



National Aeronautics and  
Space Administration



GRC-ARES-I-1-REQ-061  
EFFECTIVE DATE: March 20, 2007

---

**Exploration Launch Project/Flight & Integrated Test Office/Ares I-1 Flight Test**  
National Aeronautics and Space Administration  
John H. Glenn Research Center at Lewis Field, OH 44135

# ARES I-1 UPPER STAGE SIMULATOR (USS) ELEMENT

## AEROSPACE WELDING REQUIREMENTS

<b>Ares I-I Flight Test, Upper Stage Simulator (USS) Element</b>		
<b>Title: USS Element Aerospace Welding Requirements</b>	<b>Document No.: GRC-ARES-I-1-REQ-061</b>	<b>Revision: Released</b>
	<b>Effective Date: March 20, 2007</b>	<b>Page 2 of 15</b>

### DOCUMENT HISTORY LOG

Status (Baseline/ Revision/ Canceled)	Document Revision	Effective Date	Description
Released	-	3/20/06	Released per Ares Directive ARES-047

CHECK THE MASTER LIST—VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

CM Controlled Document. Uncontrolled when printed.

<b>Ares I-I Flight Test, Upper Stage Simulator (USS) Element</b>		
<b>Title: USS Element Aerospace Welding Requirements</b>	<b>Document No.: GRC-ARES-I-1-REQ-061</b>	<b>Revision: Released</b>
	<b>Effective Date: March 20, 2007</b>	<b>Page 3 of 15</b>

**CLV Project/Ares I-1 Flight Test  
Upper Stage Simulator (USS) Element  
Aerospace Welding Requirements**

**Signature Page**

**SUBMITTED BY:**

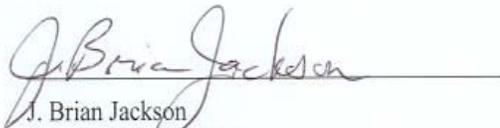


Salvatore M. Anzalone  
Ares I-1 USS Element  
Materials and Processes/Welding Engineer  
Science Application International Corporation

3/20/07

Date

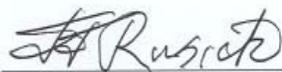
**CONCURRENCE BY:**



J. Brian Jackson  
Ares I-1 USS Element  
M&P Lead  
Glenn Research Center

3-20-07

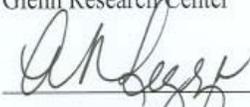
Date



Jeffrey J. Rusick  
Ares I-1 USS Element  
S&MA Lead  
Glenn Research Center

3/20/07

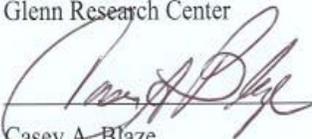
Date



Adabelle Narvaez-Loeza  
Ares I-1 USS Element  
Element Chief Engineer  
Glenn Research Center

03.20.07

Date



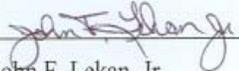
Casey A. Blaze  
Ares I-1 USS Element  
Manufacturing Lead Engineer  
Glenn Research Center

3/20/07

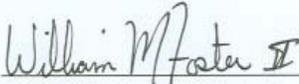
Date

<b>Ares I-I Flight Test, Upper Stage Simulator (USS) Element</b>		
<b>Title: USS Element Aerospace Welding Requirements</b>	<b>Document No.: GRC-ARES-I-1-REQ-061</b>	<b>Revision: Released</b>
	<b>Effective Date: March 20, 2007</b>	<b>Page 4 of 15</b>

**CLV Project/Ares I-1 Flight Test  
Upper Stage Simulator (USS) Element  
Aerospace Welding Requirements  
Signature Page**

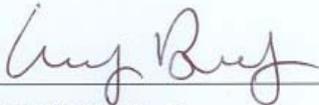
  
\_\_\_\_\_  
John F. Lekan, Jr.  
Ares I-1 USS Element  
Ground Systems & Processing Manager  
Glenn Research Center

3/20/07  
Date

  
\_\_\_\_\_  
William M. Foster II  
Ares I-1 USS Element  
Flight Test Article Manager  
Glenn Research Center

03/20/2007  
Date

**APPROVED BY:**

  
\_\_\_\_\_  
Vincent J. Bilardo, Jr.  
Ares I-1 USS Element  
Element Manager  
Glenn Research Center

3/20/07  
Date

<b>Ares I-I Flight Test, Upper Stage Simulator (USS) Element</b>		
<b>Title: USS Element Aerospace Welding Requirements</b>	<b>Document No.: GRC-ARES-I-1-REQ-061</b>	<b>Revision: Released</b>
	<b>Effective Date: March 20, 2007</b>	<b>Page 5 of 15</b>

## TABLE OF CONTENTS

1.0	INTRODUCTION .....	6
1.1	Purpose.....	6
1.2	Scope.....	6
1.3	Safety .....	6
1.3.1	Safety Policy .....	6
1.3.2	Scope of Safety Policy .....	6
2.0	DOCUMENTS.....	7
2.1	Applicable Documents.....	7
2.1.1	Applicable NASA Welding Standards.....	7
2.1.2	Applicable Glenn Research Center Documents	
2.1.3	Applicable Commercial Industry Codes and Standards .....	7
2.2	Reference Documents .....	7
3.0	REQUIREMENTS.....	8
3.1	Specific Flight Hardware and Related GSE Welding Components and Materials.....	8
3.1.1	Structural Components To Be Welded .....	9
3.1.2	Welding Materials and Materials To Be Welded .....	9
3.1.3	Welding Attachments for Alignment.....	9
3.2	Welding.....	9
3.2.1	Welding Processes .....	9
3.2.2	Welding Specifications .....	9
3.2.3	Welder Qualifications .....	10
3.2.4	Weld Classifications .....	10
3.2.5	Weld Request Form .....	11
3.3	Weld Joint Fit-Up Requirements and Temporary Attachments .....	12
3.3.1	Compatibility of Temporary Attachment.....	12
3.3.2	Required Welder Certifications .....	12
3.3.3	Removal of Temporary Attachments.....	12
3.3.4	Final Surface Requirements.....	12
3.4	Weld Inspections.....	12
3.4.1	Inspection Type Determined by Weld Class .....	12
3.4.2	Acceptance Criteria.....	13
3.4.3	Qualifications of Inspectors .....	13
3.5	In-Process Weld Corrections .....	14
3.5.1	Number of Weld Corrections.....	14
3.5.2	Weld Correction Process.....	14
3.5.3	Inspection of Weld Corrections .....	14
3.5.4	Documentation of Weld Corrections .....	14
	APPENDIX—ACRONYMS .....	15

## LIST OF TABLES

Table 3.1—Weld joint classes versus welding standards, codes, and specifications. ....	11
Table 3.2—Weld joint classes versus required inspections.....	13

CHECK THE MASTER LIST—VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

CM Controlled Document. Uncontrolled when printed.

Ares I-I Flight Test, Upper Stage Simulator (USS) Element		
Title: USS Element Aerospace Welding Requirements	Document No.: GRC-ARES-I-1-REQ-061	Revision: Released
	Effective Date: March 20, 2007	Page 6 of 15

## 1.0 INTRODUCTION

### 1.1 Purpose

These aerospace welding requirements were developed through a consolidation of applicable NASA standards and specifications and of commercial industry codes to design, fabricate, inspect, and nondestructively examine carbon steel developmental Flight Test Article hardware and its related ground support equipment (GSE) to high-quality standards in a cost-effective manner. This “hybrid” approach to the selection of applicable standards and codes has been developed to reflect best practices for the welding and nondestructive evaluation (NDE) of  $\geq 1/8$ -in.-thick welded steel structures.

### 1.2 Scope

The aerospace welding requirements contained in this document shall be used in the design, fabrication, and inspection of the Ares I-1 Pathfinder 2 hardware, and they are expected to bridge the gap between the “GRC Welding Manual,” GLM-QE-8730.2 Revision D, and the release of revision E of the manual, in order to satisfy the unique needs of the Ares I-1 project.

### 1.3 Safety

#### 1.3.1 Safety Policy

It is the policy of all Ares I-1 Upper Stage Simulator (USS) personnel to manage and conduct operations in such a manner as to eliminate or minimize all potential hazards and to avoid accidents involving injury to personnel, damage to property, or loss of research operating time and effectiveness. In addition, it is our policy to eliminate pollution to the atmosphere, ground water, or land and to minimize potential exposure to hazardous materials. Ares I-1 operations, design, fabrication, and assembly will follow all applicable Federal, state, and local laws; NASA safety, health, and environmental standards and policies; and the best practices of all recognized professional organizations.

#### 1.3.2 Scope of Safety Policy

This policy applies to all Government and contract employees at the NASA Glenn Research Center (GRC) as well as to employees working offsite and covers all activities taking place at GRC as well as those taking place offsite. Specific safety and health requirements for this procedure are included within this document.

Ares I-I Flight Test, Upper Stage Simulator (USS) Element		
Title: USS Element Aerospace Welding Requirements	Document No.: GRC-ARES-I-1-REQ-061	Revision: Released
	Effective Date: March 20, 2007	Page 7 of 15

## 2.0 DOCUMENTS

### 2.1 Applicable Documents

#### 2.1.1 Applicable NASA Welding Specifications and Standards

Document number	Document name
NASA-SPEC-5004	Welding of Aerospace Ground Support Equipment (GSE) and Related Non-conventional Facilities
NASA-STD-5006	General Fusion Welding Requirements for Aerospace Materials Used In Flight Hardware

#### 2.1.2 Applicable Glenn Research Center Documents

GLM-QE-8730.2, Revision D	GRC Welding Manual
GRC-P4.7	Corrective and Preventive Action

#### 2.1.3 Applicable Commercial Industry Codes and Standards

Document number	Document name
AWS A5.18	Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding
AWS A5.20	Specification for Carbon Steel Electrodes for Flux-Cored Arc Welding
AWS B2.1	Specification for Welding Procedure and Performance Qualification
AWS D1.1	Structural Welding Code—Steel (Sections 1, 2, 3, 5, 6, & 7 apply, incl. Annexes A to J & Q.)
AWS D17.1	Specification for Fusion Welding for Aerospace Applications (Sections 1, 2, 3, and 8.1(1) apply.)
AWS QC1	Standard for AWS Certification of Welding Inspectors
NAS 410	Nondestructive Testing Personnel Qualification and Certification
SNT-TC-1A	Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing

### 2.2 Reference Documents

Document number	Document name
JSC-PRC-0005	Process Specification for the Manual Arc Welding of Carbon Steel and Nickel Alloy Hardware
MSFC-SPEC-560	The Fusion Welding of Steels, Corrosion and Heat Resisting Alloys

Ares I-I Flight Test, Upper Stage Simulator (USS) Element		
Title: USS Element Aerospace Welding Requirements	Document No.: GRC-ARES-I-1-REQ-061	Revision: Released
	Effective Date: March 20, 2007	Page 8 of 15

### 3.0 REQUIREMENTS

The convention used in this document to indicate requirements, goals, and statements of fact follows:

- **Shall** is used to indicate a binding requirement.
- **Should** is used to indicate a desired goal.
- **Will** is used to indicate a statement of fact.

Every requirement containing a “shall” is binding and will be verified. Goals and statements of fact are nonbinding. The following requirements are in accordance with the current version of the “GRC Welding Manual,” GLM-QE-8730.2, Revision D, contained within GRC’s online Business Management System (BMS) with the following editorial exceptions:

- “Specification for Fusion Welding for Aerospace Applications,” American Welding Society (AWS) D17.1, replaces all references to SAE-AMS-STD-2219.
- “Specification for Welding Procedure and Performance,” AWS B2.1, replaces all references to SAE-AMS-STD-1595.
- ASTM A517 replaces reference to ASTM A516 in paragraph 4.1.7 (typographical error).

The following requirements for the welding of  $\geq 1/8$ -in.-thick steel shall be implemented by engineering in accordance with the project Configuration and Data Management Plan.

#### 3.1 Detailed Welding Requirements for Flight Hardware and Related Ground Support Equipment (GSE) Components and Materials

The welding requirements contained herein, are a reconciled compilation of applicable commercial aerospace and steel fabrication and design Codes, and NASA Flight and non-Flight specifications and standards. This “Hybrid” Code approach implements specific sections from each of the applicable Codes to address the key AWS Code sections pertaining to the, “General Requirements, Design of Welded Connections, Qualification of Welding Procedures, Qualification of Welders and Welding Operator Performance, Fabrication and Inspection” as follows:

- AWS D17.1, “Specification for Fusion Welding for Aerospace Applications” (Requirements in Sections 1, 2, 3, and 8.1(1) apply.)
- AWS D1.1, “Structural Welding Code—Steel” (Requirements in Sections 1, 2, 3, 5, 6, and 7 apply, including Annexes A to J and Q.)
- AWS B2.1, “Specification for Welding Procedure and Performance Qualification” (All requirements apply in lieu of those in Sections 4 of AWS D17.1 and AWS D1.1)

The applicable NASA specifications and standards referenced herein Paragraph 2.1 complement this “Hybrid” Code approach with specific NASA and aerospace industry welding requirements related to Flight and non-Flight Hardware addressing the key areas of, “aerospace weld joint classification, in-process weld repairs, weld repairs and their documentation, welding inspector certifications, dimensional requirements and welder performance joint qualification testing”.

Ares I-I Flight Test, Upper Stage Simulator (USS) Element		
Title: USS Element Aerospace Welding Requirements	Document No.: GRC-ARES-I-1-REQ-061	Revision: Released
	Effective Date: March 20, 2007	Page 9 of 15

### 3.1.1 Structural Components To Be Welded

Flight structural components shall be designed in accordance with the requirements of “Structural Welding Code—Steel,” AWS D1.1, for cyclically loaded nontubular connections. GSE structural components shall be designed in accordance with the appropriate AWS D1.1 loading and connection type categories (e.g., static or cyclic loading with a nontubular or tubular type connection).

### 3.1.2 Welding Materials and Materials of Construction

The materials of construction shall be well-characterized, robust standard materials listed in “Structural Welding Code—Steel,” AWS D1.1, and “Specification for Fusion Welding for Aerospace Applications,” AWS D17.1, and shall be joined with filler metals listed in the filler metal specifications—“Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding,” AWS A5.18, and “Specification for Carbon Steel Electrodes for Flux-Cored Arc Welding,” AWS A5.20—for which the strength, fatigue, and fracture properties are known or for which adequate material test data can be generated.

### 3.1.3 Welding Attachments for Alignment

Weld joints shall be fit-up and aligned as described in Section 3.3, and dimensional tolerances shall be verified prior to the commencement of welding out the joint per the work traveler document.

### 3.1.4 Fillet welds for Flight Hardware

Continuous fillet welds (Flight only) shall have a minimum of 10% penetration beyond the root of the joint (10% of the fillet size) for their entire specified length. Intermittent fillet welds shall have fusion to, but not necessarily beyond the root of the joint for their entire specified length.

## 3.2 Welding

### 3.2.1 Welding Processes

Welding shall be performed utilizing “Structural Welding Code—Steel,” AWS D1.1, Code-approved welding processes. Ares I-1 shall use the following Code-approved welding processes:

- Pulsed gas metal arc welding (GMAW)
- Flux-cored arc welding (FCAW)

Additional code-approved welding processes may be utilized with engineering approval in accordance with the ARES I-1 “Configuration and Data Management Plan”, GRC-ARES I-1-PLAN-005

### 3.2.2 Welding Procedure Specifications

Welding shall be performed utilizing qualified welding procedure specifications (WPSs).

- “Structural Welding Code—Steel,” AWS D1.1, Code “prequalified” welding procedures and joint configurations shall be used where applicable, along with code-approved prequalified welding processes.

Ares I-I Flight Test, Upper Stage Simulator (USS) Element		
Title: USS Element Aerospace Welding Requirements	Document No.: GRC-ARES-I-1-REQ-061	Revision: Released
	Effective Date: March 20, 2007	Page 10 of 15

- Unique welding procedures shall be qualified in accordance with “Specification for Welding Procedure and Performance,” AWS B2.1, utilizing code-approved welding processes.

### 3.2.3 Welder and Welding Operator Performance Qualifications

Welds shall be made by welders and welding operators qualified in accordance with “Specification for Welding Procedure and Performance,” AWS B2.1.

#### 3.2.3.1 Welder and Welding Operator Performance Qualification Mock-up Tests -

Prior to performing welding on any production hardware at GRC for the ARES I-1 project, welders and welding operators shall fabricate a weldment that is representative of the joint in production, henceforth referred to as a “Mock-up”

Mock-ups shall be performed for the following production weld joint configurations:

- Flange to Flange (F-F)
- Skin to Skin (S-S)
- Skin to Flange (S-F)
- Lifting Lugs to Skin and Flange

These Mock-ups are in addition to the welder qualifications stated in Paragraph 3.2.3 herein. The Mock-up inspections and acceptance criteria for these weld joints shall be the same as those specified in production, except for those of the Lifting Lug fillet welds.

The Lifting Lug Mock-up shall be fabricated and inspected and tested per the requirements stated in AWS B2.1 for the “Fillet Weld Bend/Break and Macro-etch Test Plate” for welder or welding operator performance qualification. In addition, the acceptance criteria for penetration stated herein Paragraph 3.1.4 shall supersede that stated in the Code, since penetration beyond the joint root is required for continuous fillet welds.

### 3.2.4 Weld Classifications

Welds shall be classified<sup>1</sup> by engineering with respect to their safety-criticality, and consequences of failure and shall be consistent with the aerospace weld class designations—A, B, or C—defined in “Specification for Fusion Welding for Aerospace Applications,” AWS D17.1; NASA-STD-5006; and NASA-SPEC-5004.

- Utilize the weld class designations given in the “GRC Welding Manual joint classes” column in Table 3.1: A, B, C1, or C2.
- The “GRC Welding Manual Joint Class” shall be stated on the engineering design drawings.

---

<sup>1</sup>Alternatively, margin of safety as determined by appropriate engineering analyses may be utilized to determine the weld class when the consequences of failure are also addressed in the analyses.

Ares I-I Flight Test, Upper Stage Simulator (USS) Element		
Title: USS Element Aerospace Welding Requirements	Document No.: GRC-ARES-I-1-REQ-061	Revision: Released
	Effective Date: March 20, 2007	Page 11 of 15

Aerospace weld joint classes	GRC Welding Manual Joint Classes <sup>a</sup> (flight and nonflight)	NASA-STD-5006 (flight)	NASA-SPEC-5004 (nonflight)	AWS D17.1 (flight)	AWS D1.1 <sup>b</sup> (non-flight)	JSC-PRC-0005 <sup>c</sup> (flight and nonflight)	MSFC-SPEC-560 <sup>d</sup> (flight and nonflight)	Factor of safety, UTS <sup>e</sup> (JSC-PRC-0005)	Loading, percent of class A (MSFC-SPEC-560)
<b>A</b>	<b>A</b> Critical <sup>f</sup>	<b>A</b> Critical and structural <sup>g</sup>	<b>A</b> Critical and structural	<b>A</b> Critical	---	<b>A</b> Critical and structural	<b>I</b> (flight), <b>III</b> (non-flight)	<2.0	100
<b>B</b>	<b>B</b> Semi-critical <sup>h</sup>	<b>B</b> Noncritical <sup>i</sup> and structural	<b>B</b> Noncritical and structural	<b>B</b> Semi-critical	---	<b>B</b> Noncritical and structural	<b>II</b> (flight), <b>IV</b> (non-flight)	≥2.0 and <3.5	80
<b>C</b>	<b>C1</b> Noncritical	<b>C</b> Noncritical, non-structural, <sup>k</sup> and contained	---	<b>C</b> Noncritical	---	<b>C</b> Noncritical and minor structural	---	≥3.5 and <5.0	---
	<b>C2</b> <sup>l</sup> Noncritical	---	<b>C</b> Noncritical and nonstructural	---	---	<b>D</b> Noncritical and nonstructural	<b>V</b>	≥5.0	---

<sup>a</sup>Extent of nondestructive testing:

- Class A welds require visual (visual testing, VT), surface (magnetic particle testing, MT, internal (ultrasonic testing (UT) and radiographic testing (RT)) examination.
- Class B welds require visual (VT) and surface (MT) examination.
- Class C1 welds require visual (VT) examination.
- Class C2 welds require only inspection to verify their type, nominal size, length, location, and that they were left in a condition exhibiting good workmanship practices. An AWS CWI is not required for class C2 welds.

<sup>b</sup>AWS D1.1 can be considered for flight welds if modified to reconcile differences with AWS D17.

<sup>c</sup>NASA Johnson Space Center.

<sup>d</sup>NASA Marshall Space Flight Center.

<sup>e</sup>UTS—ultimate tensile strength.

<sup>f</sup>Critical—Would result in a loss of life, mission, or spacecraft if failure occurred; no redundant load path for stress redistribution.

<sup>g</sup>Structural—Significant load-bearing capacity required to maintain the efficiency of a system or prevent hazard to personnel if failure occurred.

<sup>h</sup>Semi-critical—Considered fail-safe with a redundant load path for stress redistribution if failure occurred.

<sup>i</sup>Noncritical—Considered fail-safe with a redundant load path for stress redistribution if failure occurred.

<sup>j</sup>Internal inspection requirements of MSFC-SPEC-560 apply.

<sup>k</sup>Nonstructural—Minor load-bearing capacity that would not affect the efficiency of the system or create a hazard to personnel if failure occurred.

<sup>l</sup>Category applies to nonflight welds only.

Table 3.1—Weld joint classes versus welding standards, codes, and specifications.

### 3.2.5 Weld Request Form

The Weld Request Form, NASA C-4025, shall be utilized for all production welding per Section V, Part 1, in the “GRC Welding Manual,” GLM-QE-8730.2. The completed form is considered to be a formal record, and duplicate archive copies shall be retained in accordance with this aerospace welding requirements document and the project’s configuration management plan.

Ares I-I Flight Test, Upper Stage Simulator (USS) Element		
Title: USS Element Aerospace Welding Requirements	Document No.: GRC-ARES-I-1-REQ-061	Revision: Released
	Effective Date: March 20, 2007	Page 12 of 15

### 3.3 Weld Joint Fit-Up Requirements and Temporary Attachments

Weld joints may be fitted, aligned, and retained in position to meet the weld joint configuration fit-up tolerances specified by the use of bars, jacks, clamps, tack welds, other means, or temporary attachments prior to and during welding. However, the alignment method used shall not result in deformation of the component.

#### 3.3.1 Compatibility of Temporary Attachment

- Bars, clamps, temporary attachments, and other items welded to the base metal shall be compatible with the base metal. They shall have the same AWS steel specification “group number” or “material number” given in “Structural Welding Code—Steel,” AWS D1.1, and “Specification for Welding Procedure and Performance,” AWS B2.1, respectively, except that a lower group or material number may be used with a higher group or material number but not vice versa.
- Such temporary attachment materials need only a Certificate of Conformance to the steel specification indicated to verify compatibility.

#### 3.3.2 Required Welder Certifications

Temporary attachments that are welded to components to provide stability during rigging or lifting shall utilize either “Structural Welding Code—Steel,” AWS D1.1, prequalified WPSs or “Specification for Welding Procedure and Performance,” AWS B2.1, qualified WPSs and shall be made by qualified welders.

#### 3.3.3 Removal of Temporary Attachments

When no longer required, the temporary attachment shall be removed by grinding or other mechanical means without causing damage to the base metal. The temporary attachment removal area shall be ground to blend uniformly with the surrounding base material and shall be examined visually and by NDE by magnetic particle testing (MT) by certified inspection and NDE personnel utilizing approved procedures.

#### 3.3.4 Final Surface Requirements

The surface shall be visibly free of cracks, undercut, arc strikes, and any other surface defects. Any defects more than 1/32 in. in depth that cannot be completely removed shall be documented on a corrective and preventative action report (CPAR) to be evaluated by engineering per GRC-P4.7 “Corrective and Preventive Action”.

### 3.4 Weld Inspections

#### 3.4.1 Inspection Type Determined by Weld Class

- The minimum level of inspection for each weld shall be in accordance with that specified for its weld class.
- Utilize the weld class designations given in the “GRC Welding Manual joint classes” column in Table 3.2: A, B, C1, or C2.

Ares I-I Flight Test, Upper Stage Simulator (USS) Element		
Title: USS Element Aerospace Welding Requirements	Document No.: GRC-ARES-I-1-REQ-061	Revision: Released
	Effective Date: March 20, 2007	Page 13 of 15

Aerospace weld joint classes	GRC Welding Manual Joint Classes (flight and nonflight)	Internal examination	Surface examination	Visual examination	Workmanship verification	Layer-by-layer surface examination in lieu of internal examination
<b>A</b>	<b>A</b> Critical <sup>a</sup>	UT/RT	MT	VT	---	Contact engineering for approval
<b>B</b>	<b>B</b> Semi-critical <sup>b</sup>	---	MT	VT	---	---
<b>C</b>	<b>C1</b> Noncritical	---	---	VT	---	---
	<b>C2</b> <sup>c</sup> Noncritical <sup>d</sup>	---	---	---	(e)	---

<sup>a</sup>Critical—Would result in a loss of life, mission, or spacecraft if failure occurred; no redundant load path for stress redistribution.

<sup>b</sup>Semi-critical—Considered fail-safe with a redundant load path for stress redistribution if failure occurred.

<sup>c</sup>Class C2 applies to nonflight welds only.

<sup>d</sup>Noncritical—Considered fail-safe with a redundant load path for stress redistribution if failure occurred.

<sup>e</sup>Class C2 welds require inspection only to verify their type, nominal size, length, location, and that they were left in a condition exhibiting good workmanship practices. The shop welding lead may perform this inspection. An AWS Certified Welding Inspector (CWI) is not required for class C2 welds.

Table 3.2—Weld joint classes versus required inspections.

### 3.4.2 Acceptance Criteria

The acceptance criteria for flight hardware visual weld inspection and nondestructive testing shall be in accordance with that stated in “Structural Welding Code—Steel,” AWS D1.1, for cyclically loaded nontubular connections. The acceptance criteria for related GSE hardware visual weld inspection and nondestructive testing shall be in accordance with the appropriate AWS D1.1 loading and connection type categories. Engineering shall reconcile the acceptance criteria for both flight hardware and its related GSE.

### 3.4.3 Qualifications of Inspectors

- NDE personnel shall be qualified to inspect flight hardware in accordance with “Nondestructive Testing Personnel Qualification and Certification,” NAS 410. If another NDE standard (e.g., “Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing,” SNT-TC-1A) is specified, it shall be acceptable to engineering depending on customer requirements and the type of hardware (flight versus GSE) being joined.
- GSE (flight-related) hardware shall be inspected by NDE personnel qualified to either, “Nondestructive Testing Personnel Qualification and Certification,” NAS 410, or “Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing,” SNT-TC-1A, as determined by engineering.
- Visual weld inspection shall be performed by CWIs in conformance with the provisions of “Standard for AWS Certification of Welding Inspectors,” AWS QC1, or by experienced individuals who by training, experience, or both in metals fabrication, inspection, and testing are competent to inspect the work.

Ares I-I Flight Test, Upper Stage Simulator (USS) Element		
Title: USS Element Aerospace Welding Requirements	Document No.: GRC-ARES-I-1-REQ-061	Revision: Released
	Effective Date: March 20, 2007	Page 14 of 15

- In-process informational weld inspections shall take place as specified by engineering, and shall be performed by certified inspection and/or NDE personnel. Inspection of each groove weld layer with a surface weld inspection method and/or inspection of a groove weld root layer and hot pass layer with an internal weld inspection method are typical examples of in-process informational weld inspections.

### 3.5 In-Process Weld Corrections

#### 3.5.1 Number of Weld Corrections

In-process weld corrections—any correction of a weld made by the welder prior to submitting the weld for final acceptance inspection—may be performed, but their number shall be limited when performed in the same area in accordance with the “GRC Welding Manual,” GLM-QE-8730.2, joint class (see Table 3.1).

- Class A welds shall be corrected only once.
- Class B welds may be corrected up to two times.
- Class C welds may be corrected in-process as many times as necessary.

#### 3.5.2 Weld Correction Process

In-process weld defects shall be removed by mechanical means to sound metal and verified with the inspection method by which they were originally found. The unacceptable portions of the weld shall be either locally repaired or entirely replaced and rewelded by qualified welders or welding operators utilizing a qualified WPS.

- Excessive weld metal shall be removed by mechanical means in the cases of overlap, excessive convexity, and excessive reinforcement.
- Weld surfaces shall be mechanically cleaned and prepared to accommodate the deposition of additional weld metal for undersized welds, undercut welds, and welds with excessive concavity or crater size.
- Excessive amounts of weld porosity or slag inclusions and any amount of incomplete fusion shall be removed by mechanical means, and the area shall be rewelded.
- When cracks are revealed, the extent of the crack shall be ascertained by acid etching, MT, or other equally positive means. Subsequently, the crack and sound metal 2 in. beyond each end of the crack shall be removed, and the area shall be rewelded.
- If the in-process correction is not satisfactory, the weld correction technique shall be referred to the Engineering Review Board (ERB) for review and disposition before proceeding.

#### 3.5.3 Inspection of Weld Corrections

The weld repair shall be subject to the inspection methods and acceptance criteria for the original weld. The defective areas shall be documented in the CPAR and, for flight hardware only, shall also be identified on the weld map (drawing TBD).

### 3.6 Documentation of Weld Corrections

Weld defects revealed during final inspection shall be documented on a corrective and preventative action report (CPAR) to be evaluated by engineering in accordance with the project configuration and data management plan.

<b>Ares I-I Flight Test, Upper Stage Simulator (USS) Element</b>		
<b>Title: USS Element Aerospace Welding Requirements</b>	<b>Document No.: GRC-ARES-I-1-REQ-061</b>	<b>Revision: Released</b>
	<b>Effective Date: March 20, 2007</b>	<b>Page 15 of 15</b>

## **APPENDIX—ACRONYMS**

AWS	American Welding Society
BMS	Business Management System
CPAR	corrective and preventative action request
CWI	Certified Welding Inspector
ERB	Engineering Review Board
FCAW	flux-cored arc welding
GMAW	gas metal arc welding
GRC	NASA Glenn Research Center
GSE	ground support equipment
JSC	NASA Johnson Space Center
MSFC	NASA Marshall Space Flight Center
MT	magnetic particle testing
NDE	nondestructive evaluation
RT	radiographic testing
USS	Upper Stage Simulator (Upper Stage/Service Module/Spacecraft Adapter)
UT	ultrasonic testing
UTS	ultimate tensile strength
VT	visual testing
WPS	welding procedure specification