Design and Test of the Orion Crew Module Launch Abort System Hatch

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Abstract

The Orion spacecraft is part of NASA's Artemis program to establish a permanent human presence on the lunar surface and further enable future crewed missions to Mars. One of the key safety features of Orion is the Launch Abort System (LAS) which pulls the Orion Crew Module (CM) away in the event of a launch vehicle malfunction. It was necessary to design a LAS hatch that allows for crew access to the CM during pad operations. This paper describes the background and evolution of the LAS hatch design, the features used to address the crew safety requirements, the testing challenges in preparation for the Artemis crewed missions, and lessons learned.

Note: This subject has not been previously published.

Introduction

The Orion Launch Abort System, or LAS, is attached to the top of the Orion Crew Module (CM). It is designed to protect the NASA astronauts if a problem arises during launch by pulling the CM away from a failing rocket. Weighing approximately ~7,250 kg, the LAS can activate within milliseconds to pull the vehicle to safety and position the CM for a safe landing. The LAS is comprised of three solid propellent rocket motors: the abort motor, an attitude control motor, and a jettison motor (Figure 1).

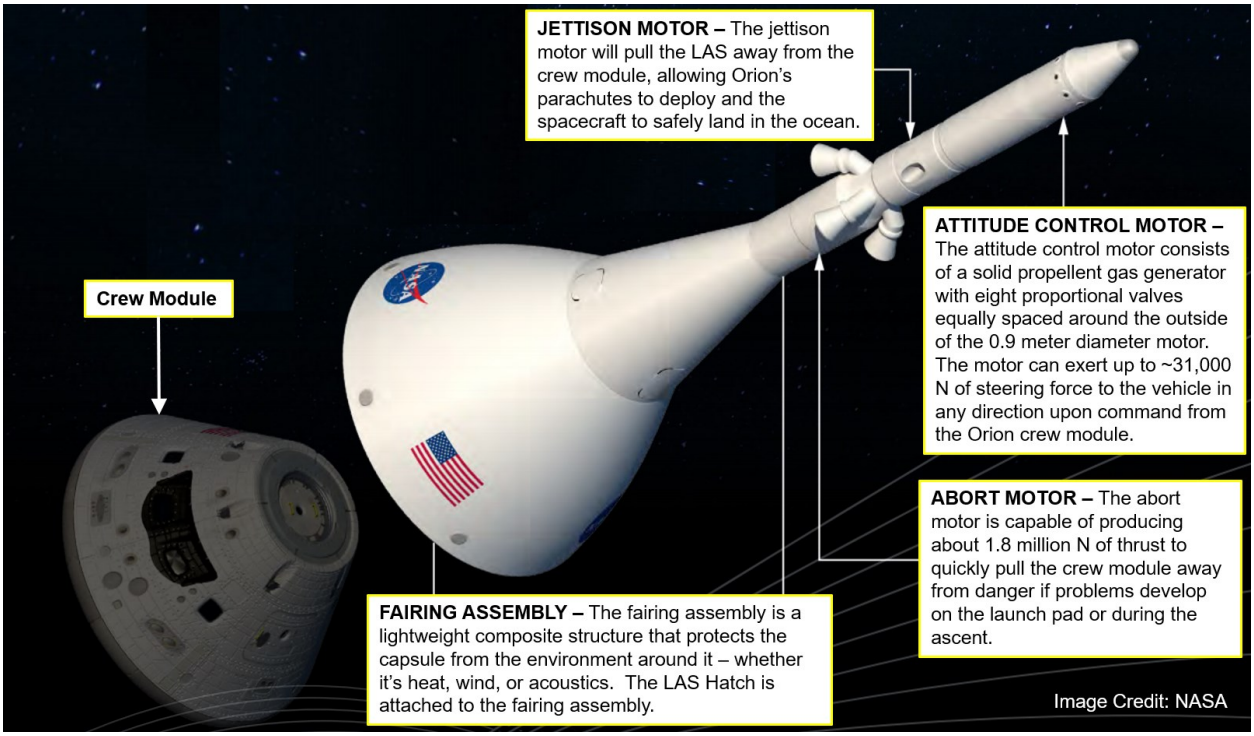

Figure 1: LAS Overview

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The Launch Abort System (LAS) Hatch is a structural / mechanical / pneumatic / electrical component that allows for ingress and egress through the LAS ogive fairing during nominal ground operations and pre-launch activities. It is also required to open quickly in emergency situations on the pad where the crew needs to exit in the event of a spacecraft or launch vehicle malfunction. The deployed LAS hatch is shown on the spacecraft in Figure 2.

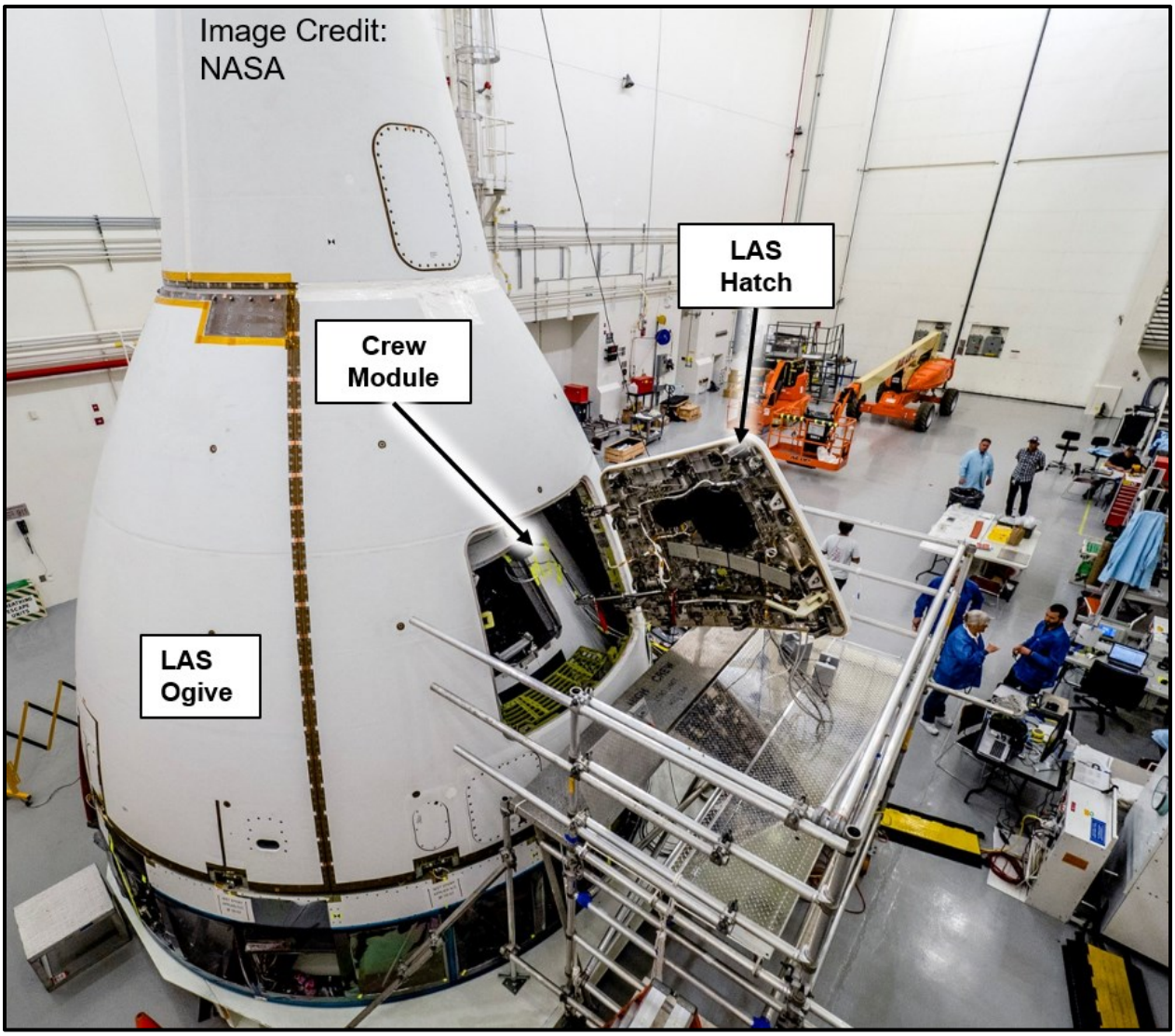

Figure 2: Orion LAS Hatch on the Ascent Abort 2 vehicle

LAS Hatch Design Details

The LAS hatch contains the following key components, reference Figures 3 and 4 (the final paper will go into more detail on the purpose and function of each component):

- Curved aluminum structural panel (conforming to the complex ogive shape of the LAS fairing)
- Window (aligned to the CM hatch ~0.6 m away)
- 10 pneumatic latches used to compress the perimeter seal and retain the hatch to the LAS structure
- Pneumatic actuation system comprised of solenoid valves, pressure transducers, check valves, batteries, a Composite Overwrapped Pressure Vessel (COPV), and steel tubing

- Perimeter weather and EMI/EMC seal
- Deployment hinges (4-bar linkage design)
- Gate Release Assembly which initiates the emergency egress function (actuated by the opening CM side hatch)
- Bumper Assembly which the CM side hatch slides along to help open the LAS hatch
- Tangential and radial hard stops which provide additional structural support
- Strut Assembly (pneumatic strut to help open the LAS hatch)
- External Handle Assembly for opening the LAS hatch from the exterior of the vehicle (for both nominal and emergency cases)
- Electrical system comprised of standalone batteries for emergency egress and sensors for crew situational awareness

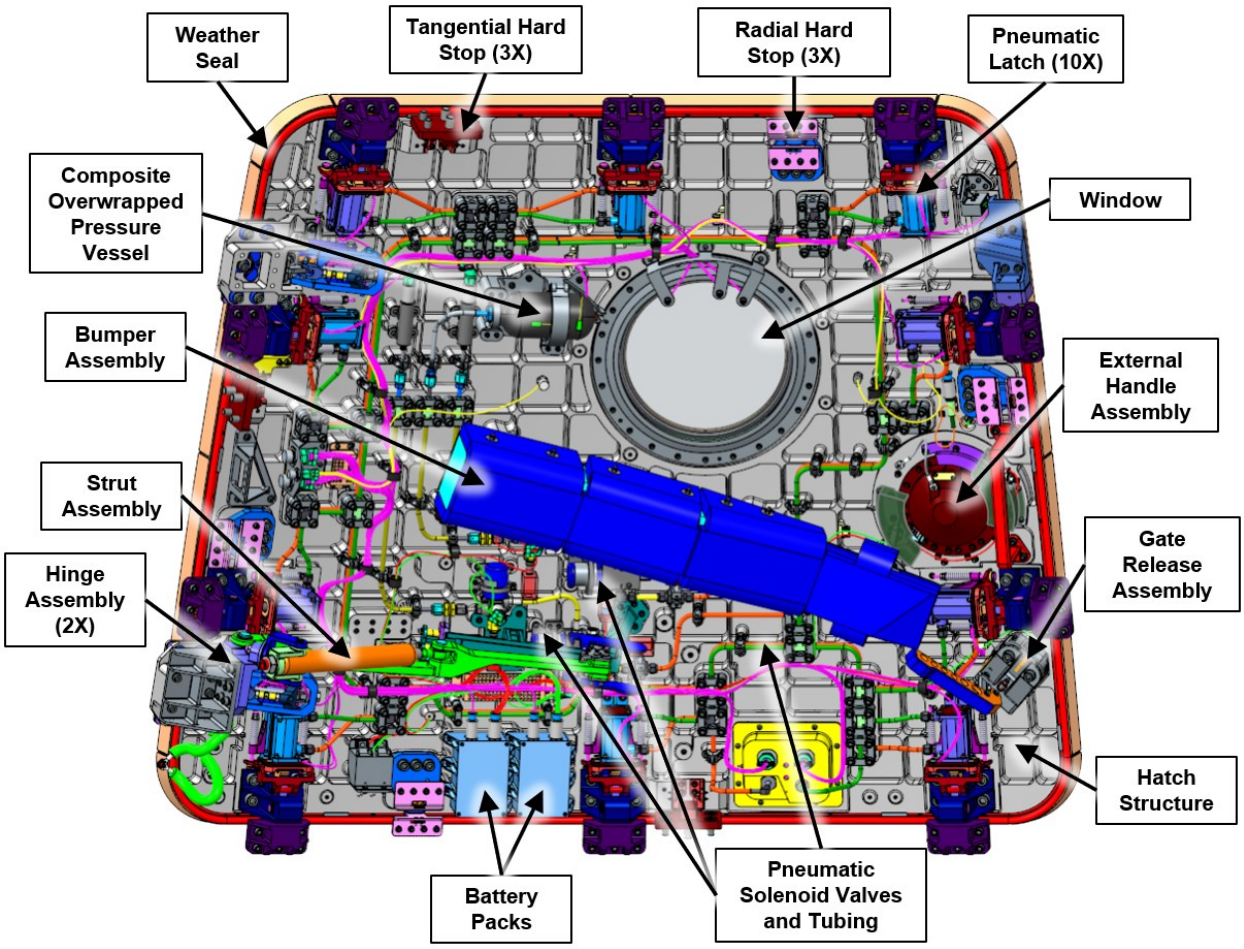

Figure 3: Orion LAS Hatch Overview (Interior View)

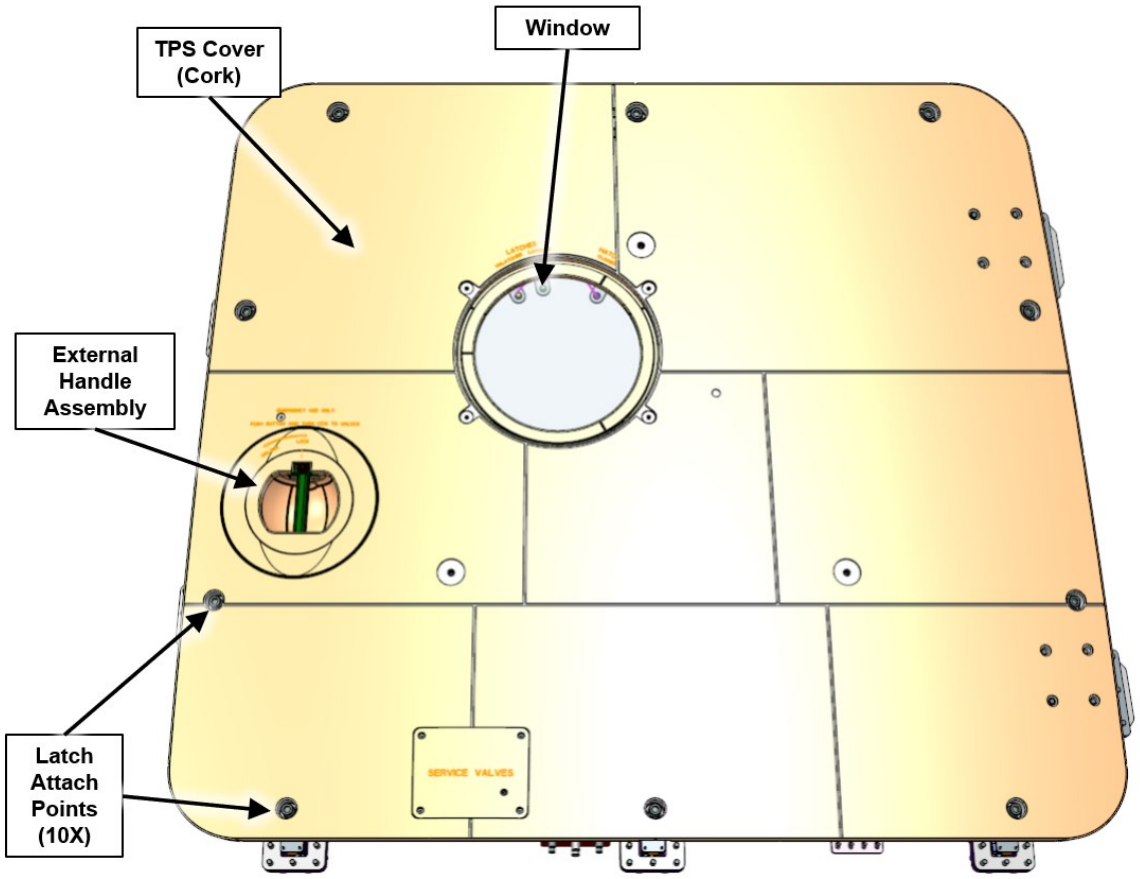

Figure 4: Orion LAS Hatch Overview (Exterior View)

Emergency Operation Function

In the event of an emergency on the launch pad where the crew needs to exit the vehicle quickly, there are two scenarios:

1. Initiated by ground operations team: Ground team member pushes a button and turns the External Handle Assembly which actuates the pneumatic system to retract the latches, which then allows the ground team to pull open the hatch (aided by the pneumatic strut assembly)
2. Initiated by the flight crew (Figure 5): An astronaut will open the CM side hatch using either the manual gearbox system or an emergency pyro system. The side hatch is pushed open with its own pneumatic "counterbalance" strut, which then impacts the Gate Release Assembly on the LAS hatch. The Gate Release Assembly actuates the LAS hatch pneumatic system unlatching the latches, which then allows the side hatch to push the LAS hatch open as it slides along the bumper interface.

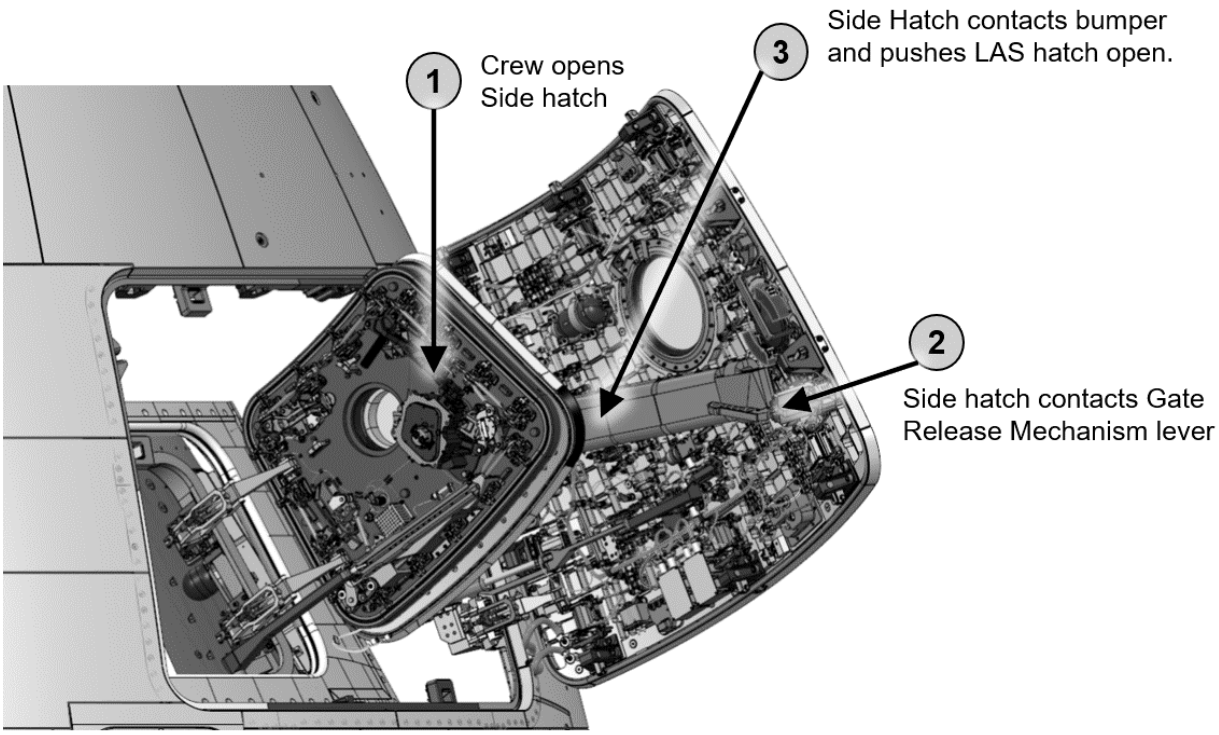

Figure 5: Orion LAS Hatch Emergency Egress Sequence

LAS Hatch Requirements

Key driving requirements for the LAS hatch were derived with the NASA customer to best balance crew safety with the environmental and mass constraints (Table 1):

Requirement	Orion
Nominal Opening Time	Hatch shall open to allow nominal crew egress within 60 seconds of the initiation command
Emergency Egress Opening Time	Hatch shall open to allow emergency crew egress within 10 seconds of the initiation command
Operable Without Tools	Hatch shall provide a method of opening without the use of tools
Random Vibration Environment	Hatch shall remain closed, latched, and survive without creating debris after exposure to nominal launch and abort random vibration environments (> 100 Grms abort levels)
Aerothermal Environment	Hatch shall remain closed, latched, and survive without creating debris after exposure to nominal launch and abort aerothermal environments
Climatic Environment	Hatch shall operate and remain sealed after exposure to climatic environments (solar, wind, humidity, rain, hail, flora/fauna)
Hatch Opening Cycle Life	536 cycles
NASA-STD-5017 (AIAA-S-114 derivative) applicability	Hatch mechanisms to be compliant with NASA-STD-5017
EMI / EMC environment	Hatch shall be capable of surviving a direct lightning strike

Table 1: LAS Hatch Key Driving Requirements

Design Development

The final paper will discuss the design process for the LAS hatch. Key discussion points will include:

- Initial design trade study process and results (numerous pneumatic, mechanical, and pyrotechnic options were considered).
- Challenges encountered with the extremely high abort scenario dynamic environments, specifically with the acoustic/vibration level derivations and determination of equivalent component static loads. Significant iteration was required, resulting in the use of some non-linear analysis methods and a hatch design that was heavier than initially anticipated.
- Use of the “Easy 5” pneumatic system software tool and associated model correlation problems and lessons learned.
- Latch actuator design challenges (the initial supplier backed out on the contract, so an in-house design had to be quickly completed).
- Pneumatic tubing manufacturing, welding, and integration issues.
- Emergency egress system electrical design problems (switch arcing and vibration deflection issues). Custom switches and special electronics had to be designed.

Test and Integration

The final paper will discuss the hatch testing and spacecraft integration. Key discussion points will include:

- Overview of the development and qualification testing completed (functional, acoustic, proof pressure, vibration, static load).
- Structural test failures on the latches and hinges with root causes and corrective actions.
- Acoustic testing at the NASA Plumbrook facility

Ascent Abort 2 (AA-2 Flight)

The final paper will discuss the preparations and results of the LAS hatch flying on the Ascent Abort 2 mission which exposed the hatch to the full abort environments. The hatch was successfully recovered from the ocean after the flight and was fully intact even after the water impact, demonstrating the design robustness (Figure 6)

Figure 6: LAS Hatch recovery after the AA-2 flight

Lessons Learned

The final paper will summarize the numerous lessons learned in the LAS hatch design, test, integration, and AA-2 flight. Currently the Artemis 1 mission is planned to launch in late 2021 and it may be possible to include some data or lessons learned from that flight. Final qualification testing of the hatch for the Artemis 2 flight is currently underway and results may be available for incorporation into the paper.

Acknowledgements / References

- Lockheed Martin Orion Mechanisms team
  - John Lawlor, Jeff Heyne, Ben Nesmith, Robert Pinkham, Ron Geiger, Evan Siracki
- NASA Orion Mechanisms Team
  - Brian Emmett, Brent Evernden, Michael Politi
- https://www.nasa.gov/sites/default/files/atoms/files/orion_las_fact_sheet_8.5x11_4page_11_19_15.pdf