Launch Control System / Spaceport Command and Control

System Engineering Internship

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Major: Electrical Engineering

Fall Session

Date: 11/8/2018

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NASA is developing the next generation launch vehicle that will take astronauts further into space than any previous manned vehicle. This project has many facets and one of them, the Spaceport Command and Control System (SCCS), was the primary focus of my work during this internship. A vital ability of SCCS is the communication from the firing rooms to the ground support equipment for the vehicle on the launch pad. During this internship, I was part of the Computer Systems Hardware Team, a group of engineers who handle the computer and networking aspects of the SCCS project. My job was to construct, handle, and test computer and network machines, configurations and cables.

Nomenclature

CAD = Computer Aided Design

CAIDA = Customer Avionics Interface Development and Analysis

CLI = Command Line Interface

DVT = Design Verification Test

EM1 = Exploration Mission 1

FR = Firing Room

HMD = Head Mounted Display

HUD = Head Up Display

HVT = Hardware Validation Test

KSC = Kennedy Space Center

LAN = Local Area Network

LCC = Launch Control Center

ML = Mobile Launcher

MPCV = Multipurpose Crew Vehicle

SCCS = Spaceport Command and Control System

SLS = Space Launch System

ICPS = Interim Cryogenic Propulsion Stage

IDEAS = Integrated Display and Environmental Awareness System

RF = Radio Frequency

UI = User Interface

ULA = United Launch Alliance

VAB = Vehicle Assembly Building

I. Introduction

SCCS is being built at Kennedy Space Center (KSC) in order to perform the checkout and launch of NASA's next generation Space Launch System (SLS) rocket, which will carry the Interim Cryogenic Propulsion Stage (ICPS) and Multipurpose Crew Vehicle (MPCV) into deep space. This project is the focus of my internship; specifically, I've been working with the computer and network systems team to support and sustain tasks on SCCS. The system is under continuing development, so in order to accomplish these tasks I learned UNIX, cable running techniques, rack construction techniques, and the SCCS network architecture. Some of the tasks were physical installations and software configurations of the Unix-based computers and network devices in use. For example, there were times when I had to run cables and then design how the racks would look once fully assembled with all of the proper devices/cabling. After these racks were assembled and the devices were installed, I helped with the configuration of these devices. This required careful attention to detail, considering there were numerous connections and one error could render the Firing Room hardware set useless since it would fail to receive all of the needed information. Additionally, if one of the devices wasn't properly configured, holes could be left in the security system, which would be very dangerous from an IT security perspective.

II. Objective

The objective of this internship was to support my mentors and engineering coworkers on hardware tasks related to SCCS. These tasks could range from installation to configuring and testing devices. In order to accomplish this objective, I had to carry over training and experiences I have gained from my previous internships with this group.

III. Approach

A. Switch Configuration

My first SCCS task was configuring and installing a new switch that was going to be part of the SCCS network. Unfortunately, the firewall and switch have different operating systems. The Command Line Interface (CLI) for the switch referenced different syntax, but part of the engineering process is being able to expand on previous experience and apply it to new work. In order to configure the switch properly, I looked at existing working configurations on similar switches and built my knowledge off of that. After the switch was configured, I had some software related tasks to perform. These tasks involved properly configuring a firewall that was part of the SCCS network. The firewall needed to have the right interfaces activated to allow data to flow in a secure manner. This worked to my advantage because I was able to experience the software aspects of the job. Once I accumulated experience with the firewall operating system, I was comfortable taking on more complicated tasks. I was assigned work orders to complete various tasks involving both the software and hardware aspect of the firewall. Two firewalls on the SCCS network needed to be clustered together in order to share the traffic processing load and provide redundancy to the network. This was new to me, but I was able to find resources to assist me in this task. The firewalls needed to be connected through fiber optic and copper links in order to communicate with each other. The setup of these cables took some time because the cables had to be run between the racks, labeled with the correct identifier, and inserted into the right ports. Once the hardware portion was complete, the software configuration was straightforward, using the command line to navigate. Afterwards, I started to receive more work orders that pertained to configuration changes on the SCCS network. These changes ranged from updating/removing/adding firewall rules and operating systems. I was then given the opportunity to perform a formal Design Verification Test (DVT) of a new firewall on the SCCS network. This test had to follow strict NASA requirements and had to be conducted with quality assurance personnel.

B. Hardware Systems

I assisted a member of the SCCS Hardware Engineering Team with the task of building server and network racks. These racks were needed to develop and test computer systems that would handle the telemetry data provided by the Customer Avionics Interface Development and Analysis (CAIDA) team. This telemetry data would be used to simulate the command and control of the vehicle at the Launch Pad. Since this would deal with critical data that is instrumental in commanding the Space Launch System (SLS), Interim Cryogenic Propulsion Stage (ICPS), and Multi-Purpose Crew Vehicle (MPCV), there had to be redundancy in the connections in case of a failure. Therefore, every rack I built had to be an identical build. When dealing with the server rooms behind the Firing Rooms, it's very important to reference what had previously been performed and to take good technical notes. Referencing design drawings/schematics in KSC's document repository became extremely crucial. Any change to hardware had to be red-lined and updated in the document repository. Furthermore, I had to document everything about the devices I installed and record the exact location/details about the connections. This made it easy for the drafters to update the design documents. Along with design documents in the document repository, work orders in the task tracking system were crucial when it came to communicating work that was assigned to and completed by other SCCS employees. Throughout the process of building these racks, I took part in referencing, updating, and creating these work orders. This process took me a few weeks to complete with all of the cables that needed to be run, devices that needed to be configured, and details that needed to be recorded for future reference. It was a great learning experience and a privilege knowing how important it was to get these connections correct.

C. Embedded Systems

As I continued to expand my software and hardware skills, I worked on more projects that tested my programming and hardware architectural skills. I first started by configuring a processor within a local area network (LAN) to emulate the latency delay between the launch pad and the firing room. In order to make the software application user friendly, I created a user interface (UI) that would allow the NASA engineer or technician to induce a specific latency delay with a graphical display. Another project required me to give advice to a University developing a cube satellite (CubeSat). They needed help setting up a communications system on their satellite so that they could record their on-board experiment and transmit it back to a ground antenna where they could receive it. I set up a system consisting of a Raspberry Pi, camera, and two radio modems to demonstrate the transferring of video files via radio frequency (RF). This proved to be beneficial to the engineers at the University and also enhanced my skills in this area.

D. 3-Dimensional Printing

The processor that I had used to induce latency delay during my last internship at KSC was lacking an enclosure. The computer was exposed so I modeled a case using SketchUp, Computer Aided Design (CAD) software, and exported it to the MakerBot 3D printer. I used calipers in the laboratory to make precise measurements of the computer and after collecting the data, I reproduced it in the CAD software. After exporting the design over to the MakerBot, I began the printing process and I had a complete case made of ABS plastic. The final step of this project was to develop a procedure for the use of the MakerBot for future NASA interns.

E. Validation Testing

Another project assigned to me was writing and conducting the Hardware Verification Test (HVT) of the vehicle umbilical cables that extend from the Mobile Launcher (ML) to the Firing Room 1 system servers in the Launch Control Center (LCC). These cables transmit all outgoing and incoming communications for the MPCV, ICPS, and

SLS while it sits in the Vehicle Assembly Building (VAB) and at the Launch Pad. These connections between the vehicle and the firing room system servers have a lot of hardware between them, including media converters, servers, firewalls, switches, gateways, taps, and patch panels. The tests need to perform latency, frame loss, throughput, and bit error checks on vehicle umbilical data cables with network analyzers. Prior to running the tests, I have to learn how to use the test equipment and properly configure the interfaces. Then I have to create the test software and make sure it includes all the necessary requirements dictated by SCCS. To ensure maximum efficiency on test day, I will perform a dry run of the LCS circuits in the VAB with the test equipment. Apart from the LCS ML HVT, United Launch Alliance (ULA) has asked our team to assist them in testing their ICPS stage circuits. ULA has been contracted to provide a functioning upper stage for NASA's SLS Exploration Mission 1 (EM-1). As a confidence check of their system, they would like to ensure that the required data rates will hold up with additional equipment on the network. Due to the fact that they designed this system around their Delta IV Heavy rocket, performance may be affected as a result. I will use my HVT procedure written for LCS ML testing and apply to an end to end test from ULA rack in Firing Room 1 to ICPS vehicle umbilical cables on the ML.

IV. Observations

While working at NASA, I had the chance to observe NASA employees working in the field. I was able to do this by shadowing. Shadowing is a great opportunity for interns to learn more about what people work on at the center. I realized that the graduates that work at NASA are extremely dedicated to their work. They work very hard and are incredibly passionate about their work. The graduates I have worked with really took me under their wing and exposed me to real NASA work. They taught me how to improve my work ethic in order to succeed in my career whether it be with NASA or some other company in the future. I have worked hard this semester and I look forward to coming back for another internship next semester.

V. Conclusion

Overall, this internship has given me a wealth of knowledge in the field of computer networking and the hardware that supports it. Before this internship began, I wasn't familiar with operating a Unix-based system. Now, I consider myself proficient in Unix-based systems and their command line interfaces. Alongside this, I've learned many other things such as how to plan and run cables between racks, how to update hardware schematics, how to install hardware, how to configure switches, firewalls, workstations, GDPs, and media converters, and the concepts of networking in general. I feel like this was an incredible experience. I was able to learn from some of the best in the industry, in our nation's space program. I'm also able to say that I contributed to the goal of launching the SLS rocket, ICPS, and Orion MPCV. I will take this knowledge and be sure to apply it to future positions and design projects at my university.

V. Acknowledgement

I would like to thank my mentors, Allan Villorin and Kelvin Ruiz, and Chau Le. Without their guidance, this internship would not have been nearly as beneficial. Along with them, I would like to acknowledge the Computer Systems Hardware Team that assisted me with many tasks that I was unfamiliar with. They were always willing to answer my questions. Finally, I would like to thank Jamie Szafran and Jill Giles. They were responsible for hosting my weekly intern meetings for my division. This was a huge benefit to me because it allowed me to see what other interns were doing and gave a lot of insight into the different kinds of work being performed at KSC and how all of it fits together to prepare for SLS, ICPS and Orion.

VI. References

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