Progress Report For RockSat-X Payload - Hephaestus

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Abstract

The Oregon State University (OSU) RockSat-X team shall be named Hephaestus. The progress of our project shall be outlined in this document. The mission requires that the payload, an autonomous robotic arm, perform a series of motions to locate predetermined targets. The hardware shall be capable of performing the motions to reach the targets. The software shall determine the targets and send the commands to the hardware to execute the motion. The combination of the hardware controlled by the software shall demonstrate Hephaestus's ability to construct small parts on orbit.

Hephaestus Mission Logo

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1 Introduction

The Hephaestus Payload is a rocketry payload that will fly onboard the 2016-2017 RockSat-X rocket. The rocket will be launched from Wallops Flight Facility filled with student-made payloads. The Hephaestus payload will be made up of a deployable arm and a video camera. The arm will perform a series of motions that will be recorded by the video camera and sensors. Following the experiment, the arm will retract back into the rocket. The Hephaestus mission will be Oregon State University's first space mission and will prove not only our ability to develop a space-ready payload, but also the viability of construction in space using a robotic arm.

1.1 Document Overview

This document will serve as a progress update following Fall term of 2016. At the time of writing, we have worked on the Hephaestus payload for ten weeks. This document will include an overview of the project goals and purpose, our work so far, the problems we have encountered, and a retrospective.

2 Project Overview

2.1 Project Purpose

The Oregon State University RockSat-X team will demonstrate that an autonomous robotic arm can locate predetermined targets around the payload under microgravity conditions by using precise movements. The technical actions performed by this demonstration will illustrate a proof of concept for creating assemblies, autonomous repairs, and performing experiments in space.

2.2 Mission Success Criteria

The Oregon State University RockSat-X team will demonstrate that an autonomous robotic arm can locate predetermined targets around the payload under microgravity conditions by using precise movements. The technical actions performed by this demonstration will illustrate a proof of concept for creating assemblies, autonomous repairs, and performing experiments in space. The mission objectives are to deploy a robotic payload capable of moving with four axes of freedom; deploy a Camera with a single axis of freedom; enact a series of pre-scripted movements by the arm including contact with stationary sensors; coordinate the Camera to track arm movements and record demonstration; and store sensor data for when arm is at rest, and when it comes into contact with station sensors.

3 Current Progress

3.1 Helena Bales

3.1.1 Week 1

- **Progress**

I made no progress over winter break, other than actually managing to take a vacation. I am very proud of myself.

Since the start of week 1, I met with the Software Team to discuss the schedule that we will have for the term. We decided that we would have an hour long meeting on Mondays after our TA meeting and an hour long meeting with the whole Hephaestus team on Thursdays at 6pm. We have not yet had a Monday meeting because the past two mondays have been cancelled due to weather and MLK Day.

We accomplished some tasks for week 1, which includes adding more content to the System Architecture for the Software Subsystem. In addition to this planning I began development of the test cases that will be used to test the Software Subsystem. Specifically, I am focusing on developing experiments to test the three functional requirements that I was assigned last term.

- **Plans**

  The plan for next week is to finish up the architecture diagram and the test cases and beginning the implementation phase of the project. We need to have a prototype completed and tested by mid February, so we are planning on implementing for three weeks then testing.

- **Problems**

  My biggest problem is that I do not have a working computer right now. I have been trying to fix my computer but it has just been a time sink so far. I don't have a solution to this problem.

3.1.2 Week 3

- **Progress**

  This week we started really diving into the motion planning in the Pathing and Automation cross-functional team. I checked out books from the library to help with research into motion planning for robotics, robotics in space, and inverse kinematics.

- **Plans**

  Over the next weeks I will be doing research into the issues of path planning and motion tracking on earth and in space.

- **Problems**

  I still don't have a working computer with which to do the research.

3.1.3 Week 4

- **Progress**

  This week was continuing research into the pathing and automation portion of the software. I have found that the A* algorithm for pathfinding within a configuration space will be a good solution. Additionally, we will be breaking up the arm into its individual links in order to move the arm to a valid configuration. Essentially, we will start at the base of the arm and move that first, then move up the arm to the next link and move that.

- **Plans**

  The next week will be finishing up the research phase for pathing and automation and starting implementations. We will be starting with building the Configuration Space.

- **Problems**

  We still haven't figured out a good way to build a C-Space.

3.1.4 Week 5

- **Progress**

  This week was focusing on figuring out how to build the configuration space (C-Space) in which to perform the path-finding algorithm for the arm's motion. We found that the C-Space need to be in R^4 because we have 4 degrees of freedom in the arm. We also know that for each possible configuration of the arms' motors, we need to know if the configuration is valid in order to map the C-Space. This week we are also starting on the slide for STR.

- **Plans**

  The next week will focus on finalizing the slides for STR. Our STR presentation will be at 6am on Friday of week 6. In addition to STR, the Pathing and Automation and Software groups will be meeting with Dr. Smart during week 6 to discuss methods for building the configuration space.

- **Problems**

  I am blocked from progressing further with the code for motion planning because we do not yet know enough about the C-Space and how to build it. This should be resolved next week after meeting with Dr. Smart.

3.1.5 Week 6

- **Progress**

  This week involved finishing the presentation for STR, a all-team social event, presenting STR, and meeting with Dr. Smart. The meeting with Dr. Smart was on Monday and provided a lot of useful information for pathfinding and automation. We discussed methods for creating the Configuration Space. Dr. Smart explained the ways in which we should limit the payload to keep the configuration space as a plane in R4. We also discussed the best way to generate the configuration space. The options that we discussed were calculating it mathematically using Inverse Kinematics, running a simulation in solid works, or physically moving the arm to valid configurations and mapping those. Each of these methods has benefits and drawbacks. STR occured on friday. In preparation we created the slides throughout the week. On thursday, at our all-team meeting, we went through all the slides in preparation for the presentation on Friday at 6am. The presentation went very well on Friday. The project reviewer said that she was excited to see our project and that our presentation and progress were both very good. The all-team social was at the All-Team meeting on Thursday after we finished all relevant business. We ordered pizza and played board games. The Software team was divided between the two teams with Michael and I against Amber. Amber's team won the first two rounds, but Michael and I brought in a win in the last round. All in all, it was an effective evening of work and team bonding.

- **Plans**

  The next week will focus on creating and recording our presentation for the Senior Design class. We will be working on the presentation on Tuesday, finishing it on Wednesday in order to record the video on Wednesday or Thursday. We will finish the project with editing and posting the video on Thursday and Friday to have it done by Friday. I will also be updating the

design documents from last term to reflect the changes we have made. I do not expect there to be significant changes, however there may be some slight modifications to the pathfinding and automation section to reflect what Dr. Smart taught us this week.

- **Problems**

  The motors have arrived, so I am no longer blocked on progressing in the code. Following the completion of the presentation for CS462, I will be able to dive into the pathfinding code.

3.2 Amber Horvath

3.2.1 Week 1

- **Progress**

  Hi all.

  Sorry, but I had almost no progress this week due to being in Boise due to a family emergency. However, over spring break, I did look into the SD Card issues more and found out that the reason a function was having undefined behavior (returning success and failure seemingly simultaneously) I found that this function was actually being called in a previous library function call that I had failed to take into account during my stack trace. This was a breakthrough in that it proved this me and this function weren't losing our "minds" but also left me with the original problem I had of not knowing why the function was failing in the first place.

- **Plans**

  The next plan is to continue investigating why this is failing to work and move implementation, hopefully, more towards the arm as the ME's and EE's are getting that in a good place for us to test it.

- **Problems**

  The main blocker was being out of town and having to focus on my family. Working remotely and while under a lot of emotional pressure is very difficult.

3.2.2 Week 2

- **Progress**

  No notable progress was made week 2 of spring term. I was unfortunately mentally and academically recovering from my absence the week prior and didn't have a lot of time to spend on senior design work. I did meet up with my team for the first time since the previous term and we designated tasks for the coming weeks including finishing code implementation for the arm and finishing up the library implementation for the SD card.

- **Plans**

  Upcoming plans include meeting with the ME Brett to figure out where we will place the touch sensors on the arm body and implement code to move the arm to these touch sensor points.

- **Problems**

  Blockers are limited to just the fact that the arm is too heavy to lift and so it will be hard to test. Testing arm movement would require us to manually check the rotation of the motors using a compass. This is not ideal.

3.2.3 Week 3

- **Progress**

  This was a hard week, boys and girls. Mostly due to the fact I was very busy with my research job as we had a paper deadline on Friday and basically had to spend every "free" hour working towards that deadline. This left minimal time to work on senior design, but fortunately I was able to make some notable progress. I met up with Jonathan from the EE's to discuss the issues with the SD card as I was at a loss as to what to do next to determine why that function wasn't working. We reworked the SPI function call but that unfortunately didn't help anything. Our next step is to try reworking our approach and seeing if we can read from a file and perhaps find some commonality between reading and writing where the software breaks to pin-point an exact issue. Our other option is dropping this stretch goal (since that's essentially what it is) and focusing our efforts on writing stable data storage to EEPROM. If we can't get this stuff working soon enough that's probably what we'll have to do. Meanwhile, we also need to start focusing our energy on programming the arm to move. That's a big one.

- **Plans**

  Next steps are to find out where EXACTLY this code is breaking. And also to implement the retract and move out parts for the deck plate holding the mechanical arm as that's part of my requirements I was assigned ("emergency retraction").

- **Problems**

  Problems are that this SD card just won't cooperate and I'm so tired of it.

3.2.4 Week 4

- **Progress**

  This week we began working on some more implementation endeavors for the arm's movements. I implemented the touch sensor and deck plate extension and retraction (which were my designated tasks from the Requirements document) as interrupts that execute code upon receiving information from the hardware.

  In the case of the deck plate, an interrupt will be sent upon a timer event line (part of the RSX rocket) going to LOW and signaling the end of our deployment period for the payload. The interrupt will trigger and power the motor attached to the bottom of the deck plate, change it's direction from outward to inwards, and step the motors to pull the plate in. The code for the touch sensors are signaled by the touch sensors being depressed, and will write a code to the telemetry line signaling that we made contact. The implementation for the touch sensor is in science.c while the retract/extend code is in its own file (retract.c and retract.h). Since this is now complete, I will be assisting Helena in her work to finish the arm pathing and movement. Unrelated to the implementation effort, I joined Sam Lundeen (from the MEs) to visit Garmin regarding doing environmental testing for the arm. We met up with Steve Horvath (my dad!) and Greg Fisher to see whether it was viable to mount our arm onto their vibration table and test how the arm faired in situations similar to what will be experienced at launch time. We are going to meet with our team to update them that this is viable and to determine what we want equipped to the arm during this time. While it would be ideal to have everything attached, we've also had funding issues and don't want to risk losing any motors or other valuable pieces that we may not be able to replace if they get damaged during the testing.

- **Plans**

  Future plans are to continue implementation efforts with Helena and I also hope to clean up our repository a bit and add some more documentation regarding how to test our code so when we have the code freeze, the TAs/McGrath aren't confused as to what's going on.

- **Problems**

  Blockers are that I still have been unable to actually test this code due to the motors and arm being not set up currently. Hopefully I will be able to do this by our (extended, thanks McGrath!) May 15th deadline.

3.2.5 Week 5

- **Progress**

  This week I was extraordinarily busy with other classes so I was unable to do much on the project. I plan to get back to work after my midterm Tuesday of next week.

- **Plans**

  Next week, I plan on getting back into the code and performing minor bug fixes to get the code operational before our code freeze deadline of May 15th. We also have an upcoming meeting with our sponsors in Colorado and expo coming up so things are getting pretty exciting!

- **Problems**

  No stoppers are known as of now.

3.2.6 Week 6

- **Progress**

  This week, Michael and I worked on fixing some bugs with our implementation of the different phases. We also enhanced the readability of the code by adding some defines within a .h file and refactoring the code to use these more readable names as opposed to the previous iteration which just used numbers like 0 and 1. We believe this makes the code easier for outsiders to understand and, if changes are made in how the implementation works, we can just change the value of the defines as opposed to having to go through and find every number to change. The remaining work is just finishing the science mode, which is Helena's responsibility. We trust her to get this over the finish line.

- **Plans**

  Future progress is to get ready for Expo (May 19th!) and FSMR which should be Wednesday (May 17th) at 11. We also need to finish recording our midterm progress update. Next week will be fun/stressful!

- **Problems**

  Blockers are that the arm still isn't moving. We spoke with Huy (a representative from the EE team) who said that we don't know whether the arm will move even in space. This is concerning but ultimately out of our hands.

3.3 Michael Humphrey

3.3.1 Week 3

This past week the Hephaestus project team accomplished several important milestones. We completed our first presentation to the RockSat-X organizers and took a group picture to start raising funding. We are also starting to narrow down our design for the final payload.

Because the mechanical and electrical design of the project is not yet finalized, the software team has not yet had any important responsibilities. The electrical team is forbidden from using a device like a Raspberry Pi or an Arduino, so they have decided to use an AVR microcontroller. Amber and I have not used one of these devices, although Helena has. Amber and I will need to start doing research on programming for these devices. We will be using C to program the microcontroller. We won't be able to write any code until the electrical design (i.e. inputs and outputs) are finalized, but we can start creating a software design of how we want the software to work.

No problems have been encountered yet.

3.3.2 Week 4

Similar to week 3's blog post, this past week the Hephaestus Software Team did not have any major responsibilities. We attended the Hephaestus team meetings where the mechanical and electrical designs are still being worked out. We are going to have more communication with the Electrical Engineering team to determine the computing platform and computation restrictions. We also began working out budget numbers.

This next week we will be creating several presentations. I will be partly responsible for a 6 minute 40 second presentation to compete for a $1,000 cash prize. Other fundraising efforts are also in progress. We will also be meeting with the Colorado Space Grant committee for our next presentation for them. We will also need to start working on revising our Problem Statement and start drafting our Requirements document and any other documentation we need.

Currently, the software team is blocked by the electrical team. Until they finalize a design, we cannot start coding. We will be in communication with them, however, to determine what considerations they need to take for the design.

3.3.3 Week 5

Since our mechanical and electrical design is still in progress, we have made no progress in the past week toward writing any software. Only work done was finishing the problem statement assignment and drafting our requirements document.

For the next week we will be getting datasheets and other information from the electrical team to aid in drafting our requirements documents. Any limitations of the hardware will be taken into consideration for the software requirements. Those materials should be made available by the electrical team by early next week.

Problems encountered this week were mostly personnel issues. Some of our team has been on vacation and one member is now sick and unable to make it on campus at all. I feel myself coming down with my second illness this term, which will make it even more difficult to get the required signatures we need.

3.3.4 Week 6

This week was spent finalizing our software requirements for the project. We did extensive research into the details of the mechanical and electrical design of our payload and drew up documents with specifics such as coordinate systems and payload layout. We now have a basis for creating our software.

For the next week, I believe we will be able to start writing the framework for the payload. We probably won't be able to start programming the actual function of the payload until it is built, but we can create the structure of how our software will be laid out.

Some problems were encountered this week with communication outside of our sub-team, but those have been resolved and shouldn't occur again in the future.

3.3.5 Week 7

Last week we developed the requirements of our system a lot. We explored technologies that we want to use and confirmed many details with the robotics and electronics team about the requirements of the payload. For me, last week was spent primarily going to meetings, relaying information to teammates, and doing research into potential technologies we can use.

Next week, we will hopefully begin implementation of the software. I need to set up a meeting with the electrical team. I can't remember what they want to talk about but we definitely meet as a team with them. Most likely all of the CS team won't be able to make it, and this is a challenge we will need to overcome.

Problems I encountered included finding adequate solutions for the telemetry technology. I thought it would be easy to find several solutions we could use, but it turns out that most of the solutions I found were not compatible with our system for one reason or another. Mostly because none of them actually dealt with the transmission of the data itself, but what it did with the telemetry after it was collected. Other reasons were that they were implemented in the wrong language.

3.3.6 Week 8

Last week I helped start our Design Document. We've created the structure for the document and pasted the relevant sections from our previous documents. I set up meetings with the Electrical team and started communication with them to nail down specific software communication requirements. They're going to create a sort of "firmware" for the payload, meaning they'll write the code that interacts directly with the hardware, and they'll expose an abstract interface for the Software team so we only need to call something like moveArm(x, y, z); to control the movement of the arm.

Next week we need to finalize the details of how we want to control the payload arm. This will probably mean writing an API that we want the Electrical team to implement. We also need to prepare for the CDR coming up in a couple of weeks. This means we need to fill out the slides the Software team is responsible for. There will probably be other work for this presentation that we will tackle as it comes up.

No problems this week.

3.3.7 Week 9

This week I didn't do much. The Software team has created an outline for our design document but I haven't added my parts in. I don't foresee it being too much work, as it's mostly already written from the tech review. More details just need to be added. Due to it being Thanksgiving week, I have delayed working on classwork in favor of helping my family prepare for Thanksgiving.

Next week we need to finish our rough draft of the design document as well as write an outline for our presentation.

No problems were encountered this week.

3.3.8 Week 10

This week we made a lot of progress finalizing the design for the payload software. This was mostly a result of writing the design document. There was much communication with the electrical team.

Next week is finals week. We will be writing our progress report and recording our presentation.

One problem we are encountered is the slow response to questions that arise about the RockSat-X program. I have several questions about the format and delivery of telemetry data that won't be answered until mid- to late-next week. That information was not able to be included in the design document.

4 Retrospective

Positives	Negatives	Changes
We communicated with the larger team by holding weekly meetings. One person per team is required to represent the group at these meetings.	We did not take advantage of only one team member being required to attend the all-team meetings and usually had all three of our team members there.	We could change to usually only having two members attending, or not.
We have established cross-functional team meetings. There are three cross functional teams, each with one member from the four main teams. The cross-functional teams meet once per week and report back to the rest of the groups.	The Electrical Integration team did not have much to talk about throughout this term due to delays in getting the motors. The Physical Integration team needed minimal software input so this time for the meeting could've been better utilized working on the project.	Motors have now been acquired, no further changes needed.
We asked for an extension on the progress update when we needed one. Asking for more time when we needed it was a goal that we set in last term's retrospective.		We accomplished the change that we wanted to from last term, no further changes needed.
We learned about conflict resolution this term.	I (Helena) was not at my usual productivity and reliability levels, which put the rest of the team in an uncomfortable situation. I completed the work that I needed to, but did not communicate well enough with the rest of the team.	We talked as a group about how to resolve these issues and have improved our group dynamic and communication.
	We were blocked from making progress on the technical side of the project for most of the term due to the delay in funding and receiving the motors.	In the future we should be more careful about parallelizing the technical tasks to decrease the affect of any blocks.
We a design review with the RockSat-X program office where we presented to a reviewer. This helped us formally document the overall project.	Due to the time difference and the limitation of accomodating 16 schedules, we had to present at 6 AM	We could stop whining about how early our design reviews always are.
We discussed the incorrect assumptions to get everyone on the same page	Occasional miscommunications between everyone regarding incorrect assumptions about the design	Continue discussing misconceptions when they come up

5 Conclusion

The Hephaestus payload will be Oregon State University's first space mission. It will prove the viability of construction in space using a mechanical arm capable of detailed maneuvers. The project is currently on schedule, with a launch in Summer of 2017. We have designed the software system to be applied to the hardware designed by the Mechanical Engineering teams and the Electrical Engineering team. During the course of this term, we encountered several problems, all of which we overcame through communication and time management. Following the completion of this term, the Hephaestus team will begin construction of the payload and develoment of the software.

6 Glossary

deployable Any portion of the payload that is expanded from its original configuration once in a space-like environment. 4

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payload A subsection of a rocket that is not essential to the rocket's operation. A payload is placed in a can, mounted on a standard base plate. A payload completes some specific task. 1, 4, 10–12, 14