

# 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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# Contents

<b>1</b>	<b>Introduction</b>	<b>3</b>
1.1	Document Overview . . . . .	3
<b>2</b>	<b>Project Overview</b>	<b>3</b>
2.1	Project Purpose . . . . .	3
2.2	Mission Success Criteria . . . . .	3
<b>3</b>	<b>Current Progress</b>	<b>3</b>
3.1	Helena Bales . . . . .	3
3.1.1	Week 1 . . . . .	3
3.1.2	Week 3 . . . . .	4
3.1.3	Week 4 . . . . .	4
3.1.4	Week 5 . . . . .	5
3.1.5	Week 6 . . . . .	5
3.2	Amber Horvath . . . . .	6
3.2.1	Week 1 . . . . .	6
3.2.2	Week 2 . . . . .	6
3.2.3	Week 3 . . . . .	6
3.2.4	Week 4 . . . . .	7
3.2.5	Week 5 . . . . .	7
3.2.6	Week 6 . . . . .	8
3.3	Michael Humphrey . . . . .	8
3.3.1	Week 3 . . . . .	8
3.3.2	Week 4 . . . . .	8
3.3.3	Week 5 . . . . .	9
3.3.4	Week 6 . . . . .	9
3.3.5	Week 7 . . . . .	9
3.3.6	Week 8 . . . . .	10
3.3.7	Week 9 . . . . .	10
3.3.8	Week 10 . . . . .	10
<b>4</b>	<b>Retrospective</b>	<b>11</b>



# 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  $R^4$ . 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 occurred 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**

This week we attempted to gather ourselves after winter break and make a game plan for this coming term. We met as a group and worked on figuring out what needs to get done within the next 5 weeks and set small goals for each coming week. We are meeting with our EE collaborators next week to figure out telemetry codes. I've downloaded Atmel studio so I can start writing code. We are divvying out work based on our design document from last term.

For the next week, I am hoping to begin work with the telemetry side of the project and help Michael.

So far, we have not encountered any barriers. The only issue is coordinating schedules, which was an issue we encountered last term as well. What mitigated that issue was clear and consistent communication across teams, which our newly established subteams should help with. I am serving as the representative for the Physical Integration team which is the team in charge of ensuring all the mechanical pieces get manufactured and put together properly.

### **3.2.2 Week 2**

This week was somewhat odd due to the short week the previous week because of snow throwing off our progress and the shortness of this week due to Martin Luther King Jr. day. Little progress was made this week. The only progress made was attempting to work on our team organizational skills and begin documenting our individual process through a scrum document that Michael set up.

There was also a change in project delegation as the EE's decided that they want a local storage for the microcontroller in the form of an SD card. I will begin looking into lightweight, Atmel-compliant storage systems that interface with an SD card.

Our barriers have been limited to lack of time between all of us. Also, due to having irregular meetings, we are having issues knowing what each other are doing and how to keep track of differing obligations and deadlines. We are attempting to overcome this with the scrum document which should allow for less in-person meetings and more communication about what we are all doing on our own time. We also are waiting on the EE's for their driver code they are writing for us. They have been tasked with writing the C code that will interface with the motors.

### **3.2.3 Week 3**

This week we got the code from the EE's for interfacing with the microcontroller. I also did research on SD card interfaces with microcontrollers that we are now using to write data from the microcontroller to an SD card. This code will be up on Github once we translate it from the Atmega 16 pins

to the Atmega 64 (which we are using). I worked with the EE's to accomplish this translation as they are more familiar with the Atmega 64 architecture than I am.

Our next step is to make the code compliant with the Atmega64 architecture. I will also begin work on writing code that utilizes this library so that we can write telemetry codes, sensor touch data, and other log data to the card for post-mortem analysis.

The problems we have encountered include illness and traveling. When we do not have teammates available, it can be difficult to be as productive due to reduced man power. These random holidays also slowed our initial progress, so it can feel like we are trying to play catch up. We are also nearing deadlines for our STR meeting with the Colorado RockSat-X group, so I am beginning to feel the pressure of that as I do not feel our team has accomplished as much as I would like us to.

#### **3.2.4 Week 4**

This week, I was able to get all the code up on Github for the SD card interface with the microcontrollers. Me and the EE's (namely Jonathan Hardman) are working on implementing the remaining functions and pre-processor directives for our SD card interface file. We should have that done by next Tuesday. Jonathan also updated the drivers and uploaded them on Google Drive, so I will import those over to Github. Now that these drivers are almost completely ready, I am looking forward to working on more implementation that actually utilizes the libraries and drivers that we have gotten. This step, however, hinges on having motors and a working prototype ready so we can determine whether our arm movements are correct. This will not be ready soon as our funding has been delayed leaving us with no money for purchasing these motors.

Next steps include nailing down with Michael what information we are sending over telemetry and what of that information should be sent to the SD Card. Next steps also include getting the updated code from Jonathan and getting the drivers up on Github and fully implemented.

The CS 462 class is also requiring that we update some of our previous documents and get all our deliverables up onto One Note, so we will do that as well. Lastly, we have a big meeting with our sponsors in Colorado next week, so we have some slideshow slides that we need to complete. We are in a stage where we need to start divvying out tasks and better communicating as a team. We also have dependencies that are reliant upon other teams that we have no way of controlling, such as the lack of motors.

#### **3.2.5 Week 5**

This week I worked on furthering the progress on our SD card implementation. I updated the Makefile such that the library now compiles with the rest of the program. Jonathan also updated the code such that it uses the correct pins and is designed with our Atmega64 in mind. Since the FatFS library is meant to be generalizable across different microcontrollers, there are some functions that are left as user-designed so that they can be written for specific microcontrollers. We completed those parts of the code, so the library should be fully functional now.

Our next work will be to test the SD card library. We are also prepping for our STR presentation with our contacts in Colorado, so we have to complete an extensive PowerPoint skeleton that they provide us. We will also be meeting with Dr. Smart (a professor in the Mechanical Engineering department) to discuss path-finding for our mechanical arm.

Our main blockers are lack of communication between team members. Despite putting a scrum document into affect and requiring each individual team member to add to the document every



Monday and Thursday, some members of the team have been failing to meet this requirement, so it is difficult to know what is going on between other subteams and what our individual team members are doing on their own time. We also have regularly scheduled meetings, but attendance has been rather lax on those with team members either forgetting or making excuses right before the meeting time. Despite us stressing the importance of attending these meetings and communicating relevant information, our team still struggles with this, so some measures must be taken. However, we are ensure at the time of writing this what those measures should be.

### **3.2.6 Week 6**

This week was focused primarily on prepping for our big STR presentation. This is a presentation where we review our subsystem testing for the RockSat-X group in Colorado. The meeting was at 6 AM on Friday and required us to prepare a lot of slides for a slideshow. We also met with Dr. Smart to learn more about preparing our C-Space for pathing the arm's movement and determining what are and aren't legal movements for the arm. There are multiple ways to do this as we can either use inverse kinematics, manually moving the arm through different legal motions and recording the different degrees of rotation the motors are in, or using sensors on the motors to determine their rotation. We are hoping to do the last option.

Next week we shall work on the presentation for this class. Fortunately, we can lift a lot of the work we did last week so it shouldn't be too cumbersome. I will also be meeting with the EE's on Friday to work on testing the SD Card implementation and also continue work on the code for moving the arm.

Blockers this week were the fact that I was running a study at IBM so I was out of town most of the weekend and could not do work for this since I was busy preparing for that. This should not be a problem now that the study is concluded.

## **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 development of the software.

## 6 Glossary

**deployable** Any portion of the payload that is expanded from its original configuration once in a space-like environment. 3

**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, 3, 8–10, 12