UPSS/G2

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The Universal Propellant Servicing System (UPSS) is a dedicated mobile launcher propellant delivery method that will minimize danger and complexity in order to allow vehicles to be serviced and ultimately launched from a variety of locations previously not seen fit for space launch. The UPPS/G2 project is the development of a model, simulation, and ultimately a working application that will control and monitor the cryogenic fluid delivery to the rocket for testing purposes. To accomplish this, the project is using the programming language/environment Gensym G2. The environment is an all-inclusive application that allows development, testing, modeling, and finally operation of the unique application through graphical and programmatic methods. We have learned G2 through classes and trial-and-error, and are now in the process of building the application that will soon be able to be tested on apparatuses here at Kennedy Space Center, and eventually on the actual unit. The UPSS will bring near-autonomous control of launches to those that need it, as well it will be a great addition to NASA and KSC's operational viability and the opportunity to bring space launches to parts of the world, and in time constraints, once not thought possible.

I. Introduction

G2 has been tasked with being one of a couple potential command-and-control environments with which it is hoped the UPSS will be able to operate from with the minimum need for direct human input. The aim is to essentially have a sequencer application that will control the propellant delivery to the vehicle according to a prescribed plan. What the team is responsible for is understanding the environment and the programming language thoroughly enough to create a unique application that will simulate data, being able to display different marks for different transducers and physical phenomena, and ultimately be able to reason about that data in order to make the best decision as to which action to apply. Along with the actual code of this logic comes the complex task of creating fault models and isolation subsystems which parse the schematics into segmented systems to better understand errors and inconsistencies during operation. These tasks can be generalized as root cause analyses and root-cause-trees. The other half of being able to accomplish our set goals is having intimate enough knowledge of fluid systems, and more specifically cryogenic fluid systems, in order to build the most accurate application and have the best simulations as possible. This report will mainly be an overview of the intern support of this project.

II. Details

This report will be mainly concerned with the preparation leading up to the actual implementation of G2 and the beginnings of the building of the application. This includes understanding the mechanical schematics of the delivery system, behavior of cryogenic fluids, becoming acquainted with the G2 environment, and finally bringing all of that knowledge together to begin constructing our simulation and application software.

A. Fluid Systems and the Mechanical Schematics

As preparation for understanding the UPSS and the way in which we want to control and detect events, a working knowledge of fluid flow and cryogenics was absolutely necessary. To gain this knowledge, the Kennedy Space Center library was more than helpful in providing reading material on fluid dynamics, cryogenic process engineering, and the nature of flow through different piping, valves, and pumps. Study of these concepts and their application was a vital part in coming to understand our end goal and providing the system with as good a command and control protocol as possible.

After a working knowledge of the nature of fluids and cryogenics was attained, it was important for the team to receive the mechanical schematics from our colleagues in the Fluids Group in order to begin looking at how we intended to model our system and the way in which we needed to control it. As an addendum to the knowledge

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gained through study of fluid and cryogenic systems, new knowledge of mechanical symbols and concepts needed to be learned and recognized without second thought. The schematics needed to be known backwards and forwards so that when it came time to build our system in G2 there was no issue in understanding its physical structure.

Along with the physical structure of the mechanical system came the CONOPS (Concept of Operations). This is the sequence of events which we think is most likely to occur during the entire process of moving the mobile launcher in proximity to a vehicle, fueling it, and ultimately seeing it to launch. The CONOPS of the UPSS includes several different phases and techniques of delivering extremely cold, volatile liquid to a vehicle in a safe and effective way. This is important in determining our own list of events for the eventual sequencer we will create.

B. G2 Training

G2 is a proprietary environment that uses object oriented programming and visual programming methods to allow the users of it to create unique applications in order to resolve their mission objectives. It is rule and logic driven, allowing it to reason about the different aspects of a design in order to make the best decision that has been programmed in by the workers.

We received an intense one week, 40-hour training session given by Kim Wilkins and Mark Walker of General Atomics, and Fernando Figueroa of Stennis Space Center. This training laid the ground work for beginning to discover the full power and intricacies of G2 while starting the foundations of our application. We learned the basics of class creation, class hierarchy, workspace hierarchy and interconnectivity, and methods and procedural code writing; as well as more complex concepts such as our fault models and root-cause trees, which will be the main components in our event detection and decision making code, which is the main goal of our application.

C. Recognition of Objects and Needs

With the G2 training that was given to us by those I've mentioned above, also came the toolkit that they have been working on for close to 10 years. In this toolkit is included multiple object libraries, excellent reusable code, and general logic that can be translated to our system with appropriate vetting. One of my main early tasks with G2 was to use my understanding of the mechanical schematics and their components and scour our G2 toolkit for objects that could be reused and code that was appropriate for what we want to accomplish. This is an excellent way to begin things for multiple reasons, but for two in particular: it improves efficiency dramatically, and it allows us to use tools that have been in use for some time already and therefore can be trusted to work when used.

After recognition of the objects and code that could be reused was near finished, we then had to create the classes that we needed that were not found in the toolkit, and prepare for code and logic that was not present either. This is more of an ongoing process as the way the system will work will not be fully understood until very piece of it is realized, but it is good to know what is had and what is needed.

D. Building Domain Sketches

My next task with G2 and the UPSS system was to begin transcribing the mechanical drawings into our application as domain sketches on their respective workspaces. Our system utilizes a LOX (liquid oxygen) and LCH4 (liquid methane) propellant combination, thus there were two systems to build. Building in G2 requires the proper components to be selected, placed in an order that is pleasing to look at and mimics the mechanical drawings as best as possible, and connected to their correct partners. After this has been done, a thorough editing process must be completed, or more than once completed, to ensure that the components are correct, they have the attributes that we need, and that they are placed in the correct spot and connected to the correct object.

E. Creation of Simulation Data; Replaying Data

After the domain sketches had been built we began working on the naming of each component and the way that we would get data to be replayed, and eventually pumped in real-time by the PLCs (Programmable Logic Controllers) in the field. The naming scheme we chose had to be indicative of the domain it was on, whether that be LOX or LCH4 because G2 does not allow different objects to have the same name on different workspaces. All of this is important because the creation of replay data has an aspect that needs unique identifiers for the different components. Using these identifiers, we are able to specify TAGs in the system which correlate to an attribute of the object and that map is the way we get data to the components. This exercise was excellent in continuing to help us understand G2 and how it processes data and displays it real time, which will ultimately help us determine how to monitor the real-time system and program it to make the best decision.

III. Results

The G2 team is planning on having a working model of the UPSS system in the next week or two. In this model we will be able to show the viability for receiving data packets in the proper protocol, displaying that data on the proper components, and hopefully demonstrating some event detection and minimal decision making capability. The physical structure of the UPSS is slated to be completed at the end of June 2014 near LC-39B. We hope to have tested at the CTL, dry and perhaps a wet run with actual LN2 (liquid nitrogen) in the time leading up to that. There is much work to do, but it is exciting and meaningful work, and we will accomplish our mission.

A. Final Product

The mission for G2's involvement in UPSS is to ultimately have a command and control application that will include an automatic sequencer that will have the ability to deliver cryogenic fluid to a vehicle with minimal human operation. In the very near term we envision G2 having monitoring abilities with the system in the CTL and eventually the test system that is being built with the actual UPSS PLCs in the OSBI (Operational Support Building One).

B. Continuation

We will continue to improve upon our models and simulation ability, while also working to secure the knowledge of how to receive and transmit the correct data to the correct components. A large part of our continuing effort will be to create the fault models and root-cause trees in order to impart that programmable logic and decision-making ability into G2 itself. I am looking forward to coming back next semester to lend my effort to seeing this project through to as far as I can.

IV. Conclusion

The UPSS will be an integral part of the way I think we will view and conduct space flight and business in the near future. Small payloads and opportunities to launch from multiple locations around the world will be needed with the growing necessity of orbital systems for the country's scientific and military needs. Being able to help create a command and control type system that will help to that end is incredibly rewarding and challenging. I am able to use my education as a mechanical engineer to understand the physical phenomena of what is actually happening in the structure to create an as realistic as possible model and simulation that will hopefully be used to deploy this system. While attempting to apply the knowledge that I have brought with me to Kennedy Space Center I also get to learn how to program and reason about things in an electronic environment that I don't believe I would have gotten anywhere else. The hands-on nature of the training and actual doing involved with helping this project is invaluable as I begin my career as a professional engineer.

My second experience here at NASA has been even better than the first. Because of the experience I brought in from having been here the previous semester, I was able to be brought on rapidly to my new project and even take the lead on some aspects of it where I was excelling. I was pushed, and the growing challenges and expectations have made me become an even better engineer and do my best work. But, even with the new challenges and raised expectations, the feeling of us all being in this together and anyone willing to offer their advice or help at a moment's notice still permeates throughout the office and the division. We are here to learn, but work as well, and to do good work, and those two overarching feelings really create an atmosphere where I feel like I can flourish and really discover what I love doing in the engineering field. And the sense of humor persists, which is always lovely to be greeted with when I get to work. I look forward to coming to work every day, and I love that feeling. Next semester should be even better.

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Appendix of Acronyms

LCH4 – *Liquid Methane*

LCS – *Launch Control System*

LCSDEV – *Launch Control System Development Network*

LOX – *Liquid Oxygen*

SSPF – *Space Station Processing Facility*

LCC – *Launch Control Center*

OSBI – *Operations Support Building I*

OSBII – *Operations Support Building II*

UPSS – *Universal Propellant Servicing System*