GODDARD TECHNICAL HANDBOOK	**GSFC-HDBK-8010**
Goddard Space Flight Center **Greenbelt, MD 20771**	**Approved:** 09-27-2023 **Revalidation Date:** 09-27-2028

GODDARD SPACE FLIGHT CENTER

GUIDELINE FOR LIMITED-LIFE ANALYSIS

September 2023

NASA GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

Prepared By:

Charles Knapp
Digitally signed by Charles Knapp
Date: 2023.09.06 12:47:26 -04'00'

Charles Knapp
Branch Head, Reliability Maintainability, and Availability Assessment (Code 371)
NASA Goddard Space Flight Center

Approved By:

Tristram Hyde
Digitally signed by Tristram Hyde
Date: 2023.09.07 17:58:51 -04'00'

Tristram T. Hyde
Chief Engineer
NASA Goddard Space Flight Center

Joanne Hill-kittle
Digitally signed by Joanne Hill-kittle
Date: 2023.09.13 19:39:55 -04'00'

Thomas V. McCarthy
Director of Engineering and Technology
NASA Goddard Space Flight Center

CATHLEEN RICHARDSON
Digitally signed by CATHLEEN RICHARDSON
Date: 2023.09.26 15:51:46 -04'00'

Cathy Richardson
Acting Director of Flight Projects
NASA Goddard Space Flight Center

DEIRDRE HEALEY
Digitally signed by DEIRDRE HEALEY
Date: 2023.09.27 14:40:00 -04'00'

Deirdre Healey
Director of Safety and Mission Assurance
NASA Goddard Space Flight Center

DOCUMENT HISTORY LOG

Status	Document Revision	Approval Date	Description
Baseline	-	09-27-2023	Initial Release

FOREWORD

This handbook is published by the Goddard Space Flight Center (GSFC) to provide uniform engineering and technical implementation guidance for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs and projects, including mission assurance methodologies.

This handbook defines a consistent approach for performing Limited-Life Analysis (LLA) on GSFC missions for risk assessment.

Requests for information, corrections, or additions to this handbook should be submitted via "Contact GTSP" to the Executive Secretary for the GSFC Technical Standards Program on the GSFC Technical Standards website at **http://standards.gsfc.nasa.gov**.

Michael Viens

Digitally signed by Michael Viens
Date: 2023.09.06 16:17:15 -04'00'

Michael J. Viens
Technical Standard Program Manager
NASA Goddard Space Flight Center

TABLE OF CONTENTS

SECTION PAGE

DOCUMENT HISTORY LOG 3

FOREWORD 4

TABLE OF CONTENTS 5

LIST OF FIGURES 6

LIST OF TABLES 6

1. SCOPE 7
   1.1 Purpose 7
   1.2 Applicability 7
   1.3 Safety 7

2. APPLICABLE DOCUMENTS 8
   2.1 General 8
   2.2 Order of Precedence 8

3. ACRONYMS AND DEFINITIONS 9
   3.1 Acronyms and Abbreviations 9
   3.2 Definitions 9

4. LIMITED-LIFE ANALYSIS METHODOLOGY 11
   4.1 General 11
   4.2 Roles and Responsibilities 11
   4.3 Analysis Methodology 13
      4.3.1 Limited-Life Item Identification 13
      4.3.2 Limited-Life Item Characterization 14
      4.3.3 Risk Assessment 15

5. REPORTING, TRACKING, and UPDATING 16
   5.1 Reporting 16
   5.2 Tracking 16
   5.3 Updating 17

APPENDIX A – RECOMMENDED RELIABILITY PROGRAM PLAN WORDING 18

LIST OF FIGURES

FIGURE PAGE

Figure 1. LLA Data Flow Diagram....12

LIST OF TABLES

TABLE PAGE

Table 1. Example Flight LLIL Format (minimal) 14
Table 2. Example Ground LLIL Format (minimal)....14
Table 3. Example Limited-Life-Item Tracking Log....17

1. SCOPE

1.1 Purpose

This handbook provides a uniform approach for performing LLA as a living risk assessment document for GSFC missions that is performed concurrently with design efforts and refined as the designs, materials, mission parameters, or processes are refined.

LLA can provide the following project benefits:

- Verification of NASA limited-life requirement and Goddard Open Learning Design (GOLD) Rule compliance
- Identification of candidates for Critical Items List
- Risk identification
- Identification of items requiring maintenance or refurbishment
- Input to sparing plans
- Input to test plans

Proper LLA greatly reduces the risk of premature mission failures by ensuring life margin for wear-out or age-limited items. It also enables missions to be extended with some confidence that hardware will not fail due to life-limiting characteristics.

1.2 Applicability

The guidance set forth in this document provides the baseline approach for LLA on all missions, spacecraft, instruments, ground systems, systems, subsystems, and components developed by, contracted by, or manufactured by GSFC and/or any subsidiary facility.

This handbook may be cited in contracts, program, project, and other Agency documents to provide technical guidance. This handbook was developed mainly with the intent of improving the reliability of flight systems. It can be tailored to apply to ground systems, e.g., use of Table 2.

1.3 Safety

Limited-Life Items (LLI) identified as affecting safety should be reported to the cognizant project safety manager for inclusion in the appropriate safety analysis.

2. APPLICABLE DOCUMENTS

2.1 General

Documents listed in this section contain provisions that constitute underlying requirements related to the implementation guidance provided in this handbook. When imposed, it is expected that the latest issuances of the cited documents will be used unless otherwise approved by the applicable Technical Authority. The applicable documents are accessible via the NASA Technical Standards System at http://standards.nasa.gov, directly from the standards developing organizations, or from other document distributors.

GPR 7120.4	Risk Management
GSFC-STD-1000	Rules for the Design, Development, Verification, and Operation of Flight Systems
NASA-STD-6016	Standard Materials and Processes Requirements for Spacecraft
NASA-STD-8729.1	Reliability and Maintainability (R&M) Standard for Spaceflight and Support Systems

2.2 Order of Precedence

When applied internally or imposed by contract on a program or project, the technical requirements in NASA and GSFC directives (or other requirements documents) take precedence over implementation guidance provided in this handbook.

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms and Abbreviations

ATLO	Assembly, Test, and Launch Operations
CDR	Critical Design Review
DID	Data Item Deliverable
DNC	Does Not Comply
CSO	Chief Safety and Mission Assurance Officer
GOLD	Goddard Open Learning Design
GPR	Goddard Procedural Requirement
GSFC	Goddard Space Flight Center
HDBK	Handbook
LLA	Limited-Life Analysis
LLI	Limited-Life Item
LLIL	Limited-Life-Items List
PDR	Preliminary Design Review
RE	Responsible Engineer
SMA	Safety and Mission Assurance
STD	Standard
WI	Work Instruction

3.2 Definitions

Expected Life	The estimated operational life of an item based on its use and the environmental/operating conditions, etc. for the given mission; or the rated life (i.e., data provided by the manufacturer/supplier/vendor based on heritage or life testing).
Life Ratio	The ratio between the Expected Life and the Required Life: $$Life\ Ratio = \frac{Expected\ Life}{Required\ Life}$$
Limited-Calendar-Life Item	Any item that deteriorates with the passage of time, i.e., items susceptible to aging. This includes installed as well as stored items.
Limited-Life / Life-Limited	Designations referring to an item with limited useful life, regardless of whether the limitation is due to operational consideration, calendar life, or a combination.
Limited-Life Analysis	Analysis performed to assess the risk to mission success/objectives resulting from the use of limited-life items.
Limited-Life Item	Any item (component or material) designated as having a limited useful life regardless of whether it is a limited operating life, limited calendar life, operating parameter sensitive, or combination.

Limited-Life-Items List	A list of all limited-life items identified by the analysis and their corresponding characteristics, e.g., expected life, required life, and life ratio.
Limited-Operating-Life Item	Any item that deteriorates with increased accumulation of operating time/cycles and thus requires periodic replacement or refurbishment to assure that its operating characteristics have not degraded beyond acceptable limits. This includes consideration for total mission time/cycles and safety factor margins.
Life-Limiting Characteristic	The environmental, use, or other factor that limits the life of the item, e.g., time, operating time, actuations, or revolutions.
Mission-Life Risk	The possibility of premature failure or margin loss due to use, environment, or aging.
Operating-Parameter-Sensitive Item	Any item that has a limited life due to variances in its operating parameters that may not be directly related to operating or calendar time.
Required Life	The life the item must meet including storage, testing, operation, duty cycle, maintenance, and refurbishment considerations for the given mission.

4. LIMITED-LIFE ANALYSIS METHODOLOGY

4.1 General

LLI identification is performed during the design and development phases by reliability engineering (at GSFC) together with design engineering and parts engineering. LLA identifies components that potentially have a finite or limited useful life inherent to the performance of their respective functions. This analysis is first performed early in the design phase and updated throughout the development and test phases, reflecting the current performance and status of the components. The goal of the analysis is to determine how much of the expected life is consumed by the stresses the component experiences during testing and operation and by time, and to assess if this will limit mission success. LLA also assists in verification of the following requirements and objectives:

- GOLD Rules (GSFC-STD-1000):
  4.2.3 A life test shall be conducted, within representative operational environments, to at least 2x expected life for all repetitive motion devices with a goal of completing 1x expected life by CDR. The differences between the life-test drive electronics and the flight drive electronics (e.g., voltage, current, duty cycle, etc.) could affect mechanism operating life and should be considered in the life-test.

- NASA-STD-6016C, section 4.2.3.5, Limited-Life Items:
  MPR 94 All materials shall be selected to meet the useful life of the hardware with no maintenance or be identified as Limited-Life Items requiring maintainability.

- NASA-STD-8729.1A, section 4.1.3, subobjective b.:
  The system and its elements remain functional for the intended lifetime, environment, operating conditions, and usage.

4.2 Roles and Responsibilities

Development of LLA requires a detailed understanding of the components and materials that are utilized within the system. Continuous risk management of the items on the list requires involvement of not only Product Design Leads but also Safety and Mission Assurance (SMA) personnel, systems engineering, and Assembly, Test, and Launch Operations (ATLO) project team members to ensure risk levels of the LLIs are managed appropriately (See Figure 1). It is important for these members of the project to have a good understanding of what items are on the Limited-Life Items List (LLIL) and have detailed knowledge regarding the item management and tracking plan.

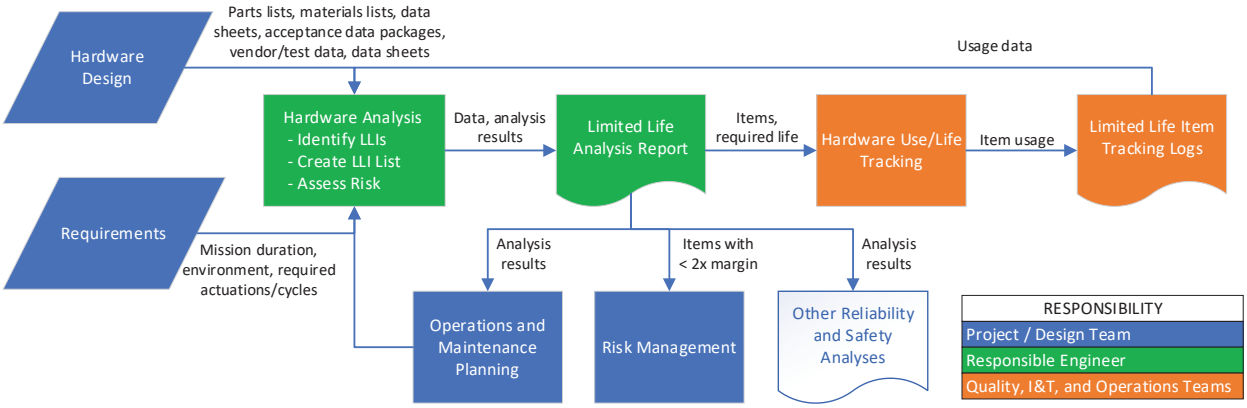

Figure 1. LLA Data Flow Diagram

Roles and responsibilities are as follows:

Responsible Engineer (RE) [Reliability Engineer for GSFC analyses]

a. Has overall responsibility for the LLA (See Appendix A for recommended reliability program plan wording).
b. Performs and documents the analysis.
c. Communicates the risks (e.g., candidate risk statements) and recommendations (e.g., mitigations, life testing) identified in the analysis.
d. Provides the list of LLIs and their life-limited parameters to the appropriate personnel for tracking.
e. Provides analysis results as inputs to safety and other reliability analyses.
f. Keeps the analysis up-to date.

Design Team

a. Provides the necessary design information, e.g., parts and materials lists and required life, to the REs.
b. Assists in the identification of LLIs.
c. Uses data to formulate life tests or design, testing, or operational mitigations to mitigate mission-life risks.
d. For items being life tested, provides the test report.
e. Reviews and approves the LLA.
f. Works with the RE to determine which LLIs should be formally proposed to the project risk management board as risks.
g. Identifies items requiring life used and remaining life tracking. This may be all LLIs, items with a life ratio below a set threshold, or items determined to have a credible chance of having their actual use result in a life ratio of less than two.
h. Ensures that processes are in place for tracking life used and remaining life.
i. Incorporates analysis results into any maintenance/refurbishment planning.

Chief Safety and Mission Assurance Officer (CSO)

a. Reviews and approves the LLA.
b. Ensures that processes are in place for tracking life used and remaining life.

c. Works with the RE to determine which LLIs should be formally proposed to the project risk management board as risks.
d. Regularly reports on LLI usage to the design team and RE and alerts the design team and RE of LLI usage exceedances.

ATLO Team

a. Tracks ATLO usage of LLIs, including pertinent conditions.
b. Ensures that the life used prior to launch does not exceed the planned use. Any exceedances should be reported to the RE for analysis updates.
c. Regularly reports on LLI usage to CSO.

Quality Assurance assists with and verifies life-used tracking, including pertinent conditions.

Operations Team tracks and reports on operational usage of LLIs, including pertinent conditions.

4.3 Analysis Methodology

There are three steps to performing LLA: (1) Limited-Life Item Identification, (2) Limited-Life Item Characterization, and (3) Risk Assessment.

4.3.1 Limited-Life Item Identification

The analysis process begins with a thorough review of all hardware, both parts and materials, required to complete the mission to identify and create a list of LLIs. Items are considered for their susceptibility to environmental or application factors such as atomic oxygen, solar radiation, calendar life, extreme temperatures, thermal cycling, wear, corrosion, fatigue, and vacuum. Typical items that will be identified include, but are not limited to:

- Items that deteriorate or degrade with time either during storage or during operational use (e.g., chemicals, lubricants, seals, O-rings, rubber seals, polymers, solar arrays, paints, adhesives, coatings)
- Items that exhibit characteristics of quality degradation or drift with age (e.g., sensors, equipment needing calibration, gases that decay or slowly leak)
- Items that are cycle/duty cycle sensitive (e.g., switches, relays, valves, Electrically Erasable Programmable Read Only Memory, connectors*, batteries)
- Items that are subject to wear (e.g., moving mechanical parts, bearings, actuators, compressors, momentum wheels, gyros, scan mechanisms)
- Consumable hardware and supplies (e.g., filters, fluid)

** NOTE: Only connectors with any of the following characteristics need to be included:*

- *Press-Fit*
- *Not using connector savers*
- *Alternate Grade*
- *Expected Life < 100 mate/de-mate cycles*

4.3.2 Limited-Life Item Characterization

For each identified LLI, the following are collected or generated:

- Name and part number
- Where used in the system
- Life-limiting characteristic(s)* (how the life of the item is limited)
- Data sources, e.g., data sheets, LLI reports, acceptance data packages, and vendor/test data
- Expected life and supporting analysis or references
- Required life (provided by the design team, accounting for replacement refurbishment)
- Maximum allowable ATLO use
- LLI Reports, Acceptance Data Packages, and Vendor/Test Data, as applicable
- Refurbishment plans, restrictions, limitations (if applicable)

The list of items and their corresponding characteristics are incorporated into a LLIL. Minimal examples are given in Table 1 for Flight and Table 2 for Ground.

** NOTE: Some items may have more than one life-limiting characteristic and, therefore, will be characterized/listed more than once.*

Table 1. Example Flight LLIL Format (minimal)

Item	Life-Limiting Characteristic	Expected Life	Required Life	ATLO Limit	Compliance & Life Ratio	Data Sources & Notes
XXXX Mirror Coating	Degradation of optical properties	10 years	5 years	N/A	Complies 2.0	Expected Life: Vendor datasheet Required Life: Requirement Doc 98765
XXX Switch	Wear-out of contacts	190 cycles	100 cycles	10 cycles	Does Not Comply (DNC) 1.9	Expected Life: Test Report 12345 Required Life: Requirement Doc 98765

Table 2. Example Ground LLIL Format (minimal)

Item	Life-Limiting Characteristic	Expected Life	Refurbishment & Repair	Required Life	Compliance & Life Ratio	Data Sources & Notes
XXX Memory	Bit errors	50,000 write/erase cycles	None	10,000 cycles (10 years)	Complies 5	Expected Life: Required Life:
XXX Battery	Decreased capacity	5 years	Replace every 3 years	3 years	Does Not Comply (DNC) 1.67	Expected Life: Required Life:
XXX Battery	Decreased capacity	1000 charge/ discharge cycles	Replace every 2 years (~ 100 cycles)	100 cycles	Complies 10	Expected Life: Required Life:

A “Conditions” column should be added, if applicable to life limit. Notes may include concerns, failure mode, failure impact, used life, required/assumed maintenance/ refurbishment details, and mitigations. It may be preferable to include this information in additional columns.

4.3.3 Risk Assessment

Each item with a life ratio less than two is assessed for risk and considered for replacement / design changes. For each item retained, the failure impact to the mission and a rationale for use of the item is provided. Examples of rationales for use of items with a life ratio less than two include:

- Lack of alternatives (parts, operations, and design options)
- Extensive heritage for similar use
- Redundancy (not affected by life-limiting characteristic)
- Alternative operations
- Item criticality
- Risk vs. cost/benefit of alternatives (trade study)
- Mitigations to be implemented

Risks should be submitted for retained items as warranted in accordance with GPR 7120.4.

5. REPORTING, TRACKING, and UPDATING

5.1 Reporting

The RE should prepare a LLA report that documents all the information included in the analysis methodology above. At Preliminary Design Review (PDR), the report will include the level of detail that is available. It is possible that only the life-limiting characteristics will be known for many items. For Critical Design Review (CDR), the RE will update the analysis/report based on the details of the more mature/detailed design. Risk statements for any proposed risks should be included in the LLA report.

Along with the report, analysis data and results should be shared as follows:

- Formal risk-management tracking considered for each item with a life ratio less than two.
- A risk proposed for any item whose expected life is less than its required life.
- A waiver to NASA-STD-6016 MPR 94 for any materials whose expected life is less than its required life.
- All LLIs related to safety hazards or controls reported the Project Safety Manager.
- LLA data and results shared to inform project planning and other analyses as is relevant, e.g.:
    - Test plans
    - Operations plans
    - Quality Assurance plans
    - Failure Modes, Effects, and Criticality Analysis (causes and modes)
    - Mission Extension
    - Availability
    - Maintenance plans
    - Refurbishment plans
    - Sparing plans

A report template can be found at https://nasa.sharepoint.com/:w:/r/sites/GSFC-SMA-Shared/Code%20371%20Documents/Other-Analyses-Documents/LLA%20Report%20Template.docx?d=w67371c0c8118454faf6e3076cc310925&csf=1&web=1&e=1Xmi27.

5.2 Tracking

The ATLO team / SMA and operations personnel track the life-limiting characteristics and maintain records of the used/remaining life of each LLI identified for tracking by the design team (e.g., Table 3). These records are used to ensure that ATLO does not result in the possibility of exceeding the required life given in the LLA and to minimize the likelihood of on-orbit exceedance. If use exceeds what was planned for an item, the analysis/report is updated, including reassessment of risk. In the event the risk assessment determines that the exceedance poses meaningful risk to mission success, a risk will be written that should remain open until the minimum mission is achieved.

Table 3. Example Limited-Life-Item Tracking Log

Limited-Life Item:				Allowable ATLO Life:	
Life-Limiting Characteristic: [Time, Rotations, Actuations…]					
Date	Remaining ATLO Life Pre-Op	Life Used	Life Used Total	Relevant Conditions	Remarks

5.3 Updating

The LLA report should be a living document and updated as additional information becomes available (e.g., design details, operations/usage plan updates, test reports, usage data from tracking logs). Report revisions are typically delivered post-CDR (including Launch Readiness Review and Safety and Mission Success Review) and as warranted by the additional information received.

The analysis may also need to be updated in support of mission extension analysis.

APPENDIX A – RECOMMENDED RELIABILITY PROGRAM PLAN WORDING

[Spacecraft/instrument/…] limited-life item identification will be performed during the design and development phases by [developer] [responsible engineer] together with design engineers and parts engineers in accordance with the [project] Mission Assurance Requirements and Appendix E. The resulting list will contain the following information:

- *Name and Part Number*
- *Where used in the system*
- *Life-limiting characteristic(s) (what limits the life of the item)*
- *Data sources, e.g., data sheets, limited-life item reports, acceptance data packages, and vendor/test data*
- *Expected life and supporting analysis or references*
- *Required life (provided by the design team, accounting for replacement refurbishment)*
- *Maximum allowable ATLO use*
- *Refurbishment plans, restrictions, limitations (if applicable)*

All hardware whose useful life is less than twice the required life (baseline and extended) when fabrication, test, storage, and mission operation are combined, will be called out along with rationale for selection/retention and the item's effect on mission success. The [project] project risk management board must approve the use and residual risk of each of these items being retained.

[Developer] [spacecraft/instrument/…] [responsible engineer] will continuously review the identified items to ensure that systems and subsystems have been properly analyzed and to confirm that each elements' performance requirements are met. [GSFC Mission Reliability will also incorporate the items into the mission-level LLA.]