Internship at NASA Kennedy Space Center's Cryogenic Test Laboratory

Final Report

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Introduction:

NASA's Kennedy Space Center (KSC) is known for hosting all of the United States manned rocket launches as well as many unmanned launches at low inclinations. Even though the Space Shuttle recently retired, they are continuing to support unmanned launches and modifying manned launch facilities. Before a rocket can be launched, it has to go through months of preparation, called processing. Pieces of a rocket and its payload may come in from anywhere in the nation or even the world. The facilities all around the center help integrate the rocket and prepare it for launch. As NASA prepares for the Space Launch System, a rocket designed to take astronauts beyond Low Earth Orbit throughout the solar system, technology development is crucial for enhancing launch capabilities at the KSC.

The Cryogenics Test Laboratory at Kennedy Space Center greatly contributes to cryogenic research and technology development. The engineers and technicians that work there come up with new ways to efficiently store and transfer liquid cryogens. NASA has a great need for this research and technology development as it deals with cryogenic liquid hydrogen and liquid oxygen for rocket fuel, as well as long term space flight applications. Additionally, in this new era of space exploration, the Cryogenics Test Laboratory works with the commercial sector.

Figure 1: Liquid Hydrogen tank supporting the launch pad seen in the background

One technology development project is the Liquid Hydrogen (LH2) Ground Operations Demonstration Unit (GODU). LH2 GODU intends to

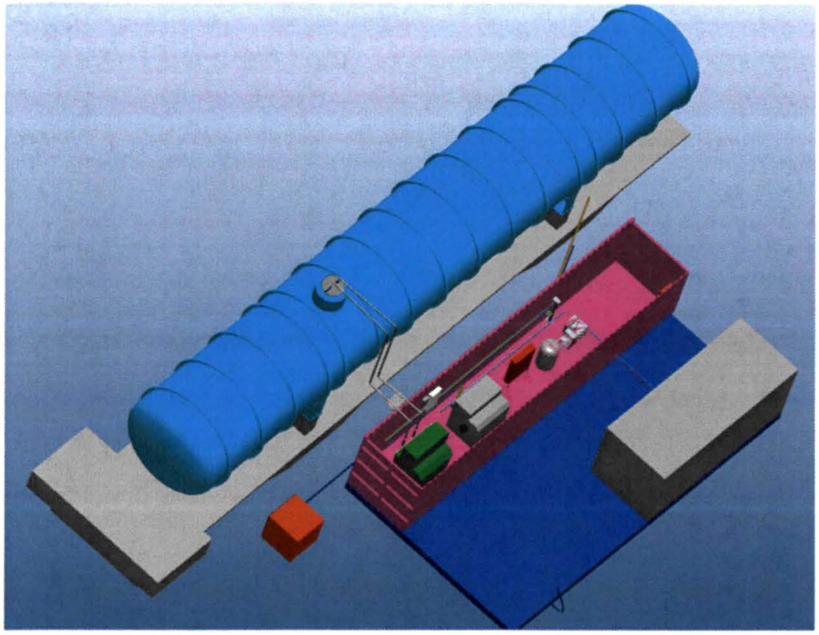

Figure 2: GODU-LH2 set-up when I finished my internship

demonstrate increased efficiency in storing and transferring liquid hydrogen during processing, loading, launch and spaceflight of a spacecraft. During the Shuttle Program, only 55% of hydrogen purchased was used by the Space Shuttle Main Engines. GODU's goal is to demonstrate that this percentage can be increased to 75%. Figure 2 shows the GODU layout when I concluded my internship. The site will include a 33,000 gallon hydrogen tank (shown in cyan) with a heat exchanger inside the hydrogen tank attached to a refrigerator capable of removing 850 Watts at 20 Kelvin (shown in green). The refrigerator and most of its supporting equipment will be kept in a standard shipping container (shown in pink). Currently, GODU is in the fabrication process and some of the large components have already been purchased.

Work Environment:

As an intern, I worked on GODU LH2 under the supervision of my mentor, Wesley Johnson, Cryogenic Engineer. Most of the time, I was in an office setting, adding to the CAD model of the shipping container, equipment inside it, and piping to support the equipment. I also worked on a few projects in the Cryogenics Test Laboratory and I would frequently work on experiments there. Occasionally, I went out to the GODU LH2 site to install equipment. All my co-workers were very intelligent and very passionate about their work. I loved being around people who were just as passionate about space, science, and engineering as I was.

Job Responsibilities:

One of my main projects has been to help model parts in the GODU shipping container floor plan in Pro Engineer (Pro-E) software. Before I came, most of the large parts and assemblies in the Figure 2 were already modeled by my mentor, but the large components were not integrated. I have added small parts such as a pump vent line support and cables, oxygen sensor and pump sampling module, liquid nitrogen pipes, water lines, a gaseous helium and gaseous nitrogen vent line, and other pluming shown in Figure 3. This moves the detailed design to completion so that fabrication can begin.

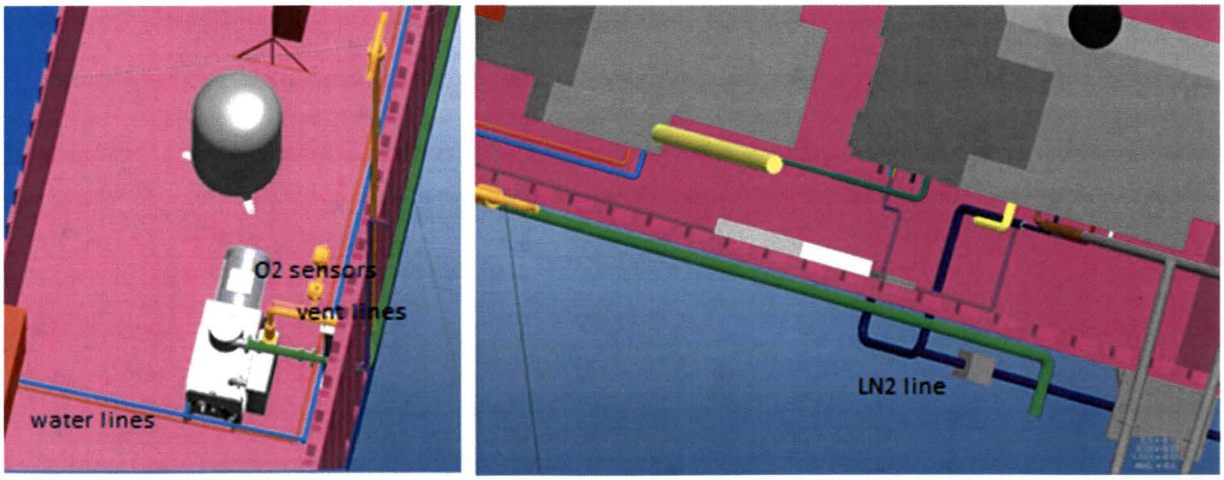

Figure 3: Some pluming that I added to the GODU LH2 refrigeration system 3D model

Along with modeling parts and adding them to assemblies, I also created drawings of the shipping container with dimensions. Figure 4 shows one of the drawings that I made—the shipping container floor-plan (without dimensions). This drawing allowed my mentor to put components where they need to be, and to drill holes in the shipping container walls were pipes will go. I also created drawings of some of the parts referenced in this drawing. These drawings

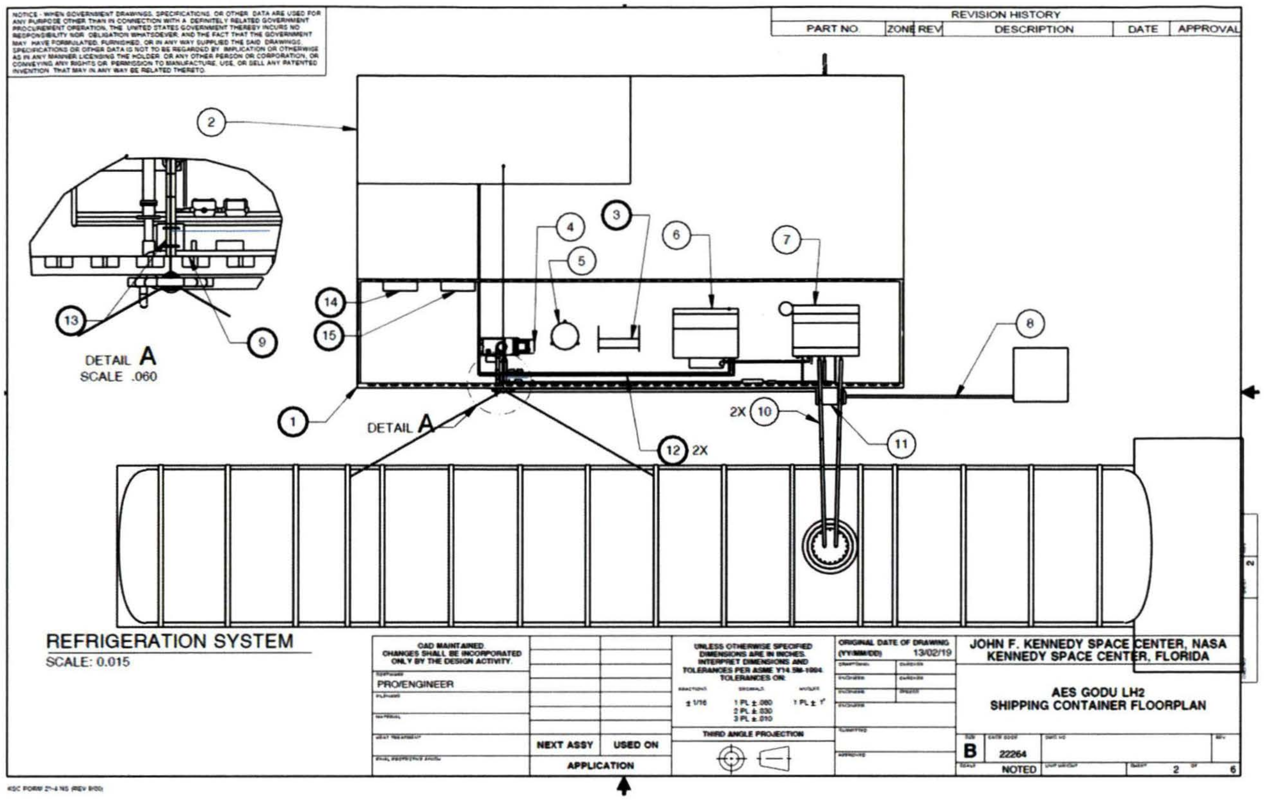

Figure 4: Drawing of shipping container floor-plan

required me to make parts lists, which allowed my mentor to know how many of which parts to order. These drawings were received and approved by the KSC chief engineer as parts of the refrigeration system Final Design review.

Along with modeling in Pro-E, I have gone to the GODU site and seen the Pro-E assembly start to be put together. When I arrived to KSC, the only two parts at the site were the empty 33,000 gallon hydrogen tank and the shipping container with some shelving inside. In order to prepare the shipping container for system assembly, I helped clean out the shelving. When the first component, the vacuum pump, arrived I helped load and assemble it inside the shipping container. While installing the pump, we noticed orientation modifications had to be made. So, I made the modifications in the Pro-E model.

I also spent a lot of time in the Cryogenics Test Laboratory. I've had the opportunity to conduct two main tests in the Cryo Lab. The first is testing a few different types of tapes under cryogenic temperatures. My mentor needed to know which tape adheres best and which shear stress they can withstand in cryogenic temperatures. I used different tapes to attach different weights to Mylar and lowered them into a vat of liquid nitrogen. I calculated shear stress on the tapes from the weights and recorded the results in my lab notebook. By increasing the weight, I determined how much shear stress the tapes could bear before detaching from the Mylar. I also wrote a lab report on my findings.

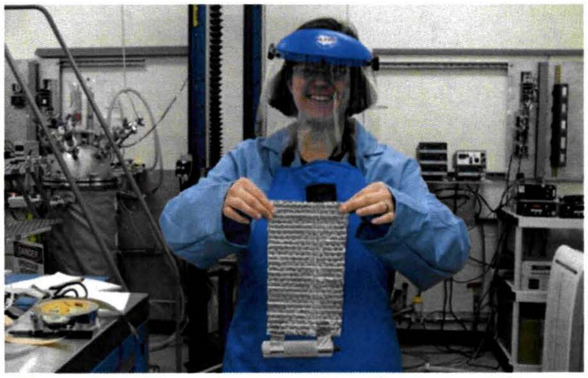

Figure 5a: Here, I am testing the tape. The tape is attached to the Mylar and is pulled down by a weight

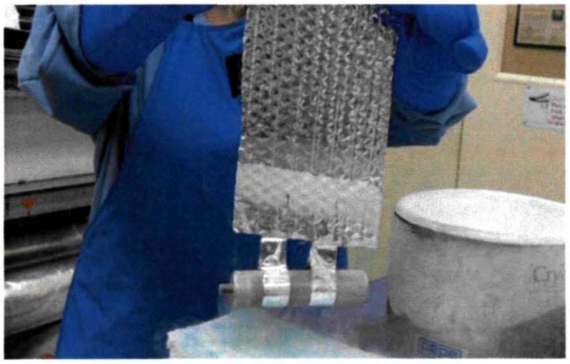

Figure 5b: Here, I am taking the tape out of the liquid nitrogen

The second project was materials testing for radiation shielding for long term space travel. One of NASA's biggest challenges for long term space travel is cosmic radiation. One idea to protect astronauts from cosmic radiation is a layer of liquid hydrogen surrounding the spacecraft. NASA needs to understand the mechanical properties of certain materials at cryogenic temperatures. I helped take measurements of deflections in materials under different pressures at cryogenic temperature. From these measurements, we were able to calculate the material's Young's modulus.

In conducting this experiment, we came across some challenges. The biggest challenge was that the liquid nitrogen would leak through clamps holding our bulge tester together. This leakage would shorten the duration for collecting data. My mentor decided that we needed a new design, in which we welded pipe components together. He put me in charge of creating a Pro-E model of the new bulge tester, making a drawing, and doing the calculations to make sure that the new design met ASME design requirements for pressure vessels. At the end of my internship, I had the opportunity to participate in a design review in which the design was approved.

Figure 6: Here, I am pouring liquid nitrogen to test materials under pressures at cryogenic temperature

I also participated in a number of miscellaneous tasks. One job was to calculate rate of pressure drop during vacuum pumping through a pipe used in GODU. My mentor showed and explained to me some equations from a book, and I used Excel to calculate pressure with respect to elapsed time and to create a graph showing this relationship. Another job was to edit some of my mentor's programing used for determining reasonable locations for refueling depots for potential spacecraft in between potential in-space destinations for exploration. The program calculated change in velocity of orbital maneuvers necessary to travel to the moon, Mars, or Lagrange points. By evaluating the data that the program generated, the concept was to analyze possible locations to build a refueling depot. Another job was to help install and perform check-out testing on a 25 Watt at 20 Kelvin lab scale cryocooler. Finally, I even got to participate in a middle school outreach in which we demonstrated how material properties of common household objects and foods change under cryogenic temperatures with liquid nitrogen.

Learning Objectives:

My first learning objective was to document the build-up of the shipping container and maintain a Pro-E model of it, incorporate cut-outs of the shipping container into the Pro-E model, work with technicians to ensure proper cuts were made and help install hardware in the shipping container. These objectives have been completed as I've updated and added to the Pro-E model of the shipping container and have created drawings of various parts and assemblies. Referencing these drawings, I've measured out and marked where holes need to be made in the shipping container walls. I've also helped install one piece of equipment into the shipping container.

My second objective was to aid technicians in performing foam depressurization testing as well as analyzing the test data. Unfortunately, I never accomplished this because the calorimeters needed for testing were undergoing a long process to obtain approval from Safety.

My third objective included testing materials in a bulge test apparatus. I've helped conduct over 30 experiments testing several different polymers of different thicknesses under different pressures at room temperature and at cryogenic temperature.

My forth objective was to help install and perform check-out testing on a 25 Watt at 20 K cryocooler. Toward the end of my internship, I got to accomplish this. It was really cool to watch the reading from the thermo couples drop well below 77 K (temperature of liquid nitrogen)! The cryocooler will be used for various experiments in the lab requiring temperatures less than 77 K.

Knowledge and Skills Learned:

I picked up a lot of skills in several areas. In software, I became experienced in Pro-E, Visual Basic programing, and Excel. In engineering I became experienced in making drawings, learned all the tiny details that need to be included in drawings, and learned about the design process. In the cryo lab I gained a lot of lab experience, gained analytical skills through problem solving, and learned how to adjust a procedure to generate meaningful and reliable results. I also gained leadership skills because sometimes I would be in charge of conducting an experiment and would have to make decisions on what to do next.

Beneficial ERAU Courses:

This internship required a lot of knowledge from several different classes. Probably the most useful class was EGR200. Learning how to model parts, assemble them into assemblies, and create and format drawings for fabrication in CATIA software helped me significantly in this internship. Even though I used a different CAD program, it was not different from CATIA and I was able to pick it up in a few days. I've gotten a chance to review everything I learned in EGR200 and also expand on that knowledge. I applied a lot of what I learned in EGR200 to real life and real parts and assemblies.

The skills I learned in Physics III Lab, considerably helped with the work I did in the Cryo Lab. The skills I learned performing experiments, collecting data, analyzing data, error analysis, and writing reports, were used and strengthened while working in the Cryo Lab.

My Thermodynamics class helped because it gave me a familiarity with thermodynamic engineering schematics. In this internship, I got a chance to observe fluid schematics of thermodynamic systems, and with help, I was able to integrate these schematics into Pro-E models with actual pipes and hardware. Also Thermodynamics class gave me background knowledge so that I knew how all the thermodynamic components such as the refrigerator, compressor, vacuum pump, can work together to maintain hydrogen in its liquid state and to reduce boil off.

My Space Mech and MATLAB courses also helped me in my internship. One of my odd tasks was to edit programing in Visual Basic that calculated rate of change in velocity required to make certain orbital maneuvers. While I was unfamiliar with Visual Basic, I was able to pick it up because of my experience with MATLAB. Also, my Space Mech course gave me knowledge of orbital mechanics so that I knew what I was doing.

Even though my Astronomy class was neither required for my degree nor for this internship, I think that it was beneficial because it gave me background knowledge so that I can better understand the ideas and concepts NASA has for future space exploration.

Usefulness of Internship:

This internship is a major step towards my dream of a career at NASA. I learned about future possibilities with NASA such as co-op positions and fellowships. The major way to a full-time position at NASA is through a reoccurring Pathways co-op program. While this internship is only temporary, it gives me valuable experience and connections so that I would be favored for a co-op position. I've applied to as many co-ops as I could for next summer here at KSC and hope to continue my work here.

I think one of the major goals of an internship (and college) is to find what you are really passionate about—find your niche. When I was searching for an internship last semester, I didn't just want another gold star on my resume (although those are great!); I wanted to find something that I would really enjoy. I didn't know exactly what I wanted, but I knew that the general area was space. Not only did I find an internship that let me work in this area, but it also allowed me to get my feet wet in an interesting area—cryogenics! I don't know if I want to spend my entire career in cryogenics, but I definitely would spend more time here if given the chance.

Conclusion:

I really enjoyed my work here at the Kennedy Space Center. It was the perfect internship for me because it was challenging, and my mentor kept me very busy, but I also had a lot of fun. I applied what I've learned in school to real life problems. This internship had the perfect mesh of engineering and science for me. I loved that I was able to do what I love in engineering such as CAD modeling, designing, creating drawings and integrating the drawings by seeing parts come in and assembled, while still being able to do what I love in science, such as conducting tests and analyzing data. One of the things that made this internship really cool was learning how critical cryogenic research and technology development is to solving major challenges of future long term space exploration. I feel like my work here was meaningful and that I contributed to NASA's goal of sending astronauts to Mars and beyond.