

National Aeronautics and  
Space Administration

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**SLS-PLAN-179**  
DRAFT FOR PDR  
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## **SLS CORE STAGE FLIGHT ARTICLE TRANSPORTATION PLAN**

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## 1.0 INTRODUCTION

This document describes the required transportation planning for the delivery of the Space Launch System (SLS) core stage, hereafter referred to as the core stage (CS) flight article, and associated equipment from Michoud Assembly Facility (MAF), the manufacturing/assembly location, to Stennis Space Center (SSC), the testing location, and to Kennedy Space Center (KSC), the launch site. This plan is developed in accordance with the goals and methodology put forth in the Logistics Support Infrastructure (LSI) developed for the Core Stage Element as detailed in SLS-PLAN-020, Space Launch System Program (SLSP) Concept of Operations, SLS-PLAN-025, Space Launch System (SLS) Integrated Logistics Support Plan (ILSP), and SLS-SPEC-030-01, Space Launch System Program (SLSP) Support Equipment Specification, Volume I: Support Equipment Planning.

### 1.1 Purpose

The purpose of this document is to identify the transportation flow and describe the transportation functions and support equipment related to the shipment of the CS flight article. Specifically, this plan identifies the CS flight article configuration for shipment; land movement at MAF, SSC, and KSC; loading and unloading the CS flight article and associated equipment onto/from a NASA barge; and water movement from MAF to SSC and SSC to KSC. Site-specific lifting and handling operations of the CS flight article are not included in this document.

### 1.2 Scope

This document is applicable to the CS flight article and associated equipment shipped by the NASA barge from MAF to SSC and from SSC to KSC.

This document is a data managed (Category 2) document used to describe Program Scope defined with SLS Baseline (Category 1) documentation. Work content and organizational responsibilities described within this documentation are provided to facilitate planning and to familiarize the reader with the interrelationship of activities within the SLS baseline. Specific SLS-PLAN-179 flight article transportation agreements in the execution of this document's Program Scope description are defined in the SLS baseline documentation. In the event of an inconsistency of this document with SLS baseline documentation, the Baseline documentation is authoritative. See section 2.0 for guidance on the primary authoritative sources for this Plan.

### 1.3 Change Authority/Responsibility

The NASA Office of Primary Responsibility (OPR) for this document is AS42.

This document is maintained as a deliverable to the SLSP. This document will be submitted, and updated, as required, at Preliminary Design Review (PDR) and Critical Design Review (CDR) to reflect the maturation of the CS flight article configuration and the refinement of the transportation functions.

Changes to this document shall be controlled at the OPR level using processes defined by the OPR.

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## 2.0 DOCUMENTS

### 2.1 Applicable Documents

The agreements that guide and enable the planning content contained in this document are captured in the SLSP Program Agreements Document (PAD), SLSP-PLAN-186. The Flight Article Transportation Agreements across organizations within the SLS Program are captured in section 6.0 of the PAD and are mapped into the sections shown in Table 2.0-1.

**Table 2.0-1: Flight Article Transportation Agreements**

Agreement Area Organization	Section
SE&I	6.1
Multiple Elements	N/A
SPIO	N/A
Booster	N/A
Stages	6.5 (TBR-1)
Engines	N/A
Cross-Program	N/A

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein. Unless otherwise stipulated, the most recently approved version of a listed document shall be used. In those situations where the most recently approved version is not to be used, the pertinent version is specified in this list.

DD1149	Department of Defense Form Requisition and Invoice Shipping Document
MWI 6410.1	Packaging, Handling, and Moving Program Critical Hardware
NPR 6000.1	Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems Equipment and Associated

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### Components

NPR 8715.3	NASA General Safety Program Requirements
NSS 1740.12	NASA Safety Standard for Explosives, Propellants, and Pyrotechnics
SLS-PLAN-020	Space Launch System Program (SLSP) Concept of Operations
SLS-PLAN-030-01	Space Launch System Program (SLSP) Support Equipment Specification, Volume I: Support Equipment Planning
SLS-PLAN-025	Space Launch System Program (SLSP) Integrated Logistics Support Plan (ILSP)
USCB MSM, Volume II	United States Coast Guard (USCG) Marine Safety Manual, Volume II, Material Inspection, Section F: Carriage of Hazardous Materials
49 CFR 107.105	Code of Federal Regulations, Application for Exemption

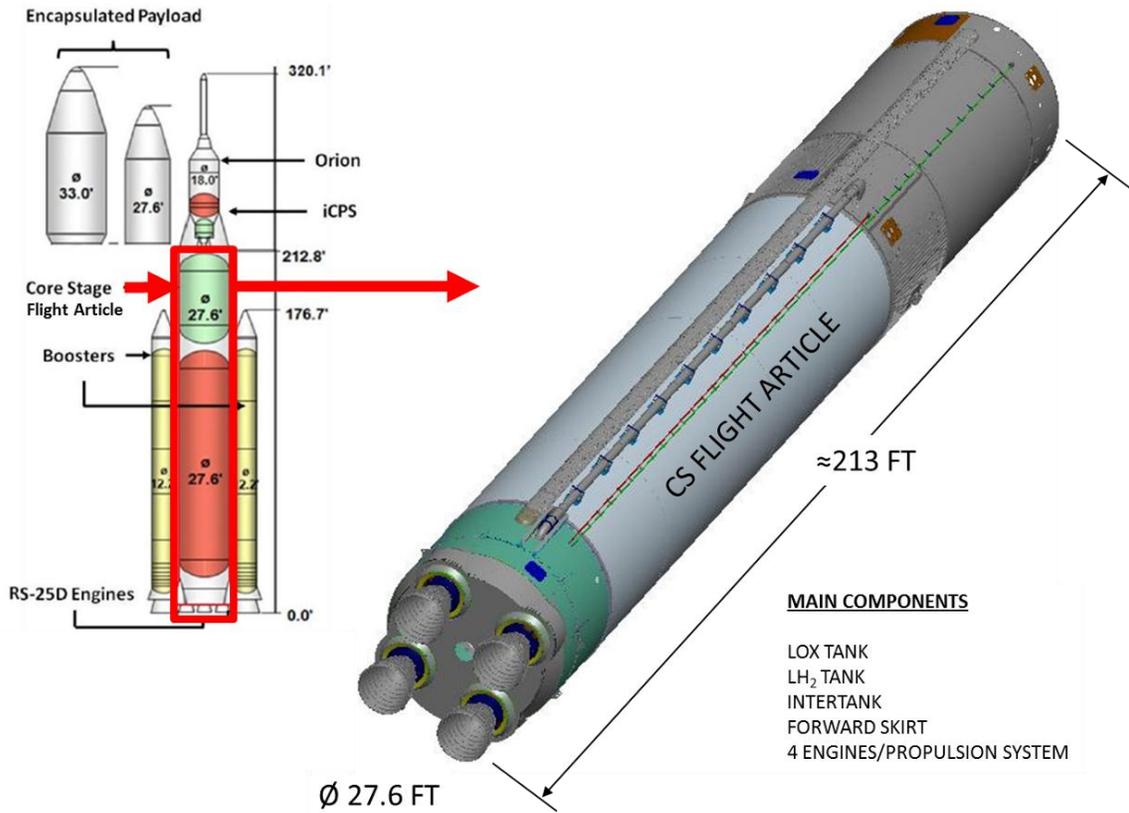
## 2.2 Reference Documents

The following documents contain supplemental information to guide the user in the application of this document.

## 3.0 TRANSPORTATION – GENERAL

### 3.1 Transportation Summary

The CS flight articles are manufactured at MAF. As a consequence of a “ship and shoot” philosophy, the CS flight article is fully assembled and includes the integrated components shown in Figure 3-1. The CS flight article is configured for shipment per specified drawings.



**Figure 3-1. CS Flight Article Configuration**

**Note:** Pyrotechnic devices/systems may be installed in various locations prior to CS transportation functions. If so, transportation of the CS flight article may be considered hazardous. For more detail, refer to Section 3.3.

The CS flight article is transported from the manufacturing facility, MAF, to the testing site, SSC, and to the launch site, KSC. It is considered program critical hardware (PCH) to be handled in accordance with Marshall Work Instruction (MWI) 6410.1, Packaging, Handling, and Moving Program Critical Hardware.

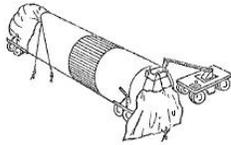
CS flight article transportation includes the following functions:

1. **Stage Preparation** – Prior to CS flight article movement, preparation includes installation of any CS flight article protection equipment, securing the CS flight article on the Multipurpose Transportation System (MPTS), and installation and checkout of any environmental control equipment and instrumentation required for transportation monitoring.

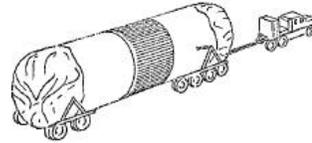
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2. **Land Transportation** – Subsequent to stage preparation, the CS flight article is moved overland in the horizontal position by means of the MPTS. Land transportation is required from the manufacturing/checkout facility to the MAF dock, at the test facility at SSC, and from the KSC point of delivery to the Vehicle Assembly Building (VAB).
3. **Barge Loading/Unloading** – The process by which the CS flight article and MPTS are positioned and secured to the barge or unsecured and extracted from the barge. Associated equipment is also positioned and secured to the barge. Transition of the CS flight article and MPTS to and from the barge is accomplished by a “roll-on/roll-off” technique at the dock.
4. **Water Transportation** – The movement of the CS flight article, MPTS, and associated equipment by towing a NASA barge along designated water routes among the manufacturing facility, MAF, the test site, SSC, and the launch site, KSC. The NASA covered barge *Pegasus* is designated as the primary transport vessel.
5. **Stage Handling** – The lifting of the CS flight article onto/from the MPTS and movement by crane and other lifting devices. Handling is required at SSC for installation into the test facility and at KSC in the VAB after land transportation from the KSC point of delivery upon delivery of the CS flight article.
6. **Stage Inspection** – CS flight article inspection occurs when custodial responsibility for the CS flight article is transferred from the sending organization to the receiving organization at identified points/times during CS flight article transportation. Stage inspection is performed by representatives of both the sending and receiving organizations to assess for appropriate CS flight article shipping configuration and damage.

These transportation functions are depicted in Figure 3-2. Each transportation function is specifically detailed for the CS flight article in Section 5.0.



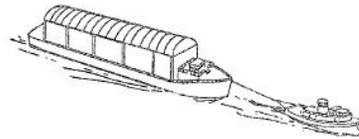
1. STAGE PREPARATION



2. LAND TRANSPORTATION



3. BARGE LOADING/UNLOADING



4. WATER TRANSPORTATION



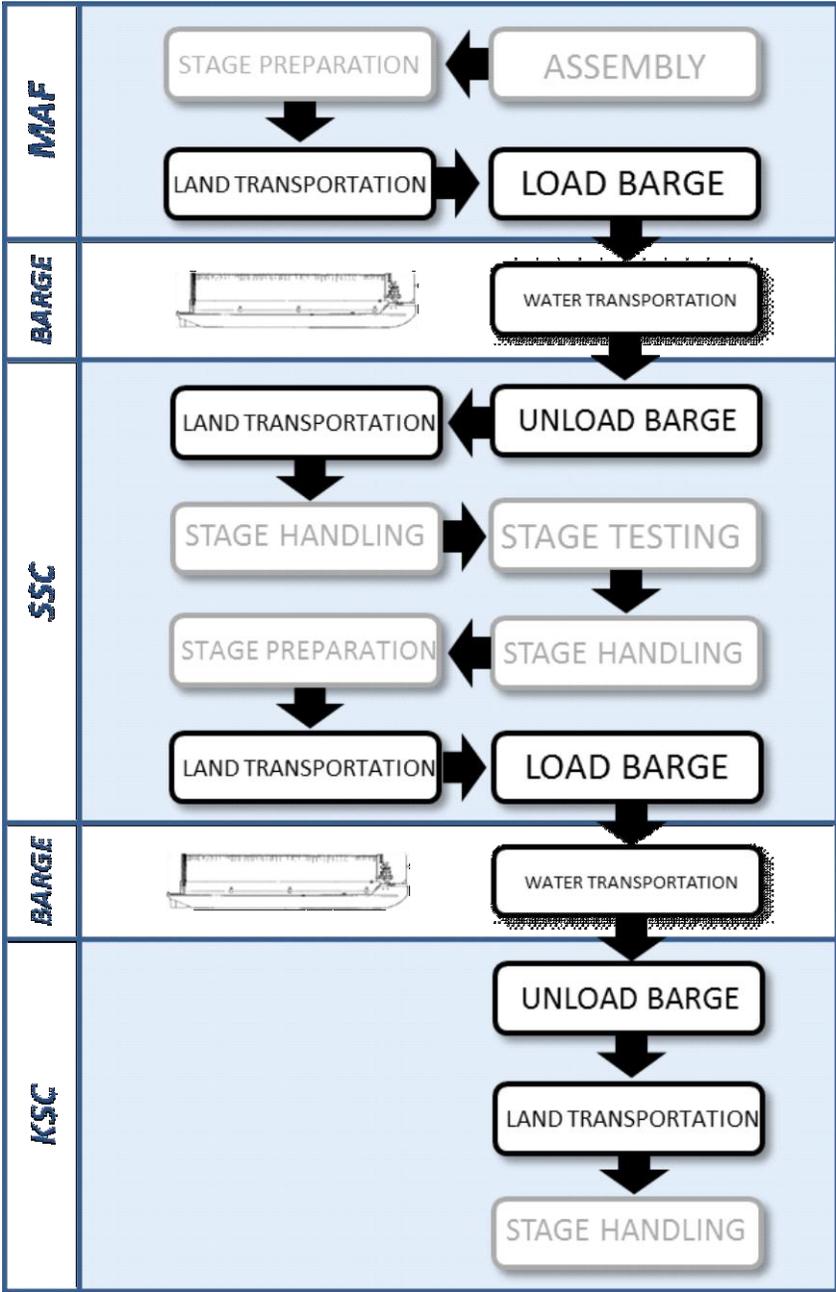
5. STAGE HANDLING



6. STAGE INSPECTION

**Figure 3-2. CS Flight Article Transportation Functions**

The nominal sequence of transportation events for CS flight articles is shown in Figure 3-3. This sequence begins with the completed CS flight article at MAF and is completed with delivery to the VAB at KSC.



**Figure 3-3. Sequence of Transportation Functions for CS Flight Articles**

*Note:* Transportation functions displayed in gray in Figure 3-3 are part of the overall sequence of transportation activities but are not included within the scope of this document.

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## 3.2 Responsibilities

CS flight article transportation is the combined responsibility of NASA (Marshall Space Flight Center (MSFC), MAF, SSC, and KSC), the marine services contractor, the CS flight article engine contractor, and the CS flight article manufacturing/assembly contractor.

The CS flight article transportation employs an “on-dock” responsibility transfer philosophy wherein operational responsibility for support equipment (SE), procedures, and personnel are transferred to the recipient upon delivery of the CS flight article.

In general, the following applies:

### **NASA/MSFC Office of Center Operations, Transportation, & Logistics Engineering Office (AS42)**

- Prepare and maintain the Level II SLS Core Stage Flight Article Transportation Plan.
- Provide CS flight article and associated equipment tie-down configurations, drawings, and marine transportation equipment (MTE).
- Provide NASA barge *Pegasus* for transport of CS flight article and associated equipment.
- Provide barge crew.
- Provide and conduct detailed ballasting and docking procedures for the barge.
- Provide commercial tugs for barge movement.
- Coordinate Bridge Tender (NASA Causeway) and Line Handlers (Port Canaveral)
- Verify proper barge configuration for water transportation.
- Operate and maintain MTE (including proof load testing).
- Acquire hazardous material transportation permits – if required.
- Prepare detailed move procedures for transport of the CS flight article and associated equipment from Building 110 at MAF to the barge.
- Prepare detailed procedures for loading and securing the CS flight article and associated equipment for transport aboard the barge at MAF, SSC, and KSC.
- Prepare detailed procedures to unload CS flight article and associated equipment from the barge at SSC, MAF, and KSC.
- Conduct barge loading and unloading operations including securing and de-securing operations at MAF, SSC, and KSC.
- Provide special purpose equipment through rental agreements, as required, to support transport of the CS flight article and associated equipment (excluding cranes).

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- Arrange for and provide return shipment of MPTS and SE.
- Install/remove land/water transportation monitoring/instrumentation (NASA required).

**NASA/MSFC Mission Operations Laboratory, Ground Operations and Logistics Branch (EO40)**

- Prepare and maintain SLS-SPEC-030-01, Space Launch System Program (SLSP) Support Equipment Specification, Volume I: Support Equipment Planning.
- Provide the MPTS including multipurpose carriers (MPCs), hardware interface structures (HISs), and purchase self-propelled modular transporters (SPMTs).
- Provide land/water transportation monitoring/instrumentation (NASA required).
- Perform the design, development, testing, and evaluation (DDT&E) for all lifting and handling GSE and associated SE for CS flight article transportation, lifting, and handling operations.
- Provide lifting and handling SE, limited to the slings, spreaders, and leveling devices, necessary to install/remove the CS flight article onto/from the MPTS (except at MAF).

**NASA/MSFC Office of Center Operations, MAF Operations Office (AS60)**

- Configure the MPTS to interface with the chosen SPMTs.
- Perform land movement of CS flight article and associated equipment at MAF and SSC.
- Provide personnel and equipment to assist in loading and securing the CS flight article and associated equipment aboard the barge at MAF and SSC.
- Provide personnel to assist in de-securing and unloading the CS flight article and associated equipment from the barge at SSC.
- Support return shipment of MPTS and SE.
- Arrange shipment of associated equipment from MAF (reference Section 4.7).

**NASA/SSC**

- Perform CS flight article lifting operations at SSC.
- Provide equipment for land movement of associated equipment at SSC.
- Arrange shipment of associated equipment from SSC (reference Section 4.7).

**NASA/KSC**

- Prepare detailed move procedures for transport of the CS flight article and associated equipment from the KSC delivery point to the VAB.
- Perform land movements of CS flight article and associated equipment.

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- Develop detailed lifting procedures and perform CS flight article lifting operations at KSC.
- Provide personnel and equipment to assist in de-securing the CS flight article and associated equipment from the barge and unloading the CS flight article and associated equipment.
- Operate CS flight article ground support equipment (GSE).
- Arrange shipment of associated equipment from KSC (reference Section 4.7).

### **Manufacturing/Assembly Contractor**

- Develop detailed procedures for CS flight article and associated equipment preparation operations, which include loading the CS flight article onto the MPTS at MAF.
- Perform preparation of CS flight article for transportation, which includes loading the CS flight article onto the MPTS at MAF.
- Provide, install, and checkout CS flight article and associated equipment protective equipment.
- Prepare detailed procedures for lifting and securing the CS flight article into and out of the test facility at SSC.
- Provide land/water transportation monitoring/instrumentation (contractor required).
- Install/remove land/water transportation monitoring/instrumentation (contractor required).
- Package associated equipment as needed for transport in support of transportation operations.

### **3.3 Transportation Safety and Contingency Planning**

Pursuant to a “ship and shoot” operational philosophy, assembly of the CS flight article at the manufacturing/assembly location, MAF, includes installation of subsystems possibly containing pyrotechnics and pyrotechnic devices. These items are manufactured with explosive materials to varying degrees and compositions. Assembled as such, the CS flight article would be considered “hazardous material” per NASA and U.S. Department of Transportation (USDOT) regulations. Handling and transport of the CS flight article would be considered hazardous.

Safety of the transportation crews, equipment, and of the CS flight article is a high priority. In general, the following safety measures will be captured in the detailed transportation procedures and apply to the activities included in this transportation plan:

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## General

- If appropriate, the CS flight article shipping configuration and operations approved through the USDOT in accordance with 49 CFR 107.105 with shipment authorized by “special permit.”
- Concurrence from the USCG in accordance with the USCG Marine Safety Manual, Volume II: Material Inspection, Section F: Carriage of Hazardous Materials.
- If appropriate, compliance with NASA Procedural Requirements (NPR) 8715.3, NASA General Safety Program Requirements, and NSS 1740.12, NASA Safety Standard for Explosives, Propellants, and Pyrotechnics to include the following:
  - Detailed transportation procedures containing safety information and developed by the relevant facility or hardware custodian applicable to specific activities throughout the complete shipment cycle.
  - Trained and certified personnel provided for hazardous operations per program/project established training requirements.
  - Transportation hazard analysis performed applicable to specific activities throughout the complete shipment cycle.
  - Adequate emergency and/or life saving equipment provided and appropriately staged.

## Land Movement

- Weather briefing prior to movement with defined limitations.
- Physical security provided to inspect and secure transportation route and provide adequate buffer zone around convoy.
- Common communications system utilized by move crew.
- Verify GSE and equipment proof testing and checkout prior to movement.

## Water Movement

- Weather/sea state briefing prior to departure with defined limitations.
- *Pegasus* certified by the American Bureau of Shipping (ABS) for seaworthiness and explosive cargo.
- When available, USCG escort provided from MAF harbor to the Gulf of Mexico for inland waterway travel.
- Adequate provisions, communication, emergency, and firefighting equipment aboard barge for personnel.

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- NASA tug inspections and towing contractor crew and equipment certifications required by the classification and permitting organizations.
- Adherence to all maritime laws, standards, and navigational regulations.
- Exclusive and continuous barge tow.
- Tie-down equipment checkout prior to movement.
- Minimize personnel required aboard the barge.

In general, the following contingency planning applies to the activities included in this transportation plan:

- Identification of “safe harbors” and criteria to transport a CS flight article to SSC or other safe harbors due to an approaching hurricane or for other special circumstances.
- Identification of safe harbors along the water movement route to KSC such that one may be reached within 48 hours from any given location along the route.
- Establishment of emergency plans applicable to specific activities/points within the complete shipment cycle.

### 3.4 Transportation Duration

Delivery of the CS flight article is as follows:

#### MAF to SSC

MAF Facility to MAF Dock	¼ day
Barge Loading/CS Flight Article Secure	½ day
MAF to SSC (Test Facility)	1 day
Barge Unload/SSC Test Facility	½ day
<hr/>	
<b><i>Nominal Transportation Time:</i></b>	<b>2¼ – 3 days</b>

#### SSC to KSC

Barge Loading/CS Flight Article Secure	½ day
SSC to Port Canaveral	5 days
Port Canaveral to KSC Dock	1 day
Barge Unload/KSC Dock to VAB	½ day
<hr/>	
<b><i>Nominal Transportation Time:</i></b>	<b>7 – 8 days</b>

The CS flight article transportation delivery schedules may vary depending on weather, sea/waterway conditions, infrastructure issues, bridge operating restrictions, and marine services contractor availability.

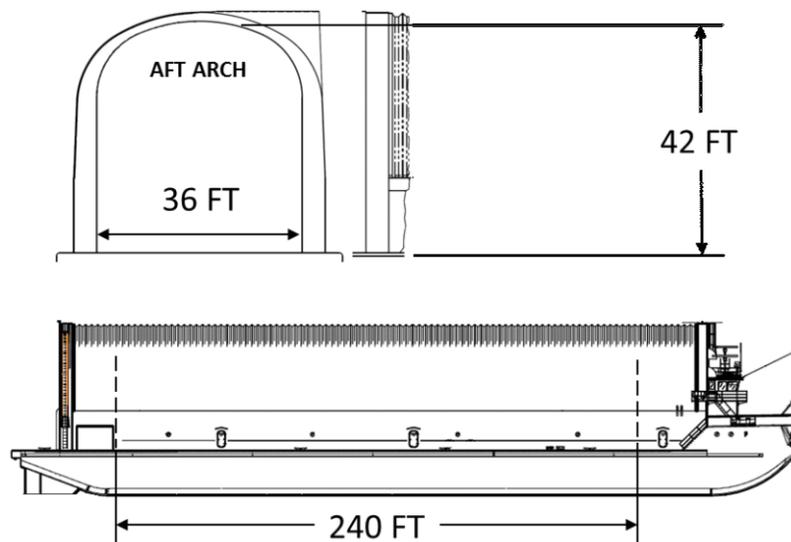
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## 4.0 TRANSPORTATION EQUIPMENT

Some transportation equipment is used for more than one of the transportation functions described in Section 3.1. The major items of equipment are listed in the following subsections with a brief description of their design and use.

### 4.1 CS Flight Article Barge

The *Pegasus* is used for movements among MAF, SSC, and KSC for delivery of the CS flight article from the manufacturing/assembly facility, MAF, to SSC, the testing location, and to KSC, the launch site. *Pegasus*, shown in Figure 4-1, with a modification to increase its current length and height, accommodates the CS flight article, MPTS, and associated equipment. *Pegasus* is configured with an enclosed main deck (covered) that provides protection from salt spray and the weather, but does not provide a controlled environment.

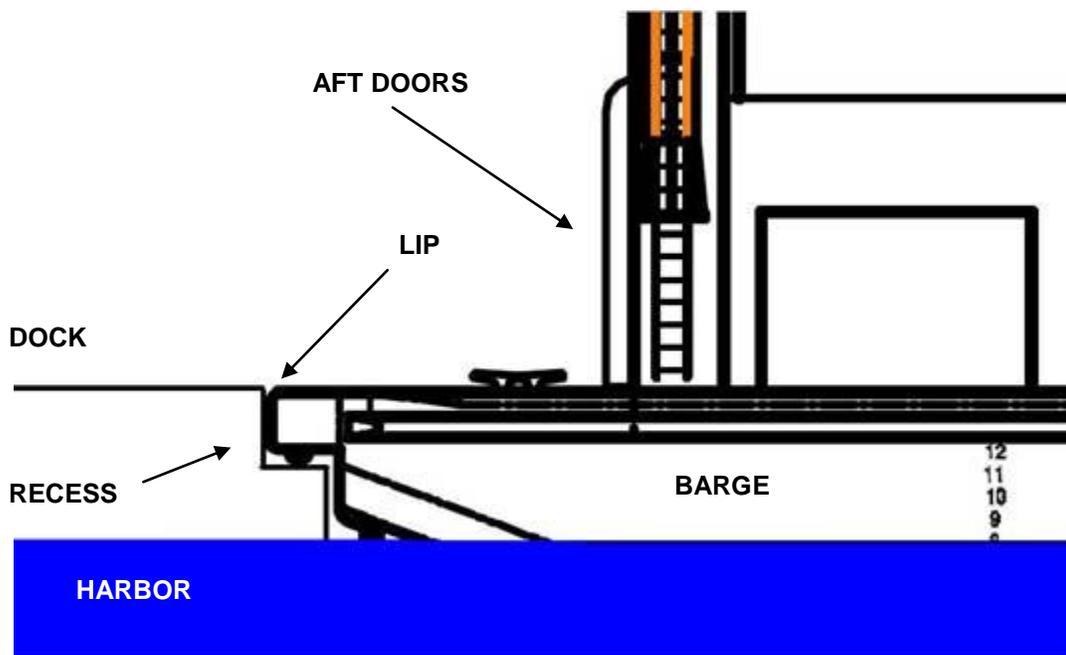


**Figure 4-1. CS Flight Article Barge *Pegasus***

Transfer of the CS flight article and the associated hardware is performed in a roll-on/roll-off manner. The stern of the barge is constructed with a lip which rests (upon ballasting) on a recess in the dock, as shown in Figure 4-2. This dock design is employed at the MAF, SSC, and KSC docking facilities. An array of D-rings, slotted pad eyes, and support pads installed onto the main deck provide the capability to secure the CS flight article, MPTS, and associated equipment. The MPTS is grounded to the barge structure during water shipment via a grounding strap. Adequate areas exist for storage of tie-down and maintenance equipment. The main deck area is 240 ft × 36 ft, with an interior cover height of 42 ft (aft arch opening, depicted in Figure 4-1).

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**Note:** Structural flex of the main deck is expected during water transportation. Appropriate analysis should be considered to characterize and accommodate.



**Figure 4-2. Roll-on/roll-off Barge Docking Configuration**

*Pegasus* is a self-sustaining vessel except for propulsion. Movement of the CS flight article barge is provided by tug(s). Power is generated by two 150 KW generators (or shore power) supplying 110-volt single phase water-tight receptacles. The main deck is lighted and can be secured. Six video cameras are installed on the main deck to allow complete and continuous monitoring/recording of the closed cargo area. Adequate berthing, messing, and sanitary provisions exist for up to four credentialed passengers.

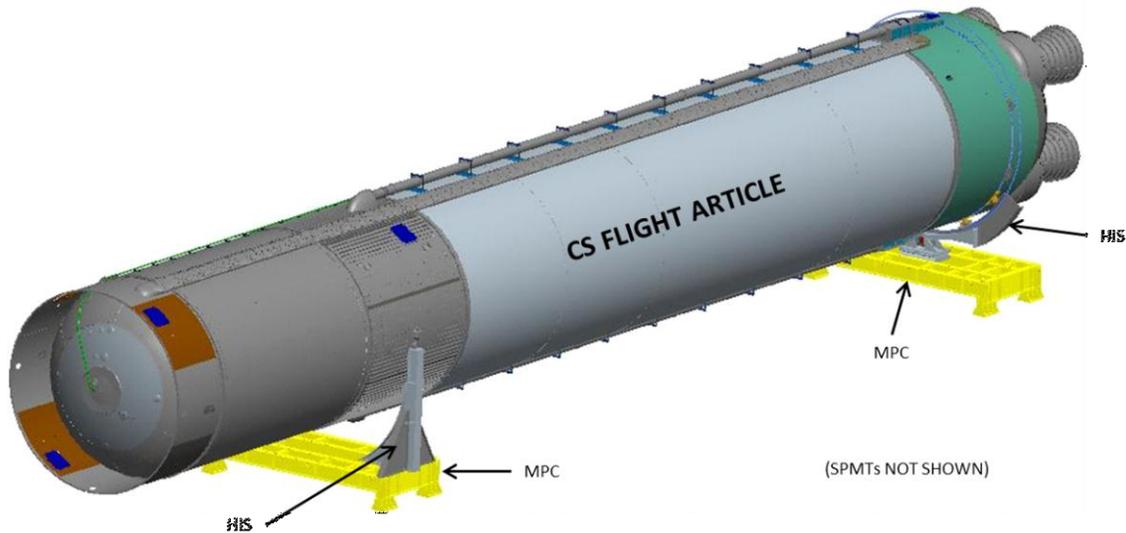
## 4.2 Multipurpose Transportation System

The MPTS consists of modular structural components assembled together as a single support structure system. This structural system interfaces with the CS flight article GSE, as well as with the barge deck. Figure 4-2 illustrates the CS flight article/MPTS configuration.

The CS flight article interfaces with GSE hardware in the horizontal orientation for transportation via a uniquely designed forward HIS and aft HIS. This attachment methodology allows the CS flight article to be safely transported in the horizontal orientation. Each HIS manages the loads imparted to the CS flight article through the MPTS.

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Each MPC component of the MPTS also employs multiple load-bearing pedestals to provide clearance beneath the structure for the SPMTs and to provide interfaces with the barge deck.



**Figure 4-2. CS Flight Article with MPTS**

### 4.3 Self-Propelled Modular Transporter

The SPMTs are government-furnished transporters configured as part of the MPTS. The SPMTs may consist of two or more transporters operated in unison. The SPMTs serve to provide propulsive power, steering, and braking for the CS flight article and MPTS movement. The SPMTs lift the CS flight article and MPTS from beneath to provide a means to transport them from the manufacturing/assembly facility to the barge, to position the CS flight article and MPTS onto the barge, to position the MPTS for lifting at the test facility, and to extract the CS flight article and MPTS from the barge at the launch site. They are not required to supply air, fluids, or electrical power to the CS flight article or other components of the MPTS.

Government-furnished SPMTs are required at MAF for land movement of the CS flight article from the manufacturing/assembly facility to the MAF dock, at SSC for land movement of the CS flight article at the test facility, and at KSC for land movement of the CS flight article from the KSC dock to the VAB. Figures 4-3 and 4-4 illustrate a typical SPMT.



Figure 4-3. Typical SPMT

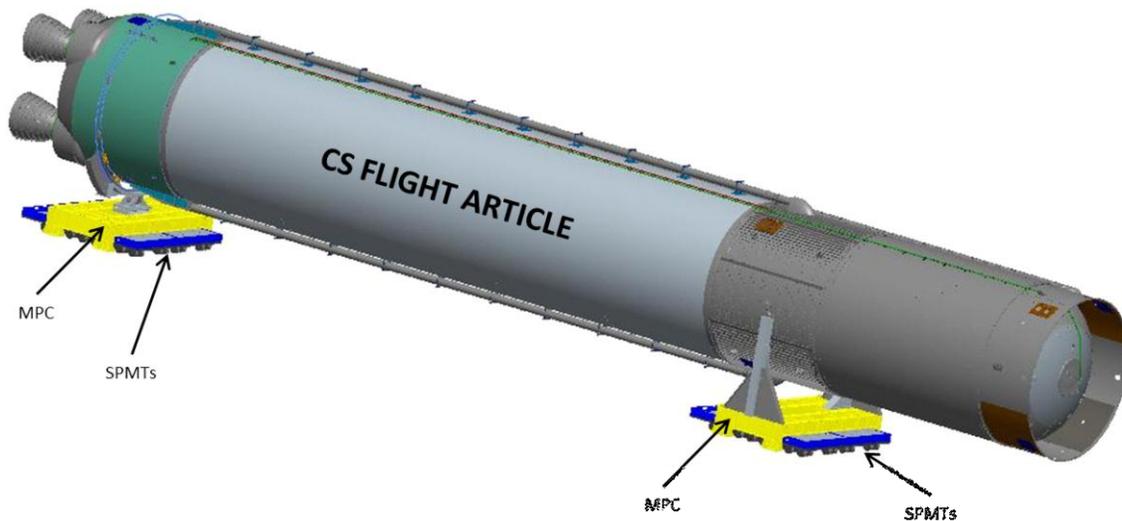


Figure 4-4. SPMTs Shown with MPCs and CS Flight Article

## 4.4 Protective Equipment

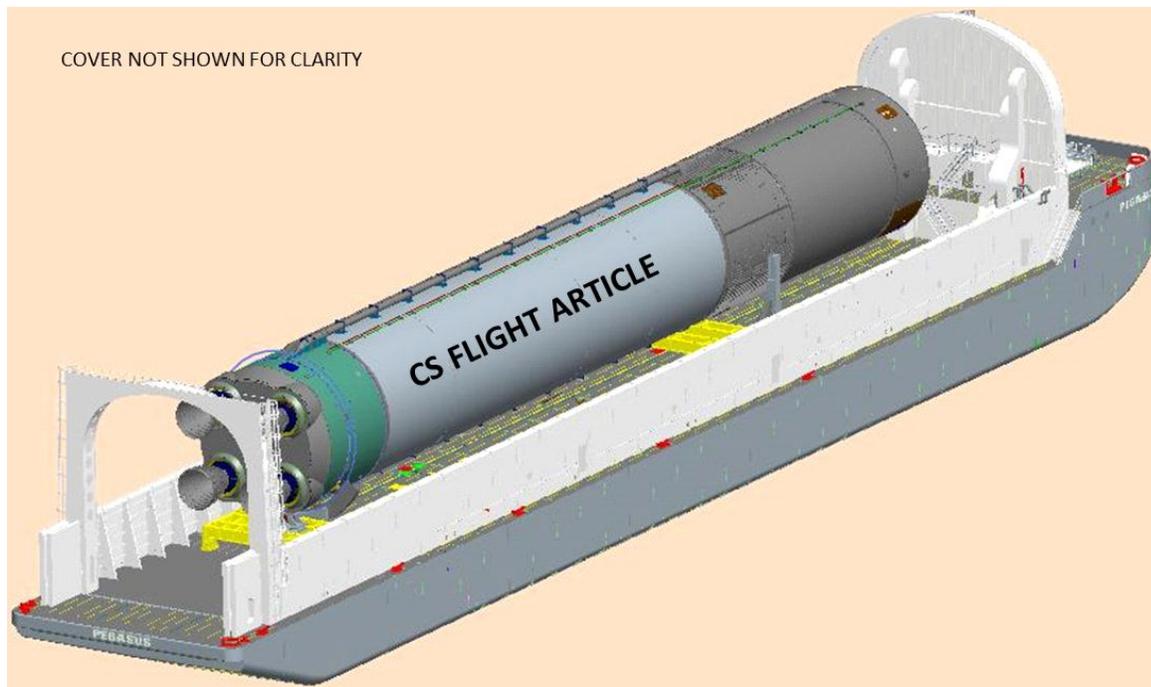
Protective equipment includes covers, plugs, temporary doors, desiccant bags, and other items used to preserve or to prevent unwanted environmental exposure for the CS flight article or certain defined areas of the CS flight article during land and water movements. Protective equipment may be installed during stage preparation prior to land movement from the manufacturing/assembly facility at MAF to the MAF dock, during land movement at the test facility at SSC, and during stage handling at KSC. No additional protective equipment is installed during land or water movement.

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## 4.5 Marine Transportation Equipment

The MTE is a system of hooks, blocks, turnbuckles, chains, cables, and other handling equipment which is used to secure the CS flight article, MPTS, and associated equipment to the barge during water transportation. This equipment is government furnished.

The MPTS tie-down configuration is based on the pedestal system used to transport the external tank for the Space Shuttle Program. *Pegasus* will be modified to utilize existing tie-down equipment and interfaces to the maximum extent possible. Figure 4-5 illustrates the CS flight article and MPTS arrangement on the barge. Also reference Figure 5-8.



**Figure 4-5. CS Flight Article and MPTS on the Barge**

One complete set of MTE, and its associated tooling and handling equipment, remains on the barge. Additional equipment is retained as spares.

## 4.6 Instrumentation and Environmental Control Equipment

During land and water movements, the CS flight article and MPTS may be instrumented to provide accurate records of the environments to which the stage is subjected during the transportation. Instrumentation may also be installed on the barge to provide information to help evaluate the interaction between the barge and the CS flight article during water shipment.

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Instrumentation may include all devices, cables, and sensors required to adequately monitor transportation environments. The following types of measurements may be recorded or monitored during the transportation of the CS flight article:

#### **CS Flight Article**

- Propellant tank pressures.
- Vibration.
- Acceleration.
- Strain.
- Interior temperature and humidity (within CS flight article envelope).

#### **Barge**

- Pitch and roll.
- Ambient temperature and humidity on main deck.
- Acceleration/vibration.

The required number and types of measurements and their locations may be selected by the government, the manufacturing/assembly contractor, and the CS engine contractor.

Environmental control equipment may include “active” systems, such as dehumidifiers and air conditioning units, required to provide a specified environment to a specific area within the CS flight article.

It is the government’s intent to minimize personnel aboard the barge during water shipment. Both the instrumentation and the environmental control equipment should be designed and operated such that minimal or no personnel are required for proper function during transportation. Consequently, these items should be self-sustaining to the maximum extent reasonably possible. Electrical power and other provisions may, however, be provided by the barge, if required. A team will be established with the goal to identify the transportation requirements, to implement the design, and to test the required items needed to control and/or measure the CS flight article and CS flight article subsystems and components during the transportation of the vehicle from MAF, to SSC, and to KSC. Data acquired during the initial CS flight article shipments will be evaluated (reference Section 6.0) to determine the extent and necessity of measurements applied to future CS flight article shipments.

### **4.7 CS Flight Article Associated Equipment**

CS flight article associated equipment may include the following:

- Flight ship loose articles.

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- CS flight article “stage specific” or “mission specific” ship loose articles (flight, GSE, or SE).
- CS flight article tooling and maintenance/emergency equipment.
- MPTS tooling and maintenance/emergency equipment.
- CS engine tooling and maintenance/emergency equipment.
- GSE or other equipment required to power or operate instrumentation, environmental control equipment, or protective equipment (example: GN<sub>2</sub> bottles/hoses, power supplies, batteries, etc.).
- Handling equipment used to position or maneuver MTE.
- Other program or project hardware or equipment required to be transported between sites.

Established or “stage specific” equipment is secured to the main deck or stored on the main deck or appropriate storage area per government-approved configurations. Proper grounding can be provided as required.

## 4.8 Lifting Equipment

Lifting equipment consists of linkages, slings, shackles, cranes, or other devices required to lift or rotate the CS flight article from the MPTS. Lifting activities occur during stage preparation prior to receipt of the CS flight article (for shipment) from the manufacturing/assembly facility at MAF, prior to and subsequent to testing at the test facility at SSC, and after delivery of the CS flight article at the launch site receiving facility (VAB) at KSC. No lifting equipment or operations are considered part of this transportation plan, but are included here to provide continuity.

**Note:** Lifting equipment may be required to position MTE aboard the barge. This lifting equipment, if required, is considered as associated MTE handling equipment, discussed in Section 4.7.

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## 5.0 TRANSPORTATION FUNCTIONS

The following sections describe, in detail, the transportation functions as they relate to the CS flight article, shown in Figure 3-3. All transportation functions are performed in a safe manner in accordance with safety requirements established at each facility or established by the custodian of the CS flight article during specific phases of transportation. Detailed procedures for transportation functions will be developed and will contain the appropriate “WARNING” and “CAUTION” notations, and the appropriate safety information, to indicate where special care should be taken during the performance of the particular operation. Pyrotechnic components and systems may be installed on the CS flight article prior to initiation of transportation functions. If so, the CS flight article would be considered “hazardous material” during performance of all transportation functions. For more detail on safety and contingency planning, see Section 3.3.

### 5.1 Stage Preparation

Core stage flight article preparation for delivery occurs at MAF after the fully assembled CS flight article has been accepted for shipment to the test site (SSC) and after the CS flight article has completed all integrated verification testing at SSC prior to shipment to the launch site (KSC). Stage preparation is completed prior to land movement and includes the following activities:

- Secure CS flight article to the MPTS in a horizontal orientation.
- Secure/lockdown CS engine(s) for transportation.
- Provide, install, and checkout protective equipment (reference Section 4.4).
- Provide, install, and checkout instrumentation, environmental control, and monitoring equipment (reference Section 4.6).
- Package associated equipment, as required (reference Section 4.7).

The CS flight article and all associated equipment is packaged and prepared for shipment per NPR 6000.1, Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems Equipment and Associated Components, and in accordance with USDOT guidelines.

Stage preparations are performed within the manufacturing/assembly facility at MAF and at the test facility at SSC. Responsibilities related to this function are included in Section 3.2.

### 5.2 Land Transportation

Land transportation of the CS flight article and associated equipment occur at MAF, SSC, and KSC utilizing the MPTS, as provided in Section 4.2.

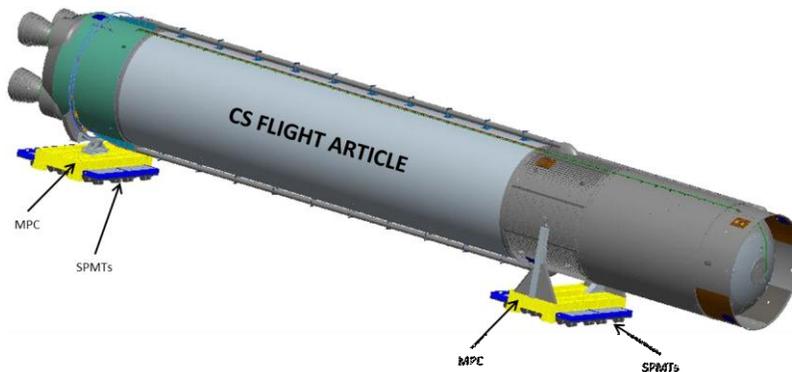
#### 5.2.1 MAF Land Movement

After all stage preparation activities are complete and prior to movement, the following land movement activities at MAF are performed:

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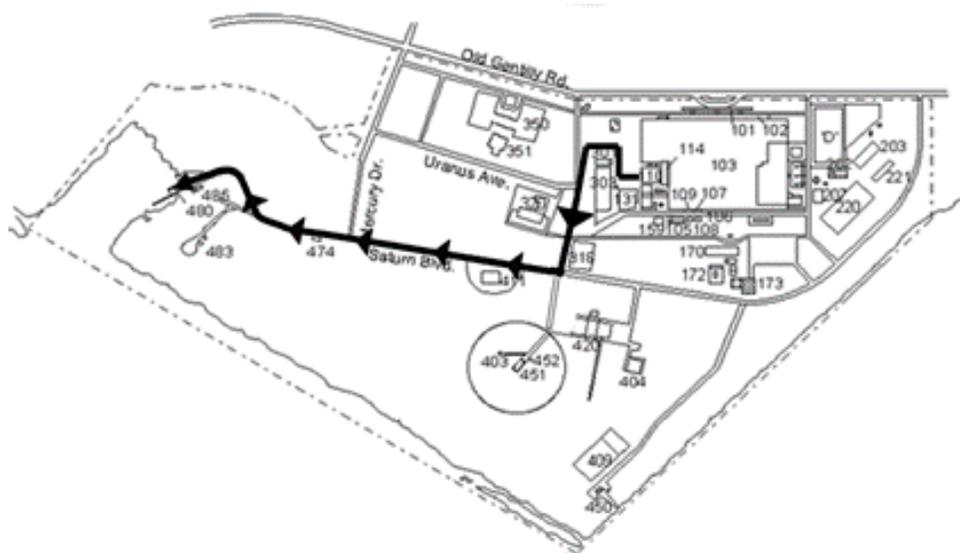
- Checkout of the MPTS.
- Activation of instrumentation, environmental control, and/or monitoring equipment.

Movement of the CS flight article is provided by the MPTS, shown in Figure 5-1.



**Figure 5-1. CS Flight Article and MPTS Land Movement Configuration at MAF**

Synchronized steering and braking are provided by an operator positioned to simultaneously operate the SPMTs. The CS flight article is lifted and transported by the MPTS over existing facility roads at very low speeds from the manufacturing/assembly facility to the MAF dock. Figure 5-2 illustrates the route.



**Figure 5-2. Land Movement of CS Flight Article and MPTS at MAF**

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The land movement is accomplished by the following minimal personnel under direction of a move director:

- SPMT operator(s).
- Lookouts.
- Technicians.

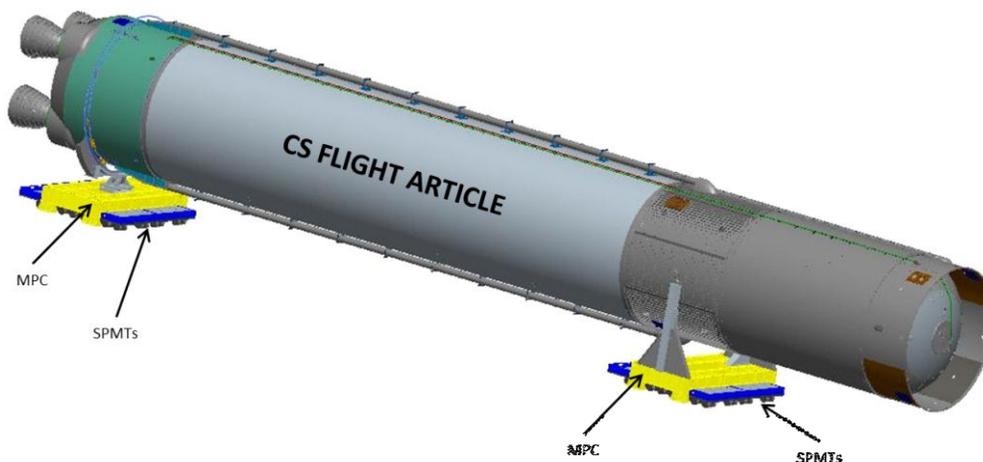
All personnel are in continuous contact via a common communications system. The technicians monitor and record necessary information required to properly utilize the MPTS.

Associated equipment packaged for water movement may be transported to the MAF dock via truck, forklift, or other conventional method, as required.

Responsibilities related to this function are included in Section 3.2.

### 5.2.2 SSC Land Movement

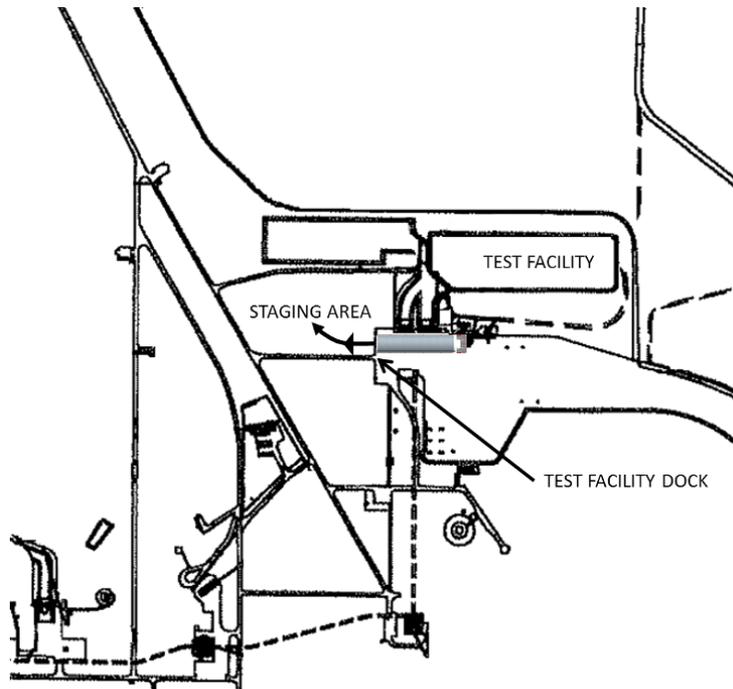
The land movement activities at SSC are performed after barge unloading at the test facility and prior to barge loading subsequent to testing activities at the test facility. Movement of the CS flight article is provided by the MPTS, shown in Figure 5-3.



**Figure 5-3. CS Flight Article and MPTS Land Movement Configuration at SSC**

Synchronized steering and braking are provided by an operator positioned to simultaneously operate the SPMTs. The CS flight article is lifted and transported by the MPTS at very low speeds from/to the test facility staging area to/from the test facility dock, depicted in Figure 5-4.

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**Figure 5-4. Land Movement of CS Flight Article and MPTS at SSC**

The land movement is accomplished by the following minimal personnel under direction of a move director:

- SPMT operator(s).
- Lookouts.
- Technicians.

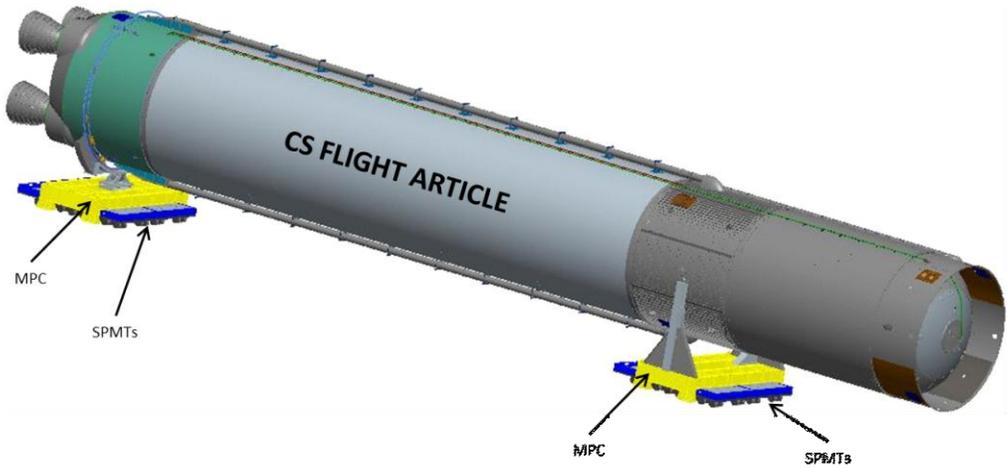
All personnel are in continuous contact via a common communications system. The technicians monitor and record necessary information required to properly utilize the MPTS.

Associated equipment packaged for water movement may be transported to/from the test facility dock via truck, forklift, or other conventional method, as required.

Responsibilities related to this function are included in Section 3.2.

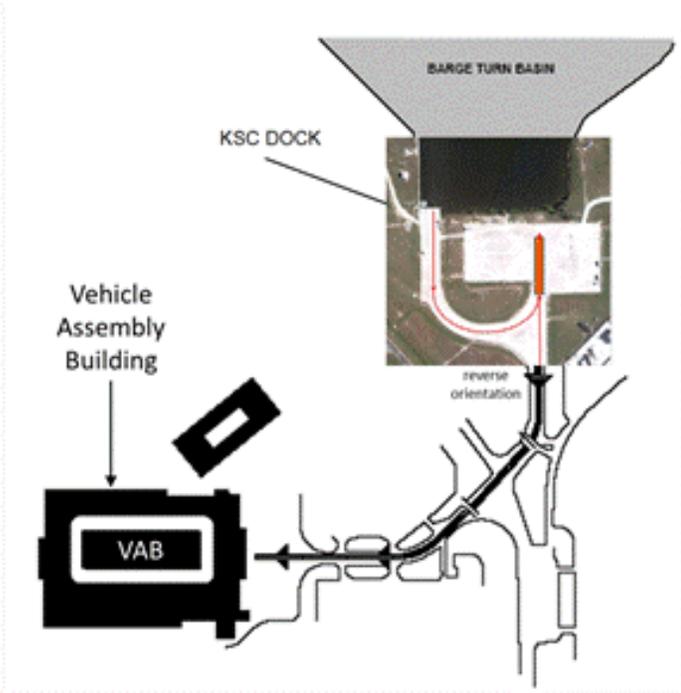
### **5.2.3 KSC Land Movement**

After all barge unloading activities are complete, the land movement activities at KSC are performed. Movement of the CS flight article is provided by the MPTS, shown in Figure 5-5.



**Figure 5-5. CS Flight Article and MPTS Land Movement Configuration at KSC**

Synchronized steering and braking are provided by an operator positioned to simultaneously operate the SPMTs. The CS flight article is lifted and transported by the MPTS over existing facility roads at very low speeds from the KSC dock to the VAB. Figure 5-6 illustrates the route.



**Figure 5-6. Land Movement of CS Flight Article and MPTS at KSC**

The land movement is accomplished by the following minimal personnel under direction of a move director:

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- SPMT operator(s).
- Lookouts.
- Technicians.

All personnel are in continuous contact via a common communications system. The technicians monitor and record necessary information required to properly utilize the MPTS.

Associated equipment packaged for water movement may be transported to the VAB via truck, forklift, or other conventional method, as required.

Responsibilities related to this function are included in Section 3.2.

### **5.3 Barge Loading/Unloading**

The barge loading and unloading function is the roll-on/roll-off operation by which the CS flight article, MPTS, and associated equipment are positioned on the barge or extracted from the barge. Prior to these activities, the barge is prepared by a government-furnished barge crew by ballasting the stern (lip) to rest on the dock recess and securing the barge to mooring locations, as shown in Figure 4-2. This provides and maintains a safe and appropriate interface for roll-on/roll-off operations. The MAF, SSC, and KSC docks are configured as such. The barge monitoring instrumentation may also be installed by the barge crew to measure desired parameters as provided in Section 4.6, if required.

Barge loading and unloading is accomplished by the following minimal personnel under direction of a move director:

- SPMT operator(s).
- Lookouts.
- Technicians.

This crew is intended to be the same personnel conducting the land movements at MAF and at SSC, respectively. All personnel are in continuous contact via a common communications system. The technicians monitor and record necessary information required to properly utilize the MPTS.

During the loading process at MAF and SSC, this function includes securing the cargo to the barge via government-furnished tie-down equipment, as noted in Section 4.5. During the unloading process at SSC and KSC, this function includes removing and stowing the tie-down equipment and a general inspection of the cargo prior to preparation for land movement.

#### **5.3.1 Barge Loading at MAF and SSC**

Barge loading occurs at the MAF dock upon land movement of the CS flight article via the MPTS from the manufacturing/assembly facility. Barge loading also occurs at the test facility dock at SSC subsequent to land transportation from the staging area after testing activities at the

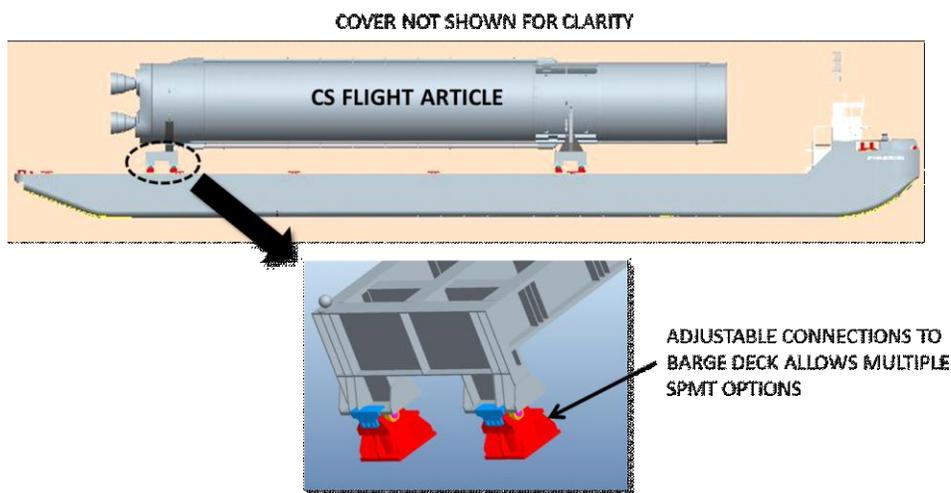
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test facility are completed. SPMTs remain positioned beneath the MPCs in the lowered, non-load carrying position available to lift and transport the CS flight article onto the barge, as shown in Figure 5-7. The CS flight article is oriented such that the CS engines are at the stern of the CS flight article barge. Markings on the main deck of the barge indicate correct positioning. Associated equipment may be positioned aboard the barge by conventional methods as required.



**Figure 5-7. Barge Loading at MAF and SSC**

After the CS flight article, MPTS, and associated equipment are loaded, those items are grounded, as required, and secured to the barge using tie-down equipment. The MPC components of the MPTS are secured to the main deck via multiple pedestals attached to the MPCs. To further retard potential movement, turnbuckles and other linkages may be secured to pad eyes and D-rings, in a specified pattern, to fully constrain the MPCs. This configuration is illustrated in Figure 5-8. Associated equipment is secured, as required, by conventional methods.



**Figure 5-8. CS Flight Article and MPTS Secured to the Barge**

The aft doors of the barge are closed and secured, and the aft curtain is drawn by the barge crew. Upon verification of the shipping configuration, the barge crew de-ballasts the barge to release it from the dock and to provide the proper draft for water transportation.

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**Note:** The SLS Program/Project, manufacturing/assembly, and/or engine contractor may desire personnel aboard to accompany the CS flight article shipments. Though this is not the operational intent, additional personnel may be accommodated (up to four total). These personnel should be minimized due to safety concerns, as outlined in Section 3.3.

Responsibilities related to this function are included in Section 3.2.

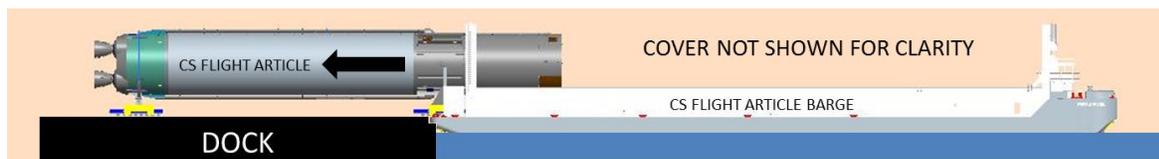
### 5.3.2 Barge Unloading at SSC

Barge unloading occurs at the test facility dock at SSC after water transportation of the CS flight article, MPTS, and associated equipment from MAF. Prior to beginning operations, a general inspection is performed by the barge crew and by the unloading crew to verify grounding, and to verify no damage has occurred to the barge, CS flight article, MPTS, and associated equipment during water transportation. All or part of the instrumentation, environmental control, and monitoring equipment (reference Section 4.6) may be removed by the barge or unloading crew. The tie-down equipment, described in Section 4.5, is then removed and stowed aboard the barge.

After all tie-down removal activities are complete, the following unloading activities are performed:

- Checkout of MPTS.
- Verify barge secure.

Movement of the CS flight article from the barge is provided by the MPTS. SPMTs are positioned beneath the MPCs in the lowered, non-load carrying position available to lift and transport the CS flight article from barge. Markings on the main deck indicate correct positioning, as shown in Figure 5-9.



**Figure 5-9. Barge Unloading at SSC**

### 5.3.3 Barge Unloading at KSC

Barge unloading occurs at the KSC dock after water transportation of the CS flight article, MPTS, and associated equipment from SSC. Prior to beginning operations, a general inspection is performed by the barge crew and by the unloading crew to verify grounding, and to verify no damage has occurred to the barge, CS flight article, MPTS, and associated equipment during water transportation. All or part of the instrumentation, environmental control, and monitoring equipment (reference Sections 4.6 and 5.0) may be removed by the barge or unloading crew. The MTE, described in Section 4.5, is then removed and stowed aboard the barge.

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After all tie-down removal activities are complete, the following unloading activities are performed:

- Checkout of MPTS.
- Verify barge secure.

Movement of the CS flight article from the barge is provided by the MPTS. SPMTs are positioned beneath the MPCs in the lowered, non-load carrying position available to lift and transport the CS flight article from the barge. Markings on the main deck indicate correct positioning, as shown in Figure 5-10.



**Figure 5-10. Barge Unloading at KSC**

The MPTS positions the CS flight article on the dock pavement in preparation for land movement to the VAB. The associated equipment may be extracted from the barge, as required, by conventional methods.

Responsibilities related to this function are included in Section 3.2.

## 5.4 Water Transportation

Water transportation is accomplished by NASA, utilizing *Pegasus*, discussed in Section 4.1, among MAF, SSC (and internal SSC movement), and KSC. The barge is towed and/or pushed via government-furnished marine towing vessels (inland rated tugs), provided through a marine services contractor, during inland waterway movement. For oceangoing travel, the barge is towed via a government-furnished marine towing vessel (ocean rated tug), provided through a marine services contractor.

The barge is pushed and/or towed along designated water routes, as displayed in Figures 5-11 through 5-15. The routes consist of four basic phases. All water movement is in compliance with maritime laws. Furthermore, the CS flight article may be considered “hazardous material” and as such, would be configured for shipment with approval from the U.S. Department of Transportation (USDOT) via “Special Permit” and with concurrence from the USCG and NASA.

Responsibilities related to this function are included in Section 3.2. The four phases of water movement are described as follows:

### Phase I

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Phase I of the water route applies to inland waterway travel from the MAF dock to the test facility dock at SSC. During this phase, the barge is towed by two tugs (a push tug and an assist tug ahead of the barge) via the Gulf Intracoastal Waterway (GIWW), the East Pearl River, and the SSC Canal System. This phase of the water route is approximately 40 miles in length and is illustrated in Figure 5-11 below.



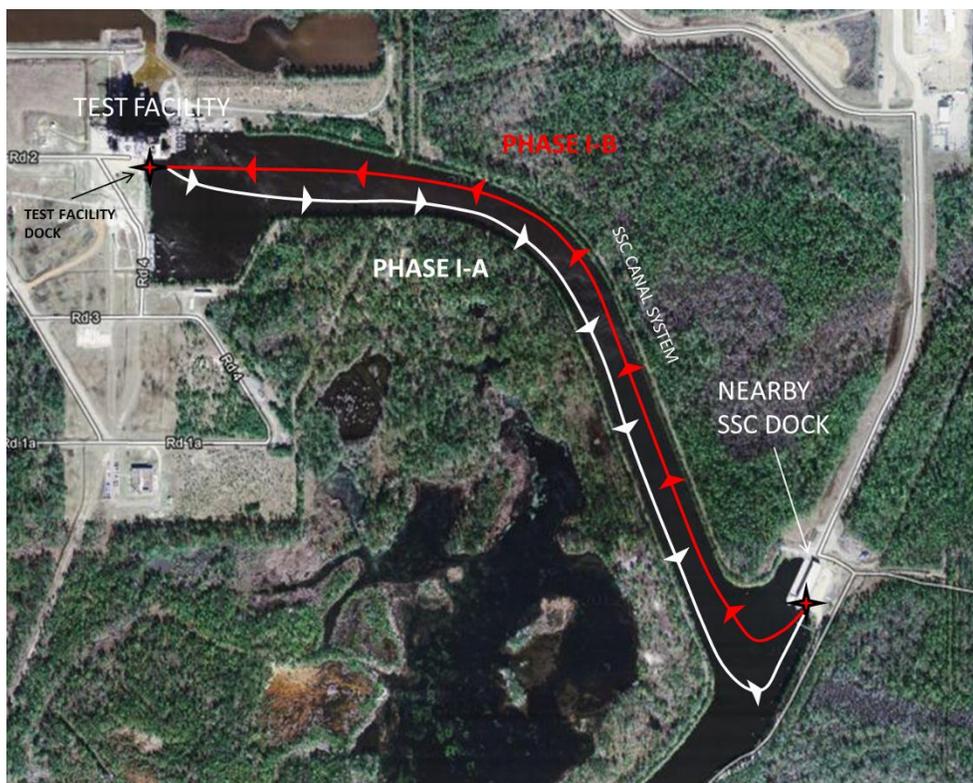
**Figure 5-11. Phase I of the CS Flight Article Water Movement Route – MAF to SSC**

Waterway restrictions include a 90 ft horizontal clearance through several bridges and other structures and a height restriction of 73 ft at the Interstate 10 bridge. Neither restriction impacts navigability of the barge in this phase of movement. However, operational planning must account for restricted usage times for the swing and draw bridges along the route.

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### Phase I-A/B

Phase I-A of the water route applies to inland waterway travel from the test facility dock to a nearby SSC dock. This movement is performed to protect the barge from damage during stage handling operations and testing operations at the test facility. During this phase, the barge is towed a short distance by two tugs (a push tug and an assist tug ahead of the barge) via the SSC Canal System. Phase I-B returns the barge to the test facility dock. This phase of the water route is approximately one-half mile in length and is illustrated in Figure 5-12 below.



**Figure 5-12. Phase I-A/B of the CS Flight Article Water Movement Route – Inland SSC**

*Note:* The local SSC government tug, Clermont II, may be utilized in lieu of commercial inland tugs to maneuver the CS flight article barge to/from the nearby SSC dock, given appropriate weather conditions.

### Phase II

Phase II of the water route applies to inland waterway travel from the test facility dock at SSC to near The Port of Gulfport, Mississippi. During this phase, the barge is towed by two tugs (a push tug and an assist tug ahead of the barge) via the SSC Canal System, the East Pearl River and, the

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GIWW. This phase of the water route is approximately 62 miles in length and is illustrated in Figure 5-13 below.



**Figure 5-13. Phase II of the CS Flight Article Water Movement Route – SSC to Gulfport, Mississippi**

The rendezvous point to relieve the inland tugs and make tow with the single ocean tug is at the intersection of the GIWW and the Gulfport Ship Channel approximately 6.2 miles offshore. The transfer of tugs may also occur in Gulfport Harbor if scheduling dictates or barge porting is required.

Waterway restrictions are the same as those for Phase I and include a 90 ft horizontal clearance through several bridges and other structures and a height restriction of 73 ft at the Interstate 10 bridge. Neither restriction impacts navigability of the barge in this phase of movement. However, operational planning must account for restricted usage times for the swing and draw bridges along the route.

### Phase III

Phase III of the water route applies to oceangoing travel from Gulf Port, Mississippi, through the Gulf of Mexico, to Port Canaveral, Florida. During this phase, the barge is towed by a single ocean tug. This phase of the water route is approximately 816 miles in length and is illustrated in Figure 5-14 below. No height or width restrictions are applicable for this phase of movement.

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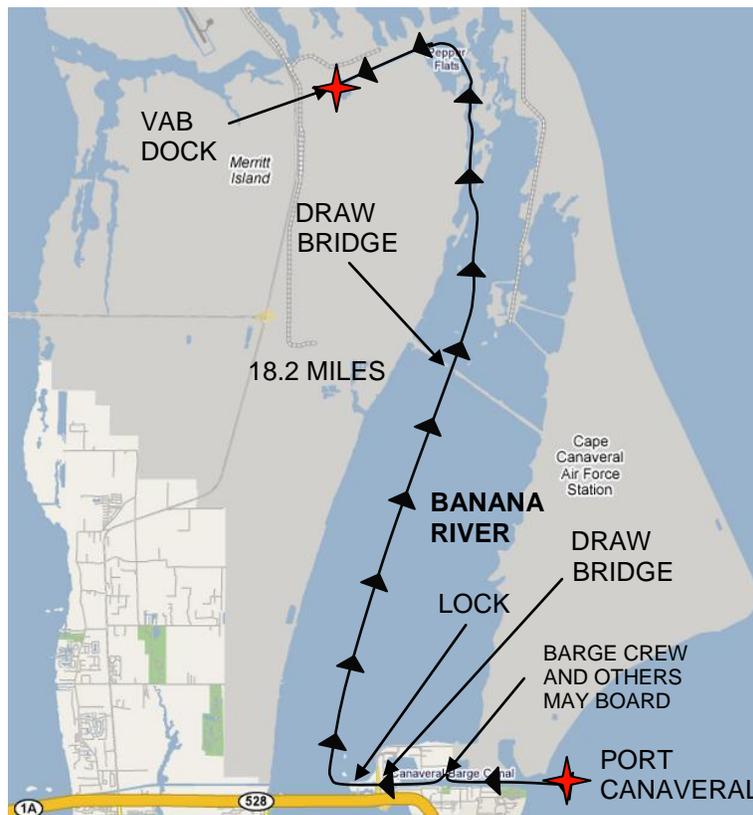


**Figure 5-14. Phase III of the CS Flight Article Water Movement Route – Gulfport, Mississippi, to Port Canaveral, Florida**

#### **Phase IV**

Phase IV of the water route applies to inland waterway travel from Port Canaveral, Florida, to the KSC dock near the VAB. During this phase, the barge is pushed by an inland tug. An assist tug ahead of the barge is also required for added control and maneuverability. The rendezvous point to relieve the single ocean tug and make tow with the inland tugs is at Port Canaveral. In addition, the government-furnished barge crew or others may board the barge at this location. The barge crew (if not already aboard) is required to activate the barge systems in preparation for docking, as well as properly ballasting the barge for inland waterway travel.

The travel route for Phase IV is the Banana River. The “Saturn Channel” is dredged and maintained specifically for NASA. This route is 18.2 miles in length and requires transit through the S.R. 401 draw bridge, the Port Canaveral Lock, and the NASA Causeway draw bridge. These are restricted to a width of 90 ft. This phase of the water route requires additional weather restrictions due to the configuration of the channel. Consequently, the barge may dwell at Port Canaveral up to several days. Historically, secure government or commercial dock space has been available (upon prior arrangement) to accommodate NASA barges until weather conditions become favorable. The Phase IV travel route is illustrated in Figure 5-15.



**Figure 5-15. Phase IV of the CS Flight Article Water Movement Route – Port Canaveral, Florida, to KSC**

## 5.5 Stage Handling

Core stage flight article handling occurs at SSC prior to and subsequent to testing and after land movement from the KSC dock to the VAB. Stage handling includes activities required to lift the CS flight article or move the CS flight article by means other than the MPTS. Specifically, this includes lifting, by crane and lifting devices, the CS flight article from the MPTS in the VAB to bring it to a vertical position for further processing and at the SSC test facility prior to and subsequent to testing activities. Stage handling, and the lifting devices required to perform handling activities, are not considered part of this transportation plan, but is included here for continuity.

## 5.6 Stage inspection

Visual inspection from walk-up access on *Pegasus* is performed by representatives of both the sending and receiving organizations to document configuration and condition of the CS flight article. Due to inspection limitations on the barge, only the visible areas of the CS are inspected. Inspection satisfies the DD1149 hardware transfer process. The DD1149 is signed by both

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sending and receiving organizations, and the hardware is transferred to the VAB where a follow-on visual inspection of the previously inaccessible areas is performed. Issues identified by the VAB inspection, that result in a “return-to-sender” decision, would require another DD1149 signoff by the sending and receiving organizations for ship-back to MAF.

**Note:** Specific points and locations for transfers of accountability of property is an SLS Element function and not included in this document. Reference SLS-PLAN-025, Section 6.4.

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## 6.0 TRANSPORTATION DATA AND DOCUMENTATION

The transportation data and documentation methodology is structured to support a concept of “ship and shoot.” A verification process is established to validate that the CS flight article has not been exposed to transportation loads or environments beyond its design limits during all transportation functions from the manufacturing/assembly facility, MAF, to the launch site, KSC.

Two methods are utilized to provide this verification: documentation and data. Each is used to establish that the CS flight article has not been exposed to transportation environments outside of its design limits.

### 6.1 Documentation

The “AS RUN” procedures provide documentation that all transportation activities are performed in accordance with the pre-approved procedures.

### 6.2 Data

The “AS RUN” data collected from the instrumentation and environmental control systems, discussed in Section 4.6, are evaluated to verify that the CS flight article is not exposed to transportation environments outside of its design limits. A comprehensive report is prepared to accompany the CS flight article end-item delivery.

All relevant documentation and data, and other supporting information, will be submitted to the SLSP as quality records to support the CS and SLS flight verification processes.

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## APPENDIX A ACRONYMS AND ABBREVIATIONS

ABS	American Bureau of Shipping
CDR	Critical Design Review
CFR	Code of Federal Regulations
CS	Core Stage
DD	Department of Defense
DDT&E	Design, Development, Test, and Evaluation
FL	Florida
FT	Feet
GIWW	Gulf Intracoastal Waterway
GN <sub>2</sub>	Gaseous Nitrogen
GSE	Ground Support Equipment
HIS	Hardware Interface Structure
ICPS	Interim Cryogenic Propulsion System
ILSP	Integrated Logistics Support Plan
KSC	Kennedy Space Center
KW	Kilowatts
LH <sub>2</sub>	Liquid Hydrogen
LOX	Liquid Oxygen
LSI	Logistics Support Infrastructure
MAF	Michoud Assembly Facility
MPC	Multipurpose Carrier
MPTS	Multipurpose Transportation System
MS	Mississippi
MSFC	Marshall Space Flight Center
MSM	Marine Safety Manual
MTE	Marine Transportation Equipment
MWI	Marshall Work Instruction
NASA	National Aeronautics and Space Administration
NO.	Number
NPR	NASA Procedural Requirements
NSS	NASA Safety Standard
OPR	Office of Primary Responsibility
PCH	Program Critical Hardware

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PDR	Preliminary Design Review
S.R.	State Road
SE	Support Equipment
SLS	Space Launch System
SLSP	Space Launch System Program
SPEC	Specification
SPMT	Self-Propelled Modular Transporter
SSC	Stennis Space Center
USCG	United States Coast Guard
USDOT	United States Department of Transportation
VAB	Vehicle Assembly Building

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## APPENDIX B OPEN WORK

All resolved TBDs, TBRs, and forward work items should be listed on the Change Request (CR) the next time the document is updated and submitted for formal review, and that will serve as the formal change record through the configuration management system.

### B1.0 TO BE DETERMINED

Table B1-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is sequentially numbered as applicable (i.e., <TBD-001> is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

**Table B1-1. To Be Determined Items**

TBD	Section	Description
TBD-001		

### B2.0 TO BE RESOLVED

Table B2-1 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBR issue is sequentially numbered as applicable (i.e., <TBR-001> is the first unresolved issue assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

**Table B2-1. To Be Resolved Issues**

TBR	Section	Description
TBR-001	2.1	PAD under revision – Paragraph Reference may change to 6.3

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**B3.0 FORWARD WORK**

Table B3-1 lists the specific forward work items identified during this document’s Change Request (CR) review and evaluation. Each item is given a sequential number using a similar format to that for the TBDs and TBRs. For each item, include the section number(s) of this document that the open work will impact, and in the Description include the specific number of the comment from the Change Evaluation (CE), i.e., CE-10, CE-27. Do not include a placeholder for forward work items in the body of the document; list them only in Table B3-1.

*Note:* If there are no forward work items, do not include this subsection in your document.

**Table B3-1. Forward Work**

FWD	Section	Description
FWD-001		