# Progress Report For RockSat-X Payload - Hephaestus

Helena Bales, Amber Horvath, and Michael Humphrey

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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** This week was a light one for Senior Design. I attended the first class on Wednesday and met with my group and the TA on Tuesday. Both meetings gave me an overview of the

deadlines and expectations for this term. I met with the whole RockSat-X group on Wednesday for a meeting, pizza, and games. The other team members kept calling me Amber. We did not have a pathing and automation cross-functional group meeting this week since we didn't figure out scheduling soon enough. I did some work on the Parser for the C-Space.

- **Plans** I plan to finish the C-Space parser next week and move on to pathfinding. I will also be making some funding requests so that we can hopefully travel to the integration testing and launch.
- **Problems** The main problem for this week is a funding shortage that may mean that we will not be able to send everyone that we need to the integration testing and launch at Wallops.

#### 3.1.2 Week 2

- **Progress** This week I finished the parser for the C-Space. It reads the configuration space data from a file. The data is in the form of four angles separated by a semicolon from the next set of angles. The parser reads these angles and uses floor to convert them to integers then marks that location in a 37x37x37x37 array as a 0, indicating that it is a valid configuration of motors, or not blocked. There were no required attendance Senior Design classes this week. I had a TA meeting on Tuesday and an all-team meeting on Wednesday. I also had a pathing and automation meeting on thursday, but due to miscommunications, only one other person showed up. It was disappointing that no one else came but it gave me the chance to get Subret caught up on what we were talking about since he replaced Ian (who graduated) as the ME rep for Pathing. In explaining the C-Space to him I realized that I missed a bug when writing my parser in that I forgot to convert negative degrees to their positive equivalents before putting them in the array.
- **Plans** Next week will involve finishing up the second draft of the RockSat-X poster and continuing work on the pathing and automation tasks. I developed a plan for the pathing and automation tasks during our meeting this week. Next week I will be fixing that bug in the parser, delegating a C-Space visualization in Matlab to James, and starting the Pathfinding portion of the code.
- **Problems** The problems that I am currently facing are in receiving enough support from the group at large for my pathfinding and automation tasks. I think this will improve next week as our schedules all become more normal.

#### 3.1.3 Week 3

- **Progress** This week I delegated making a visualization of the configuration space to James. I had trouble explaining what I needed and what to do because we were not able to meet in person. That resulted in some frustration, but I think he will be able to get the visualization done. I also spent a lot of time on the poster this week. There were a lot of tiny edits to be made in the formatting and content. I also took another group picture of all of the Software Team and some individual photos of everyone for them to use on other things.
- **Plans** Next week will be continuing work on the pathing and automation tasks. I will also continue working with James on the visualization of the C-Space.
- **Problems** I am currently having problems communicating how to make a visualization of a 4D array with James over text.

#### 3.1.4 Week 4

- **Progress** This week I was able to get the final visualization from James. I was able to answer the last few questions he had, and he produced a good quality visualization for us to include on our poster. I also took updated group pictures for us as well as some individual pictures for everyone to use on their linkedin profiles. I once again continued working on Pathing and Automation tasks. Finally, I continued to make some changes to the Final Expo Poster and got it approved by McGrath and Dr. Squires.
- **Plans** On Monday I will submit the final expo poster for printing and turn in the photo release form. Next week I will interview Evan on Thursday and write the WIRED-style review of his project. As always, I will be continuing my work on the Pathing and Automation code.
- **Problems** I am having trouble getting support from the Electrical Engineers. They are also very busy with work and classes.

#### 3.1.5 Week 5

- **Progress** This week I submitted our final poster for printing and turned in my photo release form to the Engineering building. I interviewed Evan on Friday and wrote my WIRED-style review. I continued working on my pathing and automation code, and finished the code that makes the motors step through a path.
- **Plans** Next week I will be finishing the Pathing and Automation code. I will continue to try to work with the Electrical Engineers and continue to try to secure funding for our travels. I will also start working on my slides for the Progress update.
- **Problems** I am still having trouble getting the support I need from the other engineers. Hopefully things improve next week.

#### 3.1.6 Week 6

- **Progress** This week I attempted to finish the pathing and automation code. I ran into some difficulties with this that will require me to finish the code next week. I was introduced to an OSU Foundation grant writer so this week I emailed with him about potential travel grants for us to apply to. He found one potential one, but it requires that someone on the team be under 21, and none of us are. He will still be able to set up a crowdfunding campaign through OSU for us. Other than that, I started working on my slides for the Midterm Progress Update due next week.
- **Plans** Next week I will be finishing up the code for the Pathing and Automation, as well as my slides for the progress update, the video of the progress update, the FSMR presentation for RockSat-X, setting up the crowdfunding campaign through OSU, creating print visuals in addition to our poster for Engineering Expo, submitting security clearance and background check authorization forms to Wallops, doing the Poster Extra Credit thing on Monday at 4 with Kirsten, and Expo on Friday.
- **Problems** Not enough hours in the day. Also my computer has some issues with AVR so I have to find another computer to use. I have also had a hard time getting in contact with the Electrical Engineer who can help me with the Program Memory part of my code, which is something that I am not particularly skilled or practiced at, so I could really use the help.

## 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 1

No progress this week.

Plan for next week is to implement more of the telemetry interface.

No problems.

## 3.4 Week 2

No progress this week.

Finish implementing telemetry.

No blockers.

### 3.4.1 Week 3

This week, in light of the SD card still being unfinished, I implemented logging to the eeprom on the microcontroller. The eeprom only has 4 kilobytes of available memory, so it is only a mediocre replacement. We no longer have time to fix the SD card library we are using, so we must pursue other means of telemetry. Telemetry via the provided telemetry pins is fully implemented. Telemetry via SD card is partially implemented, but cannot be finished if the SD card library can't be fixed. Telemetry via eeprom is fully implemented. Until SD card is unblocked, the telemetry component is complete.

Last week, we had a team meeting. We have further split up the work, and my part is to meet with the instructors to review deadlines. I also plan on getting the poster completed and submitted. I will also be taking control of writing a readme for the github repo and copy test code into science mode file.

No problems.

### 3.4.2 Week 4

This week I am making sure me and my team is ready for expo. I am following up with important people and assignments to make sure everything is complete and deadlines are being met. This includes but is not limited to making finals edits on our poster, getting out client's signature for the poster, submitting the poster, and making sure everyone has signed the necessary forms for expo.

I have completed both the video and telemetry components. I have only the data processing component left to implement as my portion of the project, but that is currently blocked until we receive further instruction from NASA. I have nothing left to implement for this project. I will spend the next week getting ready for expo and working on my presentation.

I am waiting for after Integration testing with Wallops and we receive the format of telemetry data. Then the implementation of the data processing component can begin. I will not be directly working on this component, but rather guiding James on implementing the component.

### 3.4.3 Week 5

This week I made some minor changes to the telemetry code.

Next week I plan to support Amber and Helena with development of the rest of the system.

No blockers.

#### 3.4.4 Week 6

This week I made some more minor tweaks to the telemetry code. I also sat down with Amber for 2 hours and worked on making the code in the repo to compiler. We also added a bunch of missing code in the off and retract phases. We also refactored a bunch of code to make it more readable.

Next week will be spent waiting for Helena to finish writing the code for the science phase.

Blocking on science phase being finished.

# 4 Retrospective

| Positives | Negatives | Changes |
|---|---|---|
| We asked for extensions when we needed one. Asking for more time when we needed it was a goal that we set in fall term's retrospective. | | We accomplished the change that we wanted to from last term, no further changes needed. |
| We were very productive this term and got a lot of our work done. | The bulk of our work had to happen this term, which was a lot of work. | We also could have been better about telling each other exactly when we were working on our different tasks. |
| 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 |
| Helena delegated some work to James! | Helena micro-managed a bit | Helena should focus on letting things go and not stressing about everything. |
| | The team is getting a bit scattered due to half of the ME's and EE's graduating and starting full time jobs. | We have to be more efficient and meeting even when some people are missing in order to compensate for this. We also have to be more mindful of our communication to make sure that we all stay on the same page. |
| We showed up to all of the required classes for CS463, and Helena even brought coffee for the team one class. | | |
| | We were a bit scattered this term, generally having divided focus when working on things because of how much work we had. | We should be more focused as this would make us more efficient. It would be better for us to focus on one task or assignment at a time before moving on instead of jumping between multiple different tasks. |
| We were a supportive team within software this term. We communicated well with each other when we were struggling and have a good team dynamic going. | We still have some conflicts within the larger group as a couple of the ME's still can't keep Amber and I straight and frequently call us by the wrong name. | We need to keep this good rapport going, and even improving our teamwork, as this will make our expo pitch even more effective. |

# 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

**OSU** Oregon State University 1

**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, 13