NASA Pathways Co-op Tour

Johnson Space Center

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Introduction

This report outlines the tasks and objectives completed during a co-operative education tour with National Aeronautics and Space Association (NASA) at the Johnson Space Center in Houston, Texas. I worked for the Attitude & Pointing group of the Flight Dynamics Division within the Mission Operations Directorate at Johnson Space Center. NASA's primary mission is to support and expand the various ongoing space exploration programs and any research and development activities associated with it. My primary project required me to develop and a SharePoint web application for my group. My secondary objective was to become familiar with the role of my group which was primarily to provide spacecraft attitude and line of sight determination, including Tracking and Data Relay Satellite (TDRS) communications coverage for various NASA, International, and commercial partner spacecraft. My projects required me to become acquainted with different software systems, fundamentals of aerospace engineering, project management, and develop essential interpersonal communication skills.

Overall, I accomplished multiple goals which included laying the foundations for an updated SharePoint which will allow for an organized platform to communicate and share data for group members and external partners. I also successfully learned about the operations of the Attitude & Pointing Group and how it contributes to the Missions Operations Directorate and NASA's Space Program as a whole.

Overview of NASA-Johnson Space Center

Since its creation in 1958, the National Aeronautics and Space Association (NASA) has been the epitome of space exploration around the Globe from the launching of the Mercury Manned space program to the lunar landing with Apollo mission. Ultimately, in transitioning from the Space Shuttle Program to the development and constant support of a global research facility (The International Space Station) currently orbiting in space, we have shown the world that NASA is unparalleled when it comes to advancement in scientific advancement, technological leadership, and exploration. NASA has successfully and safely launched over 130 Space Shuttles and taken over 350 astronauts into orbit. Another unequaled feat in systems engineering that NASA was able to accomplish was the construction of the International Space Station. Various components of the Space Station had to be constructed on the ground and taken up to space. Due to the complexity and size of the Space Station, it wasn't possible to construct a full test article on the ground which makes the precision achieved by NASA engineers in assembling the ISS in space astonishing. This feat also involved an international relationship with various space programs around the globe including Russia, Japan, Canada, Europe, and multiple commercial partners.

NASA is divided into multiple organizations working on global projects, from the Jet Propulsion Laboratory overseeing the Curiosity Mars project to the development of the Multi-purpose Crew Vehicle by the Orion Team at various space centers including Johnson Space Center for deep space exploration. Overall, NASA has become a beacon for scientific and technological innovations striving to achieve and go beyond the realm of mankind.

Johnson Space Center (JSC) or more famously known as the Mission Control Center (MCC) is at the heart and soul of NASA. JSC is home to many advanced research and engineering facilities. The organization of JSC is essentially based on a functional structure. Each organization within JSC has a specific role which ultimately ties to the main purpose of the center—to support and manage the human space exploration program. The directorates within JSC can be divided into three main categories: management, research & development, mission support. Management includes all of the facilities operations, human resources, and any external relations operation such as procurement, or opportunity and strategic development. They make sure that JSC's operations and projects are running normally. They are also responsible for bridging JSC to its external partners and advertising JSC's programs to the global community.

The two central themes of JSC are supporting human space flight and exploration. The majority of the programs and directorates are dedicated to this cause. These include the Astro-materials & space science directorate which comprises of 25 state-of-the-art research laboratories equipped with advanced analytical equipment to study and test both terrestrial and extra-terrestrial samples acquired through various missions. The JSC Engineering Directorate is geared towards engineering human space flight. This includes designing, developing, and testing of every material aspect of the flight program. This includes the designing of new vehicles and spacecraft systems. Some of the current projects include the Vertical Test Bed lander designed by the Morpheus team. This vehicle has the capability to perform vertical landing which will allow it to be used as a platform to integrate advanced laboratory technology for exploration missions. JSC's Structural Engineering division is focusing on developing thermal barriers and radiation shields for future vehicles. NASAs Robotics division is responsible for the development of the Robonaut—a dexterous android robot currently aboard the ISS that will assist the astronauts perform a plethora of tasks.

Some of the other directorates concentrate on special projects or development of a new vehicle like JSC's Multi-Purpose Crew Vehicle (MPCV), and the ISS program which is responsible for sustaining and utilization of the International Space Station. Finally, the Mission Operations Directorate which is responsible for the operations of the Space Vehicles is where I was placed this fall.

Overview of Mission Operations Directorate

Mission Operations Directorate (MOD) is the directorate responsible for managing all of the flight related activities and programs associated with America's Human Space Flight Program. MOD consists of various divisions that are responsible for the pre-flight management and real time support of the Space Flight Program. Responsibilities include plan and execute operations on the ISS and Visiting Vehicles; provide oversight of future commercial crew missions and potentially plan and execute missions for those vehicles. MOD is also planning for MPCV missions scheduled to launch in the fall of 2014.

The Mission Control Center or more commonly known by its call sign MCC is at the center of MOD. The MCC is the ground control center for all human space flight operations. The MCC houses Flight Controllers and support personal who constantly monitor various activities of a mission analyzing data and various measurements using telemetry. Each flight controller specializes in a particular aspect of the mission and communicates this information with the rest of the mission control team. The communication of data is done via console support systems and follows specific procedures as mandated according to the content of the information. This includes computer operating systems as well as Voice Communication loops. In order to become familiar with these regulations regarding MCC systems, vehicle subsystems, and flight controller roles and responsibilities, one must go through a flight controller's certification program.

Some of the Divisions that fall under MOD are the Mission Systems Division, the Spacecraft Systems Division, the Robotics and Space Crew Division, and the Flight Dynamics Division. The Mission Systems division is responsible for development, operations and engineering of mission operations facilities in support of agency's flight programs. The Spacecraft Crew Systems and Robotics division is responsible in the areas of robotics, extra vehicular activities (EVA), mechanisms, onboard maintenance, crew systems, and photo/TV. Example of the operations planning phase will include the scheduling of crew activities such as research experiments, or EVAs for a camera repair. These are planned months in advance. An example of the various robotics functions can include the usage of the Canadian Robotic arm (SSRMS) on the ISS to assist in the berthing of a visiting vehicle. The trajectory related aspect of the mission falls under the realm of the Flight Dynamics Division.

Flight Dynamics Division

The Flight Dynamics division is mainly responsible for the trajectory and orbit planning of the vehicles and all activities that are related to the dynamics aspect of the Mission. This Division mainly falls into three sub-branches; Motion Control Systems Branch, Trajectory Operations and Analysis Branch, and Orbit Dynamics Branch. The Motion Control Systems Branch primarily deals with the flight systems such as Guidance systems and Navigation Control (GNC). These system monitor vehicle guidance, navigation, and vehicle control. The branch is also responsible for monitoring vehicle propulsion systems. The Trajectory Operations and Analysis branch works on the MPCV and future commercial crewed vehicles. They perform analysis, planning and operations for all phases of flight for those vehicles. These include the ascent, entry, and orbit phases of flight.

Lastly, the Orbit Dynamics Branch manages ISS trajectory operations, automated vehicle’s orbit analysis, docking of automated cargo vehicles with the ISS, grappling of automated vehicles with the SSMRS robotic arm on the ISS, and scheduling the communication satellites for the ISS. The branch also is also engaged in attitude and orientation related operations of the commercial cargo vehicles, MPCV, and future crewed vehicles. The group that I was assigned to during my Co-op tour within this branch is known as the Attitude & Pointing Group. My supervisor Christine Reichert is the branch chief of the Orbit Dynamics Branch. Her main duties are to overview and manage the groups within the Orbit Dynamics branch and to ensure the safe operations for the on orbit vehicles and the crew members.

Attitude & Pointing Group

The Attitude & Pointing (A&P) group is the part of the Orbit Dynamics branch that deals with Spacecraft Attitude determination, Line of Sight determinations, and communications coverage with the Tracking and Data Relay Satellite Systems (TDRSS). The group lead and my primary mentor is Charles P. Barrett. His essential role is to manage the group in terms of assigning tasks, dealing with any technical issues, and ensuring that products and information required for a mission or project is available to any necessary internal or external partner. He also is responsible for ensuring that there are sufficient certified Pointing flight controllers to safely fly the vehicles they support. Before getting into my specific roles within the Attitude & Pointing Group, it is imperative to layout some background information and define concepts regarding attitude determination, and its various applications to space crafts.

Attitude Frames & Satellite Concepts

An important question one can ask is how can we set or determine the orientation of an object such as a satellite or a spacecraft in space? Or a better question would be; how would one tell where an object is located in space? The answers to these questions are vital to many of the operations that occur during a mission or a planned activity on the ISS such as a photo opportunity or viewing of a satellite or for the docking and berthing of a visiting vehicle. The orientation of an object with respect to an inertial reference frame is referred to as the attitude of the object. We consider earth to be our inertial object and define a Local Vertical Local Horizontal (LVLH) reference frame with the z axis is parallel to the earth's radius vector. The positive y axis is pointing in the negative direction of the angular momentum of the orbit and the positive x axis (local horizontal) completing the right hand system. We also need to be aware that the earth is not completely spherical with an even distribution of mass. Therefore, the torque applied to the spacecraft from the earth is not balanced and in order to maintain the required attitude control, the space craft must use an attitude control method. The attitude control can be achieved by guidance navigation control (GNC) sensors and reorientation is done via massive gyroscopes producing a torque in order to compensate. Attitude control can also be regained by burn maneuvers as well. Another important concept is the convention with which the orientation of the space craft can be described. This is done via a set of angles called the Euler's angles; Yaw, Pitch, and Roll. Each is used to define a rotation of the object about the z, y, and x axis respectively.

We must also discuss the importance of satellite systems used for communication of telemetry, video, and voice. The satellite systems used to communicate between the ISS and the ground is called the Tracking and Data relay Satellite System (TDRSS). TDRSS contains antennae that process different frequency and types of data. The S-band is for low bandwidth data versus Ku-band which allows for a higher bandwidth and content of information including video feed. This is vital to us since most planned activity require constant monitoring. The ISS and other vehicles have antennae attached to them that must be aligned with the satellite so that communication is possible. The specific orientation of a vehicle must be such that the antenna is visible to the satellite.

These are types of line of sight problems that are handled by A&P officers or Pointers. These calculations include the determination of structural and solar array blockages. The ISS contains many moving components and keeping track of each object is essential when determining communication coverage since these blockages will cause disruptions in coverage, and stops crew from observing objects such as a typhoon or a comet. Also, antennae and other components line of sight on the ISS can be blocked by solar arrays. The group develops graphs and models of these blockages called “masters” using a tool called OBIWAN. This tool generates a blockage model from the field of view of the object or in our case the antennae. Another important tool used by the group is the attitude time line (ATL) for the spacecraft. The ATL gives the specific attitude for a vehicle at various increments in addition to providing other vital information such as the velocity and maneuver calculations required to get to the next orientation. It also contains information regarding the activities performed during the time frame of the specific attitudes. During real-time operations, the Pointing officer uses these tools to produce TDRS coverage predictions and to schedule the TDRS based on planned activities for the ISS and various Visiting Vehicles. In addition to these products; the group also produces various types of simulation products for future missions using TDRS predicts, and blockage models. One of my projects was to become familiar with the on console tasks of the Attitude & Pointing group.

On Console Training

As a Pointing & Attitude Co-op, I received first-hand on console experience of the specific duties of a Pointer. I was able to sit in on two visiting vehicle missions; one was the HTV mission which is the visiting vehicle for The Japanese Space Agency (JAXA). During the HTV mission, I learned about the MCC software used by our group; Multipurpose Attitude & Pointing Software (MAPS). MAPS has various tools and applications that are specifically designed to generate important data sets such as the ATL, develop masters for structural and solar array blockages, and to predict TDRS coverage data also known as Scheduled Handover (SHO) data. Some of the tasks are to provide TDRS coverage and schedule SHOs for planned activities for the ISS and other vehicles. Scheduling TDRS is based on the criticality level of the activity. In our case, it was critical that the HTV had both Ku-band and S-band coverage during the docking and undocking process from the ISS. Such requests are processed as TDRS Communication Request (TCR).

I also learned about TDRS Unused Time (TUT). This is unused time (time that is still available to be used) on a certain antenna of a TDRS that users schedule for a certain activity or to close communication gaps for a scheduled activities. These gaps can be caused by either the trajectory dispersions, structural blockages of other components on the ISS, or activity timeline changes (such as another critical activity taking precedence over a planned activity such as an antenna repair). The most important thing which I noticed was the necessity to follow certain procedures and protocols when scheduling a SHO or requesting TUT to fill a gap on console. After combining and analyzing all of these essential details as mandated by protocols, one is able to properly schedule communication coverage for a certain activity on board the ISS or a visiting vehicle in space. This thoroughness and discipline is the key to having safe and successful missions.

On my second mission, I was able to experience the very first vehicle launched by NASAs commercial partner Orbital Sciences, Cygnus-1 demonstration flight. This mission was different from others because there was a launch slip which led to major real time changes in the TDRS scheduling. I learned the importance of real time support and the discipline required to effectively communicate and responding during an off nominal situation. Furthermore, the situation highlighted the importance of listening attentively and picking out essential information through the loops at any given time and respond promptly to it. I also learned the importance of having etiquettes on console which vary from dress code to communication through loops with other personnel. Another important task on console is to constantly keep a log of notes for members on different shift to catch up on vital information.

Overall this was a very enriching experience for me in terms of coping and adapting to a situation. In addition, I learned some other vital technical skills such as becoming familiar with the Linux operating system since most of the console systems were using Linux. I learned fundamental navigational commands as well as became familiar with writing a program script using languages such as Perl and Tcl/TK in a Linux environment. My second project revolved around two very important industrial skills; project management and Web Designing.

Development of the Group SharePoint

SharePoint is a web application developed by Microsoft utilized by industries all over the globe. Its main purpose is to provide a platform to effectively share/ communicate vital information within a group. My project was to develop and design a SharePoint for the Attitude & Pointing group. The two main objectives for the SharePoint is to provide a functional structure that will allow easy access to vital information within the group, and to develop a public section that external MOD members can access vital and necessary information provided by Attitude & Pointing group. I was successful in meeting the primary objectives. The internal section of the SharePoint was given organizational preference. However, the public section required a professional theme that would reflect the culture of the group. To meet these requirements, I had to familiarize myself with SharePoint Design which included developing a

SharePoint, becoming familiar with its data storage capabilities, learn SharePoint Branding, and make sure that the web application will function properly and launched on time for the group to utilize.

In order to accomplish all of these goals while being on a shortened time schedule due to the Government shutdown, I had to develop and learn project management skills. I learned the importance of sound planning which includes developing project charters, and detailed outlines. One of the most important tools I acquired was the necessity to have a detailed schedule of the SharePoint project. This was accomplished by developing a detailed Gantt chart for the project. This allowed me to see important deadlines and keep a regular track of my progress including determining dependencies of tasks and plan accordingly. These skills led to the successful development of the Attitude & Pointing site.

Tour benefits and acquired skills

Throughout my tour, I was challenged every single day constantly required to learn a new set of technical skills as well as applying core engineering skills which include problem solving and critical thinking. Coming in as a chemical engineering major, the transition was always a challenge. However, I learned to quickly adapt to the environment by constantly communicating with my mentor and asking essential questions. Effective communication is the most important intrapersonal skill one can utilize in the industry. Books can only give you so much information. Also, you must have the persistence to tackle a given problem and use core problem solving skills to break it down, and solve it in bits. This was advice given to me from a group member and a friend of mines. Another important lesson I learned was the importance of maintaining a work life balance. This was very difficult for me in the beginning, but in due time, I learned to manage my time and have fun at work as well. This will allow you to become a productive asset to the organization for a long time rather than overworking yourself and burning out in a short period. This will probably be my advice to any new Co-op or intern joining in: “take a deep breath and relax, you’ll be fine…it’s just rocket science!”

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During the course of this tour, I have gotten the chance meet many wonderful, courteous, and exceptional individuals who put their achievements aside to help one another succeed. This is my first internship and I doubt I will ever come across such a considerate group of individuals. I would first like to give gratitude to the entire Attitude & Pointing group for accepting me in their home and pushing me towards success. I would like thank both my mentors Charles P. Barrett (Charlie), David Lantz and my Supervisor Christine Reichert for being there for me from day one. Regardless of the issue that I had or the extraneous amount of questions I asked, they always were there to help. Both Charlie and David calming me down when I start to panic! Thank you for being such great mentors and friends. I would also like to thank Andrew Lalich, Refugio Molina, Marcella Mendoza, Bryan Kelly, Mark Blanton, Marcos Stocco, Matt Dunne, Walker Gabriel, and Greg Hemingson and all the other Pointing members making it a memorable work experience. Without these wonderful individuals, none of my projects would be possible to accomplish and this tour wouldn’t have been the same. In addition, I would like to thank The NASA Pathways Internship program especially Amber Harrington, and Bryan Grant for giving me this once in a life time opportunity to work at

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