Problem Statement For RockSat-X Payload - Hephaestus

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Abstract

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. In order to accomplish the Hephaestus mission, the software team shall collect telemetry data and develop the arm control software. The telemetry shall be sent to the ground station in real time in order to monitor the progress of the flight. The software shall be responsible for deploying and moving the arm assembly body. Hephaestus will be successful if the arm performs the given motions and if the motions are recorded by the on-board video camera and telemetry data.

Approved By ______________________________ Date ______________

1 Problem Description

1.1 RockSat-X Program Overview

The Hephaestus Project is part of the RockSat-X 2017 program. This program provides students with a rocketry platform on which to launch scientific and technical payloads into Low Earth Orbit (LEO). The program is divided into three stages: design, build/test, and integration/flight. This is Oregon State University's first time participating in this program. Participation this year will allow OSU to pursue more aerospace projects in the future. The RockSat-X program is based at Wallops Flight Facility and funded by the Space Grant Consortium. The rocket will be launched from Wallops and will expose students' experiments to space at the rocket's apogee. The program requires that students design and build an experimental or technical payload that makes use of microgravity or a space-like environment.

1.2 Limitations of Space Travel

Currently space travel is limited by the need for constructing spacecraft on earth and launching into orbit. Because of this, the scale of spacecraft is limited to what can be launched by current launch vehicles. The limited power of launch vehicles means that traveling beyond LEO has serious mass constraints. In order to travel further, we must circumvent this mass limitation. This can be solved by launching raw materials and parts and constructing the structure on orbit.

The International Space Station is currently evaluating possible solutions to this problem. They are investigating the efficacy of 3D printing parts on orbit and of performing repairs with the help of a large robotic arm. The arm on the ISS has limited functionality because of its size. It has the ability to move astronauts around the outside of the ISS but is not capable of the detailed maneuvers that would be required for it performing repairs itself.

Software limitations are directly related to the limitations of constructing all equipment on earth, prior to launch. Writing code that is robust enough to handle all of the potential situations that can occur in space requires years of planning and foresight. Software that is able to maintain itself is currently not possible, but software that is able to make repairs on hardware autonomously, while difficult, is reasonable.

2 Proposed Solution

The Hephaestus payload shall be an assembly containing a mechanical arm capable of performing intricate maneuvers. This project is a proof of concept for construction and repair on orbit using a mechanical arm. The ability to perform detailed maneuvers using an arm is critical for construction on orbit because it replaces the current need for a spacewalk to perform the same task, saving time and money and decreasing risk.

2.1 RockSat-X Platform for Proof of Concept

The RockSat-X Platform will be used for this demonstration because of the low barriers to entry and the future opportunities it will provide OSU for research and study in space. It is far more cost effective and less error prone to use an already existing rocketry platform for this demonstration than to attempt to build a rocket dedicated to only the Hephaestus mission. RockSat-X provides a standardized and consistent platform for building experiments to send into space. The Hephaestus team only needs to build a payload that meets the design specifications set forth by RockSat-X to successfully deploy that payload into LEO. The RockSat-X platform provides 10 cannisters that each contain telemetry and power hookups. Each cannister may accommodate 1 or 2 experiments. Additionally, if the Hephaestus mission is a success, it will provide more opportunities for space research such as CubeSat missions through the Space Grant Consortium.

2.2 Mechanical Arm For Construction On Orbit

The Hephaestus project attempts to prove that a mechanical arm is a viable solution for construction on orbit. This is accomplished by launching a prototype of a small autonomous robotic arm as a RockSat-X payload. The arm will execute a series of maneuvers to make contact with pre-defined targets on the rocket. The maneuvers will be observed using the telemetry from sensors and motors on the arm and a video camera mounted on the payload. The arm will be controlled using a micro-controller and motors that will allow it to make precise movements. The deployment and movement of the arm will determine if a mechanical arm is a viable solution to performing construction and repairs during flight.

2.3 Software Solution for Arm Control and Telemetry

The Software for the Hephaestus payload will collect telemetry data, store the video feed from the camera, and control the arm assembly body motors. The Software will be responsible for recording every input it receives, output it sends, as well other important information. The Software will transmit that information to the ground station via the telemetry hookups. Additionally, the Software must handle sharing of the telemetry hookups with the neighboring RockSat-X cannister. The Software will also be responsible for controlling the movement of the arm assembly body. To do this, we can load the body with the Atmel software framework which provides drivers and libraries to glue together the pieces of a software design using Atmel devices. Our electrical engineers will be using an Atmega 128 Microcontroller, so our software must be compliant with their device. Finally, the Hephaestus Software must store the output from the video camera into a persistent storage location.

3 Metrics For Success

3.1 Mission Success Criteria

The success of the Hephaestus mission shall be evaluated based on two success landmarks. These landmarks are the minimum success criteria and the maximum success criteria. The minimum success criteria defines the minimum task that we could accomplish and still consider the mission to be successful while the maximum mission success criteria describes the tasks that would make a fully successful mission.

3.1.1 Minimum Mission Success Criteria

1. The arm assembly body shall deploy and a video sweep is successfully recorded.

2. The arm assembly body shall be fully retracted after data collection.

3.1.2 Maximum Mission Success Criteria

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

3.2 Software Success Criteria

The software can be successful without the mission being successful. For example in the drastic case where the rocket is destroyed on launch, our software could still be successful if it met all of the following requirements prior to the flight.

1. The software shall deploy the arm assembly body and perform a video sweep.
2. Test points shall be generated and stored.
3. The movements to reach each generated point shall be generated.
4. The arm shall perform the generated tasks and record the motions using the video camera and telemetry channels.
5. The software shall retract the arm assembly body.

3.3 Evaluation of Success Criteria

The mission will be considered successful if the success criteria have been varifiably met. This means that in order for the mission to be fully successful, the arm must deploy, perform its motions and retract as well as record all motions using the video camera and telemetry. We will use the recorded video and the telemetry data of motor motion and pressure sensors to determine whether the arm has performed all tasks. Using that data and the benchmarks described in this document we will determine the level of success of the Hephaestus mission.