MODERNIZATION OF NASA'S JOHNSON SPACE CENTER CHAMBER A PAYLOAD TRANSPORT RAIL SYSTEM TO SUPPORT CRYOGENIC VACUUM OPTICAL TESTING OF THE JAMES WEBB SPACE TELESCOPE (JWST)

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ABSTRACT

NASA is the mission lead for the James Webb Space Telescope (JWST), the next of the "Great Observatories", scheduled for launch in 2018. It is directly responsible for the integration and test (I&T) program that will culminate in an end-to-end cryo vacuum optical test of the flight telescope and instrument module in Chamber A at NASA Johnson Space Center. Historic Chamber A is the largest thermal vacuum chamber at Johnson Space Center and one of the largest space simulation chambers in the world. Chamber A has undergone a major modernization effort to support the deep cryogenic, vacuum and cleanliness requirements for testing the JWST.

This paper describe the challenges of developing, integrating and modifying new payload rails capable of transporting payloads within the thermal vacuum chamber up to 65,000 lbs. Ambient and Cryogenic Operations required to configure for testing will be explained. Lastly review historical payload configurations stretching from the Apollo program era to current James Webb Space Telescope testing.

INTRODUCTION

As with most large thermal vacuum test facilities, integration of test hardware into facility test chambers has its challenges. Chamber A was originally designed with a removable payload rail delivery platform which ferried the Apollo command module from the High bay and into the chamber. Four chamber dedicated 25 ton cranes hoisted the command module to an elevation necessary to place the Apollo command module onto chamber interface fixtures. The maximum test vehicle weight limits of the chamber floor "Lunar Floor" structure was 68,039 kg (150,000 lbs.) No payload rails remained within the chamber during thermal vacuum testing at 80 Kelvin. The Apollo program era rails served their purpose for that program. They were an integral part of the agencies mission to land on the moon. The payload rails were subsequently stored and eventually excessed. From the mid 70's to the 2012, test articles were lifted into the chamber using mobile motorized cranes driven into the high bay.

New Payload requirements for NASA's Johnson Space Center, Chamber A are to provide a method to traverse the JWST hardware, JWST Ground Support Equipment in an out of the chamber in a class 10000 clean room with loads of 74842 kg (165,000 lbs.) and sustain cryogenic cycling from 320 Kelvin to 20 Kelvin.

This paper will compare and contrast preexisting and current test article payload rails and provide insight on design capacities, facility and chamber integration, test operations and use at ambient and test conditions.

Apollo Program Payload Rail Configuration

The Apollo payload rails were constructed of I-beam and tubular framing and the materials were 300 series stainless steel. The track was similar to a common railcar track. The payload rails extended approximately 6 meters (20 ft.) into the chamber from the 12.2 meter (40 ft.) diameter vehicle access door. The assembly was segmented and bolted together. From archived photographs the payload rails could have extended 15.25 meters (50 ft) beyond the vehicle access door into the high bay. The carriage carrying the command module was pulled into the chamber using the High bay crane and a set of pulleys and rope move the carriage into the and out of the chamber. Prior to going into a thermal vacuum space simulations test all components within the chamber and within the vehicle access door footprint would have to be removed.

JWST Program Payload Rail Configuration

The current 2017 payload rails have a total length of 33.5 meters (110 ft.) and a span of 3.84 meters (12.6 ft.) The interface rail component is a 50.08 mm (2 in) stainless steel round linear race shafting at each side at a centerline of 3.66 meters (12 ft.). The 440C stainless steel round linear race shafting is the interface between the facility and the test hardware vehicle or platform. The test hardware vehicle or platform is outfitted with roller bearings. All materials for this new rail are either 304, 316 or 440C stainless steel. The payload rails consist of three major segments: 1) the clean room rail (formally called the highbay rails), 2) Threshold ("Bridge") rails and lastly 3) the in chamber rails. All connections are bolted and torques are verified prior to use. The clean room rails and half of the bridge rails are removed in one lift and positioned within the cleanroom to allow the 12.2 meter (40 ft.) diameter vehicle access door to close. The other half of the bridge rails are removed and stored within the chamber between the 80 Kelvin Liquid Nitrogen panels and the 20 Kelvin Helium panels. The bridge rails survive the cryogenic temperatures without thermal protection. The "In Chamber Rails" are permanently fixed to the chamber and are directly loaded to the same structure as the Apollo Program. The "In Chamber Rails" are thermally isolated from the 300 Kelvin structural floor support structure with G-10CR and optical shielding. The support stanchions for the rails pass through three thermal boundaries, 300 K, 80 K and 20 K. The length of each side of the "In Chamber Rails" are one monolithic laser welded I-beam. The I-beams were then retrofitted with 1-1/2" Schedule 10 pipe stitch welded to the I-beam to serve as the 20 Kelvin cooling loop for the "In Chamber Rails." The "In Chamber rails" share the 20 Kelvin helium cooling loop with the 20 Kelvin Helium floor zone. Eight silicon diodes are strategically located to monitor the warmest areas of the structure to ensure the structure meets the required cryogenic temperature. All exposed surfaces were painted with Aeroglaze® Z307 Black coating. All bolts and screws are vented to prevent virtual leaks during thermal- vacuum testing.

Modification of Rails to increase Working Load Limit.

A request was submitted to increase the working load limit of the payload rail assembly from 30,000 lbs to 60,000 lbs. A design was developed with supporting stress analysis. Five phases were implemented to strengthen the already installed rail assembly. The first was to add and strengthen the crossmembers, secondly a reinforcement to both sides of the main I-beam flange at key locations to full length of the payload rail assembly, third the bridge rail I-beam flanges were completely reinforced with plate, fourth the bridge rails were reinforced with a structure that was permanently welded to the Chamber vessel lower head, lastly the "In-Chamber Rails" were outfitted with outriggers at each corner of the rail assembly. Initial and modification alignment were made possible by using a Leica TS30 Total Station to ensure the payload rails were positioned, aligned and leveled as required by the JWST interface control drawing. A proof load was performed in spring on the full length of the payload rail assembly at 1.25 x Working load limit, 34,019 kg (75,000 lbs). Subsequently a request was submitted to increase the working load limit to 29,484 kg (65,000 lbs.) A stress analysis yielded only one negative margin with the load in a certain configuration. A one time proof load was performed at 65,000 lbs. and the payload rails have a new rating of 29,484 kg (65,000 lbs.)

Ambient and Space Simulations Environment Operations

At ambient operations the payload rails are fully integrated connecting the clean room to the chamber. The payload rails in the clean room serve as a platform to assemble, integrate and (build up) the hardware package utilizing the 22680 kg (25 ton) clean room crane and utility man lifts. Once loaded the hardware package is pulled into the chamber by means of an electric winch in the clean room and pulleys within the chamber. With the hardware package situated within the chamber and lifted with isolators the outriggers can be removed followed by the bridge rails and the clean room rails can be lifted in one monolithic lift using a spreader bar and the clean room 22680 kg (25 ton) crane is used to lift and move the rails to allow the vehicle access door to close. The "In chamber rails" requires no adjustments to go to thermal vacuum operations. The stresses and thermal shrinkage were taken into consideration in the design and therefore the payload rails may cycle between 293 K to 20 K with a total maximum linear expansion of -3.57 cm (-1.4041 in.).

CHALLENGES

Clean Room Footings

The Apollo series program had installed ten recessed footings beneath concrete grade with a baseplate fixture which were bolted and welded to bolts imbedded into the concrete. These baseplate fixtures allowed the Apollo series vehicle transport rail system to be anchored to the floor. These baseplate anchor plates were deemed to be unserviceable with significant surface corrosion, broken welds and no adhesion to grout and did not allow for the required elevation and alignment with “In Chamber Rails.” All ten of the existing baseplate fixture completely removed and the concrete was chipped to meet payload rail elevations by up to -1.9 cm (-.75 in). New 3/4” x 9-5/8” L anchor bolts were epoxied into the concrete which supported new 3/4” thick A36 steel nickel plated plates. The legacy baseplate fixtures were reused by machining them flat and nickel plating. The clean room rail assembly was assembled on top of the new ten footings and the Leica Total work station was used to level the Payload Rail assembly and each baseplate fixture was welded to the 3/4’ plate assuring elevation and alignment tolerances. After this task epoxy grout filled any void beneath the 3/4’ plates. A coat of epoxy paint covered all exposed concrete.

Retrofitting structural reinforcements

Working in a OZ2 environment presented its technical difficulties with tools, lubricant, cutting fluids, precautionary cleanliness requirements. The JWST program contamination team assisted us in selecting the most suitable solution to complete the project.

The retrofitting of the crossmembers required our technicians to drill 360 holes thru holes for ½” and ¾” bolts thru 13mm (1/2 “) thick stainless steel in an OZ2 clean chamber environment, on newly Z307 painted surfaces. The crossmembers were in excess of 400 lbs and each was cut to length, tacked welded, fit checked, adjusted, welded, painted with Z307 and reinstalled.

The installation of the bridge rail mid support required the removal of two Liquid Nitrogen cooling structures (diffusers). The diffusers required the cutting of supply and return LN2 aluminum tubing, extracting them from the chamber with a mobile crane, cutting an 12” x 12” hole into them for the allowance of the a 8” x 8” support beam, redirecting LN2 flowpath, helium leak testing and pressure testing the LN2 modification.

The installation of the actual bridge rail mid support was a task upon its own. A company with an ASME code stamp was selected to weld the W12 X 40 W beams onto the interior vessel head. 100 percent of the work was performed within the confined space of the chamber plenum, below chamber floor elevation. All structural beams were pre-cut and lowered by crane and held in place until welds were complete.

The retrofitting of the bridge rails with ¾” plate on each end of the flange was performed at a machine shop. The I-beam was stripped of railway and a total of 452 thru holes were drilled on the web with a diameter of 6.9 mm (.272 in). a total of 16 ¾ “ 304 stainless steel drilled and tapped plates were installed creating a much robust bridge rail assembly.

Summary

The modification to the Chamber A Vehicle Payload rails have enhanced the capabilities of this facility. The JWST payload rail requirements for Chamber A were surpassed. The logistics of installing, aligning and torqueing consists a crew of 2 riggers and 4 technicians and is completed in 2 days. The logistics of removing, storing and positioning the rails is accomplished 1.5 days and performed by a crew of 2 riggers and 4 technicians. This capability in addition to the size and scale of the Chamber, its Thermal Vacuum capabilities, Class 10000 clean environment, location boosts Chamber A’s capabilities to support long duration deep space environments unmatched by any facility in the U.S.