEMENTATION

3.5.1 The special consideration items drawing shall be implemented by all affected Denver and field site organizations as directed by operations directive and standard procedures. These organizations shall utilize the requirements/limitations in this drawing when ordering, receiving, handling, storing, repairing, testing and approving hardware as well as the preparation of data products required to support any of the above functions. Affected departments shall prepare or revise internal operating practices, procedures, process plans, shop folders, log books and related instructions to insure that the requirements/limitations of this drawing are implemented.

3.6 CONTROL OF SPECIAL CONSIDERATIONS ITEMS

3.6.1 All items listed in this drawing with the exception of small electronic piece parts, bolts, nuts, panel fasteners, bearings and clamps shall be identified as having special considerations by means of decals on the container or package, and on the part.

3.6.2 The part decals shall be propellant compatible and shall be applied at the point of acceptance. Part decals shall be applied only after the final finish is applied, and will be applied only on non-bearing surfaces in a manner that does not impede the operation of the item. Sound judgement will be used when applying decals. If there is a possibility that the decal would contaminate the item, or if the item is too small, the decal will not be utilized. The part decal shall be applied near the name plate or the part number of the item and positioned so that it does not obscure any information. Part decals shall be applied in accordance with the requirements set forth in EPS 45012.

SECTION 3.0 (CONTINUED)

SPECIAL CONSIDERATION ITEM

1. PART NUMBER	2 PROGRAM EFFECTIVITY	3 NOMENCLATURE	4 CRITICALITY	5 CREW SAFETY REVIEW	6 FLOW CHART	7 AUTOMATIC FAILURE ANALYSIS	8 CUSTOMER FAILURE REPORTS REQUIRED
PD2600023		BOLT, EXPLOSIVE	NC	YES	NO	YES	DURING ACCEPTANCE TEST AT VENDOR

9 SUBCONTRACTOR/VENDOR CONTROL	10 TRACE-ABILITY	11 DATA REVIEW REQUIRED	12 CRITICAL SPARE	13 DATA TO BE SHIPPED WITH SPARE	14 AFTO FORMS REQUIRED	15 CLEAN LEVEL
N-64-119	SERIAL LOT	YES, ACCEPTANCE DATA	NO	AMMUNITION DATA CARD	NEXT ASSEMBLY 208 T-IIIM OCL-51	NA

16 OPERATING LIMITATION: LIMITATION	16 OPERATING LIMITATION: REMARKS	17 CALENDAR LIFE: LIMITATION	17 CALENDAR LIFE: REMARKS	18 SHELF LIFE	19 EAT VIBRATION LIMITATION
NONE	NA	36 MONTHS (D)	FROM DATE OF MANUFACTURE	NONE	NONE

20 DISPOSITION INSTRUCTIONS	21 RETEST INSTRUCTIONS	22 QUALIFICATION TEST	23 EXTENDED ACCEPTANCE TEST	24 CRITICAL LAUNCH SITE REPLACEABLE ITEM
DISPOSE OF IN ACCORDANCE WITH RANGE ORDNANCE REGULATIONS.	NA	YES	NA	YES

25 PACKAGING REQUIREMENTS	26 HANDLING REQUIREMENTS	27 STORAGE REQUIREMENTS
1. PACKAGE PER SPECIAL STUDY DRAWING A6D215.	1. PER AFM 127-100. 2. DO NOT HANDLE IN FACTORY WITH EXPLOSIVE INSTALLED. 3. SSD EXHIBIT 66-4, 17 JUNE 1966, PARAGRAPH 3.1.9.2.	1. PER AFM 127-100. 2. STORE IN EXPLOSIVE STORAGE AREA IN VENDOR'S CONTAINER OR THE SHIPPING CONTAINER AND DUNNAGE OR EQUIVALENT. 3. SSD EXHIBIT 66-4, 17 JUNE 1966, PARAGRAPH 3.1.9.2.

ENG.	CODE IDENT. NO.	SIZE	
BF	04236	B	80801Y90000

SCALE

SPECIAL CONSIDERATION ITEM

1 PART NUMBER	2 PROGRAM EFFECTIVITY	3 NOMENCLATURE	4 CRITICALITY	5 CREW SAFETY REVIEW	6 FLOW CHART	7 AUTOMATIC FAILURE ANALYSIS	8 CUSTOMER FAILURE REPORTS REQUIRED
PD4600005		CYLINDER ASSEMBLY, ACTUATING, LINEAR - ROLL NOZZLE CONTROL	MC	YES	YES	YES	DURING ACCEPTANCE TEST AT VENDOR

9 SUBCONTRACTOR/VENDOR CONTROL	10 TRACEABILITY	11 DATA REVIEW REQUIRED	12 CRITICAL SPARE	13 DATA TO BE SHIPPED WITH SPARE	14 AFTO FORMS REQUIRED	15 CLEAN LEVEL
M-64-119 AND VENDOR RELIABILITY PROGRAM PLAN	SERIAL	YES, ACCEPTANCE DATA AND VIBRATION TIME RECORDS	YES	AFTO FORM 2E	2E; OC-305 T-IIIM OCL-52	E

16 OPERATING LIMITATION — LIMITATION	16 OPERATING LIMITATION — REMARKS	17 CALENDAR LIFE — LIMITATION	17 CALENDAR LIFE — REMARKS	18 SHELF LIFE	19 EAT VIBRATION LIMITATION
NONE	OC-305, OBSERVE AND RECORD CALENDAR LIFE FROM THE DATE OF MANUFACTURE OR REPLACEMENT OF SOFTWARE AND FUNCTIONAL TEST.	54 MONTHS AFVA 60 MONTHS LAUNCH (R)	DUE TO SEAL LIFE	NONE	85 MINUTES ALL AXIS (S)

20 DISPOSITION INSTRUCTIONS	21 RETEST INSTRUCTIONS	22 QUALIFICATION TEST	23 EXTENDED ACCEPTANCE TEST	24 CRITICAL LAUNCH SITE REPLACEABLE ITEM
1. RETURN TO VENDOR FOR REPLACEMENT OF SOFTWARE AFTER EXPIRATION OF CALENDAR LIFE. 2. IF VIBRATION LIMITATION IS EXCEEDED, RETURN TO VENDOR FOR COMPLETE DISASSEMBLY AND INSPECTION, REPLACEMENT *	PARAGRAPH 4.1.5.1, PD4600005	YES	IN ACCORDANCE WITH SSD-CR-65-275, VOLUME VI	YES

25 PACKAGING REQUIREMENTS	26 HANDLING REQUIREMENTS	27 STORAGE REQUIREMENTS
NA * DISPOSITION INSTRUCTIONS (CONTINUED) OF DIFFERENTIAL PRESSURE TRANSDUCER, POTENTIOMETER (WHERE APPLICABLE) AND SOFTWARE. REMOVED PARTS WILL BE SCRAPPED. AFTER TWO (2) REFURBISHMENTS (TOTAL VIBRATION TIME OF 255 MINUTES), THE ITEM IS TO BE SCRAPPED.	1. USE THE VENDOR'S CONTAINER WITH DUNNAGE IN PLACE WHEN PRACTICAL. 2. WHEN THE VENDOR'S CONTAINER IS NOT PRACTICAL WRAP THE PART IN POLYURETHANE FOAM AND BOX INDIVIDUALLY IN A CORRUGATED OR WOOD CONTAINER. 3. MOVE ASSEMBLY ONLY WHEN PROTECTION IS INSTALLED.	1. STORE AND ISSUE WITH PROTECTION ON THE ITEM.

CODE IDENT. NO.	SIZE	
04236	B	80001Y90000
CHG. BE	SCALE	SHEET 320

SECTION 3.0 (CONTINUED)

SPECIAL CONSIDERATION ITEM

1 PART NUMBER	2 PROGRAM EFFECTIVITY	3 NOMENCLATURE	4 CRITICALITY	5 CREW SAFETY REVIEW	6 FLOW CHART	7 AUTOMATIC FAILURE ANALYSIS	8 CUSTOMER FAILURE REPORTS REQUIRED
6160T060000		CONNECTOR, RECEPTACLE, ELECTRICAL	MC	YES	NO	YES	DURING ACCEPTANCE TEST AT MARTIN MARIETTA

9 SUBCONTRACTOR/VENDOR CONTROL	10 TRACE-ABILITY	11 DATA REVIEW REQUIRED	12 CRITICAL SPARE	13 DATA TO BE SHIPPED WITH SPARE	14 AFTO FORMS REQUIRED	15 CLEAN LEVEL
NA	SERIAL	NO	NO	DD 829-1	DD 829-1 T-IIIM OCL-52	NA

16 OPERATING LIMITATION		17 CALENDAR LIFE		18 SHELF LIFE	19 EAT VIBRATION LIMITATION
LIMITATION	REMARKS	LIMITATION	REMARKS		
NONE	NA	NONE	NA	120 MONTHS (R)	NONE

20 DISPOSITION INSTRUCTIONS	21 RETEST INSTRUCTIONS	22 QUALIFICATION TEST	23 EXTENDED ACCEPTANCE TEST	24 CRITICAL LAUNCH SITE REPLACEABLE ITEM
1. RETURN TO VENDOR FOR REPLACEMENT OF SOFTWARE UPON EXPIRATION OF SHELF LIFE.	1. RERUN ACCEPTANCE TEST.	NA	NA	YES

25 PACKAGING REQUIREMENTS	26 HANDLING REQUIREMENTS	27 STORAGE REQUIREMENTS
NA	1. MAINTAIN UNITS IN VENDOR PACKAGING OR PLASTIC BAGS PRIOR TO USE. 2. PLACE CUT WIRE LENGTHS AND CAPPED FITTINGS IN PLASTIC BAGS, IDENTIFY AND SEAL. 3. IN-HOUSE MOVEMENT OF ASSEMBLIES SHALL BE MADE IN PADDED (FOAM OR FOXPAC) CARTONS, TOTE PANS OR CARTS DEPENDING ON SIZE OF ASSEMBLY. CONTAINER MUST PROVIDE ONE INCH CLEARANCE ON ALL SIDES. 4. PLUG ASSEMBLIES WITH MULTI-CONDUCTOR CABLES, WRAP WITH CORRUGATED TUBING AND SECURE.	1. STORE WITH HANDLING PROTECTION IN PLACE.

CODE IDENT. NO.	SIZE	
04236	B	80801Y90000
REF	SCALE	SHEET 71

SPECIAL CONSIDERATION ITEM

1 PART NUMBER	2 PROGRAM EFFECTIVITY	3 NOMENCLATURE	4 CRITICALITY	5 CREW SAFETY REVIEW	6 FLOW CHART	7 AUTOMATIC FAILURE ANALYSIS	8 CUSTOMER FAILURE REPORTS REQUIRED
81600000900		TANK, FUEL - STAGE I	SC	YES	YES	YES	DURING ACCEPTANCE TEST AT MARTIN MARIETTA

9 SUBCONTRACTOR/VENDOR CONTROL	10 TRACEABILITY	11 DATA REVIEW REQUIRED	12 CRITICAL SPARE	13 DATA TO BE SHIPPED WITH SPARE	14 AFTO FORMS REQUIRED	15 CLEAN LEVEL
NA	SERIAL	YES, ACCEPTANCE DATA AND X-RAYS	NO	NA	NA	CC

16 OPERATING LIMITATION: LIMITATION	16 OPERATING LIMITATION: REMARKS	17 CALENDAR LIFE: LIMITATION	17 CALENDAR LIFE: REMARKS	18 SHELF LIFE	19 EAT VIBRATION LIMITATION
30 HYDROSTATIC PRESSURE CYCLES	OBSERVE AND RECORD THE NUMBER OF HYDROSTATIC PRESSURE CYCLES ON THE CONTRACTOR TEST DATA SUMMARY SHEET FROM DATE OF MANUFACTURE.	NONE	NA	NONE	NONE

20 DISPOSITION INSTRUCTIONS	21 RETEST INSTRUCTIONS	22 QUALIFICATION TEST	23 EXTENDED ACCEPTANCE TEST	24 CRITICAL LAUNCH SITE REPLACEABLE ITEM
IF OPERATING LIMITATION IS EXCEEDED, ITEM IS TO BE SCRAPPED.	NA	YES	NA	NO

25 PACKAGING REQUIREMENTS	26 HANDLING REQUIREMENTS	27 STORAGE REQUIREMENTS
NA	1. THE LOGS FOR THIS ASSEMBLY WILL CALL OUT THE MISSILE MOVEMENT METHODS TO BE USED.	1. SPECIAL ARRANGEMENTS WILL BE PROVIDED BY MANUFACTURING AT THE TIME OF STORAGE.

CHG.	CODE IDENT. NO.	SIZE		SCALE	SHEET
BE	04236	B	80801Y90000		972

B. McDONNELL DOUGLAS ASTRONAUTICS COMPANY, EASTERN DIVISION

The following pages are excerpts from McDonnell Douglas Astronautics Company Eastern Division's MOL Program Gemini B System Segment AVE Preventive Maintenance Requirements Summary, Report P. S. 338, dated 31 December 1968.

4. Under the column heading "LIFE LIMIT" calendar time and operating time or cycles to which an item may be subjected prior to its retirement from service as a flight-worthy component are identified. Appendix A, Life Limited Equipment Index, represents supplementary information in addition to the LIFE LIMIT column. All life limited items in the document are compiled in this index as a ready-reference. In addition, the preflight portion of equipment life limit is identified in two parts; preinstallation life limit and prelaunch life limit.

   a. Maximum allowable preinstallation usage defines the optimum number of operating hours or cycles which may be expended on an item before installation in the flight spacecraft. This figure is designed to prevent installation of an item which could experience wear out before mission completion.

   b. Maximum allowable prelaunch usage defines the number of operating hours or cycles that may be expended on an item up to launch. An item experiencing more than the number of hours or cycles defined by this figure are subject to wear out before mission completion and should not be flown.

   The determination of life limit is based on analysis of equipment characteristics. Any item judged to be incapable of operating 150% of the anticipated operating life from manufacture to mission termination is considered life limited.

5. "STORAGE LIFE" identifies the period of time that an item may remain in controlled storage without overhaul, parts replacement or requalification.

STORAGE LIFE in this instance refers to noninstalled equipment stored in a specified environment.

6. "SHELF LIFE" specifies the minimum period of item storage life, during which it remains in a ready-for-installation status. Shelf life is specified separately from storage life in order that a distinction can be made between levels of maintenance associated with the established maintenance concept. Generally speaking, maintenance intervals associated with shelf life represent the maximum time an item can remain in storage prior to installation as a flight-worthy component without first undergoing a revalidation test. The "SHELF LIFE" maintenance requirement is not mandatory if the item is not to be maintained in the ready-for-installation status. If the item is to be maintained in the ready-for-installation status to support the launch, then the maintenance must be performed when the specified SHELF LIFE interval is exceeded.

7. "INSTALLED LIFE" represents the projected time period that an item may remain installed in the spacecraft and still conform to specified requirements of performance. This column is subdivided into two categories; installed operating life and installed nonoperating life.

   a. Installed Life - Operating - This subcolumn indicates the period of time or number of cycles an item may sustain before it must be removed from flight status or requalified in accordance with the PERIODIC MAINTENANCE TEST DESCRIPTION column. An N/A in this column denotes tha the item must be removed when the life limit has been reached or exceeded.

b. Installed Life - Nonoperating - This subcolumn indicates, in calendar time only, how long an item may remain inactive in the system before it must be reverified as operational by the system test engineer. The figure in this column assumes a condition of "dry storage" where specified precautionary measures have been taken for protection from extreme environments and contamination.

8. "PERIODIC MAINTENANCE TEST DESCRIPTION" defines maintenance frequencies and descriptions of tasks required to maintain an item in accordance with life requirements specified in the previous columns.

a. Frequency - For each life column of the left page, the FREQ. column will contain a figure denoting the frequency at which the item must be maintained. A frequency entry will be entered for all life limit items. Only those items that the life limit is critical to the mission and coded AT or AC will continuous life monitoring be required to prevent exceeding the indicated frequency. In addition to figures corresponding to the left page, this column also lists "interim" maintenance frequencies of a cyclic nature.

b. Installed or Stored - An "X" in either of these columns indicates whether the figure in the FREQ. column is applicable to stored or installed equipment or both.

c. Maintenance Description - This column provides a narrative description of the stored or installed maintenance required at the indicated frequency. A notation to confidence test prior to installation if a particular time period has elapsed since the last EFC is based on the following concepts:

(1) Each replacement component of flight hardware is assigned an EFC validity period which establishes the period of time during which it may remain in a stored or otherwise inactive condition since the last EFC without requiring reverification before installation in the flight spacecraft.

(2) If a replacement component is required for installation in the spacecraft and has exceeded the validity period, it must undergo a confidence test prior to installation.

(3) A confidence test consists of a sufficient amount of verification testing to establish the flight worthiness of unit to be installed Confidence tests are run only before installation and only when the assigned validity period is exceeded. The degree of testing necessary to establish confidence is a function of the equipment physical and operational characteristics and may increase or decrease in magnitude as equipment operating history dictates.

Recycle testing requirements are established for those equipments whose history indicates a tendancy toward degradation from inactivity. These degradation tests may vary in magnitude from a "burn-in" period to a complete EFC depending upon the individual equipment requirement. It is noted that several approaches to equipment disposition are required to minimize preinstallation tests at the launch site. To eliminate extensive delays, the following methods are employed to maintain the maximum quantity of ready-for-installation spares:

- o Components with short EFC validity periods, (confidence test intervals of 90 days or less), will be shipped on demand as a replacement for a failed component. These components will be stored at MDAC-ED St. Louis. The required recycle EFC requirements are scheduled to provide a ready-for-installation spare set of S/C hardware, unless VAFB has the capability to perform the confidence test required. In those instances where confidence test cannot be accomplished using system test equipment, components will be returned to St. Louis and disposition made in conformance with program requirements.
- o Those items requiring cyclic test not in the nature of an EFC will be returned to St. Louis receiving inspection for revalidation at the intervals specified herein only if the test capability does not exit at VAFB.
- o Equipment is maintained at the launch site for performing tests on components whose physical, material or operational characteristics are not conducive to recycle testing in St. Louis.
- o S/C peculiar components will be shipped to Vandenberg within 90 days of scheduled launch date or concurrent with S/C shipment and disposition made in conformance to program requirements.

MOL PROGRAM

GEMINI B SYSTEM SEGMENT

SYS. ITEM NO.	PART NOMENCLATURE AND NUMBER	LIMITED LIFE DATA CODE	LIFE LIMIT	STORAGE LIFE	SHELF LIFE	INSTL. LIFE	
						OPR.	NONOPR.
4C1WA	Cartridge, LIoH (70210) 52-83700-789	AT	52H	Indef.	N/A	N/A	N/A
4C1XO	Valve, Regulating, Demand Relief and Manual Shutoff (70210) 52-83700-1171	B	2000H or 120M	** 30M	90D	N/A	N/A
4C1YO	Valve, Shutoff, Manual (99193) 52-83700-3057	B	2000H or 120M	** 30M	90D	N/A	N/A

PERIODIC MAINTENANCE TEST DESCRIPTION					SPECIAL HANDLING AND STORAGE REQUIREMENTS	SYS. ITEM NO.
FREQ	INSTL	STOR	MAINTENANCE DESCRIPTION	REF DOC.		
52H	X		Submit to Material Review Board for disposition at accumulation of specified useage.	----	Store in original sealed cannister only, under positive pressure.	4C1WA
5H	X		Replace prior to Launch after accumulation of specified time of ground useage.	----		
2000H 120M	X	X	Submit to Material Review Board for disposition when valve has been subjected to operating pressure for hours specified, or has accumulated months specified from date of delivery	----	Requires handling compatible with GOX cleaned components. Ref. MAC P.S. 20505, except cleanliness per MAC P.S. 12302. -NOTE- If valve is not stored in a metal container, the replacement frequency of elastomer components will be 18 months in lieu of 30 months. Ref. MAC P.S. 23600.	4C1XO
30M		X	At accumulation of months specified from date of assembly, submit to Material Review Board for disposition on replacement of elastomer components installed in valve, EFC, and subsequent extension of storage life.	----		
90D		X	Confidence test prior to installation if over 90 days since last EFC.	STDR B3-70		
74D PTI		X	EFC.	STDR B3-70		
2000H 120M	X	X	Submit to Material Review Board for disposition when valve has been subjected to operating pressure for hours specified, or has accumulated months specified since date of delivery.	----	Requires handling compatible with GOX cleaned components. Ref. MAC P.S. 20505, except cleanliness per MAC P.S. 12302.	4C1YO
30M		X	Perform EFC to verify serviceability, and re-establish storage life.	STDR B3-70		
90D		X	Confidence test prior to installation if over 90 days since last EFC. (continued)	STDR B3-70		

C. McDONNELL DOUGLAS COMPANY, GEMINI SPACECRAFT

The following pages are excerpts from McDonnell Douglas Company's Gemini Spacecraft Systems Maintenance Summary, Report No. SEDR 306, dated 8 August 1966.

MAINTENANCE SUMMARY

SECTION I

SYSTEM MAINTENANCE SUMMARY

SCOPE

1. FOR PURPOSES OF THE ACCESS AND REMOVAL TASK ANALYSIS CONTAINED IN THE FOLLOWING SECTION THE FOLLOWING ASSUMPTIONS ARE MADE WITH RESPECT TO THE SPACECRAFT CONFIGURATIONS -
   A. THE SPACECRAFT IS ON THE PAD JUST PRIOR TO ERECTOR LOWERING.
   B. SQUIB BUSSES ARE DISARMED AND ALL CONTROL SWITCHES AND CIRCUIT BREAKERS PLACED IN A STANDARD -SAFE- POSITION.
   C. THE NECESSARY STEPS HAVE BEEN TAKEN TO INSURE THAT CRITICAL PRESSURE AND TEMPERATURE PARAMETERS CAN BE MONITORED UNDER ESTABLISHED -HOLD AND RECYCLE- CONDITIONS.

   PRIMARILY, PHYSICAL ACCESS ONLY HAS BEEN CONSIDERED. UNLESS COMPLETELY OBVIOUS, THE MANY POSSIBLE INTANGIBLES THAT MAY AFFECT REMOVAL TIME HAVE NOT BEEN SHOWN. AS AN EXAMPLE, CREW REMOVAL IS INDICATED ONLY IN THOSE INSTANCES AS REQUIRED FOR PHYSICAL ACCESS OR IN CASE OF A VERY OBVIOUS REQUIREMENT SUCH AS DEMATING EXTENDING HOLDS, ETC.

   FOR THE PURPOSES OF THE ACCESS AND REMOVAL TASK ANALYSIS CONTAINED IN THE TDA SECTION, THE FOLLOWING ASSUMPTIONS ARE MADE WITH RESPECT TO THE TDA CONFIGURATION.
   A. PYROTECHNICS ARE NOT INSTALLED.
   B. THE LAUNCH SHROUD HAS NOT BEEN INSTALLED.

2. ALL AGE REQUIRED IS CONSIDERED ON LOCATION AND AVAILABLE.

3. REMOVAL TIME ESTIMATES ARE BASED ON THE MANPOWER SHOWN AS BEING AVAILABLE.

4. UNDER THE HEADING -STORED PERIODIC MAINTENANCE- THE INDICATED PRE-INSTALLATION AND RECYCLE TEST REQUIREMENTS ARE BASED ON THE FOLLOWING BASIC GROUND RULES -
   A. EACH ITEM OF REPLACEMENT FLIGHT HARDWARE SHALL BE PIA TESTED PRIOR TO INSTALLATION IN THE FLIGHT SPACECRAFT. TO AVOID DELAYS IN INSTALLATION, PIA TESTING SHALL BE SCHEDULED CONSISTENT WITH THE LOCATION AND AVAILABILITY OF THE NECESSARY TEST EQUIPMENT.
      REQUIREMENTS FOR TESTING UPON INITIAL RECEIPT ARE DETAILED IN SEDR 307. THOSE EQUIPMENTS REPAIRED, OVERHAULED OR MODIFIED BY EITHER THE VENDOR OR THE CONTRACTOR SHALL BE SUBJECT TO THE SAME INITIAL PIA TEST REQUIREMENTS AS NEW ITEMS.

   B. EQUIPMENT ITEMS SHALL BE REMOVED FROM THE FLIGHT SPACECRAFT FOR PURPOSES OF PERFORMING PIA TESTS, ONLY WHEN ABNORMAL CIRCUMSTANCES REQUIRE THAT SUCH AN EVALUATION IS REQUIRED. EQUIPMENT REMOVED TO FACILITATE THE REMOVAL OF OTHER HARDWARE SHALL REQUIRE RE-PIA ONLY WHEN SPECIFIED BY COGNIZANT SYSTEMS ENGINEERS.

MAINTENANCE SUMMARY

4. /CONTINUED/

C. UNDER THE COLUMN HEADING -STORED PERIODIC MAINTENANCE-, A NOTATION TO CONFIDENCE TEST PRIOR TO INSTALLATION IF A PARTICULAR TIME PERIOD HAS ELAPSED SINCE THE LAST PIA TEST IS BASED ON THE FOLLOWING DEFINITIVE PREREQUISITES -

1. EACH REPLACEMENT COMPONENT OF FLIGHT HARDWARE IS ASSIGNED A PIA VALIDITY PERIOD WHICH ESTABLISHES THE PERIOD OF TIME DURING WHICH IT MAY REMAIN IN A STORED OR OTHERWISE INACTIVE CONDITION SINCE THE LAST PIA TEST WITHOUT REQUIRING RE-VERIFICATION BEFORE INSTALLATION IN THE FLIGHT SPACECRAFT.

2. IF A REPLACEMENT COMPONENT IS REQUIRED FOR INSTALLATION IN THE SPACECRAFT AND HAS EXCEEDED THE VALIDITY PERIOD DESCRIBED IN 1. ABOVE, IT MUST UNDERGO A -CONFIDENCE- TEST PRIOR TO INSTALLATION. A CONFIDENCE TEST CONSISTS OF A SUFFICIENT AMOUNT OF VERIFICATION TESTING TO ESTABLISH THE FLIGHT WORTHINESS OF A UNIT TO BE INSTALLED. CONFIDENCE TESTS ARE RUN ONLY PRIOR TO INSTALLATION AND ONLY WHEN THE ASSIGNED VALIDITY PERIOD IS EXCEEDED. THE DEGREE OF TESTING NECESSARY TO ESTABLISH CONFIDENCE IS A FUNCTION OF THE EQUIPMENT PHYSICAL AND OPERATIONAL CHARACTERISTICS AND MAY INCREASE OR DECREASE IN MAGNITUDE AS EQUIPMENT OPERATING HISTORY DICTATES. COMPONENT PIA TEST PROCEDURES CONTAIN APPROPRIATE IDENTIFICATION OF THOSE PORTIONS OF THE PROCEDURE WHICH CONSTITUTE A CONFIDENCE TEST.

D. RECYCLE TESTING SHALL BE ESTABLISHED FOR THOSE EQUIPMENTS WHOSE HISTORY INDICATES A TENDENCY TOWARD DEGRADATION FROM INACTIVITY. THESE DEGRADATION TESTS MAY VARY IN MAGNITUDE FROM A -BURN-IN PERIOD- TO A FULL PIA DEPENDING UPON THE INDIVIDUAL EQUIPMENT REQUIREMENT.

E. ONE SET OF SPACECRAFT EQUIPMENT THAT REQUIRES TWO OR MORE SHIFTS TO PIA SHALL BE MAINTAINED AS READY SPARES BY APPROPRIATE UP-DATING ACTION.

5. IT IS NOTED THAT SEVERAL APPROACHES TO EQUIPMENT DISPOSITION ARE REQUIRED TO MINIMIZE PRE-INSTALLATION TESTS AT THE LAUNCH SITE. TO ELIMINATE EXTENSIVE DELAYS, THE FOLLOWING METHODS ARE EMPLOYED TO MAINTAIN THE MAXIMUM QUANTITY OF READY-FOR-INSTALLATION SPARES -

5. /CONTINUED/

B. COMPONENTS WITH SHORT PIA VALIDITY PERIODS, /CONFIDENCE TEST INTERVALS OF 90 DAYS OR LESS/, WILL BE SHIPPED ON DEMAND AS A REPLACEMENT FOR A FAILED COMPONENT. THESE COMPONENTS WILL BE STORED AT MAC ST. LOUIS. THE REQUIRED RECYCLE PIA REQUIREMENTS ARE SCHEDULED TO PROVIDE A READY-FOR-INSTALLATION SPARE SET OF S/C HARDWARE, UNLESS CAPE HAS THE CAPACILITY TO PERFORM THE CONFIDENCE TEST REQUIRED. IN THOSE INSTANCES WHERE CONFIDENCE TEST CANNOT BE ACCOMPLISHED USING SYSTEM TEST EQUIPMENT, COMPONENTS WILL BE RETURNED TO ST. LOUIS AND DISPOSITION MADE IN CONFORMANCE WITH PROGRAM REQUIREMENTS.

C. THOSE ITEMS REQUIRING CYCLIC TESTS NOT IN THE NATURE OF A PIA WILL BE RETURNED TO ST. LOUIS RECEIVING INSPECTION FOR REVALIDATION AT THE INTERVALS SPECIFIED HEREIN ONLY IF THE TEST CAPABILITY DOES NOT EXIST AT CAPE.

D. EQUIPMENT IS MAINTAINED AT THE LAUNCH SITE FOR PERFORMING TESTS ON COMPONENTS WHOSE PHYSICAL, MATERIAL OR OPERATIONAL CHARACTERISTICS ARE NOT CONDUCIVE TO RECYCLE TESTING IN ST. LOUIS.

E. S/C PECULIAR COMPONENTS WILL BE SHIPPED TO CAPE WITHIN 90 DAYS OF SCHEDULED LAUNCH DATE OR CONCURRENT WITH S/C SHIPMENT AND DISPOSITION MADE IN CONFORMANCE TO PROGRAM REQUIREMENTS.

F. IN THOSE CASES WHERE EXPEDIENCY IN CORRECTING A MALFUNCTION REQUIRED THE REPLACEMENT OF A MODULE AS OPPOSED TO REPLACING A COMPONENT, THE REQUIRED MODULES ARE STOCKED, TESTED AND DISPOSITIONED IN ACCORDANCE WITH THE SAME OPERATIONAL PROCEDURES STATED IN A THRU E ABOVE.

6. UNDER THE COLUMN HEADING - INSTALLED PERIODIC MAINTENANCE - /SPACECRAFT IS CONSIDERED TO BE IN DRY STORAGE/. IN MANUFACTURING BUILDUP, OR SST TESTING THE PERIODIC MAINTENANCE REQUIREMENTS IN THIS COLUMN ARE NOT APPLICABLE UNLESS SO NOTED.

7. AN ITEM MARKED -NON-REPAIRABLE- DOES NOT PRECLUDE THE POSSIBILITY OF FAILURE ANALYSIS.

8. PARTS AUTHORIZED FOR REMOVAL BY U.S. GOVERNMENT CONTRACTING OFFICER FROM FLOWN SPACECRAFTS SHALL BE RETURNED TO MAC ST. LOUIS - GFAE CRIB FOR CONTRACT ACCOUNTABILITY AND/OR DISPOSITION, WITH THE EXCEPTION OF EXPERIMENTS AND GFAE OPERATIONAL EQUIPMENTS.

MAINTENANCE SUMMARY
ACCESS, REMOVAL, AND REPAIR

SYSTEM ECS & COLDPLATES

SYS. ITEM NO.	ITEM NAME AND PART NO.	ACCESS & REMOVAL			REPAIR-ABLE AT				DESCRIPTION OF REPAIR POSSIBLE
		ITEM	TIME (HRS)	MANPWR.	VEND.	STL.	CAPE	NONREPAIR	
01-061	VALVE, MANUAL VENT INFLOW 52-83700-895 MODIFIED TO 52-83162- -33 S/C 11-12	OPEN CREW HATCHES.	0.10	2	X				REBUILD AND/OR REPAIR AT THE VENDOR FACILITY. COMPONENT CONTAINS SILICONE RUBBER -O- RING AND PACKING. NOTE WILL ALSO REQUIRE REMOVAL OF 52-83711, SEAL ASSEMBLY.
		CREW EGRESS AND PYROTECHNIC DISABLING, REF. PAGE 12-22.	0.60	2					
		REMOVE BOTH EJECTION SEATS, REF. PAGE 12-12.	2.50	3					
		INSTALL SERVICE SEAT.	0.20	2					
		REMOVE SHINGLE NO. 78A.	.450	1					
		DISCONNECT SUIT FAN SWITCH AT VALVE ARM.	0.30	1					
		DISCONNECT MANUAL CONTROL CABLE AND SPRING.	0.30	1					
		RELEASE FLEXIBLE TUBE CLAMP	0.30	1					
		REMOVE SIX /6/ BOLTS AT SMALL PRESSURE BULKHEAD.	0.80	2					
01-062	VALVE, SUIT AND TEMPERATURE CONTROL 52-83700-255 MODIFIED TO 52-83156 -11 S/C 11-12	OPEN CREW HATCHES.	0.10	2	X				REBUILD AND/OR PREAIR AT THE VENDOR FACILITY.
		CREW EGRESS AND PYROTECHNIC DISABLING, REF. PAGE 12-22.	0.60	2					
		DESERVICE COOLANT SYSTEM PER SEDR K506.	0.50	3					
		REMOVE ECS FLOW CONTROL PANEL.	0.50	1					
		DISCONNECT FOUR /4/ COOLANT LINES.	0.50	1					
		REMOVE TWO /2/ VALVE RETAINING BOLTS.	0.30	1					
		REMOVE VALVE.	0.10	1					
01-063	VALVE, TEMPERATURE CONTROL 52-83700-719 S/C 11 - 12	DEMATE S/C FROM L/V, REF. PAGE 12-10.	3.55	4	X				REBUILD AND/OR REPAIR AT THE VENDOR FACILITY. COMPONENT CONTAINS -O-RING VITON -A- MATERIAL.
		DESERVICE COOLANT SYSTEM CONCERNED PER SEDR K506.	1.50	3					
		DISCONNECT INLET, OUTLET AND BY-PASS FITTING.							
		REMOVE VALVE.	0.10	1					

MAINTENANCE SUMMARY
PERIODIC MAINT. AND TEST

SYSTEM ECS & COLDPLATES

PAGE 01-043

PERIODIC MAINTENANCE & TEST						SPECIAL STORAGE & HANDLING REQUIREMENTS	SYS. ITEM NO.
STORED			INSTALLED				
TYPE OF MAINTENANCE	FREQ. (MO.)	REF. DOC.	TYPE OF MAINTENANCE	FREQ. (MO.)	REF. DOC.		
CONFIDENCE TEST PRIOR TO INSTALLATION IF OVER 18 MONTHS SINCE LAST PIA TEST.		SEOR 380				REQUIRES HANDLING COMPATIBLE WITH LOX CLEANED COMPONENTS. REF. PS 20505	01-061
REPLACE SEAL 3 YRS. FROM CURE.	36						
RETURN TO VENDOR AND RE-PLACE SILICONE RUBBER -O- RING AND PACKING 5 YRS. FROM DATE OF MFG.	60						
PIA TEST AFTER SEAL CHANGE.							
CONFIDENCE TEST PRIOR TO INSTALLATION IF OVER 18 MONTHS SINCE LAST PIA TEST.		SEOR 380				REQUIRES HANDLING COMPATIBLE WITH LOX CLEANED COMPONENTS. REF. PS 20505	01-062
PIA TEST AND RETURN TO STORAGE.	30						
RE-PIA TEST PRIOR TO INSTALLATION IF OVER 18 MONTHS SINCE LAST PIA.		SEOR 380				REQUIRES HANDLING COMPATIBLE WITH LOX CLEANED COMPONENTS. REF. PS 20505	01-063
RETURN TO VENDOR AND REPLACE VITON -A- -O- RING 5 YRS. FROM DATE OF MFG.	60						
PIA TEST AND RETURN TO STORAGE.	30						

D. GRUMMAN AIRCRAFT ENGINEERING CORPORATION

The following are excerpts from Grumman Aircraft Engineering Corporation's AAP/LM-A Time/Cycle Sensitive Items Summary, No. ARP255-015, dated 10 September 1968; AAP Data Development Form - Flight Hardware Limited Operating Life Equipment; LM Reliability Shelf Life Log by Equipment No./Serial No., dated 3-11-69; and LM Reliability Shelf Life Program Storage/Non-Operational Restrictions, dated March 1969.

1.0 SCOPE

This summary of the time/cycle sensitive items to be used on the AAP/LM-A vehicle has been prepared in response to Data Requirement Description (DRD) TM-020, in accordance with Modification 9 to Contract NAS 9-6608.

Those equipments tentatively identified as candidates for the AAP/LM-A Limited Life List and the AAP/LM-A Shelf Life List are shown in Tables I and II, respectively.

The extensive checkout requirements programmed for the LM-A at Bethpage and KSC demonstrate a need to identify, monitor and control the use of time/cycle sensitive equipments. As a result of these requirements, equipment that will operate for a few hours or actuate only a few times during the mission can conceivably accumulate hundreds of hours or cycles of test operation prior to vehicle launch, thus jeopardizing mission success or crew safety because of the premature and possible unnecessary wearout of the item during the AAP/LM-A mission.

The AAP/LM-A Limited Life/Shelf Life Limited Equipment Program forms the basis for identifying, tracking and maintaining records of elapsed time/cycle sensitive entries, to assure replacement or refurbishment of those equipments that might be expected to wear out or deteriorate with age or use. The ground rules and criteria in use on this program are identical to those established for the Apollo LM program in effect on 21 August 1968, in accordance with paragraph 3.5 of the AAP/LM-A Reliability Plan (APL255-1).

In view of the open-ended nature of the AAP/LM-A mission, the current list of NASA approved Apollo LM limited life equipments will be expanded to include equipments that were originally considered for entry in the Apollo LM limited life list. These equipments will be considered as candidate entries only, subject to further analysis and review by the cognizant engineers.

This document will be revised as required by additions and/or deletions in the AAP/LM-A Hardware Configuration List, applicable milestones, cycle definitions, equipment design changes or operating restrictions.

2.0 PROGRAM DEFINITION

2.1 Definition of Terms

2.1.1 Equipment Identification

For purposes of this report, the term equipment is considered synonymous with the terms: piece part, item, part, component, hardware or assembly.

2.1.2 Limited Life Equipment

Limited life equipment is defined as a vehicle item where one or more of the following apply:

a. The estimated pre-launch and mission usage is close enough to the estimated operating life that time and/or cycle usage history must be known to assure that an adequate mission life remains after the last KSC functional test.

b. A scheduled calibration, adjustment, or replacement is required periodically and usage history must be maintained to allow scheduling or such action during pre-launch operations.

c. Analysis of development and test data justifies maintaining time and/or cycle usage history during pre-launch operations.

d. All propellent tanks and high pressure vessels.

2.1.3 Limited Shelf Life Equipment

Limited shelf life equipment is defined as an item which is subject to degradation of performance beyond acceptable limits due to aging within a specified period after its date of manufacture.

2.1.4 Shelf Life Limit

Shelf life limit is defined as the maximum calendar time which an equipment can accrue without risk of degradation of performance beyond acceptable limits.

2.1.5 Operating Time

Operating time is defined as the cumulative time measured in hours, minutes or seconds that an equipment has been used functionally in a standby or operational mode.

2.0 PROGRAM DEFINITION (continued)

2.1.6 Cycle

The cycle is defined uniquely for each item and approved by Engineering. A cycle generally implies activation and return to the initial state. Exceptions are the definitions applied to pressure vessels and cabin inner window panels for determining cycle occurrence, as discussed in paragraph 4.0 and subparagraph thereof.

2.2 ESTABLISHING OPERATING AND MILESTONE LIMITS

Following the identification of time/cycle sensitive equipments (Sellers Maintainability Analysis), preliminary operating and milestone limits are established by Grumman. These limits are based upon an Engineering and Reliability evaluation of the time constraining characteristics of an item, an appraisal of its anticipated usage during all ground test phases and an analysis of mission requirements. Operating and milestone limits that are allocated to each phase of equipment operation (i.e., Seller, Bethpage and KSC facilities), assures that hardware will not have entered its wearout zone prior to mission completion. This allocation of time/cycles also serves to prevent indiscriminate and unnecessary cycling of an equipment (e.g., RCS valves) which could result in premature entry into the wearout zone. The specific causes of an item's limited life characteristics are periodically analyzed and recommendations to eliminate or moderate them are submitted to the cognizant LM-A organizational element. Design changes, test experience and historical data are continually reviewed and revisions to operating and milestone limits are prepared, where applicable. Equipment lists will be submitted to NASA for approval. The limited life entries which are provided in Section 4.0 reflect the milestone limits established for the Apollo LM program and mission. These items, prefixed, with a double asterisk, are those for which the milestones previously established are not compatible with the present AAP/LM-A mission considerations. Therefore additional evaluations as reflected in the AAP/LM-A Equipment Suitability Report, ARP255-3 must be performed in order to establish the suitability of the items and corresponding milestone limits compatible with the results of these evaluations and the AAP/LM-A

2.2 ESTABLISHING OPERATING AND MILESTONE LIMITS (continued)

mission requirements.

2.3 SHELF LIFE LIMITED EQUIPMENT SPARES LIST

A program has been initiated for the reverification of shelf life limited spares to insure that the item is ready for issue. The preparation of a spares list commences with identification of equipments requiring refurbishment or inspection during its term in storage. This is accomplished by the cognizant engineer, utilizing the Shelf Life Data Development Form shown as Exhibit H.

A preliminary listing of shelf life limited equipment and restrictions is provided in Section 4.0. These entries are applicable to the Apollo LM mission. Entries will be revised, as required, to reflect equipments and restrictions applicable to the AAP/LM-A mission. The list includes those equipments which wholly or partially deteriorate with calendar time, and require periodic operation, alignment, calibration or testing. The list includes the equipment name, number, storage life restriction and interval between actions prior to and after installation on the vehicle. Restriction entries indicate a required action, e.g., parts to be replaced, scrap, test, etc., and the test procedure to be followed in case of retest.

2.4 OPERATING TIME/CYCLE LOGS

Operating logs developed for the Apollo LM limited life and shelf life limited program will be utilized. Logs will be maintained by Inspection on a current basis from completion of equipment manufacture throughout their operating life. These records will remain with the equipment and contain as a minimum, the part number, part name, serial number, operating life limit, cumulative operating time/cycles, and if applicable, exercise time/cycle requirements as directed by the cognizant engineers, history or special storage restraints.

2.5 SPECIAL PROGRAM REQUIREMENTS

It is the responsibility of Quality Assurance to implement the following actions necessitated by changes in the referenced limited life equipment and/or applicable milestones.

a. Revise the milestones appearing on currently used Equipment

2.5 SPECIAL PROGRAM REQUIREMENTS

Operating Time Logs to reflect newly amended limitations, established by Engineering.

b. Enter applicable "header" data, including the applicable milestones, on all required LM-A Equipment Historical Data Sheets, and effect distribution.

2.6 AAP/LM-A HARDWARE LIST - APOLLO LM EQUIPMENT

Apollo LM hardware that has been approved for entry in the Apollo LM Limited Life Equipment List and is utilized for the AAP/LM-A, is numerically ordered on the lists shown in Section 4.0. Entries include those equipments added to the Apollo LM program list as of June 26, 1968, via Apollo LM document, LPC550-1669, Revision I.

As specific items on the Apollo Limited Life Equipment List are identified as requiring modification for use on the AAP/LM-A, an asterisk will be affixed to these entries for identification. Identification of these equipments in this manner, prior to the specific issuance of firm commitments on the extent of proposed modifications, will serve to flag an entry for further analysis to determine its eligibility to remain on the list. It should be noted that there is only one (1) such item presently identified, i.e., the PCA.

2.7 AAP-LM-A HARDWARE LIST - APOLLO LM ORIGINALLY LISTED EQUIPMENT

In view of the open-ended nature of the LM-A mission, Apollo LM hardware which had originally been considered for entry on the Apollo Limited Life List but subsequently deleted, will be re-evaluated by Grumman prior to being re-submitted to NASA for further consideration.

2.8 AAP/LM-A HARDWARE LIST - NEW EQUIPMENT

AAP/LM-A new hardware will be incorporated into the AAP/LM-A Limited Life Equipment List on the basis of their anticipated design similarity to Apollo LM developed hardware. It should be recognized that until the individual items are more clearly defined, the limited life values shown are estimates and will be revised as necessary. Early identification will serve to flag a component for an indepth analysis to (1), determine its eligibility for design improvement to abrogate usage limitations, or (2), determine its eligibility to remain on the Limited Life Equipment List.

2.9 READJUSTMENT OF CYCLES/HOURS - APOLLO LM VERSUS AAP/LM-A

The present open-ended aspect of the AAP/LM-A mission may require that certain adjustments be considered in the operating time and milestone limits which are now specified in Section 4.0. To determine if any adjustment is in fact necessary and can be tolerated, an analysis of the equipment's test history will be performed and recommendations submitted to NASA for review. NASA concurrence will result in issuance of a revised list. In performing an analysis, the following will also be considered:

a. All improvements in the learning curve which have been made on preceding LM vehicles that have resulted in anticipated reduction in test time or cycles.

b. All improvements in integrating required tests which have materially lowered the period of time an equipment is energized or cycled.

2.10 SURVEILLANCE OF APOLLO LM CHANGES

An internal Grumman agreement has been made to assure that all changes in the Apollo LM limited life and shelf life limited program are brought to the attention of the AAP/LM-A program. Analyses, recommendations and the rationale for accepting, modifying or rejecting Apollo LM changes will be submitted to NASA for final disposition.

2.11 IDENTIFICATION OF TEST OPERATIONS AND PROCEDURES

A summary of the test operations involving the use of limited life and shelf life limited equipment is presented below. Succeeding paragraphs indicate where a test is performed, identifies the forms required for limited life data entries and the agency responsible for maintaining the forms.

2.11.1 ACCEPTANCE TEST

This test is performed at the seller's facility. A notation of the hours of operation and/or cycles expended by the seller after equipment assembly is entered on Form G631 (Suppliers Quality Surveillance Report), Form G1265 (Operating Time Log) and Form G503 (LM Equipment Historical Data). Sample formats are shown as Exhibits A, B AND C respectively.

AAP/LM-A LIMITED LIFE EQUIPMENT LIST

TABLE I

PART NUMBER	PART NAME	OPERATING TIME LIMIT	MILESTONE LIMITS KSC START OF COUNTDOWN	MILESTONE LIMITS GAEC SHIPMENT OF VEHICLE	MILESTONE LIMITS GAEC RECEIPT OF EQUIPMENT	
LDW280-11030	Inner Window Panel, Left Forward	5.8 PSID/ 40 CYCLES	40	20	-	4.1
		7.7 PSID/ 8 CYCLES	8	6	-	
LDW280-11030	Inner Window Panel, Right Forward	5.8 PSID/ 40 CYCLES	40	20	-	4.1
		7.7 PSID/ 8 CYCLES	8	6	-	
LDW28010283	Inner Window Panel, Upper Docking	5.8 PSID/ 40 CYCLES	40	20	-	4.1
		7.7 PSID/8 CYCLES	8	6	-	
LSC300-110	Gyro, Rate	2000 Hours	1500	1100	400	
LSC300-370	Sensor Assembly, AB/GB	1000 Hours	700	500	170	
LSC300-390	Data Entry & Display Assembly	1000 Hours	-	-	-	
LSC300-710	Coupler, Program	* 1000 Hours	700	500	300	
LSC310-301	Tank, Helium	100 Cycles	75	50	25	4.1
LSC310-403	Valve, Solenoid, Propulsion	1000 Cycles	750	300	-	4.2
LSC310-405	Tank, Propulsion, Positive Expulsion	100~~0~~ Cycles	75~~0~~	50	25	4.3
LSC310-405	Bladder, Propulsion, Positive Expulsion	6 Cycles	6	3	1	4.3
LSC330-191	Recirculation Assembly, Cabin Air	** 300 Hours	100	75	50	

Notes - Effective Start

1. Seller Acceptance (Date)
2. Last GAEC Test (Date)
3. Includes Seller Testing (Hr./Cycles), Accumulated To Date

AAP/LM-A

EQUIPMENT SHELF LIFE RESTRICTION DATA

TABLE II

PART NUMBER	PART NAME	STORAGE / NON - OPERATIONAL RESTRICTION	INTERVAL	START (NOTE	INSTALLED / OPERATIONAL RESTRICTION	INTERVAL	START (
LSC 300-370	Abort Sensor Assy.	PIT test per LTP375-3002/3003. Return to stock if acceptable.	30 days	2	Check performance per LLR 370-82 prior to expiration of period. Return to seller if unacceptable.	60 days	2
		PAT test at vendor per TPL 2065.4C. Return to stock if acceptable.	1800 days	1			
LSC 300-390	Data entry & display assy. (DEDA)	PIT test per LTP375-3002/3003. Return to stock if acceptable.	180 days	2			
		Replace "O" ring seal. PAT test per TS2-38	1800 days	1			
LDW 300-28800	Thrust Translation Controller	Operational check per LPC 902-46001	720 days	2			
		Overhaul & replace boot, LDW 300-11812-21. PAT test per LPC 90243001E.	1800 days	1	Overhaul & replace boot, LDW 300-11812-21. PAT test per LPC 90243001E.	1800 days	1

GRUMMAN AIRCRAFT ENGINEERING CORPORATION - ENGINEERING DEPARTMENT
AAP DATA DEVELOPMENT FORM - FLIGHT HARDWARE
LIMITED OPERATING LIFE EQUIPMENT

Sub-System and Section ______________________ Seller Part No. __________

Part Name ______________________ Grumman Part No. __________

Seller ______________________ Date __________

Mission Requirements (hours/cycles, etc): ______________________

____

Specification Design Life: ______________________

Operating time Limits

	Previous	Revised
At receipt from seller		
At shipment from Grumman		
At start of countdown		
Maximum operating life (Eng'g Est)		

Rationale (May include but is not limited to: Apollo LM success history
Design improvements and/or deletion of test requirements)

____

Special Instructions for handling: ______________________

____

Cognizant Engineer ______________________ Plant No ____ Extension ____
Reliability Engineer ______________________ Plant No. ____ Extension ____

MSFC Concurrence ☐ Rejected ☐

Authority: ______________________ Telephone ____

Distribution: Cognizant Engineer / Reliability/Quality Assurance/Data Management
1-S-760

EQUIPMENT NO	GAEC SER NO	VENDOR SER NO	CL CD	VEH	LOC	MAINT INT	REPL INTVAL START DATE	NEXT SCHD REPL DATE	ACTIVE INTVAL START DATE	NEXT ACTIVE DATE	MAINT INTVAL START DATE	NEXT SCHD MAINT TASK	OVER-HAUL INTVAL START	NEXT SCHD OVER-HAUL	NEXT SCHD REPL	NEXT SCHD MAINT TASK	SEQ NO
LSC270-701-3		2219138	N		G	1800					670828	720828					00338
LSC270-701-3		2219139	N		G	1800					670711	720711					00339
LSC270-701-3		2219140	N		G	1800					670823	720823					00340
LSC270-701-3		4133103	N		G	1800					650616	700616					00312
LSC270-701-3		4133104	N		G	1800					650616	700616					00311
LSC270-701-3		4133105	N		G	1800					650610	700610					00310
LSC270-701-3		4459106	N		G	1800					650804	700804					00309
LSC270-701-3		4459107	N		G	1800					650804	700804					00300
LSC270-701-3		4459108	N		G	1800					650901	700901					00313
LSC270-701-3		4459109	N		G	1800					680403	730403					00314
LSC270-701-3		5065143	N		G	1800					681025	731025					00374
LSC270-701-3		5065144	N		G	1800					681021	731021					21009
LSC270-701-3		6878154	N		G	1800					681217	731217					21008
LSC270-701-3		6878155	N		G	1800					681204	731204					21007
LSC270-701-3		7534110	N		G	1800					660406	710406					00315
LSC270-701-3		7534111	N		G	1800					660316	710316					00316
LSC270-701-3		7534112	N		G	1800					660315	710315					00317
LSC270-701-3		7534113	N		G	1800					660406	710406					00318
LSC270-701-3		7534114	N		G	1800					680123	730123					00319
LSC270-701-3		7534115	N		G	1800					660408	710408					00320
LSC270-701-3		8344116	N		G	1800					660425	710425					00321
LSC270-701-3		8344117	N		G	1800					660422	710422					00307
LSC270-701-3		8344118	N		G	1800					660422	710422					00322
LSC270-701-3		8344119	N		G	1800					660422	710422					00305
LSC270-701-3		8344120	N		G	1800					660422	710422					00306
LSC270-701-3		8344121	N		G	1800					660422	710422					00323
LSC270-701-3		8545122	N		G	1800					660826	710826					00324
LSC270-701-3		8545123	N		G	1800					660826	710826					00325
LSC270-701-3		9619124	N		G	1800					661007	711007					00326
LSC270-702-1		2689141	N		G	1800					670914	720914					00376
LSC270-702-1		3226143	O	36	G	1800											00437
LSC270-702-1		5471147	N		G	1800					681010	731010					00439
LSC270-702-1		5471148	N		G	1800					680919	730919					00431
LSC270-702-1		5471149	N		G	1800					680919	730919					00432
LSC270-702-1		5471150	N		G	1800					680919	730919					00433
LSC270-702-1		5471151	N		G	1800					681010	731010					00438
LSC270-702-1		7038120	N		G	1800					660203	710203					00380
LSC270-702-1		7684122	N		G	1800					660303	710303					00381
LSC270-702-1		7684123	U	32	G	1800											00436
LSC270-702-1		8087128	N		G	1800					660504	710504					00378
LSC270-702-1		8087129	N		G	1800					660524	710524					00377
LSC270-702-1		8087130	N		G	1800					660524	710524					00379
LSC270-702-1		8087134	N		G	1800					680903	730903					00434
LSC270-702-1		8087135	O	18	G	1800											00435
LSC270-702-3		0021131	N		G	1800					661114	711114					00430
LSC270-702-3		0021132	N		G	1800					661115	711115					00414
LSC270-702-3		0021133	N		G	1800					661115	711115					00413
LSC270-702-3		0021134	N		G	1800					661115	711115					00412

COMPLIANCE DUE

PART NUMBER	* - PART LOT/SERIAL NUMBER - *		PART NAME	SEQUENCE
LSC390-25-3-2	GAEC 140	VENDOR	ELECT CONTRL ASY,A/S	12110

NEXT SCHEDULED MAINTENANCE TASK DATE--- 690520 MAINTENANCE LOCATION- GAEC
MAINTENANCE TASK NARRATIVE. PIT PER LTP390-28-3 RETURN TO STOCK IF ACCEPTABLE

COMPLIANCE DUE

PART NUMBER	* - PART LOT/SERIAL NUMBER - *		PART NAME	SEQUENCE
LSC330-505-3-3	GAEC	VENDOR 840363	DISCONNECT,INTERSTGE	10523

NEXT SCHEDULED MAINTENANCE TASK DATE--- 690522 MAINTENANCE LOCATION- GAEC
MAINTENANCE TASK NARRATIVE. PIT PER LTP330-39.RETURN TO STOCK IF ACCEPTABLE

COMPLIANCE DUE

PART NUMBER	* - PART LOT/SERIAL NUMBER - *		PART NAME	SEQUENCE
LSC390-25-3-5	GAEC 142	VENDOR	ELECT CONTRL ASY,A/S	12122

NEXT SCHEDULED MAINTENANCE TASK DATE--- 690522 MAINTENANCE LOCATION- GAEC
MAINTENANCE TASK NARRATIVE. PIT PER LTP390-28-3 RETURN TO STOCK IF ACCEPTABLE

COMPLIANCE DUE

PART NUMBER	* - PART LOT/SERIAL NUMBER - *		PART NAME	SEQUENCE
LSC330-307-5-9	GAEC 132	VENDOR	VLV,CABIN RELIEF+DMP	09501

NEXT SCHEDULED MAINTENANCE TASK DATE--- 690523 MAINTENANCE LOCATION- GAEC
MAINTENANCE TASK NARRATIVE. PIT PER LTP330-22.RETURN TO STOCK IF ACCEPTABLE

COMPLIANCE DUE

PART NUMBER	* - PART LOT/SERIAL NUMBER - *		PART NAME	SEQUENCE
LSC270-717-14	GAEC 416	VENDOR	VALVE,HE PRES RELIEF	C1328A

NEXT SCHEDULED MAINTENANCE TASK DATE--- 690527 MAINTENANCE LOCATION- GAEC
MAINTENANCE TASK NARRATIVE. PIT PER LTP270-717.RETURN TO STOCK IF ACCEPTABLE

COMPLIANCE DUE

PART NUMBER	* - PART LOT/SERIAL NUMBER - *		PART NAME	SEQUENCE
LSC330-290-7-1	GAEC 134	VENDOR	COOLANT RECIRC ASSY	09433

NEXT SCHEDULED MAINTENANCE TASK DATE--- 690528 MAINTENANCE LOCATION- GAEC
MAINTENANCE TASK NARRATIVE. PIT PER LTP330-19.RETURN TO STOCK IF ACCEPTABLE