

Environmental Control System Development

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Nomenclature

<i>CAD</i>	=	Computer Aided Design
<i>EC</i>	=	Environmental Chamber
<i>ECS</i>	=	Environmental Control System
<i>EM-1</i>	=	Exploration Mission 1
<i>EM-2</i>	=	Exploration Mission 2
<i>GN2</i>	=	Gaseous Nitrogen
<i>HMI</i>	=	Human Machine Interface
<i>KSC</i>	=	Kennedy Space Center
<i>LAS</i>	=	Launch Abort System
<i>LASF</i>	=	Launch Abort System Facility
<i>LCC</i>	=	Launch Control Center
<i>ML</i>	=	Mobile Launcher
<i>MPPF</i>	=	Multi-Payload Processing Facility
<i>MPPU</i>	=	Mini Portable Purge Unit
<i>NASA</i>	=	National Aeronautics and Space Administration
<i>O&C</i>	=	Operations and Checkout Building
<i>PLC</i>	=	Programmable Logic Controller
<i>PPU</i>	=	Portable Purge Unit
<i>RIO</i>	=	Remote Input/Output
<i>SLS</i>	=	Space Launch System
<i>SM</i>	=	Service Module
<i>V&V</i>	=	Validation and Verification
<i>VAB</i>	=	Vehicle Assembly Building

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Abstract

With the ever-growing desire for mankind to reach destinations whose distances had been deemed impossible to transit, the largest rocket known to man was designed and is being developed. The Space Launch System (SLS), National Aeronautics and Space Administration’s (NASA) solution for deep space travel, will begin its missions with the launch of Exploration Mission 1 (EM-1) and Exploration Mission 2 (EM-2). In order to accommodate the larger rocket, Kennedy Space Center made crucial upgrades to its existing facilities. At Launch Complex 39B, an entirely new Environmental Control System (ECS) was developed to supply the vehicle with the appropriate air or nitrogen gas mixture for launch. The new ECS displays must undergo Validation and Verification (V&V) using testing procedures developed to meet this requirement.

I. Introduction

NASA’s vision to “reach new heights and reveal the unknown for the benefit of humankind” is a feat that NASA has continued to accomplish since its establishment. In the 1900s, the unreachable height for mankind was to travel beyond the Earth and touch another celestial body floating in space. On July 20, 1969, NASA accomplished that goal by landing the first man on the moon. In the 2000s, a new height has been set for mankind - to establish itself as a spacefaring society. The first step in attaining this new height is to go further into space and put humans on Martian soil (see Figure 1).

NASA’s Space Shuttle was a remarkable spacecraft, but due to its fixed wings and sheer size, it was not feasible to travel deep into space. All four of NASA’s Shuttles were decommissioned by 2011, and a new era of space exploration was ushered in. The Space Launch System, larger than any launch vehicle ever created, will use its immense payload mass to launch four humans into deep space utilizing the Orion space capsule. To facilitate a rocket this size, and the newly engineered space capsule, Kennedy Space Center made major modifications to its structures. Upgrades have been made to the high bays in the Vehicle Assembly Building (VAB), a complete remodel at Launch Pad 39B, as well as others on the Kennedy Space Center (KSC) compound.

An increase in environmental requirements for the new SLS rocket created the need for a total remodel of the Environmental Control System at Launch Pad 39B. Along with the new ECS equipment, a completely new display configuration was created. The localized software application has been developed, and upon completion of the equipment installation will be configured to be used onsite. In the meantime, the remote display application is in development at the Launch Control Center (LCC). Both applications must go through rigorous testing to certify functionality prior to being used to manipulate the new equipment. Without the use of proper procedures, damage to the equipment may occur.



Figure 1. Artist's concept image of a boot print on the moon and on Mars.¹

¹ NASA, "NASA Images," NASA, [Online]. Available: <https://images.nasa.gov>.

II. Projects and Tasks

A. Preliminaries

Getting started was no easy feat. It took some time to get access to the different websites and applications required to complete expected tasks. Hurricane Irma prolonged this process by causing Kennedy Space Center to close for an entire week. Getting in after the storm and finalizing access permissions took another week. While waiting for permissions, an undertaking to limit the learning curve was taking place. This included training in safety, facilities, IT Security, ECS equipment operations, and a remote desktop program. As the internship progressed and tasks were accomplished, the need to install and learn 3D Computer Aided Design (CAD) parametric modeling tools and compressible and incompressible fluid dynamic simulation tools arose.

B. Local Display

The local displays were developed using Human Machine Interface (HMI) software. The software communicates directly with the Programmable Logic Controllers (PLCs) that control the equipment. Before allowing the displays to operate physical equipment, the PLC circuitry connection with the local displays needs to be tested. A verification of accurate programming of control and feedback commands is the process for validation. A signal will be sent, either from the equipment to the software, or vice versa. To accomplish this verification, test procedures were written to simulate the signals being sent from the equipment to the PLCs in the Remote Input/Output (RIO) cabinets. There are 582 signals that required testing procedures. **Table 1** is an example of a test procedure. The real procedures go into more detail to allow the tester to easily find the specific displays needed, and what to look for on each display.

Table 1. Example Test Procedure for Valve 001

Pin #	Signal	Name	TAG#	At RIO	At Display
A	0-20VDC	VLV ON CMD	EXAMPLE_VLV001_J10_412_ON_CMD	Read Meter	Press on command
B	0-20VDC	VLV ON IND	EXAMPLE_VLV001_J10_412_ON_IND	Input Signal	Verify VLV 001 indicator On

The procedure requires two people to complete. One person will be stationed at the RIO, and the other will be stationed at the Local Display Console. For inputs from the equipment, a simulated signal will be placed on the appropriate pin at the RIO, and the corresponding indicator will be verified at the display console. For commands that are sent to the equipment, the signal will be verified at the corresponding pin at the RIO. Procedures were written for all equipment being operated through the PLCs.

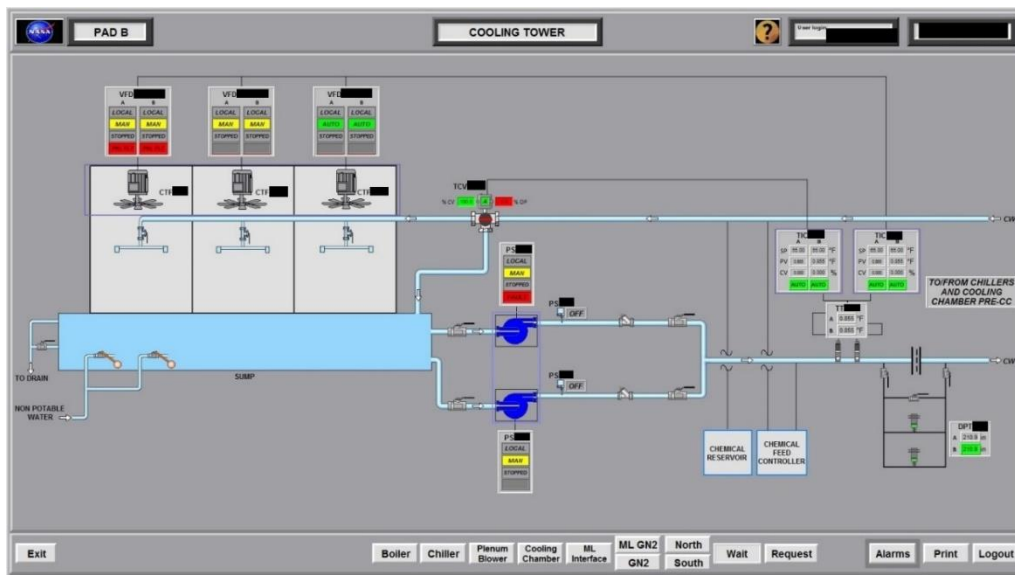


Figure 2. Cooling Tower Local Display²

² Image has been edited to protect sensitive information.

C. Remote Display

The remote displays will be located on the consoles in the Launch Control Center. The displays are in a state of constant change until the new ECS at Launch Complex 39B is turned over to NASA. NASA has already built the displays, but vendor updates to system configurations and settings are requiring changes to the displays. Once all the changes have been employed, the displays will be loaded into the firing room. At that point, testing will commence to verify programming was successful prior to deployment. The screens will undergo functional testing to identify any errors within the displays before being connected to any equipment. Test procedures were generated using existing NASA software to simplify the process.

The program created by the software will be used to automate the testing procedure, thus shortening the time and effort expended. The software maps the display to show the user what is being tested (see figure 3). The program uses the numbers to identify the correlated function on the display, and sends values to the display via the unique identifiers embedded in the display. For feedback, the program will insert a value across the unique identifier, and the user will verify the correct value displays on the screen. For commands, the program will ask the user to press the corresponding button and determine if there is a correct argument placed on that button. Manually writing and executing these procedures previously took too long (see **Table 2**)**Error! Reference source not found.****Error! Reference source not found.****Error! Reference source not found.****Error! Reference source not found.****Error! Reference source not found.****Error! Reference source not found.****Error! Reference source not found.**, but this program drastically reduces unnecessary labor hours.

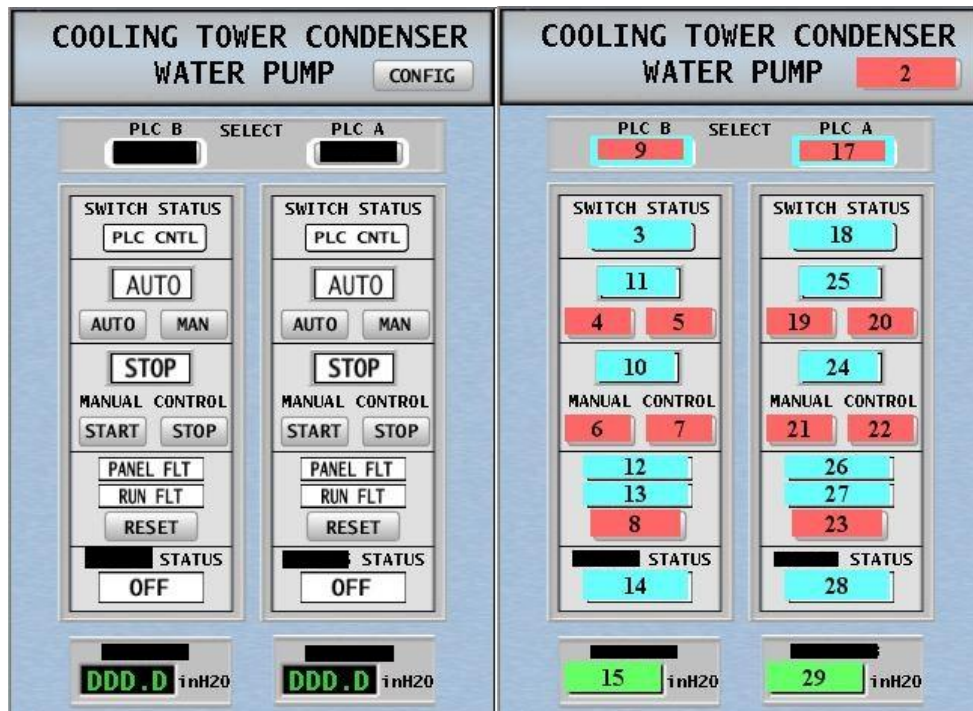


Figure 3. Cooling Tower Condenser Water Pump remote display, and map used by the Auto Test Generated program.³

Personnel will not be allowed to operate the equipment via the local console during launch due to its proximity to the rocket. Therefore, it is imperative to have a fully tested remote display system at the LCC. There are a high number of remote displays created to control the environmental settings that feed the EC components with air or GN2. Proper control of these settings are needed for a successful launch of the new SLS rocket.

Table 2. Example test procedure for remote display testing

TestName	ECS_PADB_CTCWP	Unique Identifier	PostText	DisplayValue	Delay (sec)
TestActions	PreText				

³ Image has been edited to protect sensitive information.

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Title	Item 15 Test				0
Measurement	Setting Item 15:	EXAMPLENAME	to	111.1	1

D. CAD Programs

NASA uses several different programs for its engineering design process. A 3D CAD parametric modeling program is used to create 3-dimensional renderings of parts. These parts are designed with extreme precision, as to be assembled together to create the specific structure needed by NASA. Once a part is designed, it goes through a process for approval and then gets manufactured. There are numerous KSC requirements that must be met before a parts gets approved. It was exciting to learn about this program and the process used at KSC for designing parts.

Other programs used by NASA are fluid dynamic simulation programs. They're used to calculate pressure drop and flow distribution in liquid and low velocity gas piping and ducting systems. Engineers use these program to aid with the creation of a detailed analysis of the flow of fluid/gas through a pipe. One tool is used for incompressible pipe flow modeling, while the other is used for compressible pipe flow modeling. Each component is modeled to reflect manufacturer's specifications, as well as each pipe's dimensions. Once the system is completely configured, the user will run the simulation and extract the data. The data is then used to make design modifications to facilitate the requirements of SLS. Contingencies must be accounted for to safeguard the systems down the line. Supplying too much or too little flow can be costly, so accurate models are crucial to NASA's success.

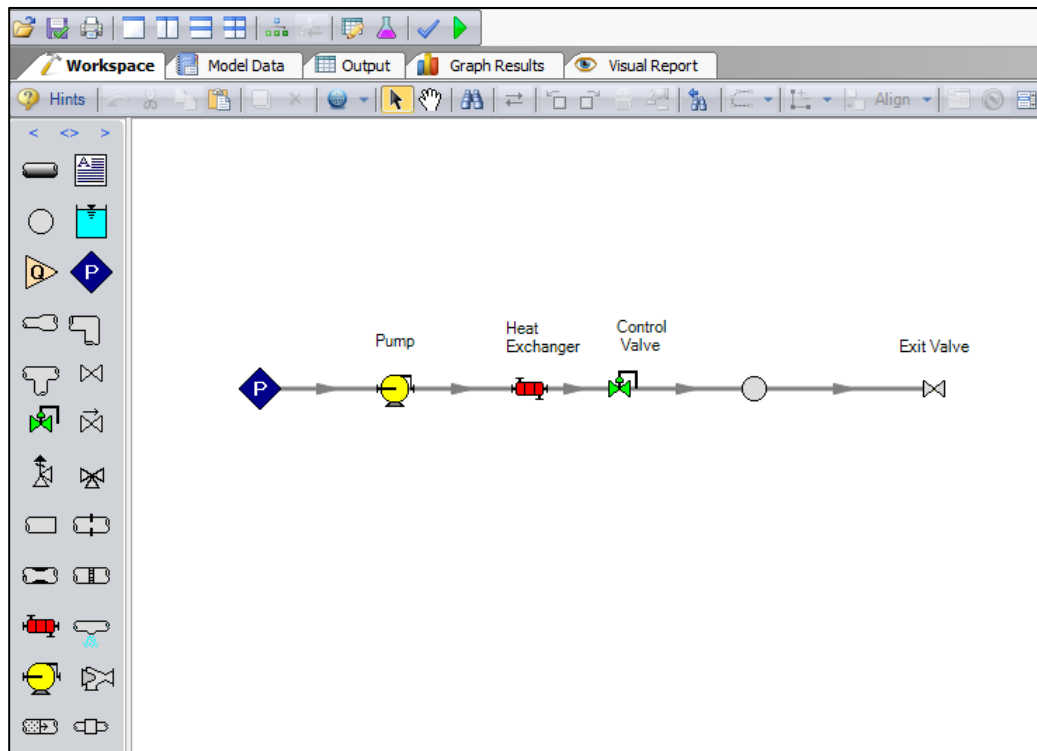


Figure 4. Example of pipe flow modeling.

E. Field Experience

The ECS at Launch Complex 39B is currently going through testing before the vendor turns the system over to NASA. It was identified that when equipment would cycle on, power to the newly installed equipment had inadequacies. One particular instance is when the glycol pump #2 initiated, it would immediately receive a panel fault. Through troubleshooting, the fault was isolated down to a software programming error. The software was reprogrammed, and the pump panel fault disappeared. Another issue, that is still unresolved, is when a standby blower starts up slowly, called a soft start, the power drawn by the blower creates a drain on the circuit causing other equipment to fault. The fault is caused by a 10 second power reading being out of tolerance. Since the soft start for the blower takes longer than 10 seconds, a fault occurs. A workaround has been implemented to not use the soft start, which allows the blower to stabilize in under 10 seconds.

During vehicle assembly at the VAB, controlled quality air is provided by 3 Portable Purge Units (PPUs). There are also 2 mini PPUs (MPPUs) on-site as backups in the event one of the PPUs becomes inoperable. Testing is currently ongoing to confirm the MPPUs can output predetermined air flow and temperature. A variance of expected

temperature between the MPPU and the Mobile Launcher (ML) interface is expected; however, the variance is currently outside marginal values. A fluid dynamic simulation tool was used to help identify where the temperature leak was occurring. It was determined that insulating the ducts can reduce the marginal difference in temperature. This is crucial to meet the requirements of vehicle specifications. The MPPU will also accompany the vehicle in its transit from VAB to the Launchpad.

The MPPUs have been around since shuttle and are being refurbished to meet the needs of the Orion spacecraft. The Orion Spacecraft will require sustained quality air as it transits from Operations and Checkout (O&C) to the Multi-Payload Processing Facility (MPPF), Launch Abort System Facility (LASF), and the VAB. One MPPU will escort Orion through this journey. There are currently 2 MPPUs residing at the MPPF. One MPPU has an issue with water entering the PLC cabinet and blowing fuses. It was discovered that the seal was improperly located and missed the knife edge of the cabinet. The current seal is ½ inch in thickness, and replacing the seal with a 1 inch thick seal would guarantee a tight seal against the knife edge. This has been an ongoing issue with this particular MPPU. A thorough cleaning, repositioning the current seal, and replacing desiccants was done to alleviate any water leak damage until a new seal is installed.



Figure 5. Orion/SM/LAS transporter from LASF to VAB. MPPU on the left.⁴

III. Conclusion

The culmination of this internship was for the author to leave NASA with skills that can only be gained through hands-on experience. The author learned the design process and the decision making process that goes into engineering projects. Having an understanding of the software development process, along with the skills of using 3-D parametric CAD programs and fluid dynamic simulation tools are key skills for any mechanical engineer to possess. In the process of learning new skills, the author was able to aid KSC in their preparations of the ECS for EM-1 and EM-2. The test procedures created will not only be used to validate local and remote displays, they'll also be used for future testing if the need arises.

Acknowledgments

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⁴ NASA, "NASA Images," NASA, [Online]. Available: <https://images.nasa.gov>.