U.S. SPACE & ROCKET CENTER
SHUTTLE PATHFINDER REPORT
4/20/22– Draft F

REPORT OUTLINE

1. Introduction
    a. History of the Shuttle Pathfinder (brief)
    b. What Shuttle Pathfinder means to the Huntsville community & space programs at large (brief)
    c. Why did the Shuttle Pathfinder come down? (brief)
    d. Explain the remaining outline items (brief)
2. Concrete
    a. Current condition
    b. Analysis by VCS
    c. Renovation Plan
3. Main Tank Covering
    a. Current condition
    b. Foam removal test outcomes
    c. Investigation by coater
    d. Renovation Plan
4. Solid Rocket Boosters
    a. Current condition
    b. Renovation Plan
5. Artifact Structure
    a. Inspection of condition
    b. Analysis of Structure
    c. Renovation Plans (if needed)
6. Cover
    a. Current condition – not usable
    b. Discussion with potential vendors (like Branch)
    c. Re-covering Plan
7. Appendixes
    a. Overall Renovation Plan Schedule – Key Milestones
    b. Estimated Budget (audience dependent)

Introduction

The iconic Pathfinder Shuttle Stack stands as a testament to the 30-year program that moved humans from a space-launch people to a space-dwelling people. The space shuttle's main engines, external fuel tank and solid rocket boosters—the heart that powered the shuttle fleet—were designed, manufactured, and built in Alabama. The 135 missions managed through the Shuttle Program Office at Marshall Space Flight Center in Huntsville oversaw the first reusable space vehicle fleet, a concept that powers today's expanding commercial space companies. And while thousands of Alabamians employed by NASA and civilian contractors helped make space flight routine, they also helped make life better here at home. NASA estimates over 1,000 products developed during the shuttle program found successful application on Earth, such as shuttle engine valve technologies leading to better artificial heart valves for humans. The Space Shuttle program also made building the International Space Station 250 miles above Earth possible. For over two decades, the ISS has been the proving ground for living off-Earth, developing space commerce capacity, and fostering advances in microgravity science available nowhere else. None of this would exist without the Space Shuttle program, and the dedicated men and women of Alabama who worked to open space to science, commerce, and human habitation.

Originally unnamed, the orbiter on display was the dynamic test artifact built at the Marshall Space Flight Center in 1977 for use in activities such as checking roadway clearances, crane capabilities and fits within structures. It was later shipped by barge to the Kennedy Space Center and was used for ground crew testing in the Vehicle Assembly Building, Orbiter Processing Facility, and Shuttle Landing Facility. As the prototype for developing the shuttle fleet, this orbiter was designated Pathfinder. Pathfinder is approximately the same size, shape and weight of a flight orbiter. Using Pathfinder allowed for facilities testing without requiring use of the more delicate and expensive Enterprise. After sitting in storage for many years, the America-Japan Society, Inc. obtained the wood and steel mockup at a cost of US$1 million and hired Teledyne Brown Engineering to refurbish it to more closely resemble an actual Space Shuttle. It was named Pathfinder and displayed at the Great Space Shuttle Exposition in Tokyo from June 1983 to August 1984.

After the exhibit, the Pathfinder orbiter returned to the United States. The U.S. Space & Rocket Center in Huntsville, Alabama designed a display to showcase the orbiter stacked atop a fuel tank and boosters. NASA provided MPTA-ET and two filament-wound Solid Rocket Booster casings, which had been designed for polar-orbit launches from Vandenberg Air Force Base. On February 16, 1988, NASA shipped MPTA-ET, an external tank which had been used for propulsion tests with MPTA-098, on an open barge from Stennis Space Center in Mississippi up the river to Michoud, where it was transferred to the Orion barge to sail up the river to Marshall Space Flight Center. The tank, not having been designed to hold the weight of an orbiter at an angle, required reinforcements. NASA installed I-beam spokes in the tank at Marshall, in building 4705. Pathfinder's weight is concentrated in the tail, though, and the tank required further reinforcements.

The tank was then transported over land to the display at the museum. In May 1988, the 89-ton Pathfinder was installed atop the display at the Space & Rocket Center. In 1999, NASA removed the forward assemblies from each SRB attached to the Pathfinder stack. Although the SRBs are recovered and reused after each flight, several of the forward assemblies

had been damaged or lost over the history of the Space Shuttle program necessitating requisition of those attached to the Pathfinder stack as spares. These items were reclaimed in the late 90's.

In 2008, repairs were made to the forward part of the mockup after decades of exposure to the weather had corroded the floor section near the vehicle's nose. This corrosion caused the "belly pan" to drop from a mounting bracket onto the external tank. The damaged area was part of the fiberglass and plywood added to the mockup before its exhibition in Japan. This was the first evidence of a deterioration of the wood and fiberglass covering that would lead to later issues.

In 2020 the Center received a "Save America's Treasures" grant for $500,000 for restoration of the artifact. This initial seed money was utilized in 2021 to begin the restoration process. However this grant and its matching funding was just enough to get the first stages of the orbiter removal completed and not much more. In January and February 2021, the project began disassembly of the wings, vertical stabilizer, and the engines from the orbiter. On February 8, 2021, the test orbiter was lowered from atop the fuel tank for the first time since May 5, 1988. Once on the ground the remainder of the deteriorated wood and fiberglass covering was removed exposing the Pathfinder steel structure.

In addition to the failing orbiter covering there is also weathering to the External tank and to the Solid rocket booster components that remain. Removal and reapplication of a new foam layer as well as stripping and repainting of solid rocket boosters remains to be completed. This is the next phase of the restoration process. Also as part of this second phase of the project, a structural analysis of the concrete display pillars was performed and methods for refurbishment of these pillars was determined. Phase 3 will see the design and installation of a new cover for the artifact. As part of this process a full structural analysis of the original Pathfinder structure will be completed to ensure the structural stability with the new cover.

Concrete Repairs

An analysis of the concrete support pillars was executed by Vector Corrosion Services of Tampa, Florida. Visible exterior cracking was observed on a pillar, with prudence the USSRC engaged VCS to analyze the magnitude of the issues. A full study was done by VCS on the structural integrity of the concrete. The study included visual inspection, sounding inspection (Impact Echo), checking electrical continuity, and Ground penetrating radar scans. There is evidence of minor water intrusion into the concrete throughout the pillars causing mostly surface delamination with a few areas of more significant water damage.

VCS has proposed a plan for the repair of the concrete issues and the use of sacrificial anodes to extend the life of the pillars. VCS is designing the protection plan and upon completion of the plan, will create the specifications for us to bid the pillar repair project.

The concrete pillar repair is estimated to cost $250,000.

Figure 4: Typical Algae Growth (Column 3)

Figure 5: Typical Algae Growth (Column 4)

Figure 6: Typical Delaminated Area

Figure 7: Typical Cracks at Base of Column (4)

External Tank

The foam on the external tank was never intended for an outdoor display. The tanks themselves were designed to disintegrate in the earth's atmosphere upon reentry. The USSRC's tank was modified slightly structurally for display as noted in the brief history above. However, it maintained the foam coating with the addition of what appeared to be a protective latex like coating. In spots the foam was showing damage especially near the top of the tank. Initial damage could have been caused by the incident where a portion of the nose from the orbiter dropped onto the tank. This damage could have also been caused and at minimum made worse by prolonged UV exposure at the top of the tank. There were also areas where bubbling was occurring on the tank. This bubbling is an indicator of delamination in areas where the foam never bonded properly to the tank on installation.

Several methods for coating the tank were considered for display purposes. LineX was considered as an option but the weight of the LineX product for the recommended coating level was too heavy. A paint coating was also considered in the process. However a simple paint layer would need to be repainted every 5-10 years and may not be sufficient to protect the metal of the tank. In discussions with NCFI, the company that produced the original foam as part of the Shuttle program, it was determined that a foam designed for exterior applications paired with protective polyurethane coating

layers for UV protection would provide the max protection for a tank designed to be on display. The current tank, not designed for outside display had foam that lasted 30+ years so the preventative and long term maintenance costs are much lower with the foam option than with a paint option.

To repair, the foam will be completely removed from the tank using Sponge jet blast media. Upon removal of the foam, an inspection will be made of the tank itself for structural integrity before a new foam layer and protective coating is applied.

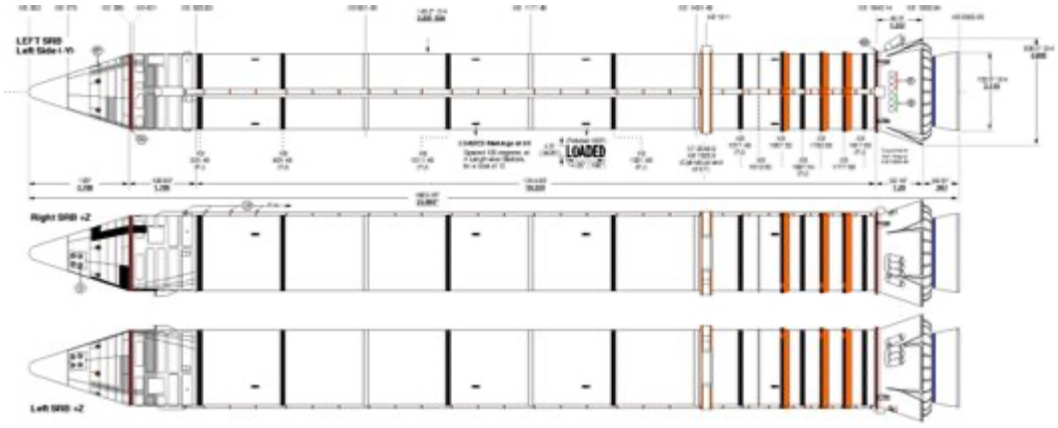
We will be going to public bid on the foam application. The refurbishment of the external tank is set to cost approximately $800,000.

Solid Rocket Boosters

For the Solid rocket boosters, the repair path is a little easier but still daunting by size of the project. The paint will be stripped using the same sponge jet technology used for removing the foam. Once the paint is removed, the boosters will be painted by the contractor that has been performing most of the restoration work to date, Signature Renovations.

In addition to the paint, there are many connecting pins where the segments of the boosters connect that have fallen out over time due to gravity and the wear of the retaining bands that held them in place. These pins will be replaced and the new retaining bands around the segment joints will be fabricated and replaced.

The solid rocket booster repair is an estimated $300,000.



The Pathfinder Artifact

The steel Pathfinder infrastructure remains in relatively good condition. KPFF Structural Engineering has completed a full review of the steel structure. Near the rear of the frame there are areas with significant water intrusion and rusting that will need to be addressed. There are also a couple of the steel support beams that have buckled over time that will need to be repaired or replaced. KPFF has recommended methods of repair and preservation of the steel artifact. Any changes or modifications needed to the frame to support the new cover would be recommended by the structural engineers and then reviewed by the exhibit team at the USSRC and by NASA to ensure the proper care of the artifact.

An initial rough estimate for repairs for the frame is $500,000.

Orbiter Cover Solution

The USSRC is preparing a bid package for the design, fabrication, and installation of a new cover for the Pathfinder artifact. This would serve as the new orbiter atop our shuttle stack. The bid package will be looking for a vendor to design the new cover utilizing additive manufacturing processes with materials used to ensure a long life as an outdoor display. The new orbiter would be full scale and attach to the Pathfinder artifact. Bids will open for this portion of the project in the very near future.

The design phase of this project would begin immediately after the contract is awarded and installation would be expected by the end of 2023. The project is estimated to cost between $3 million and $5 million.

Project Timeline

Orbiter Removal- Completed

Concrete Pillars Structural Analysis- Completed

External Tank and Solid Rocket Booster Renovation- January 2022-August 2022

Pathfinder frame structural analysis- Completed

Pathfinder frame repairs- October 2022- January 2023

Orbiter Cover Design and Fabrication- March 2022- May 2023

Concrete Pillars Repair- July 2022- December 2022

Orbiter Installation- May 2023-September 2023

Budget Summary

Orbiter Removal- $1 Million

External Tank Foam Removal, Solid Rocket Booster Strip and Repaint- $900,000

External Tank Re-Foam- $200,000

Concrete Pillar Refurbishment- $250,000

Structural Engineering Costs- $60,000

Orbiter Cover Fabrication- $3 Million

Orbiter Installation- $750,000

Engine Bell Refurbishment Allowance- $25,000

Pathfinder Frame and External Tank Structural Repairs Allowance- $500,000

Total Estimated project cost- $6.7 Million