NASA Johnson Space Center
Title: CryoCart Restoration and Vacuum Pipe Construction
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Propulsion systems that utilize hypergolic propellants have been used to power space vehicles since the beginning of the space program. Liquid methane and oxygen propulsion systems have emerged as an alternative and have proven to be more environmentally friendly. The incorporation of liquid methane/liquid oxygen (LOX) into the propulsion system has demonstrated an increase in engine performance, as well as a reduction in the volume, size and complexity of the system. Consequently, reducing the total mass of the vehicle which is a crucial aspect that is considered when planning space missions to both the Moon and Mars [1]. Project Morpheus has made significant advancements in liquid oxygen/liquid methane propulsion system technologies by incorporating a LOX/methane propulsion system to a vertical test bed. The vehicle consisted of a 5,000 lb main engine and four 20 lb remote control system (RCS) engines that utilize liquid methane/LOX as its propellant [1]. The vehicle completed successful flight testing at Kennedy Space Center in 2014 which marked the completion of the Morpheus project. Subsequent projects utilizing Morpheus' vertical test bed have been developed to make further advancements. One of the subsequent projects consisted of the addition of a smaller 2,000 lb main engine and a cold helium heat exchanger which would make it possible for a pressurant tank systems to be send to Mars or the Moon by significantly decreasing the overall mass and volume of the pressurant tank. The hot fire tests of the integrated system with the smaller main engine and cold helium heat exchanger were successful at sea level, but further studies are being conducted to better understand how the vertical test bed will behave under thermal-vacuum conditions. For this reason, the integrated vehicle will be taken to Plum Brook to be tested in a chamber capable of simulating these conditions.

To ensure that the vehicle will function properly under vacuum conditions, testing will be first completed at the component level. During this process, the igniter of the main engine and the RCS thrusters will be tested under a vacuum. To complete the testing of the components, the test setup first needed to be finalized. The CryoCart is being used to feed the propellants to the test article. The CryoCart is a movable test set-up that was developed in 2009 to provide a mobile platform for testing oxygen/methane systems with hot-fire capability up to 100 lbf. The CryoCart consists of three different systems: Oxygen, Methane, and liquid Nitrogen. The Oxygen and Methane systems are placed into two different carts while the liquid nitrogen system is mainly located in the methane cart. Over the years, the CryoCart has been utilized for different projects and has undergone deterioration. For this reason, a new phase has been developed to rebuild it to working conditions once again. During my internship, I was aiding in the construction and restoration of the CryoCart. In the initial stages of the process, I updated the fluid and electrical schematics for the oxygen, methane, and test article systems. The original CryoCart consisted of an electrical panel that utilized electromechanical relays and a terminal to drive the igniter power and signal, as well as the main fuel and oxygen valves. This electrical panel connected to the CryoCart through various wire harnesses that could be found exiting from the CryoCart. First, it was determined how these harnesses connected to the electromechanical relays so that they worked correctly. Once the electrical system was understood, an alternative for the electromechanical relays and the Molex connectors used throughout the system was sought since these components can often prove to be unreliable. Solid State relays and MIL connectors were purchased to serve as replacements. Upon arrival of the parts, crimping and wiring was completed to install the new solid state relays and MIL connectors. During the replacement of the relays and connectors, system checks of the electrical system were ran to ensure that the system was working correctly. While completing system checks, the pressure transducers that were not functioning properly were also replaced and any issue with the wiring or signal was addressed.

Once the electrical components were replaced, the restoration of the fluid system began. Parts of the tubing in the CryoCart had to be rebuild and often consisted of sizing, cutting, bending, filing, and sanding the tubing to prepare it to be flared. Many components had to be proof-tested to bring their certifications up to date, and several components had to be replaced. Various flex hoses, valves, and fittings were send to the Clean Lab because they were new, dirty, or had gone through proof-testing. Once they arrived from the cleaning lab they had to be put back to the system and leak checks and functional tests were conducted. In the Nitrogen system, the copper tubing located in the Oxygen cart was rebuild and Aerogel insulation was added to this section. A new gaseous nitrogen system was added to the CryoCart to purge the vacuum tube which will serve as the test chamber.

Figure 1: Oxygen CryoCart

Once the CryoCart was completed, construction of parts of the vacuum tube began. A flange was manufactured with welded fittings to hold the line of the vacuum pump as well as some extra fittings which will serve as extra inlets used to introduce fluid lines to the vacuum tube. Stress analysis was ran in this flange to ensure that it would not fail under vacuum conditions. The fluid lines leading from the air side of the vacuum to the test article were also constructed and added to the mount that had already been manufactured. Three different sets of tubing were constructed to accommodate the seven different RCS thruster and the main engine igniter that are going to be tested. Full electrical system checks were completed to ensure that all the wire harnesses and valves were functioning.

Upon the completion of the CryoCart and the vacuum tube, hot fire testing for the RCS thrusters and the main engine igniter are going to begin. During this time any issues encountered with the engines or igniter will be addressed to ensure that the components function under vacuum conditions. After successful completion of testing, the vertical test bed, Morpheus, will be rebuilt and prepared to be sent to Plum Brook. In Plum Brook, the vehicle will be tested in the thermal-vacuum chamber to demonstrate that integrated lox-methane propulsion system operation in space-like conditions. This internship has allowed me the opportunity to gain valuable hands on experience and to develop skills that will aid in my education as well as in the workforce, while at the same time helping me determine that I would like to further pursue a career in propulsion engineering.

References

[1] Olansen, J. B., PhD, Munday, S. R., & Devolites, J. L. (2014). Project Morpheus: Lander Technology Development. *AIAA SPACE 2014 Conference and Exposition*.