Winter Progress Report for RockSat-X Payload - Hephaestus Group 26

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1 Introduction

This document is a progress update for the Hephaestus RockSat-X payload as part of the Computer Science Capstone course. It is an update on progress since the submission of the Midterm Progress Report at the end of Week 7. This project is sponsored by Nancy Squires. It is part of the RockSat-X program and will launch from Wallops Flight Center in August of 2017. The Hephaestus payload is a half-can robotic arm capable of precise movements. It is a collaboration between four Senior Design teams. This document will cover the progress of Helena Bales.

1.1 Mission Overview

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.

1.2 Mission Success Criteria

1.2.1 Minimum Mission Success Criteria

- The arm assembly body shall deploy and a video sweep is successfully recorded.
- The arm assembly body shall be fully retracted after data collection.

1.2.2 Comprehensive Mission Success Criteria

- The arm assembly body shall deploy and a video sweep is successfully recorded.
- The arm shall make contact with predetermined targets around the payload.
- The camera shall record all instances of contact between the arm and the targets.
- The arm assembly body shall be fully retracted after data collection.

1.3 Mission Goals

The purpose of this mission is two-fold. The first goal is to be Oregon State University's first mission in space. This will pave the way for future teams to participate in this and other programs. The second goal of this mission is a proof-of-concept for construction in space using a robotic arm capable of accurate motions. This will be a crutial technology for the future of space travel as we attempt to cover greater distances.

2 Project Status

2.1 Overall Project Status

The Hephaestus project has gone through several design reviews with the RockSat-X program. We have now successfully completed our ISTR review. All of the mechanical components have been machined and purchased. Most have also been assembled and tested. Preliminary mechanical tests have been completed. Further mechanical tests will be performed at Wallops in June and at Wallops before the launch in August. All electrical components have been designed. Some PCBs have been printed but the final ones have not been completed. All drivers and power controllers have been completed. Further electrical tests will be completed next term and at Wallops in June and August.

2.2 Overall Software Status

The software subsystem has been completely designed. The final implementation is still in its preliminary phase as we were delayed by our dependency on custom hardware and electronics. Going into this next term, we have almost everything that we need to complete the software subsystem. The final dependency that we will be missing at the start of spring term is sample telemetry data. This dependency will be met after integration testing at Wallops in June.

2.3 Pathing and Automation

Pathing and automation compromises the bulk of the scientific mission of the Hephaestus payload. This portion of the code shall move the arm around the payload without collisions. This is accomplished using a pre-computed IR4 Configuration Space and Dijkstra's algorithm.

2.3.1 Constructing the Configuration Space

The configuration space shall be a 4-D array of boolean values. Each value in the array will be a 0 to represent a valid configuration of motor theta values and a 1 to represent an invalid configuration. For example, given the motor configuration ¡0, 7, 30, 220¿, we could look at the value of C_Space[0][7][30][220] to see if it is valid or not.

This configuration space was constructed using a set of three motors attached to an Arduino UNO. We then back-drove the motors and collected the theta values. We ran the arm through every position that we could put it in. This data set contains (in theory) every possible configuration of the motors.

Future progress for this section will include parsing the collected C-Space data. I would also like to create a visualization tool for the Configuration Space. I think this will be helpful in repairing and discontinuities in the C-Space data.

2.3.2 Pathfinding in an IR4 Configuration Space

In order to generate a path for the arm to follow through the coniguration space I will be implementing Dijkstra's pathfinding algorithm. Process on this step is blocked pending completion of the Configuration Space. The path generated by Dijkstra's algorithm will be returned to the arm control software.

2.4 Moving the Arm

The arm motion will be controlled by the On Board Computer (OBC). The arm will start out in its retracted, callibration, position. From there, the payload will deploy and the arm will move to its first target point. In order to move between the current position and the target position, the arm control software will receive a path generated through the configuration space to execute. It will then move the motors sequentially starting at the base of the arm along the path. This is the point at which the software interfaces with the Electrical Team's drivers.

2.5 Tracking the Position of the Arm

Tracking the position of the arm will be accomplished mostly by the nature of the arm control software and pathfinding process. The arm control software knows where the arm is at all times because it moves the motors by small amounts at a time and stores the current position. This current position is then used to calculate how far to move in order to reach the target position.

2.5.1 Counting Steps

The motors are stepper motors, so we will be counting the number of steps that the motor has been moved. We will use the change in position and the known starting position to track the arm's location.

2.5.2 Concerns About Error Propagation

Error propagation in tracking the arm's location is a concern. This is because we will be performing many arithmetic operations on the location value. We were planning on tracking the location in degrees, but that may introduce more errors. In order to combat this propagation, we have implemented a recallibration point.

2.5.3 Recallibrating Mid-Experiment

In order to keep the position of the arm as accurate as posible throughout the experiment, we will need to have the ability to recallibrate mid-experiment. This will be accomplished in software by telling the arm to return to its default position after a pre-determined amount of time. The arm will be funeled back into its exact starting position, at which point the position will be reset to zero.

3 Progress Update

3.1 Week 7

3.1.1 Progress

This week was focused on preparing the Midterm project update for the Senior Design course. I started the slides on Monday using our STR presentation as a base and added more details on the software side of the project and deleted many of the slides from STR that were focused on the hardware side. On Thursday we met as a group to finalize the slides and record the audio. Michael then edited the audio while I worked on updating our written documents for last term, compiling my blog posts, and starting the retrospective. Also on Thursday was the all-team meeting. We discussed funding issues because AIAA will not be contributing as much money to the project as they initially said they would, so we now have about $30,000 to fund raise. We will all be reaching out to previous employers, etc. to raise the remainder of the funds.

3.1.2 Plans

The next week will focus on building the configuration space. We are still trying to get motors to use for this step since they need to be back-driven and have encoders. We will be buying foam to line the payload. We will then line the payload with foam to provide a buffer of forbidden space in the C-Space before any collision occurs between the arm and payload. Next we will attach the motors to the arm and an arduino. We will use the arduino to read values from the motors as we back-drive them through every valid configuration. Finally, we will use this data to build the c-space. This will take up most of the week. The only other plan is that the Tuesday Senior Design class is required attendance.

3.1.3 Problems

We have not yet found motors to use for building the C-Space.

3.2 Week 8

3.2.1 Progress

This week was focused on preparing the payload to build the configuration space. On Tuesday I went to the required Senior Design class. I wrote and practiced pitching and talking about the Hephaestus project. After class I talked to McGrath about getting motors with encoders to build the Configuration Space. He gave us three motors that we can back-drive and hook up to an arduino. Later in the day on Tuesday I worked with the Pathfinding and Automation team to prepare the payload to build the C-Space. I bought foam board and cut out pieces of it to line the payload. With this complete, we need to attach the motors to the arm and the arduino then read the values from the motor.

3.2.2 Plans

The next week will mostly be working on the C-Space more and the arm control software. I will be starting by writing arduino code that we can use to build the C-Space. I will be working on that this weekend. Once that is complete, we will build the C-Space. After we have the C-Space, I will start the arm control software that will plot the path through the C-Space and move the arm along the path.

3.2.3 Problems

None.

3.3 Week 9

3.3.1 Progress

My primary goal this week was to get an initial mapping of the C-Space. I met this goal. On Tuesday I met with Pathing and Automation to start work on the Arduino code to map the C-Space. They had a start to it with three motors on interrupts and printing their values to Serial out. Unfortunately, the Arduino UNO only has two interrupt pins, so I had to switch one of the motors to poll instead of interrupt. This took a few tries, but by Thursday, which is when we met next, I had a motor polling instead of interrupting. I had also fixed the print statements to be more useful to us. However the code still had some bugs. We ran out of time on Thursday and had to go to the All-Team meeting, so we met up the next day as well. On Friday I finished debugging the Arduino code and we were finally ready to map the C-Space.

Arduino Code for C-Space Data Collection:

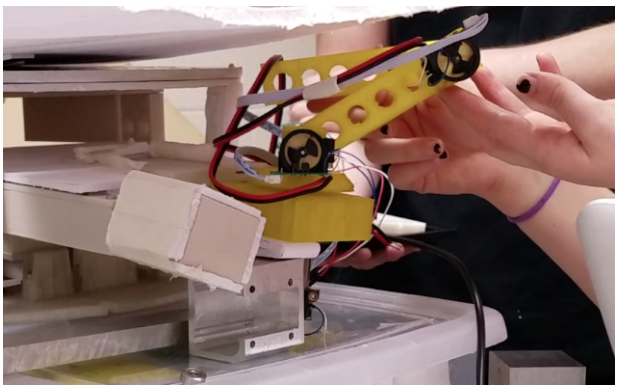
```
#include <stdio.h>

//=========DEFINITIONS==================
int encA_pin1 = 6;
int encB_pin1 = 7;
long encA_ticks1 = 0;
//for polling implementation
int n = LOW;
int encA_pin1_prev = LOW;

unsigned long time;
char buffer [50];
int i = 0;

int encA_pin2 = 2;
int encB_pin2 = 4;
volatile long encA_ticks2 = 0;

int encA_pin3 = 3;
int encB_pin3 = 5;
volatile long encA_ticks3 = 0;

const float pi = 3.14;
```

```
volatile int state = HIGH;

volatile float encA_degree1 = 0;
volatile float encA_degree2 = 0;
volatile float encA_degree3 = 0;

/*
2 - Motor 1: A
3 - Motor 1: B
4 - Motor 2: A
5 - Motor 2: B
6 - Motor 3: A
7 - Motor 3: B


*/
//=========SET-UP==================
void setup() {
  // put your setup code here, to run once:
pinMode(encA_pin1, INPUT);
pinMode(encA_pin2, INPUT);
pinMode(encA_pin3, INPUT);

digitalWrite(encA_pin1, HIGH);
digitalWrite(encA_pin2, HIGH);
digitalWrite(encA_pin3, HIGH);

pinMode(13, OUTPUT);

// INIT interrups
attachInterrupt(digitalPinToInterrupt(encA_pin2),encoderA2,RISING);
attachInterrupt(digitalPinToInterrupt(encA_pin3),encoderA3,RISING);

Serial.begin(9600);
}


//========= LOOP ==================
void loop() {
  // put your main code here, to run repeatedly:

  time = millis();

  //Poll innermost motor to circumvent limited number
  //of Arduino UNO interupts
  n = digitalRead(encA_pin1);
   if ((encA_pin1_prev == LOW) && (n == HIGH)) {
     if (digitalRead(encB_pin1) == LOW) {
       encA_ticks1 -= 1.0;
     } else {
       encA_ticks1 += 1.0;
     }
   }
   encA_pin1_prev = n;
```

```
  digitalWrite(13,state);

  //if enough time has passed, print a status update
  //print status update every .5 seconds

  //output the valid configurations to Serial which will then be stored in a file
  encA_degree1 = encA_ticks1*2.25;
  encA_degree2 = encA_ticks2*2.25;
  encA_degree3 = encA_ticks3*2.25;

  Serial.println("0");
  Serial.println(encA_degree1);
  Serial.println(encA_degree2);
  Serial.println(encA_degree3);
  Serial.println(";");

  delay(500);
}

void encoderA2(){
  state=!state;
  if(digitalRead(encB_pin2)==HIGH){
    encA_ticks2=encA_ticks2+1.0;
  }else{
    encA_ticks2=encA_ticks2-1.0;
  }
}

void encoderA3(){
  state=!state;
  if(digitalRead(encB_pin3)==HIGH){
    encA_ticks3=encA_ticks3+1.0;
  }else{
    encA_ticks3=encA_ticks3-1.0;
  }
  }
```

I ran the arm all around the payload so we now have an initial data set on the shape of the C-Space to play with.

Photo Documentation of C-Space Data Collection:



The first data collection of Hephaestus configuration space by the Pathing and Automation Team. Three back-driven motors are wired to an arduino. The arduino is running the code shown above and reporting motor theta values back to the attached computer.

3.3.2 Plans

My next step in the software is to write a parser for the C-Space data. It is currently in the form of one motor angle per line, with the triples separated by a line with a semicolon on it. So I will go from $\theta_1\theta_2\theta_3$; to $point_n =< 0, \theta_1, \theta_2, \theta_3 >$.

I will have a 4D array of 1's, then fill in a 0 in every location indicated by $point_n$ above. The 4D C-Space will then contain a 0 for every valid configuration of motors and a 1 for every invalid configuration.

Once I have an initial C-Space, I will need to do some repair on it to smooth out the C-Space. This will account for angles that are valid but were not sampled.

My other goal for Week 10 is to help the ME's test the payload. They are all finishing up their capstone class, so they need to have a bunch of tests done to show that their parts of the project work. They will need some help from CS and EE in order to test how their hardware parts all work in motion. I will be helping them to write code to move the arm and to devise test cases.

3.3.3 Problems

I currently have way too many projects going on. All of my classes have final projects, so I am worried that I will not have time to get it all done.

3.4 Week 10

3.4.1 Progress

This week has been an extremely stressful one. All of my classes have final projects. I have not had time to write the parser for the C-Space data. I did update the presentation for the Final Update video. I have some more visuals to add, but I have recorded most of my audio.

We are also working on the presentation today. We did not realize that it was due tonight, so we will be getting most of it done at 4pm today. Needless to say, we are stressed by this looming deadline.

3.4.2 Plans

My next step in the software is still to write a parser for the C-Space data. I will have a 4D array of 1's, then fill in a 0 in every location indicated by $point_n$ above. The 4D C-Space will then contain a 0 for every valid configuration of motors and a 1 for every invalid configuration. Once I have an initial C-Space, I will need to do some repair on it to smooth out the C-Space. This will account for angles that are valid but were not sampled.

My other goal for Finals Week is to contact people to ask for funding for our project. We also have ISTR on Friday of Finals week, so we will be spending some time during Finals week working on the presentation for that. We will also be finishing up our presentation and video for this class.

Finally, we will be completing the Expo poster next week as we got an extension from Kirsten. I have defined the general sections on the poster in the poster template. My Week 10 blog post on Github outlines these sections as well as writing assignments for our team.

3.4.3 Problems

I currently have way too many projects going on. All of my classes have final projects, so I am worried that I will not have time to get it all done. Additionally, I feel the stress of the end of the term is affecting the effectiveness of our team. Spring break will help with that.

3.5 Finals Week

3.5.1 Progress

Since last week most of my energy has been focused on completing project for other classes. My work on Senior design deliverables was relegated to the end of the week. This week focused on delivering all of the assigned documents by Friday. The first such document to be due was ISTR. ISTR is the Integration design review with the RockSat-X program. Our presentation was Friday morning at 8am. We finished our presentation on Thursday evening. The whole software team worked on the slides together on Thursday morning, then Amber and I finished them during the all-team meeting at 6pm on Thursday.

The other deliverable that we worked on this week was the poster. Since we got an extension from last week, we finished the poster up on Thursday as well. Amber and Michael had already completed their parts so I went in to add my text and reformat to fit everything on the poster.

We also put the finishing touches on our video and presentation on Thursday. We had completed most of it last week but had some final visuals to add and editing to finish up.

The last deadline for Senior Design before break is this document which will be completed by the end of the day on Friday.

3.5.2 Plans

Over Spring break I plan to finish my parser for the C-Space data and to create the configuration space. I would also like to write some visualizer for the configuration space as I think this will help us in identifying and correcting errors in the C-Space.

3.5.3 Problems

None.

4 Evaluations

4.1 Self-Evaluation

My focus within the team is on Pathing and Automation. I am responsible for completing the bulk of the scientific mission of the payload. As such, I have taken on the role of Software Team Lead as well. I feel that I have, for the most part, filled this role successfully. I know that I did not do my best at the start of this past term, and that is an issue that was addressed within the group members and with Kirsten. Since then I have been the definition of reliability. I feel that I have also completed exemplary work throughout the past two terms.

My level of contribution is generally above that of my group members. For the first half of the term I feel that it was slightly lower than Amber and Michael, but that was more than made up for in Fall term and over the last few weeks.

My working relationship with my group members is very effective and we make a powerful team. We all have diverse backgrounds and experiences and technical skills, so when we are all unleashed on a task, we get it done in unique ways. I think that we balance each other out very well and are generally good at providing support to each other. We had a couple of bumps this term but I think our group is now stronger than before.

I would like to continue to improve on my time organizationaly skills. I think this would help me with communicating my progress with the rest of the group, which was the root of the conflict this past term. I would also like to continue to improve my relationship with Michael, as I feel it is still a bit strained.

4.2 Evaluation of Michael

Michael has taken on the tasks of telemetry and wire pathing and sensor placement. He has helped the ME's and EE's a lot as the CS representative because of that. Other than that, he is the best organized of us all, so he always knows when everything is due.

Michael's level of work has been very consistently good throughout the year. He has done less than either Amber or I at this point, but that mostly has to do with the type of work that he has to do.

Michael and I are occationally in conflict with each other. Michael and Amber always seem to get along, but Michael and I are very different. We have been working on resolving these differences, but I still do not feel comfortable around him. I feel that he is very quick to blame and guilt me for any failure on my part, but is not willing to recognize the reciprocity of communication. For example, I feel that his communication style tends towards being passive agressive, which I do not think is an effective method of communicating. I would like to be able to work through this communication barrier with him, but a good opportunity has not yet presented itself.

4.3 Evaluation of Amber

Amber has taken on the tasks of data insurance and mechanical integration. She has been working a lot with the EE's to get the SD Card writing working. Amber also brings humor to the group and I think much of the credit for our group being close goes to her.

Amber works exactly the right amount. She is often too busy for scheduling with her to be easy, but she always delivers quality work when she says that she will.

At this point I have covered this pretty fully, but our team works well together. Amber and I get along well. We should be extra careful about resolving any conflicts that arise in this project since we are also friends, which may cloud the situation. I think that Amber fills an essential role in our group and makes us more effective.

5 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. Since the Midterm Update, we took better advantage of this attendance requirement with Michael, and I each missing a Thursday meeting.		If we wanted to improve our organization on this we could plan at the start of the term who will go to each meeting.
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. We talked as a group about how to resolve these issues and have improved our group dynamic and communication.	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.	Since the midterm update, we have not had any major communication breakdowns.
	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 had a design review with the RockSat-X program office where we presented to a reviewer. This helped us formally document the overall project. The presentation went very well and we received very positive feedback from the reviewer.		
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

6 Conclusion

Progress has been made on the Hephaestus payload since the Midterm Report. Much of the progess was in having accomplished the ISTR presentation successfully. Moving forward into next term the Software team will be implementing the bulk of the subsystem. We will be preparing for our next design review with RockSat-X at the begining of May. We will also be preparing for the Engineering Expo and the travel to Wallops from June 20th to 25th. Finally, we have the launch of the rocket to look forward to. This launch will occur in August of 2017 from Wallops. We hope that the whole team will be able to attend the launch.