NASA USRP internship Final Report

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I. Abstract

The purpose of this report is to describe the body of work I have produced as a NASA USRP intern in the spring 2010. My mentor during this time was Richard Birr and I assisted him with many tasks in the advanced systems group in the engineering design lab at NASA's Kennedy space center. The main priority was and scenario modeling for the FAA's next generation air traffic control system and also developing next generation range systems for implementation at Kennedy space center. Also of importance was the development of wiring diagrams for the portable communications terminal for the desert rats program.

II. Introduction

The purpose of my internship at NASA's Kennedy space center was to assist my mentor in his areas of expertise while experiencing the project load of an electrical engineer in a professional setting. The areas that I have concentrated on in my education are communications, electromagnetic, radio frequency electronics, and antenna design. I was able to apply my knowledge of these areas to my work at NASA in many different ways on a variety of complex projects. The projects that I was able to apply input to were as diverse as they were challenging. I was able to work on modeling three dimensional buildings for application in satellite tool kit such as TIREM and Urban Propagator which were used to model unmanned aerial systems that were to be used by the federal aviation administration and NASA to evaluate UAS systems for potential integration into the national airspace using various scenarios that were selected for consideration by a committee of experts. I also worked on a project to use a commercially available microprocessor and associated software to program and test the processor with the system designed to test the validity of the programming algorithm. I was also involved in the PCT program whose purpose was to design and build a lunar communication relay platform. In this capacity I was responsible for drawing block diagrams of the technical components as well as integrating the wiring systems of all the related components into a final cohesive document. Three dimensional communication scenarios were also created to analyze communications links for the desert rats testing phase of the PCT project in the Arizona desert.

III. Details

A. Satellite Tool Kit

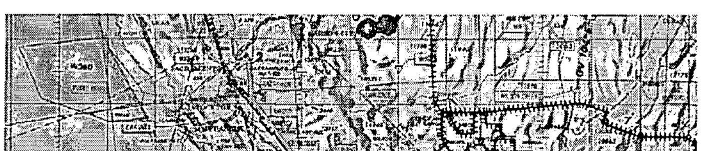
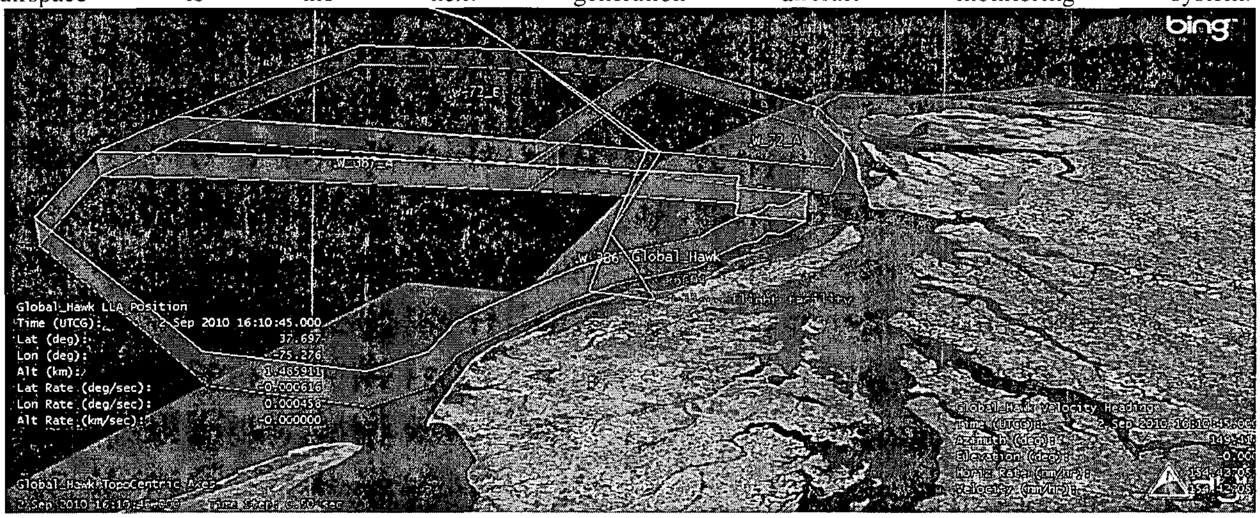


Figure 40 Caravan - Planned Route

The main body of work that was produced was in relation to the FAA's and NASA's next generation technology, the idea is to use NASA's technical capabilities to integrate UAS and commercial space operations into the national airspace system. The guidelines for this proposal are being formulated by the Radio Technical Commission for Aeronautics (RTCA), a not-for-profit corporation that develops consensus-based recommendations regarding communications, navigation, surveillance, and air traffic management system issues. The work that I was involved in revolved around the Federal Aviation Administration and the RCTA group, was to develop the technological requirements for the FAA guidelines. The general idea was to model several scenarios in which the FAA and NASA could

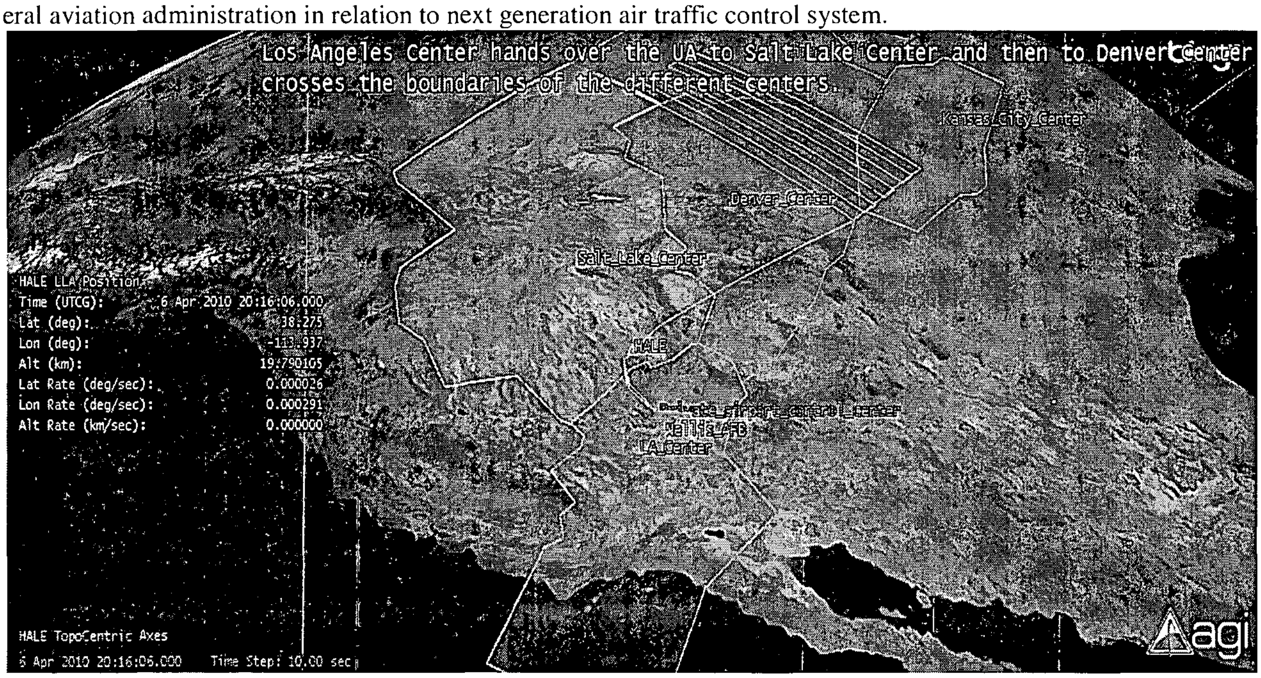
Center, University of Florida.

incorporate unmanned aerial systems into the national airspace system in various applications. The scenarios were designed to assess communications access between ground stations and UAS systems. It was very interesting and a great learning opportunity to be involved in meeting with NASA officials and FAA officials to see how the agencies interacted and worked together to bring this project to fruition and to have contributed to a project that will be used to create our nations next generation air traffic control system. The results will be used to upgrade the national airspace to the next generation aircraft monitoring system.



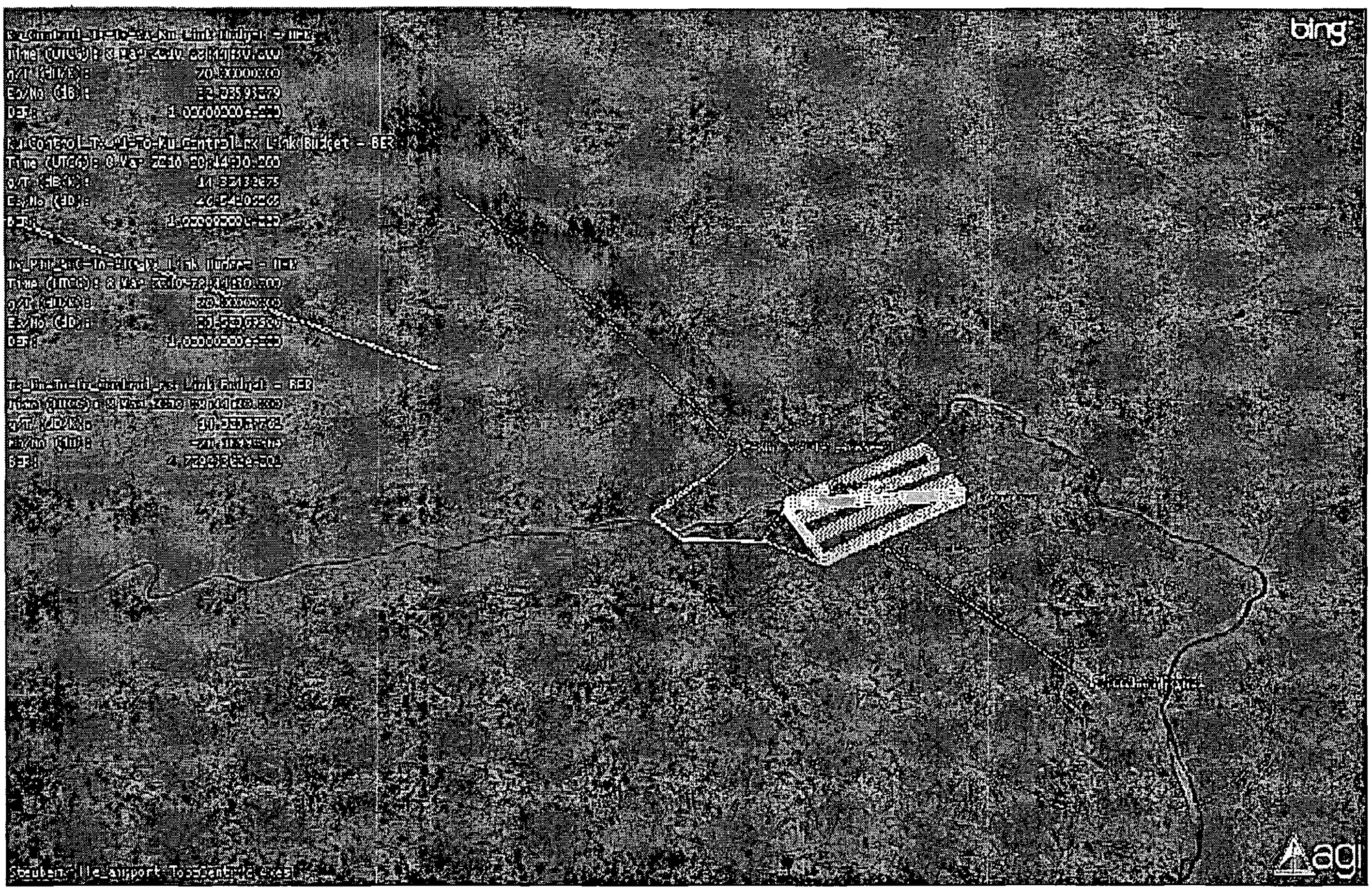
Scenario 7 with warning areas and aircraft flight path visible

There were also applications for using UAS to monitor the range for NASA to improve airspace security while minimizing costs. The scenarios were modeled using a simulation software satellite tool kit which allows the user to model ground and space based scenarios with great accuracy. I was responsible for implementing three dimensional buildings in the scenarios to observe the effect of urban infrastructure on communication links between different communication system components. Most of the scenarios that were created were to be used for analysis by the federal aviation administration in relation to next generation air traffic control system.



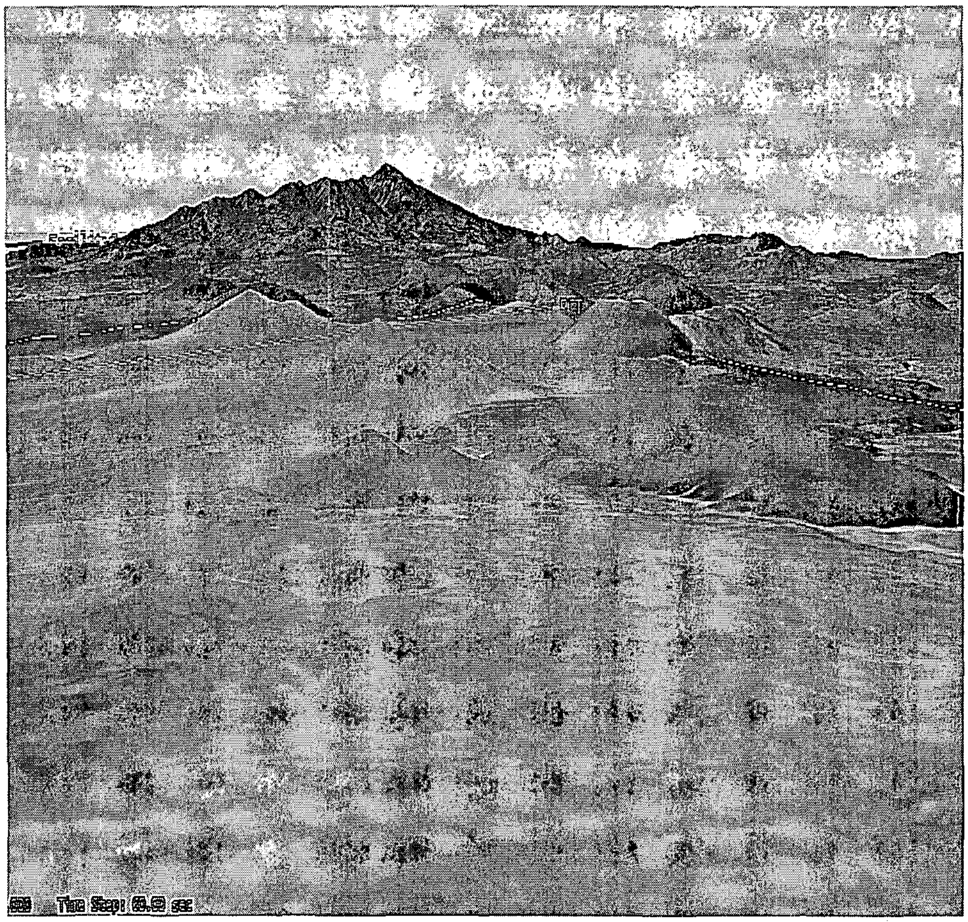
Scenario 9 with ARTCC boundaries and aircraft flight path overlaid.

The various scenarios that were created included a UAS tracking a stolen car in the Los Angeles basin and the required communications links and how the terrain and the urban landscape interfere with radio communications. Areas of interest covered by this scenario are low-altitude urban operations, Class D and Class B airspace, special visual flight rules, and random tracking activities. A second scenario was created to model a UAV monitoring the emissions of coal fired power plants in the Ohio region which used satellites to communicate between the UAV and the ground control.



Scenario 4 with aircraft grid patterns, Class B airspace, and sensors visible.

In this scenario the UAV fly in a stacked formation at alternating altitudes over a fixed grid for a pre-specified amount of time and part of the flight plan is in class B airspace form the Pittsburgh international airport and requires approval from air traffic control each time the airplanes enter the restricted airspace at a different elevation. Areas of interest covered by this scenario are two aircraft operating in close proximity under separate visual flight rules flight plans, Class B and Class D airspace, UAVs operating by satellite link, and remote environmental sensing by UAVs. The flight plans were created using AGI's mission modeler which allows the user to create a detailed flight plan for the desired aircraft. A third scenario was created to model a helicopter UAS supporting media and traffic report in the Denver metropolitan area. The weather conditions at the time of the flight are normal though visibility is obscured due to smog and the addition of smoke from a nearby forest fire. The route follows predetermined locations near major highway intersections and consists of orbit maneuvers that are fifteen minutes in duration. Once in flight adjustments are made to cover any developing traffic situations that need to be monitored. Areas of interest covered by this scenario include visual flight rules in controlled airspace, towing operations, controlled airport operations, urban environment, and dense air traffic environment in Class D airspace. A third scenario was created to model a delivery of spare parts utilizing a UAV over a distance of 440 nautical miles through California. Instrument meteorological conditions exist at the time of departure with periods of rain expected, during the flight the aircraft is to encounter moderate to severe turbulence, which will in most cases necessitate a quick and determined response from



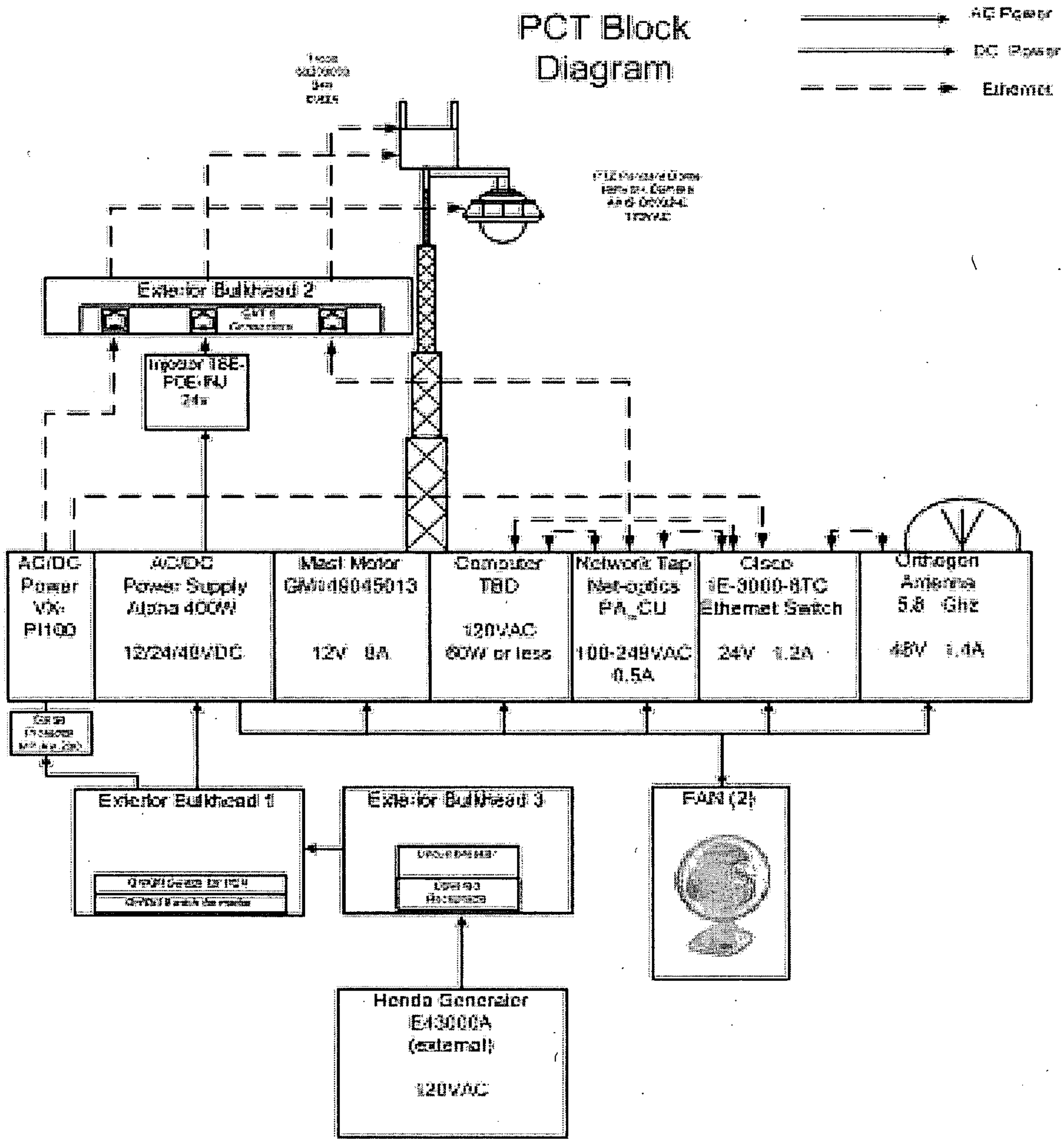
3D Communications Link Availability.

the pilot. The areas of interest that this scenario covers are highly distributer control station operations, coordination with other aircraft in a traffic pattern at a non towered airport, compliance with noise abatement procedures, lateral visual passing maneuver, and change over from instrument flight rules to visual flight rules. The most unique aspect of this scenario is that the pilot in command makes use of a mission support pilot that is not co-located in the same building as the pilot. The mission support pilot is responsible for overseeing the operation of several aircraft simultaneously and switches between an active and monitoring status depending on the phase of the flight or as required by the pilot in command with whom he or she is working. A forth scenario was created to model a marine fisheries protection and monitoring operation by the department of the interior in the Dry Tortugas marine sanctuary. The national park is situated within Aircraft warning area W-174B and the Tortugas military operations area which restricts flight operations in the area. In this scenario there is a reported sighting of an unknown and unlicensed fishing vessel possibly fishing illegally in the Dry Tortugas National Park. The vessel has been spotted in the area the previous day. A department of the interior vessel which is equipped with a Scan Eagle UAV is dispatched to the scene to investigate. Areas of interest in this scenario include use of a low visibility aircraft, Class E defense visual flight rules (DVFR) operations, crossing into and out of an air defense identification zone (ADIZ), unique launch and recovery methods, planned search pattern areas followed by random tracking of a vessel, coordination with air traffic control (ATC), VFR cloud clearance, and separation with observed local VFR traffic. The control station and the Scan Eagle are capable of electric line-of-sight (ELOS) and beyond electric line-of-sight (BLOS) operations. The aircraft can be flown via direct pilot command input or in a preprogrammed autonomous flight pattern. The communications links that were modeled in this scenario were ship to ship communications, ship to satellite, ship to ground, ship to UAV, and UAV to satellite communications. The links were analyzed for their availability and robustness during the flight operations period which included weather conditions that included rain and scattered thunderstorms over the observation area. Another scenario that was created was a converted airship used for mining exploration in portions of southern Ohio and northern West Virginia. Specialty sensors aboard the airship are heavy, sensitive, and require very slow speeds and low altitudes to effectively scan the terrain for low density rock formations. Areas of interest covered by this scenario include slow flight in instrument flight rules environment, visual flight rules environment, use of a relief pilot due to long duration flights, and frequent general aviation activity at altitudes surrounding the UAS .Communications for the UAS airship control and operational communications are networked from various locations in the United States. Because the mission is close to the surface where control and data transmission might be interrupted the system has satellite communications and tracking capability. The difficult processes in creating this scenario were finding and having the aircraft follow the victor airways route V103 to the exact specifications of the FAA and determining the frequencies that the communications take place on as they were not specified in the scenario and are not readily available to the public. The main components of the scenarios were the UAV, the ground control station, the various air traffic control centers, the various airports, areas of interest, the communications equipment receivers and transmitters, and other various objects such as cars, ships, and satellites. The various elements were all moving simultaneously around the terrain in the scenarios and the communication link availability was monitored to see when it diminished or was lost completely. The scenarios were three dimensional to allow for excellent visualization of the interaction of all the elements. The most difficult part of creating scenarios in this manner is coordinating the motion of all the vehicles at the correct speed and heading because if one component is modified all of the other component interactions will also be affected. Some of the scenarios have as many as five different airplanes interacting and coordinating movements in the same airspace at the same time at various altitudes which make for a very challenging scenario development

Scenario 5 published airport approach with GA traffic present.

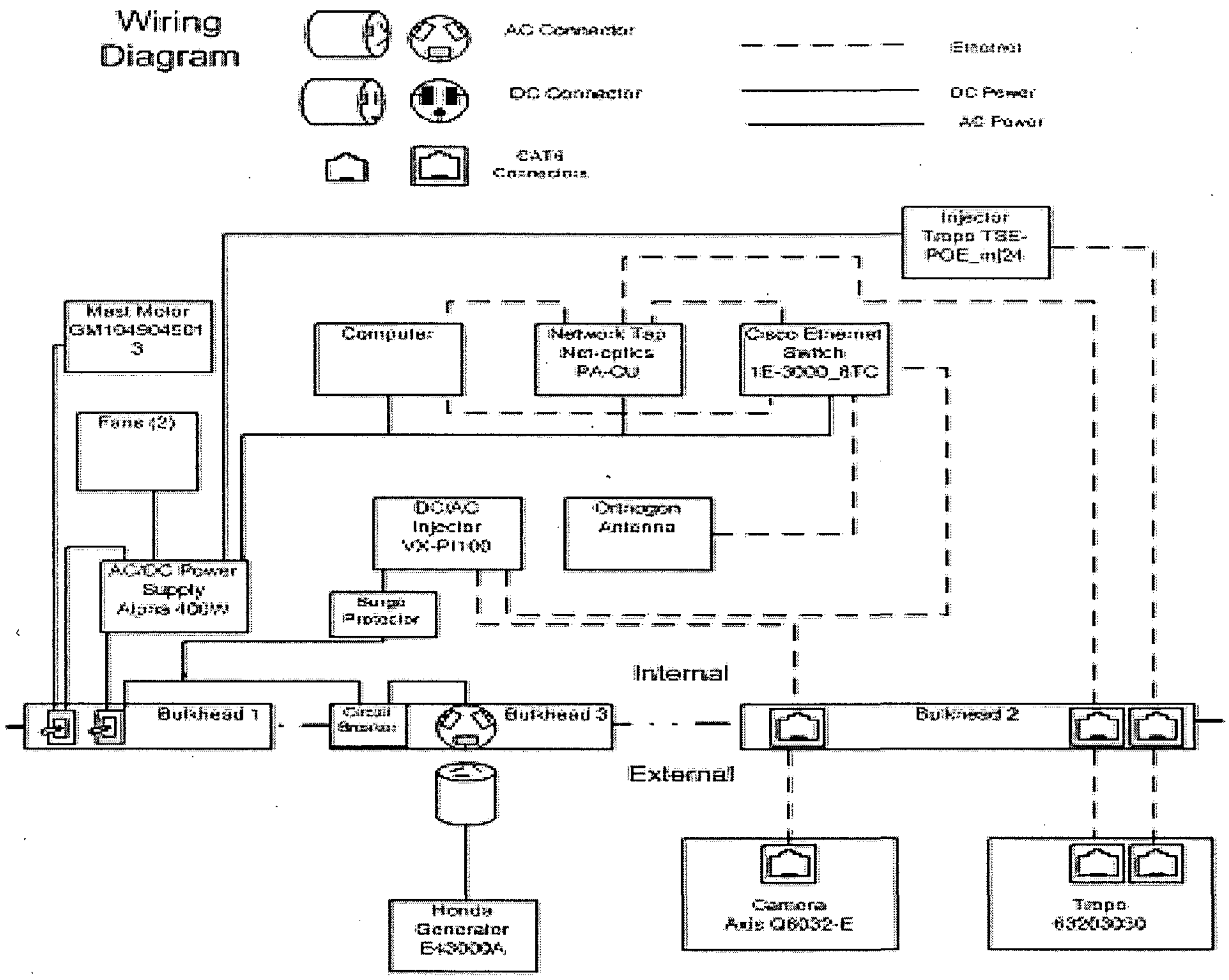
environment. Also of great importance to the FAA is the different classes of airspaces the UAV's will be entering and exiting during the course of their flights, such as class A,B,C,D,E,F as well as military operation areas, international boundaries, and various restricted airspaces and warning areas. I was also responsible for creating and presenting a PowerPoint slide show and report to the operational services and definition (OSED) RCTA committee regarding the scenarios that my mentor and I had created, along with Roy Spencer of the FAA. The report and slide show consisted of pictures representing each scenario, a brief description of each scenario, specific questions that arose from each scenario description when the model of the scenario was created in STK and general overall questions that pertained to creation of the scenarios. I was responsible for giving the presentation and answering some questions from the committee about the scenarios and also presenting the questions that arose during the creation of the scenarios to the committee for their consideration with the hope that they could provide us with more details to help make the scenarios more accurate.

B. Portal Communication Terminal (PCT) Another aspect of my work with NASA involved work on the portable communications terminal which is a way to increase communications range on the lunar surface. I was responsible for creating block diagrams for the selected components and creating wiring diagrams to aid in the construction of the portable communications terminal (PCT). It was also required to select the electrical components such as plugs, receptacles, switches, circuit breakers, fans, and voltage regulators that were necessary to connect all the electrical



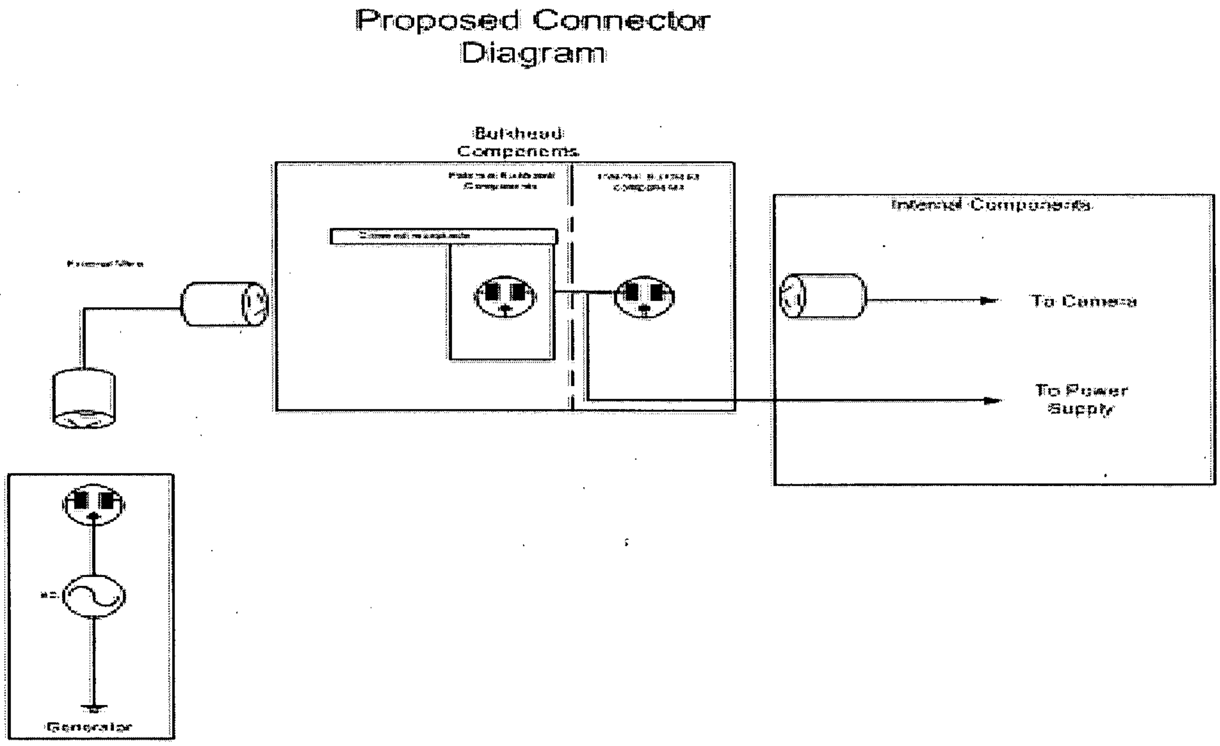
PCT block diagram of all components.

components of the project. Another important function was to compute the voltage and current values of the selected components to analyze the overall power consumption of the PCT to make sure it was compatible with the generator that was to supply the power. Additionally it was necessary to make sure the heat tolerances were met by all the selected components to make sure they would function properly in the high temperature environment of the desert where they were to be tested. The diagrams that were created for this project is included below they include the PCT block diagram, the PCT wiring diagram, and the proposed connector diagram. I also assisted the project by creating and analyzing communications scenarios used for lunar rats testing in the Arizona desert. The communications models were created using satellite tool kit's tirrem terrain modeling software. The scenario covered several communications links such as the PCT to base station, Aerostat balloon to base station, and the aerostat balloon to the PCT. Each communications link was analyzed at several different frequencies to determine which provided the best communications link from the available hardware and the available and underutilized communication frequency bands. Satellite took kit was also used to model the interference introduced into the system by other communications systems operating in the area so the over quality of the communications links could be determined. The received isotropic power from each of the communication system components was calculated and displayed on the terrain model to facilitate the selection of the appropriate frequency for each desired communications link at the selected frequency for each communication link at the appropriate distances and angles.



PCT wiring diagram showing external and internal components

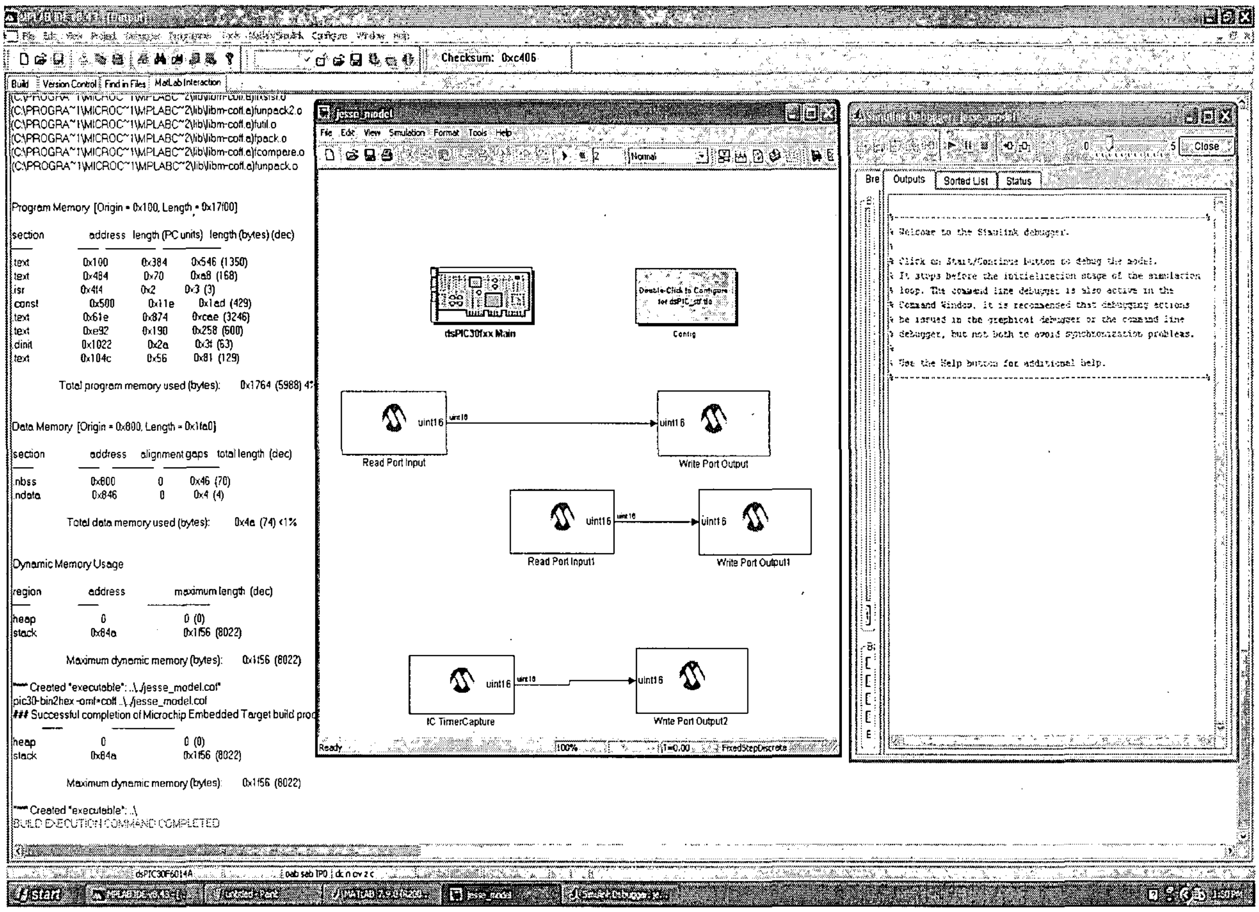
The modeling also produced graphical diagrams that were used to analyze the area and display visually the areas where no communications links were available so the testers in the desert could avoid those areas. The diagrams of the work that was created are displayed on this page adjacent to the text. The creation of the block diagrams consisted of gathering information from the different groups involved in the project on the selected components and incorporating the data into a comprehensive form that described how all the components fit together. The wiring diagrams were created to assist the mechanical engineers and the fabricators of the PCT in the actual construction of



PCT diagram of electrical connectors and proposed structure

the device. The wiring diagrams show all the necessary connectors and the location and type of the wires used in construction. The diagram was revised several times during the process as components were added, deleted, and modified by the selecting groups in the project. The most challenging part of the process was the integration of alternating current devices with the predominantly direct current devices within the PCT. The presence of alternating current complicates the project by introducing varying amounts of electrical interference that requires special cables to shield the radio frequency components from any interference the alternating current might introduce to the system. All the selected component specifications were put into a spreadsheet to facilitate ordering and make everyone aware of the growing weight and power requirements of the overall design so that if possible unnecessary or underutilized components could be reduced in size or possibly eliminated from the final design.

C. MPLAB Another project that I worked on was using Microchip's MPLAB integrated development environment in conjunction with MATLAB, and MATLAB's simulink tools combined with real-time workshop to model and simulate microprocessor activity. The purpose of this process was to simulate the behavior of the microprocessor on a development board provided by Microchip semiconductor technologies. The technology was to be used to easily maintain the code written for the microprocessor by a technician that does not necessarily have the direct knowledge of how the code was created. The project consisted of learning how to use the software provided by the vendor to create and simulate very simple process such as reading and writing to different ports of the desired microprocessor and then progressively moving up to more complicated and detailed processes. The simulated code was then to be downloaded into the development board purchased from the vendor and then testing the validity and robustness of the design. The microprocessor that was used during this procedure was the dsPIC30F6014A manufactured



MPLAB with model, code generation report, and debugger shown in the same window.

by the Microchip Corporation. The above diagram is the schematic that was created during the process and tested on the development board. It was at this point of the process that several bugs that were discovered in the code provided by the vendor which prevented proper operation of the simulator and the development board. Progress on the project was halted after the bugs were discovered in the code and the Microchip Corporation was contacted concerning the bugs in the code and if the issues can be resolved the project will continue as planned otherwise other means of developing and maintaining code will be pursued.

D. Other In my time at Kennedy Space Center I also had the opportunity to participate in many small but interesting projects. One project involved going onto the roof of the vehicle assembly building to install an antenna for testing, at 525 ft tall the assembly building is the largest in the area and offered unprecedented views of the space center and surrounding areas and is something I will remember for a long time. I was also privileged to go out to the Cape Canaveral Air Force Station and view a predator aircraft and tour the adjacent control station being utilized by the customs and border control service for border patrol operations. I opened and verified the operation of 14 play station 3 gaming console that are being combine to created a supercomputer for ray tracing operations. The supercomputer will be used to model real world communications by simulating the reflection, refraction, and combination effects of radio waves bouncing off various surfaces in the modeling area. I was also very involved with the RCTA committee RS-203 regarding the integration of unmanned aerial vehicles in the national airspace. I was fortunate enough to be able to create documents and spreadsheets for the committee's review and also to participate actively in the committees discussions on UA modeling and simulation and to actually engage others and provide insight into the project we were working on.

V. Conclusion

During the course of my internship at NASA's Kennedy Space Center I have been exposed to a diverse array of people, ideas, and projects and I have learned many new things. I have been fully integrated into the engineering team and have been treated as an equal, I feel like my input on the various project has been taken into consideration and even valued by the other engineers on the teams. I have learned what it means to be part of a program with ambitious goals and the hard work and diligence required to meet those goals. I have learned much about the field of communications and I was able to apply what I learned during my undergraduate degree program at the University of Florida to real world communication problems and applications. The internship program allowed me to understand the big picture in communications theory that was not quite clear when I took communication theory classes in school. I believe that the NASA USRP internship has helped me prepare to enter the workforce after the completion of my undergraduate degree, and that the knowledge and insight I have gained is invaluable to my progress as an engineer. My participation in the NASA undergraduate student research program was a direct influence in my selection in the Navy's naval career acquisition intern program. Most importantly this internship has given me a chance to actually learn and grow as an electrical engineer and prepare me for the exciting career that lies ahead.

Acknowledgments

The author would like to thank my mentor Richard Birr for his guidance and support. I would also like to extend my thanks to Roy Spencer of the FAA for his insight and help creating the scenarios for the RCTA committee and the FAA. I would like to thank everyone in the education office who helps bring the interns out to Kennedy Space Center and allows them to integrate seamlessly into the highly skilled workforce here. I would like to also acknowledge everyone else who helped me integrate into the Kennedy Space Center workforce because they made me feel like a valuable part of the team. I would also like to thank the NASA undergraduate student research program (USRP) for offering me the opportunity to do an exciting and memorable internship at NASA's Kennedy Space Center.

References

Papers

[1]RCTA SC-203 Operational Services and Environmental Definition (OSED) – 23 October 2009 Draft.