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AEROSPACE REPORT NO.
TOR-2010(8591)-19

Objective Criteria for Heritage Hardware Reuse

June 30, 2010

Dana J. Speece

Mission Assurance Subdivision
Systems Engineering Division

Prepared for:

Space and Missile Systems Center
Air Force Space Command
483 N. Aviation Blvd.
El Segundo, CA 90245-2808

Contract No. FA8802-09-C-0001

Authorized by: Space Systems Group

Developed in conjunction with Government and Industry contributions as part of the U.S. Space Programs Mission Assurance Improvement Workshop.

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Executive Summary

Developers of space flight equipment often look for opportunities to reuse heritage hardware (previously qualified space flight hardware) as opposed to developing new equipment. Based on the existing knowledge of the heritage hardware, reuse can provide benefits to the development effort such as reduced risk due to fewer “unknown-unknowns” and reduced development activity (design, fabrication, verification), which can translate into decreased development cost, schedule, and contingencies (interfaces, mass, volume, power, environmental). Due to these benefits for complex high-reliability space flight equipment developments, heritage hardware reuse planning and processes should be an integral part of the space flight development process.

However, heritage hardware reuse needs to be treated with caution for several reasons. Reusing existing hardware, equipment and/or designs can constrain the design options at the next higher level of integration; i.e., interfaces. Also, reuse decisions are typically made early in the development process, often prior to system level preliminary design, before requirements have been finalized. As a result, the development planning may assume reuse benefits that are not realized due to subsequent system level design. This can result in inadequate resources identified for heritage hardware re-design, rework, and re-verification needed to accommodate the maturing design. This can lead to programmatic issues (increased cost and schedule), high risk technical compromises, or both. Finally, if the reuse decision is not revisited as the system level development matures, then needed heritage hardware modifications may not be identified, resulting in technical deficiencies that may not be identified until the next level of integration or, of more concern, on orbit.

To help mitigate these concerns associated with heritage hardware reuse, several aerospace organizations collaborated to generate this guideline document, which describes objective criteria for heritage hardware reuse. These objective criteria are presented in the form of a Heritage Readiness Level (HRL) Scoring Matrix. This tool is intended for use by those involved in heritage hardware reuse during space flight development and is based on industry best practices. This document focuses on the reuse of space flight units that have been successfully qualified and used on previous missions i.e., a functional replaceable unit made up of units and delivered for integration. These guidelines are intended to be used by those responsible for delivering the flight unit, as well as the customers and integrators of the flight unit.

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Acknowledgements

This document has been produced as a collaborative effort of the Mission Assurance Improvement Workshop. The forum was organized to enhance Mission Assurance processes and supporting disciplines through collaboration between industry and government across the US Space Program community utilizing an issues-based approach. The approach is to engage the appropriate subject matter experts to share best practices across the community in order to produce valuable Mission Assurance guidance documentation.

The document was created by multiple authors throughout the government and the aerospace industry. For their content contributions, we thank the following contributing authors for making this collaborative effort possible:

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1. Introduction

1.1 Background

While it is common practice in the space industry to use heritage designs in new applications, certain problems with this practice persist. For example, the term "heritage" lacks objective criteria to grade hardware pedigree. Poor assumptions are sometimes made regarding the heritage hardware suitability for new programs. Decision makers often lack appropriate tools and methods to make decisions regarding the reuse of heritage hardware.

The Mission Assurance Improvement Workshop (MAIW) has made it a priority to address these problems and has worked to develop tools and methods that would facilitate achieving the intended benefits of using heritage designs. First, the 2008 MAIW chartered the development of an assessment process to address reuse. The 2008 MAIW product, Reuse of Hardware and Software Products, Aerospace TOR-2009(8546)-8604 Rev. A, (Reference 1) outlines an assessment process for contractors, suppliers, and customers to uncover potential issues and identify options associated with the reuse of products. Subsequently, the 2010 MAIW chartered further work, building on the 2008 MAIW effort, to produce the present document.

1.2 Applicability

This document identifies and defines the objective criteria required to assess the applicability of an existing qualified product (heritage hardware) for a new application (heritage reuse) and to quantify the program level risk associated with the reuse decision. Although the objective criteria and processes discussed in this document could apply to multiple levels of hardware products from complex parts to subsystems, the focus of this document is at the flight unit level.

The intent of the heritage readiness level (HRL) score is to have a standard method to determine and communicate the technical and programmatic risks associated with reuse of heritage hardware. The concept is similar to the technology readiness level (TRL) metric used to evaluate the risks associated with new or emerging technology designs. The heritage reuse assessment determines the degree to which previously qualified heritage hardware requirements envelop the new flight unit's application, requirements, and design margins.

The tasks involved in performing the heritage hardware reuse assessment include a thorough evaluation of the new program's unit requirements, a mapping of those unit requirements into the candidate heritage hardware capabilities, an analysis of heritage hardware existing versus current use requirements, and a supporting risk assessment.

Calculation of the HRL score for a proposed hardware unit is most valuable if accomplished during the early phases of a program (i.e., proposal, concept development, architectural definition, etc.) and then revisited if changes occur.

1.3 Definitions

Flight Unit – A complex assembly specified and designed to perform specific functions in launch and/or space mission of a spacecraft, capable of being fabricated repeatedly.

Flight Unit Qualification – The formal verification (by tests, analyses, inspections, demonstrations, and/or similarity) of design requirements including margin, product robustness, and workmanship.

Heritage Hardware – A product (e.g., complex part, unit, assembly, subsystem or system) whose design has previously undergone qualification and flown.

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Heritage Readiness Level (HRL) Score – A numeric rating (e.g., a value between 1 and 9) which quantitatively indicates the likelihood a heritage product will meet program requirements and enhance program success, mission success, and predictability with low risk.

Heritage Reuse Plan – A summary of the steps required to perform necessary product development and risk mitigation. The plan outlines actions needed to replicate the unchanged portions of the product, and minimize risk in portions that require modification.

Heritage Reuse Review – A technical review of the objective criteria as defined by the HRL matrix parameters.

Objective Criteria – The standard against which heritage hardware is assessed or the state required for the hardware to be deemed fully ready for reuse. As it relates to heritage hardware reuse, an individual objective criterion sets a bar for complete reuse readiness within the context of the specific criterion.

Qualified Hardware – A product (e.g., complex part, unit, assembly, subsystem or system) whose design has previously undergone qualification.

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2. Overview

Briefly stated, the heritage hardware reuse assessment objectively quantifies the degree of compliance of a heritage flight unit with new program's requirements and the risk involved in making the unit ready for reuse.

Heritage hardware reuse assessment is performed at the level of a flight unit. The assessment reviews objective evidence about the subject unit relative to the requirements of the new target program in order to determine the compliance of the unit with applicable requirements. In addition, any supplemental activities necessary to achieve compliance become part of the assessment. The unit is scored on each criterion and the results are rolled up into an overall HRL score. The HRL scoring matrix is presented herein as a tool to support this heritage hardware reuse assessment process (See Appendix A).

2.1 Tiered Approach to Reuse Assessment

The tiered approach provides for assessment to be performed and communicated at several levels of detail. Each successive tier provides more specific insight and requires more specific investigation. A program can choose the tier of the assessment based on factors such as the type of decision to be supported by the assessment and resource allocation.

2.1.1 Tier 1 Assessment

A Tier 1 assessment deals with broad criteria and is designed to support high level reuse decisions, such as narrowing the field among a range of design options. A Tier 1 assessment is not designed to provide specific insight to support a final reuse decision.

Since the Tier 1 assessment relies on a small number of objective criteria, it is especially important that the criteria be carefully chosen and well-correlated predictors of successful reuse. Tier 1 assessment focuses on highlighting whether reuse will involve any of the following five reuse risk factors.

1. **Design:** Will a design change be required?
2. **Performance:** Are the performance requirements more stringent?
3. **Manufacturing:** Will manufacturing be done differently from the heritage manufacturing?
4. **Environmental:** Will the environmental exposure be more severe?
5. **Program Controls:** Does the program require more stringent controls that affect the practicality of reuse?

2.1.2 Tier 2 and Tier 3 Assessment

Tiers 2 and 3 involve more specific criteria, and provide more specific conclusions about the reuse. For example, a Tier 1 assessment might identify that a unit design change is required, while a Tier 3 assessment will provide detail as to which requirements necessitate the design change and what activities will be necessary as a result. An example of a complete Tier 3 assessment can be found in Appendix B.

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2.2 Assessment Timing

Reuse assessment should be timed to support program decisions. The following are examples of decision and planning events for which the program should consider obtaining reuse assessments.

- **Requirements development.** Use information about heritage units to develop program requirements which achieve mission objectives and also obtain the benefits of hardware reuse.

- **Design development.** For unit selection trade studies, compare reuse assessments among alternatives heritage and new units.

- **Program planning.** Determine activities necessary to incorporate heritage hardware into the new program. Complete detailed cost estimation, staffing, scheduling, and set aside appropriate programmatic reserves based on uncertainties.

- **Proposal preparation.** Perform reuse assessments in order to document and communicate the extent of unit compliance and the activities involved in reuse.

- **Program baselining.** Perform reuse assessment to ensure all factors have been addressed in final requirements, design configuration, and program planning.

- **Program execution milestones.** Reassess planning assumptions as the program matures. Review aspects of planning, design, and verification, and possibly make revisions to accommodate changes in the program or system level requirements and design.

Adequate readiness assessment and reuse planning need to be completed prior to the new program's authority to proceed (ATP) to enable detailed cost estimating, staffing, and scheduling. Proper reuse planning, including appropriate programmatic reserve based on uncertainty, will minimize risk associated with technical compromises due to lack of resources.

Throughout the program life cycle, the planning assumptions for heritage hardware reuse (like new flight unit development) need to be re-examined in light of the maturing nature of the program. Aspects of planning, design and verification of heritage hardware reuse, and flight unit development need to be reviewed and possibly changed to accommodate changes in the program or system level requirements and design.

2.3 Hardware Certification/Heritage Review

The qualification to baseline application requirements and the associated flight usage history of the proposed reuse unit need to be assessed to confirm/certify its heritage. To examine the qualification of the proposed reuse unit with regard to its baseline application requirements, the unit qualification data (including its qualification certificate) are evaluated as deemed necessary in light of the guidelines of Reference 2. A positive outcome of the evaluation serves as objective evidence for the basis of the unit qualification. In addition, the flight usage history of the proposed reuse unit is examined as deemed appropriate with respect to its mission success. The effort that is required to establish the unit heritage becomes a part of its heritage reuse assessment.

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3. Objective Criteria

Objective criteria for reuse specify the standards for the subject unit to be deemed fully ready for reuse. Reuse criteria mirror the program's standards for flight units to be deemed fully ready for flight. For each program requirement, the standards for reuse readiness are that:

- The substantiating evidence is objective and completely available.
- The target program requirements are completely defined.
- The unit is fully compliant with target program requirements and is substantiated by objective evidence.
- No non-recurring activity or adaptation is necessary for reuse.

The unit is scored on each of the above points and the results are rolled up into an overall HRL score. Note that these criteria set standards for full reuse readiness, and that a real-life unit which falls short of a perfect HRL might still provide the best design option compared to the alternatives. Criteria should be carefully selected to be predictive of successful reuse and practical to utilize for an assessment within program resource allocations.

3.1 Heritage Hardware Objective Criteria Assessment

The HRL scoring matrix (see Appendix A) establishes a method for quantitatively scoring readiness of heritage hardware, used on a previous program, for reuse in the new application (i.e., the target program, or that program targeting reuse of heritage hardware). To that end the HRL scoring matrix consists of objective criteria that are defined by combining heritage readiness technical parameters (rows) with evaluation measures (columns). The HRL scoring matrix supports a comprehensive reuse assessment by capturing a user's evaluation (scores) of each technical parameter relative to each of the measures listed below:

1. Is the objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program? (Measure 1: Heritage Hardware Objective Evidence Availability)

   The purpose of this measure is to ensure that objective evidence is available for the heritage hardware from the previously qualified program (application). This evidence is necessary to establish the baseline for this hardware coming into consideration for its new application. If previous qualification data does not exist for a specific technical parameter (the rows), there exists a risk in being able to assess the previous performance within the target program's application.

2. Are the target program's requirements completely defined for heritage hardware? (Measure 2: Target Program Requirements Definition)

   In order to assess the application of the heritage hardware to the new application, there must be a clear determination of the new program's requirements. If any requirements are undetermined for the target program, then a clear assessment cannot be made and an associated risk will exist in determining the applicability of the heritage hardware.

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3. Does the heritage hardware objective evidence indicate compliance with the target program's requirements, including verification method compliance?
   (Measure 3: Heritage Hardware Compliance to Target Program)

   This is when specialty engineering (subject matter experts – SMEs) make the technical assessment of the heritage design and performance against the new target program's requirements. This is the quantitative determination (evaluation) of heritage hardware's ability to function with the new program requirements and constraints.

4. What is the extent of activity required for the heritage hardware to meet the target program's requirements?
   (Measure 4: Heritage Hardware Activity for Target Program)

   When the other three HRL scoring matrix measures above (1, 2, and 3) indicate that either information, testing, performance, or previous qualification data is sufficiently lacking, this is the technical or programmatic assessment of the work (analysis, testing, redesign, etc.) necessary to ensure compliance with the new target program requirements and environments.

Once the HRL score has been determined using the objective criteria from the matrix, this score can be used for communicating the relative risk of reuse among people associated with the program based on the set of objective criteria. If the HRL scoring matrix is used consistently on a program, then the score can be the basis for trade-offs between development options e.g., newly developed hardware option versus one heritage hardware option versus another heritage hardware option, etc.

Of course, as is true of any process or assessment tool, the HRL scoring matrix results are as good as the information provided as input. Even though the HRL score can be used for decision making throughout the program, the score itself should be generated and reviewed with the support of appropriate SMEs. The parameters that need to be measured for reuse assessment and planning are technical and often subtle. Determining the applicability of heritage hardware requires a detailed review of objective evidence such as existing requirements documentation, design, qualification and verification records, waivers, anomaly resolutions, and the like.

3.2 Objective Criteria Assessment Responsibilities

Using the objective criteria to identify any reuse issues is typically the responsibility of the hardware responsible engineer and supported by specialty engineering and SMEs. A program reuse committee is then assembled to review new application (target program) requirements and proposed reuse of designs that have been qualified and flown. The program reuse committee is typically led by program systems engineering with participation from the Qualification Review Board, mission assurance, specialty engineering, program design engineering, manufacturing, applicable SMEs, and program management personnel. Additional guidance on this subject is available in Reference 1.

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4. Generating the Heritage Readiness Level (HRL) Score

4.1 Introduction to HRL Tool

It is recommended that the HRL scoring matrix be implemented as a spreadsheet for ease of use for data entry and scoring calculation/display. As a note, a Microsoft Excel tool is available from the Aerospace Corporation upon request which has worksheets both for data entry and for display of scoring results. To fill out the HRL scoring matrix, place a score in the matrix cells for each technical parameter (within each row) relative to each evaluation measure (within each column) using the scoring definitions for each measure (shown at the top of each column). The overall HRL score can simply be the average of all the matrix cells. A program may also add different weighting for measures and/or technical parameters.

The HRL scoring matrix is a tool that can be used by the program for early trade studies and proposal planning relative to multiple heritage hardware options, as well as used for final reuse decisions. By scoring only Tier 1 and/or Tier 2 technical parameters against the evaluation measures, the program can get a preliminary assessment of heritage hardware reuse. This preliminary assessment can be useful in performing trade studies or proposal planning often done early in the program before all the SMEs are available to perform a complete assessment. However, scoring of all the technical parameters against each evaluation measure should be done by the appropriate SMEs prior to the final reuse decision e.g., entrance criteria for heritage hardware reuse reviews. NOTE - In this case, the Tier 1 and Tier 2 "technical parameters" would simply be categories that summarize the average scores of the detailed technical parameters.

4.2 HRL Scoring Matrix Utilization

A program can tailor the technical parameters, evaluation measures, weighting of parameters/ measures and scoring definitions to meet their needs. Any tailoring should be clearly documented and communicated throughout the program to avoid misunderstanding. Also, any tailoring should be approved by the customer, especially if the HRL scoring is being used as a basis for competitive selection of a supplier. Use of this tool should be clearly described in a program's reuse plan.

The column labeled "Weighting for Tier 1 Technical Parameters" can be used to weight the Tier 1 technical parameter categories, with the weights summing to "1". Weighting of Tier 2 and Tier 3 technical parameters could be done as well, but this is not recommended due to the complexity and uncertainty of determining these weights and interpreting the associated scores. The row labeled "Measure Weighting >>>" can be used to weight each measure, with the weights summing to "1".

When entering scores for technical parameters, the use of scores that range from 1 to 9 allows for simply averaging. It is recommended that the scores be further restricted to a subset to ease data entry and better delineate between scoring results e.g., subset of scores such as 1, 5 and 9 as shown in the HRL Scoring Matrix.

Relative to verification, it is assumed that each technical parameter for the heritage hardware was verified using a specified verification method e.g., analysis, test, inspection, demonstration, qualification by similarity, etc. It is also assumed that each technical parameter for the target program is required to be verified using a specified verification method. Based on these assumptions, when entering scores for Measure 3 in the matrix, SMEs should consider the compliance of the heritage hardware to the target program's requirements and the specified verification method for each requirement.

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5. Acronym List

ATP	Authority to proceed
HRL	Heritage Readiness Level
HRP	Heritage Reuse Plan
HRR	Heritage Reuse Review
MAIW	Mission Assurance Improvement Workshop
QRB	Qualification Review Board
ROM	Rough Order of Magnitude
SME	Subject Matter Expert
TOR	Technical Operating Report
TRL	Technology Readiness Level

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6. Reference Documents

1. Reuse of Hardware and Software Products, Aerospace TOR-2009(8546)-8604 Rev. A, January 27, 2010.

2. Flight Unit Qualification Guidelines, Aerospace TOR-2010(8591)-20.

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Appendix A. Heritage Readiness Level Scoring Matrix

Heritage Hardware Nomenclature & P/N: _____ & _____

Heritage Readiness Level (HRL) Scoring Matrix

HRL Score *	Weighting for Tier 1 Technical Parameters	Technical Parameter Average Scores	Technical Parameters NOTES: 1. Tier 1 & 2 technical parameters can be used for heritage hardware options' early trade studies & proposal planning OR as category summaries. 2. Complete set of technical parameters can be used to support final reuse decisions.	Measure 1: Heritage Hardware Objective Evidence Availability - Objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program. Measure 1 Scoring definitions: 1 - Not available or unknown . 5 - Partially available . 9 - Completely available or not applicable	Measure 2: Target Program Requirements Definition - Target program requirements are completely defined for heritage hardware. Measure 2 Scoring definitions: 1 - Not defined or unknown . 5 - Partially defined . 9 - Completely defined or not applicable	Measure 3: Heritage Hardware Compliance to Target Program - Heritage hardware objective evidence indicates compliance with target program requirements, including verification method compliance. Measure 3 Scoring definitions: 1 - Not compliant or unknown . 5 - Partially compliant . 9 - Completely compliant or not applicable	Measure 4: Heritage Hardware Activity for Target Program - Extent of activity for heritage hardware to meet target program requirements. Measure 4 Scoring definitions: 1 - Extensive activity required or unknown . 5 - Moderate activity required . 9 - No activity required or not applicable
			Measure Weighting >>>	**0.25**	**0.25**	**0.25**	**0.25**
1			**Measure Average Scores >>>**	**1**	**1**	**1**	**1**
	0.2	**1**	**Performance (Tier 1)**	**1**	**1**	**1**	**1**
		1	**Requirements (Tier 2)**	**1**	**1**	**1**	**1**
		1	Mechanical	1	1	1	1
		1	Thermal	1	1	1	1
		1	Electrical	1	1	1	1
		1	Electrical-Mechanical	1	1	1	1
		1	Electronic	1	1	1	1
		1	Radio Frequency	1	1	1	1
		1	Other performance requirements	1	1	1	1
		1	Measure / command / telemetry	1	1	1	1
		1	**Flight history (Tier 2)**	**1**	**1**	**1**	**1**
		1	Performance on orbit	1	1	1	1
		1	Anomalies	1	1	1	1
		1	Latent HW / SW bugs	1	1	1	1
		1	Operational signatures & constraints	1	1	1	1
	0.2	**1**	**Design (Tier 1)**	**1**	**1**	**1**	**1**
		1	**Interfaces (Tier 2)**	**1**	**1**	**1**	**1**
		1	Functional	1	1	1	1
		1	Physical	1	1	1	1
		1	Mechanical	1	1	1	1
		1	Thermal	1	1	1	1
		1	Electrical	1	1	1	1
		1	Electronic	1	1	1	1
		1	Radio Frequency	1	1	1	1
		1	Software	1	1	1	1

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		1	Human	1	1	1	1
		1	User	1	1	1	1
		1	GSE	1	1	1	1
		1	STE	1	1	1	1
		1	Fixturing	1	1	1	1
		1	Other	1	1	1	1
		1	**Physical Requirements (Tier 2)**	**1**	**1**	**1**	**1**
		1	Dimension	1	1	1	1
		1	Weight	1	1	1	1
		1	Center of gravity	1	1	1	1
		1	Storage	1	1	1	1
		1	**Systems Safety (Tier 2)**	**1**	**1**	**1**	**1**
		1	Physical constraints	1	1	1	1
		1	Hazards	1	1	1	1
		1	Stored Energy	1	1	1	1
		1	On-ground & On-orbit Safety	1	1	1	1
		1	Inhibits	1	1	1	1
		1	Standards	1	1	1	1
		1	**Structural (Tier 2)**	**1**	**1**	**1**	**1**
		1	Quasi-static loads	1	1	1	1
		1	Margins of safety	1	1	1	1
		1	Factor of safety	1	1	1	1
		1	Mounting loads	1	1	1	1
		1	Thermal loads and stresses	1	1	1	1
		1	**Maintainability (Tier 2)**	**1**	**1**	**1**	**1**
		1	Personnel access	1	1	1	1
		1	Line of sight	1	1	1	1
		1	Mean time to repair (ground)	1	1	1	1
		1	Mean time to restore (flight)	1	1	1	1

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		1	**Reliability (Tier 2)**	**1**	**1**	**1**	**1**
		1	Design life	1	1	1	1
		1	Mission life	1	1	1	1
		1	Operational reliability (MTBF)	1	1	1	1
		1	Mission reliability (Probability of success)	1	1	1	1
		1	Inherent availability	1	1	1	1
		1	Operational availability	1	1	1	1
		1	Redundancy architecture	1	1	1	1
		1	Baseplate operating temperature	1	1	1	1
		1	Part electrical / thermal stresses	1	1	1	1
		1	FMEA / FMECA adequacy	1	1	1	1
		1	Single point failure (retention rationale)	1	1	1	1
		1	Failure mode propagation constraint	1	1	1	1
		1	Common cause failure potential	1	1	1	1
		1	Functional fault analysis inputs	1	1	1	1
		1	Critical items list	1	1	1	1
		1	Worst case analysis	1	1	1	1
		1	Wearout constraints	1	1	1	1
		1	Duty cycle	1	1	1	1
		1	Life limiting factors	1	1	1	1
		1	**Parts and Materials (Tier 2)**	**1**	**1**	**1**	**1**
		1	Parts list	1	1	1	1
		1	Part obsolescence	1	1	1	1
		1	Part long lead	1	1	1	1
		1	Part quality factors (production/vendor change)	1	1	1	1
		1	Part failure history / supplier defects	1	1	1	1
		1	Part duty cycle	1	1	1	1
		1	Part life limiting factors	1	1	1	1
		1	Part derating (margin)	1	1	1	1
		1	Part thermal, electrical environmental stresses	1	1	1	1

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Heritage Hardware Nomenclature & P/N: _____ & _____

Heritage Readiness Level (HRL) Scoring Matrix

HRL Score *	Weighting for Tier 1 Technical Parameters	Technical Parameter Average Scores	Technical Parameters **NOTES:** 1. Tier 1 & 2 technical parameters can be used for heritage hardware options' early trade studies & proposal planning OR as category summaries. 2. Complete set of technical parameters can be used to support final reuse decisions.	**Measure 1: Heritage Hardware Objective Evidence Availability -** Objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program. **Measure 1 Scoring definitions:** 1 - Not available or unknown . 5 - Partially available . 9 - Completely available or not applicable	**Measure 2: Target Program Requirements Definition -** Target program requirements are completely defined for heritage hardware. **Measure 2 Scoring definitions:** 1 - Not defined or unknown . 5 - Partially defined . 9 - Completely defined or not applicable	**Measure 3: Heritage Hardware Compliance to Target Program -** Heritage hardware objective evidence indicates compliance with target program requirements, including verification method compliance. **Measure 3 Scoring definitions:** 1 - Not compliant or unknown . 5 - Partially compliant . 9 - Completely compliant or not applicable	**Measure 4: Heritage Hardware Activity for Target Program -** Extent of activity for heritage hardware to meet target program requirements. **Measure 4 Scoring definitions:** 1 - Extensive activity required or unknown . 5 - Moderate activity required . 9 - No activity required or not applicable
		1	Part stress conditions	1	1	1	1
		1	Part class	1	1	1	1
		1	Part screening	1	1	1	1
		1	Part statistical quality factors (lot sampling)	1	1	1	1
		1	Part burn-in	1	1	1	1
		1	Part DPA	1	1	1	1
	0.2	**1**	**Environmental (Tier 1)**	**1**	**1**	**1**	**1**
		1	**Thermal (Tier 2)**	**1**	**1**	**1**	**1**
		1	Storage thermal analysis	1	1	1	1
		1	Pre-flight ground handling	1	1	1	1
		1	Transportation	1	1	1	1
		1	Launch	1	1	1	1
		1	Assent	1	1	1	1
		1	Transfer orbit	1	1	1	1
		1	Beginning of life deployments	1	1	1	1
		1	On-orbit	1	1	1	1
		1	Thermal cycling	1	1	1	1
		1	Thermal vacuum cycling	1	1	1	1
		1	Thermal balance	1	1	1	1
		1	**Dynamics / Statics (Tier 2)**	**1**	**1**	**1**	**1**
		1	Pre-flight ground handling	1	1	1	1
		1	Transportation	1	1	1	1
		1	Launch assent	1	1	1	1
		1	Transfer orbit	1	1	1	1
		1	Beginning of life deployments	1	1	1	1
		1	On-orbit	1	1	1	1
		1	Sine Vibration	1	1	1	1
		1	Random Vibration	1	1	1	1
		1	Acoustic	1	1	1	1
		1	Shock	1	1	1	1

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Heritage Hardware Nomenclature & P/N: _____ & _____							
Heritage Readiness Level (HRL) Scoring Matrix							
HRL Score *	**Weighting for Tier 1 Technical Parameters**	**Technical Parameter Average Scores**	**Technical Parameters** **NOTES:** 1. Tier 1 & 2 technical parameters can be used for heritage hardware options' early trade studies & proposal planning OR as category summaries. 2. Complete set of technical parameters can be used to support final reuse decisions.	**Measure 1: Heritage Hardware Objective Evidence Availability -** Objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program. **Measure 1 Scoring definitions:** 1 - Not available or unknown . 5 - Partially available . 9 - Completely available or not applicable	**Measure 2: Target Program Requirements Definition -** Target program requirements are completely defined for heritage hardware. **Measure 2 Scoring definitions:** 1 - Not defined or unknown . 5 - Partially defined . 9 - Completely defined or not applicable	**Measure 3: Heritage Hardware Compliance to Target Program -** Heritage hardware objective evidence indicates compliance with target program requirements, including verification method compliance. **Measure 3 Scoring definitions:** 1 - Not compliant or unknown . 5 - Partially compliant . 9 - Completely compliant or not applicable	**Measure 4: Heritage Hardware Activity for Target Program -** Extent of activity for heritage hardware to meet target program requirements. **Measure 4 Scoring definitions:** 1 - Extensive activity required or unknown . 5 - Moderate activity required . 9 - No activity required or not applicable
		1	Structural Loads	1	1	1	1
		1	**EMC / EMI / ESD (Tier 2)**	**1**	**1**	**1**	**1**
		1	Lightning susceptibility (launch site, vehicle)	1	1	1	1
		1	Parts substitutions affecting E3 performance	1	1	1	1
		1	Grounding, bonding, and shielding	1	1	1	1
		1	ESD Susceptibility (on-orbit charging, tribo-elec.)	1	1	1	1
		1	Conducted Susceptibility	1	1	1	1
		1	Conducted Emissions	1	1	1	1
		1	Radiated Susceptibility	1	1	1	1
		1	Radiated Emissions	1	1	1	1
		1	**Survivability (Tier 2)**	**1**	**1**	**1**	**1**
		1	Radiation hardness assurance	1	1	1	1
		1	Radiation total ionizing dose environments	1	1	1	1
		1	External interfaces (e.g., thermal)	1	1	1	1
		1	Protective features, shielding, vulnerable paths	1	1	1	1
		1	Parts substitutions affecting survivability	1	1	1	1
		1	Single event effects	1	1	1	1
		1	Natural / man-made micrometeoroid fluence	1	1	1	1
		1	Venting	1	1	1	1
		1	Outgassing	1	1	1	1
		1	Contamination	1	1	1	1
	0.2	**1**	**Manufacturing (Tier 1)**	**1**	**1**	**1**	**1**
		1	**Processes (Tier 2)**	**1**	**1**	**1**	**1**
		1	Processes	1	1	1	1
		1	Bonding	1	1	1	1
		1	Cleaning	1	1	1	1
		1	Soldering	1	1	1	1
		1	Welding	1	1	1	1
		1	Standards	1	1	1	1

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Heritage Hardware Nomenclature & P/N: _____ & _____							
Heritage Readiness Level (HRL) Scoring Matrix							
HRL Score *	**Weighting for Tier 1 Technical Parameters**	**Technical Parameter Average Scores**	**Technical Parameters** **NOTES:** 1. Tier 1 & 2 technical parameters can be used for heritage hardware options' early trade studies & proposal planning OR as category summaries. 2. Complete set of technical parameters can be used to support final reuse decisions.	**Measure 1: Heritage Hardware Objective Evidence Availability -** Objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program. **Measure 1 Scoring definitions:** 1 - Not available or unknown . 5 - Partially available . 9 - Completely available or not applicable	**Measure 2: Target Program Requirements Definition -** Target program requirements are completely defined for heritage hardware. **Measure 2 Scoring definitions:** 1 - Not defined or unknown . 5 - Partially defined . 9 - Completely defined or not applicable	**Measure 3: Heritage Hardware Compliance to Target Program -** Heritage hardware objective evidence indicates compliance with target program requirements, including verification method compliance. **Measure 3 Scoring definitions:** 1 - Not compliant or unknown . 5 - Partially compliant . 9 - Completely compliant or not applicable	**Measure 4: Heritage Hardware Activity for Target Program -** Extent of activity for heritage hardware to meet target program requirements. **Measure 4 Scoring definitions:** 1 - Extensive activity required or unknown . 5 - Moderate activity required . 9 - No activity required or not applicable
		1	**Construction, Safety & Human Factors (Tier 2)**	**1**	**1**	**1**	**1**
		1	Identification	1	1	1	1
		1	Markings	1	1	1	1
		1	Workmanship	1	1	1	1
		1	Interchangeability	1	1	1	1
		1	Safety EH&S	1	1	1	1
		1	Hazardous materials	1	1	1	1
		1	Human factors	1	1	1	1
		1	Standards	1	1	1	1
		1	**Delivery (Tier 2)**	**1**	**1**	**1**	**1**
		1	Handling	1	1	1	1
		1	Protective handling containers	1	1	1	1
		1	Perseverations & packaging	1	1	1	1
		1	Connector protection	1	1	1	1
		1	Marking	1	1	1	1
		1	Cleanliness	1	1	1	1
		1	Transportation	1	1	1	1
		1	**Manufacturer Consistencies (Tier 2)**	**1**	**1**	**1**	**1**
		1	Manufacturer	1	1	1	1
		1	Facility	1	1	1	1
		1	Equipment	1	1	1	1
		1	Active line	1	1	1	1
		1	Key personnel	1	1	1	1
		1	Labor Rules	1	1	1	1
		1	Management	1	1	1	1
		1	Special Test Equipment (STE)	1	1	1	1
		1	Specialized training / education	1	1	1	1
		1	Interfacing tools and equipment	1	1	1	1
		1	Sparing	1	1	1	1
		1	Original development team members	1	1	1	1

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Heritage Hardware Nomenclature & P/N: _____ & _____

Heritage Readiness Level (HRL) Scoring Matrix

HRL Score *	Weighting for Tier 1 Technical Parameters	Technical Parameter Average Scores	Technical Parameters **NOTES:** 1. Tier 1 & 2 technical parameters can be used for heritage hardware options' early trade studies & proposal planning OR as category summaries. 2. Complete set of technical parameters can be used to support final reuse decisions.	**Measure 1: Heritage Hardware Objective Evidence Availability -** Objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program.	**Measure 2: Target Program Requirements Definition -** Target program requirements are completely defined for heritage hardware.	**Measure 3: Heritage Hardware Compliance to Target Program -** Heritage hardware objective evidence indicates compliance with target program requirements, including verification method compliance.	**Measure 4: Heritage Hardware Activity for Target Program -** Extent of activity for heritage hardware to meet target program requirements.
				Measure 1 Scoring definitions: 1 - Not available or unknown . 5 - Partially available . 9 - Completely available or not applicable	**Measure 2 Scoring definitions:** 1 - Not defined or unknown . 5 - Partially defined . 9 - Completely defined or not applicable	**Measure 3 Scoring definitions:** 1 - Not compliant or unknown . 5 - Partially compliant . 9 - Completely compliant or not applicable	**Measure 4 Scoring definitions:** 1 - Extensive activity required or unknown . 5 - Moderate activity required . 9 - No activity required or not applicable
	0.2	**1**	**Program Controls (Tier 1)**	**1**	**1**	**1**	**1**
		1	**Residual Risk (Tier 2)**	**1**	**1**	**1**	**1**
		1	Deviations	1	1	1	1
		1	Waivers	1	1	1	1
		1	FRB Actions/UVF	1	1	1	1
		1	ERB	1	1	1	1
		1	QRB Actions	1	1	1	1
		1	Configuration Management	1	1	1	1
		1	SMRT Actions	1	1	1	1
		1	GIDEP Alerts	1	1	1	1
		1	Risk Board	1	1	1	1
		1	Lessons Learned	1	1	1	1
		1	**Data/Configuration Management (Tier 2)**	**1**	**1**	**1**	**1**
		1	End Item Data Package (EIDP)	1	1	1	1
		1	Requirements documents	1	1	1	1
		1	Design data	1	1	1	1
		1	Analyses	1	1	1	1
		1	Test procedures	1	1	1	1
		1	Test reports	1	1	1	1
		1	Product cert documents	1	1	1	1
		1	Qualification certificate documents	1	1	1	1
		1	Other component history documentation	1	1	1	1
		1	**Engineering Processes and Tools (Tier 2)**	**1**	**1**	**1**	**1**
		1	Engineering development validated tools	1	1	1	1
		1	Design notes	1	1	1	1
		1	Revision notes	1	1	1	1
		1	Simulators and Modeling	1	1	1	1
		1	Design maturity	1	1	1	1
		1	Design modification feasibility	1	1	1	1

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*** HRL Score Definitions**							
9 - Heritage hardware complies with target program requirements in all cases; no activity required for reuse except acceptance testing.							
8 - Heritage hardware complies with target program requirements in all cases; minimal additional activity required for reuse.							
7 - Heritage hardware complies with target program requirements in most cases; minimal additional activity required for reuse.							
6 - Heritage hardware complies with target program requirements in most cases; moderate additional activity required for reuse.							
5 - Heritage hardware complies with target program requirements in some cases; moderate additional activity required for reuse.							
4 - Heritage hardware complies with target program requirements in some cases; significant additional activity required for reuse.							
3 - Heritage hardware complies with target program requirements in few cases; significant additional activity required for reuse.							
2 - Heritage hardware complies with target program requirements in few to no cases; major activity required for reuse.							
1 - Heritage hardware complies with target program requirements in few to no cases; no apparent benefit for reuse.							

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Appendix B. HRL Implementation Example

This appendix provides an example of a heritage reuse assessment and HRL index determination. The example is generic and no manufacturer or corresponding proprietary data will be discussed. It is assumed that a heritage reuse committee, analyst and component responsible engineer have been organized to conduct the heritage reuse assessment.

The example used is a propulsion subsystem service valve. In this example a service valve design has been qualified on Program A that has not yet flown, and a design variant that has been qualified and flown on Program B. Program C wishes to claim heritage and qualify the service valve by design similarity to Programs A and B. The existing service valve manufacturer has recently sold the design to another company and the new owner has moved the manufacturing line to another regional area.

The example heritage reuse assessment uses the three Tier objective criteria model to develop an average HRL by Tier as defined in Appendix A. The user is expected to accumulate the key objective evidence that relates to the objective criteria that is being scored. As you recall, Tier 1 has 5 technical parameters (i.e., categories), Tier 2 has 20 technical parameters, and Tier 3 has 177 technical parameters. Each technical parameter is scored 1 thru 9. Tier scores represent an average contained within the Tier group. For this analysis, the resultant Tier scores are summarized in Table B-1. This table gives a full view of all objective criteria scores assigned and summarized to the Tier level.

The Tier 1 heritage reuse assessment is a rough order of magnitude (ROM) assessment based on 5 summary technical parameters (categories). The Tier 1 HRL of 6 is low and somewhat conservative since it is based on a broad view of objective criteria. It is noted that a more detailed assessment is required to surface areas that need to be worked.

The Tier 2 heritage reuse assessment is more introspective and provides a HRL of 7. It does provide more insight into the objective criteria summary categories that may prevent a complete Qual by design similarity to Programs A and B qualification compliance evidence.

The Tier 3 assessment provides an HRL of 8. This detailed assessment identifies exact qualification of design and workmanship processes and any weaknesses that need to be addressed by the Program C qualification review board (QRB) and costed within the Program C basis of estimate.

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Table B-1. HRL Scoring Matrix for Propulsion Valve – Tier 1

Heritage Hardware Nomenclature & P/N: Propulsion Service Valve & XYZ-123-456							
Heritage Readiness Level (HRL) Scoring Matrix							
HRL Score *	**Weighting for Tier 1 Technical Parameters**	**Technical Parameter Average Scores**	**Technical Parameters** **NOTES:** 1. Tier 1 & 2 technical parameters can be used for heritage hardware options' early trade studies & proposal planning OR as category summaries. 2. Complete set of technical parameters can be used to support final reuse decis	**Measure 1: Heritage Hardware Objective Evidence Availability -** Objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program.	**Measure 2: Target Program Requirements Definition -** Target program requirements are completely defined for heritage hardware.	**Measure 3: Heritage Hardware Compliance to Target Program -** Heritage hardware objective evidence indicates compliance with target program requirements, including verification method compliance.	**Measure 4: Heritage Hardware Activity for Target Program -** Extent of activity for heritage hardware to meet target program requirements.
				Measure 1 Scoring definitions: 1 - Not available or unknown . 5 - Partially available . 9 - Completely available or not applicable	**Measure 2 Scoring definitions:** 1 - Not defined or unknown . 5 - Partially defined . 9 - Completely defined or not applicable	**Measure 3 Scoring definitions:** 1 - Not compliant or unknown . 5 - Partially compliant . 9 - Completely compliant or not applicable	**Measure 4 Scoring definitions:** 1 - Extensive activity required or unknown . 5 - Moderate activity required . 9 - No activity required
			Measure Weighting >>>	**0.25**	**0.25**	**0.25**	**0.25**
6			**Measure Average Scores >>>**	**6**	**9**	**6**	**6**
	0.2	**9**	**Performance (Tier 1)**	**9**	**9**	**9**	**9**
	0.2	**8**	**Design (Tier 1)**	**7**	**9**	**7**	**7**
	0.2	**8**	**Environmental (Tier 1)**	**7**	**9**	**7**	**7**
	0.2	**3**	**Manufacturing (Tier 1)**	**1**	**9**	**1**	**1**
	0.2	**5**	**Program Controls (Tier 1)**	**4**	**9**	**4**	**4**

*** HRL Score Definitions**

9 - Heritage hardware complies with target program requirements in all cases; no activity required for reuse except acceptance testing.
8 - Heritage hardware complies with target program requirements in all cases; minimal additional activity required for reuse.
7 - Heritage hardware complies with target program requirements in most cases; minimal additional activity required for reuse.
6 - Heritage hardware complies with target program requirements in most cases; moderate additional activity required for reuse.
5 - Heritage hardware complies with target program requirements in some cases; moderate additional activity required for reuse.
4 - Heritage hardware complies with target program requirements in some cases; significant additional activity required for reuse.
3 - Heritage hardware complies with target program requirements in few cases; significant additional activity required for reuse.
2 - Heritage hardware complies with target program requirements in few to no cases; major activity required for reuse.
1 - Heritage hardware complies with target program requirements in few to no cases; no apparent benefit for reuse.

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Table B-2. HRL Scoring Matrix for Propulsion Valve – Tier 2

Heritage Hardware Nomenclature & P/N: Propulsion Service Valve & XYZ-123-456							
Heritage Readiness Level (HRL) Scoring Matrix							
HRL Score *	**Weighting for Tier 1 Technical Parameters**	**Technical Parameter Average Scores**	**Technical Parameters** **NOTES:** 1. Tier 1 & 2 technical parameters can be used for heritage hardware options' early trade studies & proposal planning OR as category summaries. 2. Complete set of technical parameters can be used to support final reuse decis	**Measure 1: Heritage Hardware Objective Evidence Availability -** Objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program. **Measure 1 Scoring definitions:** 1 - Not available or unknown . 5 - Partially available . 9 - Completely available or not applicable	**Measure 2: Target Program Requirements Definition -** Target program requirements are completely defined for heritage hardware. **Measure 2 Scoring definitions:** 1 - Not defined or unknown . 5 - Partially defined . 9 - Completely defined or not applicable	**Measure 3: Heritage Hardware Compliance to Target Program -** Heritage hardware objective evidence indicates compliance with target program requirements, including verification method compliance. **Measure 3 Scoring definitions:** 1 - Not compliant or unknown . 5 - Partially compliant . 9 - Completely compliant or not applicable	**Measure 4: Heritage Hardware Activity for Target Program -** Extent of activity for heritage hardware to meet target program requirements. **Measure 4 Scoring definitions:** 1 - Extensive activity required or unknown . 5 - Moderate activity required . 9 - No activity required or not applicable
			Measure Weighting >>>	0.25	0.25	0.25	0.25
7			**Measure Average Scores >>>**	6	9	6	7
	0.2	9	**Performance (Tier 1)**	9	9	9	9
		9	Requirements (Tier 2)	9	9	9	9
		9	Flight history (Tier 2)	9	9	9	9
	0.2	9	**Design (Tier 1)**	9	9	9	8
		9	Interfaces (Tier 2)	9	9	9	9
		9	Physical Requirements (Tier 2)	9	9	9	9
		9	Systems Safety (Tier 2)	9	9	9	9
		9	Structural (Tier 2)	9	9	9	9
		9	Maintainability (Tier 2)	9	9	9	9
		9	Reliability (Tier 2)	9	9	9	9
		7	Parts and Materials (Tier 2)	6	9	6	5
	0.2	8	**Environmental (Tier 1)**	7	9	8	7
		7	Thermal (Tier 2)	6	9	6	5
		7	Dynamics / Statics (Tier 2)	5	9	6	6
		9	EMC / EMI / ESD (Tier 2)	9	9	9	9
		9	Survivability (Tier 2)	9	9	9	9
	0.2	5	**Manufacturing (Tier 1)**	2	9	3	4
		5	Processes (Tier 2)	2	9	4	5
		5	Construction, Safety & Human Factors (Tier 2)	2	9	4	5
		5	Delivery (Tier 2)	2	9	4	5
		3	Manufacturer Consistencies (Tier 2)	1	9	1	1
	0.2	6	**Program Controls (Tier 1)**	4	9	4	6
		7	Residual Risk (Tier 2)	5	9	5	7
		6	Data/Configuration Management (Tier 2)	5	9	4	6
		5	Engineering Processes and Tools (Tier 2)	3	9	3	5

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* HRL Score Definitions
9 - Heritage hardware complies with target program requirements in all cases; no activity required for reuse except acceptance testing.
8 - Heritage hardware complies with target program requirements in all cases; minimal additional activity required for reuse.
7 - Heritage hardware complies with target program requirements in most cases; minimal additional activity required for reuse.
6 - Heritage hardware complies with target program requirements in most cases; moderate additional activity required for reuse.
5 - Heritage hardware complies with target program requirements in some cases; moderate additional activity required for reuse.
4 - Heritage hardware complies with target program requirements in some cases; significant additional activity required for reuse.
3 - Heritage hardware complies with target program requirements in few cases; significant additional activity required for reuse.
2 - Heritage hardware complies with target program requirements in few to no cases; major activity required for reuse.
1 - Heritage hardware complies with target program requirements in few to no cases; no apparent benefit for reuse.

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Table B-3. HRL Scoring Matrix for Propulsion Valve – Tier 3

Heritage Hardware Nomenclature & P/N: Propulsion Service Valve & XYZ-123-456							
Heritage Readiness Level (HRL) Scoring Matrix							
HRL Score *	**Weighting for Tier 1 Technical Parameters**	**Technical Parameter Average Scores**	**Technical Parameters** **NOTES:** 1. Tier 1 & 2 technical parameters can be used for heritage hardware options' early trade studies & proposal planning OR as category summaries. 2. Complete set of technical parameters can be used to support final reuse decisions	**Measure 1: Heritage Hardware Objective Evidence Availability -** Objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program. **Measure 1 Scoring definitions:** 1 - Not available or unknown . 5 - Partially available . 9 - Completely available or not applicable	**Measure 2: Target Program Requirements Definition -** Target program requirements are completely defined for heritage hardware. **Measure 2 Scoring definitions:** 1 - Not defined or unknown . 5 - Partially defined . 9 - Completely defined or not applicable	**Measure 3: Heritage Hardware Compliance to Target Program -** Heritage hardware objective evidence indicates compliance with target program requirements, including verification method compliance. **Measure 3 Scoring definitions:** 1 - Not compliant or unknown . 5 - Partially compliant . 9 - Completely compliant or not applicable	**Measure 4: Heritage Hardware Activity for Target Program -** Extent of activity for heritage hardware to meet target program requirements. **Measure 4 Scoring definitions:** 1 - Extensive activity required or unknown . 5 - Moderate activity required . 9 - No activity required or not applicable
			Measure Weighting >>>	**0.25**	**0.25**	**0.25**	**0.25**
8			**Measure Average Scores >>>**	**7**	**9**	**7**	**7**
	0.2	**9**	**Performance (Tier 1)**	**9**	**9**	**9**	**9**
		9	**Requirements (Tier 2)**	**9**	**9**	**9**	**9**
		9	Mechanical	9	9	9	9
		9	Thermal	9	9	9	9
		9	Electrical	9	9	9	9
		9	Electrical-Mechanical	9	9	9	9
		9	Electronic	9	9	9	9
		9	Radio Frequency	9	9	9	9
		9	Other performance requirements	9	9	9	9
		9	Measure / command / telemetry	9	9	9	9
		9	**Flight history (Tier 2)**	**9**	**9**	**9**	**9**
		9	Performance on orbit	9	9	9	9
		9	Anomalies	9	9	9	9
		9	Latent HW / SW bugs	9	9	9	9
		9	Operational signatures & constraints	9	9	9	9
	0.2	**9**	**Design (Tier 1)**	**9**	**9**	**9**	**9**
		9	**Interfaces (Tier 2)**	**9**	**9**	**9**	**9**
		9	Functional	9	9	9	9
		9	Physical	9	9	9	9
		9	Mechanical	9	9	9	9
		9	Thermal	9	9	9	9
		9	Electrical	9	9	9	9
		9	Electronic	9	9	9	9
		9	Radio Frequency	9	9	9	9
		9	Software	9	9	9	9
		9	Human	9	9	9	9
		9	User	9	9	9	9
		9	GSE	9	9	9	9

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Heritage Hardware Nomenclature & P/N: Propulsion Service Valve & XYZ-123-456

Heritage Readiness Level (HRL) Scoring Matrix

HRL Score *	Weighting for Tier 1 Technical Parameters	Technical Parameter Average Scores	Technical Parameters **NOTES:** 1. Tier 1 & 2 technical parameters can be used for heritage hardware options' early trade studies & proposal planning OR as category summaries. 2. Complete set of technical parameters can be used to support final reuse decisions	**Measure 1: Heritage Hardware Objective Evidence Availability -** Objective evidence available relative to successful requirements implementation, verification and space flight operation of heritage hardware on previous program. **Measure 1 Scoring definitions:** 1 - Not available or unknown . 5 - Partially available . 9 - Completely available or not applicable	**Measure 2: Target Program Requirements Definition -** Target program requirements are completely defined for heritage hardware. **Measure 2 Scoring definitions:** 1 - Not defined or unknown . 5 - Partially defined . 9 - Completely defined or not applicable	**Measure 3: Heritage Hardware Compliance to Target Program -** Heritage hardware objective evidence indicates compliance with target program requirements, including verification method compliance. **Measure 3 Scoring definitions:** 1 - Not compliant or unknown . 5 - Partially compliant . 9 - Completely compliant or not applicable	**Measure 4: Heritage Hardware Activity for Target Program -** Extent of activity for heritage hardware to meet target program requirements. **Measure 4 Scoring definitions:** 1 - Extensive activity required or unknown . 5 - Moderate activity required . 9 - No activity required or not applicable
		9	STE	9	9	9	9
		9	Fixturing	9	9	9	9
		9	Other	9	9	9	9
		9	**Physical Requirements (Tier 2)**	**9**	**9**	**9**	**9**
		9	Dimension	9	9	9	9
		9	Weight	9	9	9	9
		9	Center of gravity	9	9	9	9
		9	Storage	9	9	9	9
		9	**Systems Safety (Tier 2)**	**9**	**9**	**9**	**9**
		9	Physical constraints	9	9	9	9
		9	Hazards	9	9	9	9
		9	Stored Energy	9	9	9	9
		9	On-ground & On-orbit Safety	9	9	9	9
		9	Inhibits	9	9	9	9
		9	Standards	9	9	9	9
		9	**Structural (Tier 2)**	**9**	**9**	**9**	**9**
		9	Quasi-static loads	9	9	9	9
		9	Margins of safety	9	9	9	9
		9	Factor of safety	9	9	9	9
		9	Mounting loads	9	9	9	9
		9	Thermal loads and stresses	9	9	9	9
		9	**Maintainability (Tier 2)**	**9**	**9**	**9**	**9**
		9	Personnel access	9	9	9	9
		9	Line of sight	9	9	9	9
		9	Mean time to repair (ground)	9	9	9	9
		9	Mean time to restore (flight)	9	9	9	9
		9	**Reliability (Tier 2)**	**9**	**9**	**9**	**9**
		9	Design life	9	9	9	9
		9	Mission life	9	9	9	9
		9	Operational reliability (MTBF)	9	9	9	9

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		9	Mission reliability (Probability of success)	9	9	9	9
		9	Inherent availability	9	9	9	9
		9	Operational availability	9	9	9	9
		9	Redundancy architecture	9	9	9	9
		9	Baseplate operating temperature	9	9	9	9
		9	Part electrical / thermal stresses	9	9	9	9
		9	FMEA / FMECA adequacy	9	9	9	9
		9	Single point failure (retention rationale)	9	9	9	9
		9	Failure mode propagation constraint	9	9	9	9
		9	Common cause failure potential	9	9	9	9
		9	Functional fault analysis inputs	9	9	9	9
		9	Critical items list	9	9	9	9
		9	Worst case analysis	9	9	9	9
		9	Wearout constraints	9	9	9	9
		9	Duty cycle	9	9	9	9
		9	Life limiting factors	9	9	9	9
		8	**Parts and Materials (Tier 2)**	**7**	**9**	**7**	**7**
		6	Parts list	4	9	4	5
		6	Part obsolescence	4	9	4	5
		6	Part long lead	4	9	4	5
		5	Part quality factors (production/vendor change)	1	9	3	5
		5	Part failure history / supplier defects	3	9	4	5
		9	Part duty cycle	9	9	9	9
		6	Part life limiting factors	5	9	4	5
		9	Part derating (margin)	9	9	9	9
		9	Part thermal, electrical environmental stresses	9	9	9	9
		9	Part stress conditions	9	9	9	9
		9	Part class	9	9	9	9
		9	Part screening	9	9	9	9
		9	Part statistical quality factors (lot sampling)	9	9	9	9

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		9	Part burn-in	9	9	9	9
		9	Part DPA	9	9	9	9
	0.2	**9**	**Environmental (Tier 1)**	**8**	**9**	**8**	**9**
		8	**Thermal (Tier 2)**	**8**	**9**	**8**	**8**
		9	Storage thermal analysis	9	9	9	9
		9	Pre-flight ground handling	9	9	9	9
		9	Transportation	9	9	9	9
		9	Launch	9	9	9	9
		9	Assent	9	9	9	9
		9	Transfer orbit	9	9	9	9
		9	Beginning of life deployments	9	9	9	9
		9	On-orbit	9	9	9	9
		6	Thermal cycling	5	9	5	6
		6	Thermal vacuum cycling	5	9	5	6
		6	Thermal balance	5	9	5	6
		8	**Dynamics / Statics (Tier 2)**	**8**	**9**	**8**	**8**
		9	Pre-flight ground handling	9	9	9	9
		9	Transportation	9	9	9	9
		9	Launch assent	9	9	9	9
		9	Transfer orbit	9	9	9	9
		9	Beginning of life deployments	9	9	9	9
		9	On-orbit	9	9	9	9
		9	Sine Vibration	9	9	9	9
		6	Random Vibration	5	9	5	6
		6	Acoustic	5	9	5	6
		6	Shock	5	9	5	6
		6	Structural Loads	5	9	5	6
		9	**EMC / EMI / ESD (Tier 2)**	**9**	**9**	**9**	**9**
		9	Lightning susceptibility (launch site, vehicle)	9	9	9	9
		9	Parts substitutions affecting E3 performance	9	9	9	9

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		9	Grounding, bonding, and shielding	9	9	9	9
		9	ESD Susceptibility (on-orbit charging, tribo-elec.)	9	9	9	9
		9	Conducted Susceptibility	9	9	9	9
		9	Conducted Emissions	9	9	9	9
		9	Radiated Susceptibility	9	9	9	9
		9	Radiated Emissions	9	9	9	9
		9	**Survivability (Tier 2)**	**9**	**9**	**9**	**9**
		9	Radiation hardness assurance	9	9	9	9
		9	Radiation total ionizing dose environments	9	9	9	9
		9	External interfaces (e.g., thermal)	9	9	9	9
		9	Protective features, shielding, vulnerable paths	9	9	9	9
		9	Parts substitutions affecting survivability	9	9	9	9
		9	Single event effects	9	9	9	9
		9	Natural / man-made micrometeoroid fluence	9	9	9	9
		9	Venting	9	9	9	9
		9	Outgassing	9	9	9	9
		9	Contamination	9	9	9	9
	0.2	**6**	**Manufacturing (Tier 1)**	**4**	**9**	**5**	**4**
		6	**Processes (Tier 2)**	**4**	**9**	**5**	**4**
		5	Processes	3	9	5	4
		5	Bonding	3	9	5	4
		5	Cleaning	3	9	5	4
		5	Soldering	3	9	5	4
		5	Welding	3	9	5	4
		6	Standards	4	9	5	4
		5	**Construction, Safety & Human Factors (Tier 2)**	**5**	**9**	**5**	**3**
		6	Identification	5	9	5	3
		6	Markings	5	9	5	3
		6	Workmanship	5	9	5	3
		6	Interchangeability	5	9	5	3

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		6	Safety EH&S	5	9	5	4
		4	Hazardous materials	1	9	3	1
		6	Human factors	5	9	5	5
		6	Standards	5	9	5	5
		9	**Delivery (Tier 2)**	**8**	**9**	**8**	**9**
		7	Handling	5	9	5	7
		9	Protective handling containers	9	9	9	9
		9	Perseverations & packaging	9	9	9	9
		9	Connector protection	9	9	9	9
		9	Marking	9	9	9	9
		9	Cleanliness	9	9	9	9
		9	Transportation	9	9	9	9
		3	**Manufacturer Consistencies (Tier 2)**	**1**	**9**	**1**	**1**
		3	Manufacturer	1	9	1	1
		3	Facility	1	9	1	1
		3	Equipment	1	9	1	1
		3	Active line	1	9	1	1
		3	Key personnel	1	9	1	1
		3	Labor Rules	1	9	1	1
		3	Management	1	9	1	1
		3	Special Test Equipment (STE)	1	9	1	1
		3	Specialized training / education	1	9	1	1
		3	Interfacing tools and equipment	1	9	1	1
		3	Sparing	1	9	1	1
		3	Original development team members	1	9	1	1
	0.2	**6**	**Program Controls (Tier 1)**	**5**	**9**	**5**	**5**
		7	**Residual Risk (Tier 2)**	**6**	**9**	**6**	**5**
		6	Deviations	5	9	5	4
		6	Waivers	5	9	5	4
		6	FRB Actions/UVF	5	9	5	4

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		6	ERB	5	9	5	4
		6	QRB Actions	5	9	5	4
		7	Configuration Management	7	9	7	4
		9	SMRT Actions	9	9	9	9
		9	GIDEP Alerts	9	9	9	9
		6	Risk Board	5	9	5	4
		6	Lessons Learned	5	9	5	4
		7	**Data/Configuration Management (Tier 2)**	**5**	**9**	**5**	**6**
		6	End Item Data Package (EIDP)	5	9	5	5
		9	Requirements documents	9	9	9	9
		6	Design data	5	9	5	6
		6	Analyses	5	9	5	6
		6	Test procedures	5	9	5	6
		6	Test reports	5	9	5	6
		6	Product cert documents	5	9	5	6
		6	Qualification certificate documents	5	9	5	6
		6	Other component history documentation	5	9	5	6
		5	**Engineering Processes and Tools (Tier 2)**	**3**	**9**	**3**	**4**
		3	Engineering development validated tools	1	9	1	1
		5	Design notes	4	9	4	4
		6	Revision notes	4	9	5	5
		3	Simulators and Modeling	1	9	1	1
		6	Design maturity	5	9	5	5
		4	Design modification feasibility	1	9	1	5

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* HRL Score Definitions
9 - Heritage hardware complies with target program requirements in all cases; no activity required for reuse except acceptance testing.
8 - Heritage hardware complies with target program requirements in all cases; minimal additional activity required for reuse.
7 - Heritage hardware complies with target program requirements in most cases; minimal additional activity required for reuse.
6 - Heritage hardware complies with target program requirements in most cases; moderate additional activity required for reuse.
5 - Heritage hardware complies with target program requirements in some cases; moderate additional activity required for reuse.
4 - Heritage hardware complies with target program requirements in some cases; significant additional activity required for reuse.
3 - Heritage hardware complies with target program requirements in few cases; significant additional activity required for reuse.
2 - Heritage hardware complies with target program requirements in few to no cases; major activity required for reuse.
1 - Heritage hardware complies with target program requirements in few to no cases; no apparent benefit for reuse.