Characterizing Asteroid Infrared Emission for HAIV

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Introduction

Imagine an asteroid moving towards the Earth's direction and potentially destroying it. What can we, the human race, do? Our client has came up with a concept called hypervelocity asteroid interceptor vehicle (HAIV) that uses both optical and infrared sensing devices to aim their nuclear warheads at the incoming asteroid. One of the goals of this project is to assemble a prototype optical and infrared sensor package that can be implemented later on a larger scale. Along the way, we have the goal of assessing technical issues (thermal noise, cooling) following the system prototype.

Problem Statement

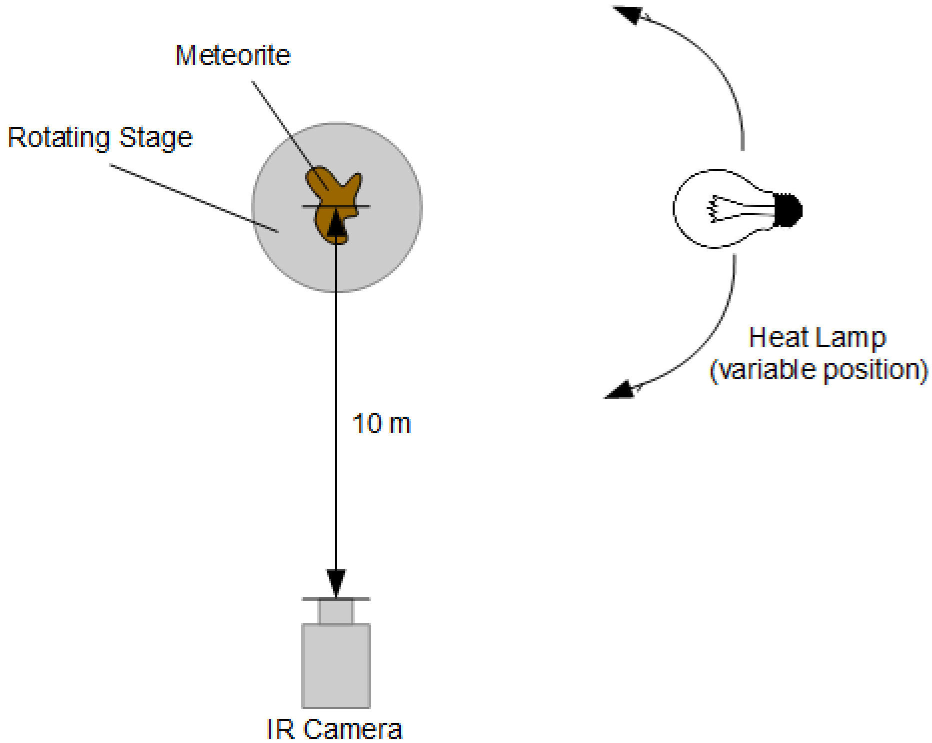
Our client and his team have been able to generate infrared and visible spectrum images of an asteroid and were able to simulate what images would look like if the asteroid was a great distance away. The parameters for their simulations are all theoretical and they desire to have more real-world parameters. They have also generated comparison images between visible spectrum image of an asteroid versus the infrared spectrum image. The problem is that they do not have any proof of how their simulated images or theoretical parameters compare to real values; we intend to provide this proof of concept and keep it very well documented so that our work can become of later use to them.

Concept Sketch

In our experiment, we plan to put the asteroid sample in front of an infrared camera with 10m distance. Then using heat-lamp we will begin heating our sample. We know asteroids are around 180 to 300 Kelvin with space's ambient temperature of around 3 Kelvin, so we will measure the ambient temperature and heat the asteroid to a specific temperature above the measured ambient temperature. This is a normalization of ambient temperature and this is how we will deal with our high ambient temperature without cooling the area around our experiment setup.

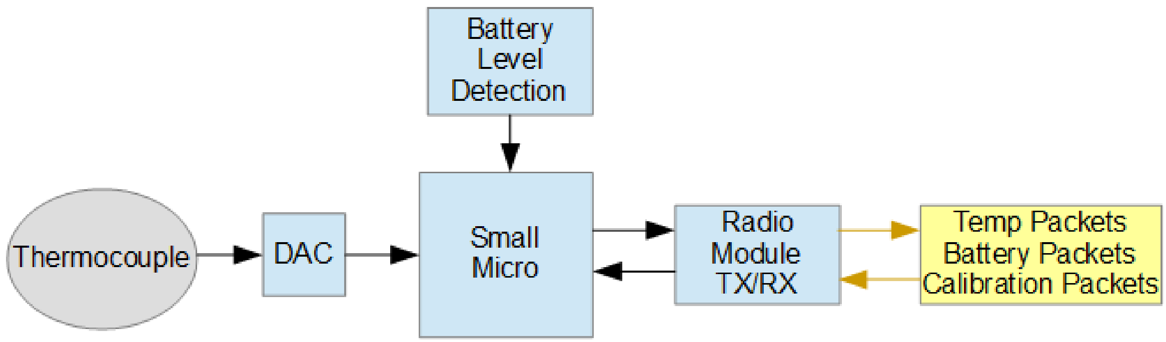
An image of our experiment setup is shown below, and the image is not to scale. We will begin rotating the meteorite sample with the heat lamp turned on until we have reached a nice uniform temperature throughout the sample. Once we have achieved this, we will stop rotation and begin taking infrared and visible images of the stationary sample. From this, we will be able to show that the infrared spectrum images versus visible spectrum images that we take will match the simulated images that Dr. Bong Wie's graduate students have produced. This is where we show our proof of concept. We will also do some post experiment analysis on the infrared images that we have taken. This will allow us to come up with figures for thermal distribution of the meteorite sample and give the information to Dr. Bong Wie's graduate students. This will help them create more realistic simulations.

Experiment Setup

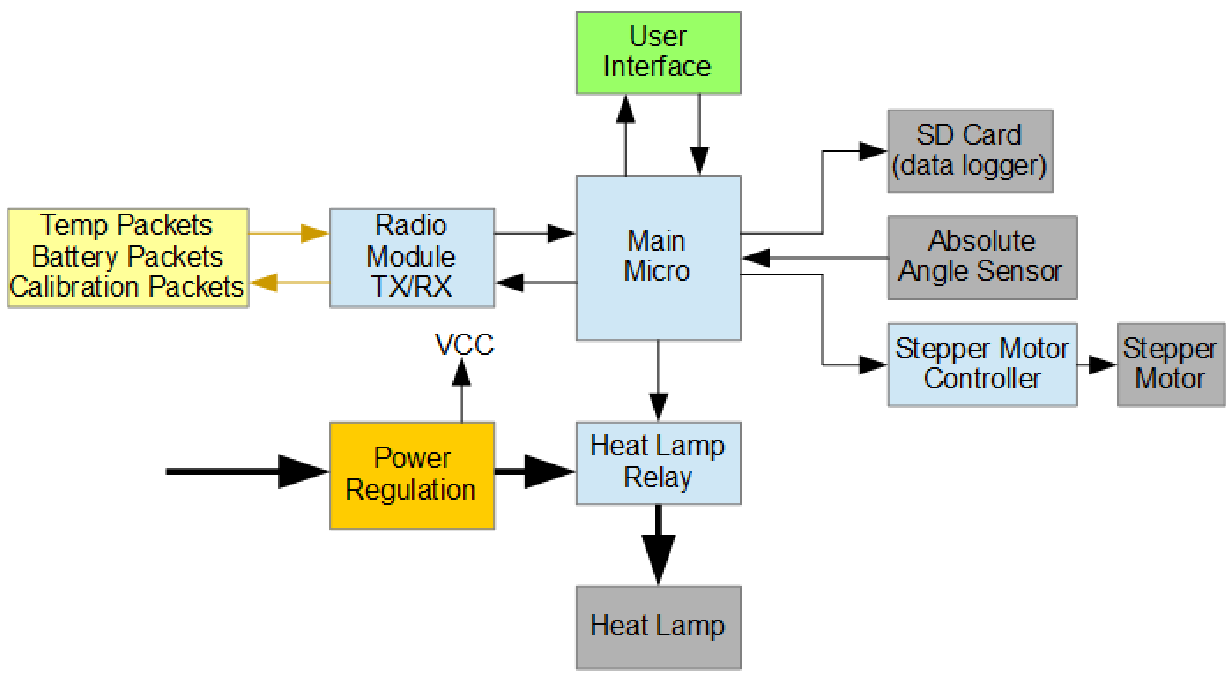


System Block Diagram

Block Diagram : Battery Power



Block Diagram : Main Power



System Description

Our system will be in two parts and will contain many peripherals to ensure proper operation. The reason we need two parts is because one will be completely battery powered since it will be in contact with the rotating stage, and the other will be stationary and supplied by main power.

The battery powered subsystem is mainly part of a temperature feedback loop that will be used to control the temperature of the specimen. The thermocouple will be attached to the specimen and shielded with thermal tape to allow for the most accurate reading. The digital to analog converter (DAC) will be in the range of 10-bit to 24-bit. This will give us a higher resolution for high quality readings. The reason why we need a wireless transmitter is because the subsystem will be attached to a rotating stage and we will need to be sending live data readings to the main system so it can keep track of the temperature of the specimen. The easiest way to do this will be to use a low power radio module; this eliminates the need for a brush-contact system.

The main system will be powered with a rectified and regulated AC source. The microprocessor on this board will need to be slightly larger, faster, and more powerful than the small subsystem microprocessor as it will be handling all peripherals of our experiment apparatus. The angle sensor and stepper motor combination will give great control over orientation of the object in testing. Another feature the main system will have is control over the heat lamp, either turning it on or turning it off. This will serve two purposes : the first ensuring that the specimen will not be overheated and the second being user control because we may not want it on 100% of the time after we have heated the specimen. The user interface will be another component of the main system and is described later in this document.

Operating Environment

The lab that we have chosen to conduct our experiments has no windows, this will become especially useful when we attempt to emulate the blackness of space. We will use a dark room to simulate space environment. The device is intended to be used within a lab scenario, so it is intended to operate in a dry environment close to room temperature. Although the sample may be heated well above room temperature, the apparatus itself will remain close to room temperature.

User Interface Description

The user interface covers the receiving and transmitting of data from and to the thermocouple, the stepper motor and also the heating lamp. For the receiving end, our interface covers from obtaining raw data from each sub-system and organizing it for easy readability. We also plan to make it easy for analyzing to plot graphs. For the transmitting end, we plan to have the user interface be able to control each sub-system with the click of a button.

We are weighing out on two options for applying our user interface on. One would be a small LCD

touch-screen module and the other would be programming an Android app
that communicates with the system via bluetooth. For the LCD touch-screen module, we would be able to program it using the manufacturer's software and make a graphical interface which would be easy to use by anyone. Our other option, the Android app, would also be graphically heavy for easy maneuverability and readability. Since we will be using it on a mobile device, bluetooth would be the best communication medium since it has stable signals. Our main concern when doing the user interface is to be able to connect or communicate with our system to have it work without many hiccups.

Functional Requirements

With our current setup, the functional requirements for our project would be the material needed to build our rotating stage. Since we are to measure the temperature of the meteorite on the stage, the material has to be a heat insulator to ensure the heat does not dissipate out of the meteorite in a short period of time.

Another functional requirement would be to have a heat lamp. The heat lamp acts as the sun for our small scale simulation which gives off heat and light.

Also, with a rotating stage, a wireless transmission between the thermocouple and our main microprocessor is a functional requirement because twisting wires would be a pain in the back.

Non-Functional Requirements

It is required that all our devices have our project logo. We will also give a name to our final product.

Market and Literature Survey

- Optical and Infrared Sensor Fusion for Hypervelocity Asteroid Intercept Guidance by Joshua Lyzhoft, Dalton Groath, and Bong Wie
    - In this paper, the team investigated the technical feasibility of a new guidance system which combines optical cameras and infrared sensors.
    - Before this, optical cameras were used for their cost-effectiveness but could only detect the side of the asteroid facing the sun due to the light reflection.
    - Having an infrared sensor, it would provide high speed image capture of the whole asteroid and with the data obtained, it will combine with the optical data to create a defined target for the guidance system to hit and have the asteroid disintegrate.
- Design and Characterization of Adaptive Microbolometers by Woo-Bin Song and Joseph J. Talghader
    - We researched mostly on finding a specific infrared sensor type that would fit our wavelength requirement and a microbolometer was the most suitable choice.
    - The wavelength characteristics of an asteroid ranges from 8.5um to 15.5um whereas the

range of detection of the microbolometer is approximately from 6um to 20um.
  - The great characteristic about the microbolometer is that it does not require a powerful cooling system to have it run optimally.
  - But our project requires a precise reading, we have considered putting a small cooling system on the sensor device to cross out any discrepancies in our readings.

Deliverables

We will have two deliverables by the end of our project over the two semesters. Our goal is to have one deliverable per semester. We have decided that our project can be clearly split into two major milestones; the first being completion of building our testing equipment, and second to run experiments. The first semester will entail completing large pieces of the hardware and showing that they work well and give accurate readings. Our first deliverable will be to show we have working hardware and that once we put the large pieces together, then our entire system will work.

The goal for the second semester will be to complete our apparatus by having both parts of the system on their final motherboards as well as installed into the actual experiment stage. That will be our first deliverable for the semester and should be done halfway through this second semester. The second and final deliverable will be the completion of our experiments with documentation of our parameters and images for the proof of concept of IR vs. Visual images.

Work Plan

Resource Requirements

The exact resources that we will need are still to be determined at the moment. We are splitting the work and doing research on how different pieces of the system will be created, therefore parts for electrical design have not yet been decided. Below is a list of resources for electrical design requirements:

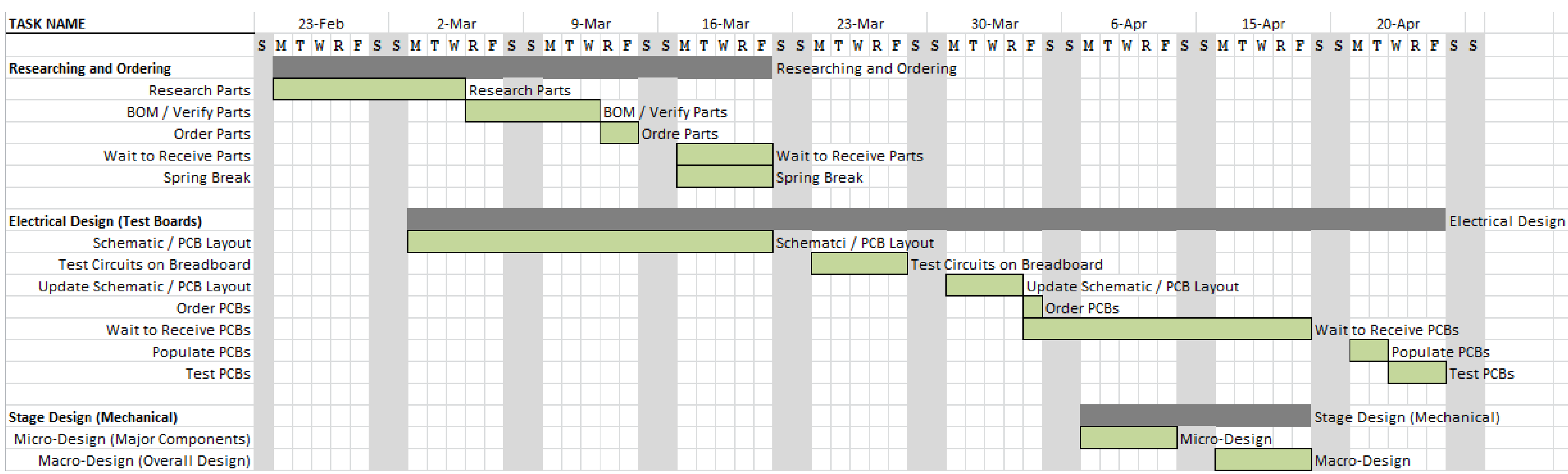
1) Printed Circuit Board (PCB) layout and schematic tools : National Instruments - Multisim and Ultiboard
2) PCB Fabrication House and Design Rules : Need to speak with Lee Harker
3) Build of Materials (BOM) : need to finish design

Below is a list of resources needed for mechanical design requirements:

1) 3D Modeling software: SolidWorks, Google Sketch, Autodesk Inventor
2) Source for stage construction materials : Josh Lyzhoft

Schedule

The schedule for the first semester is attached on the following page.


TASK NAME
23-Feb
2-Mar
9-Mar
16-Mar
23-Mar
30-Mar
6-Apr
15-Apr
20-Apr
Researching and Ordering
Research Parts
BOM / Verify Parts
Order Parts
Wait to Receive Parts
Spring Break
Electrical Design (Test Boards)
Schematic / PCB Layout
Test Circuits on Breadboard
Update Schematic / PCB Layout
Order PCBs
Wait to Receive PCBs
Populate PCBs
Test PCBs
Stage Design (Mechanical)
Micro-Design (Major Components)
Macro-Design (Overall Design)
Researching and Ordering
Research Parts
BOM / Verify Parts
Ordre Parts
Wait to Receive Parts
Spring Break
Electrical Design
Schematci / PCB Layout
Test Circuits on Breadboard
Update Schematic / PCB Layout
Order PCBs
Wait to Receive PCBs
Populate PCBs
Test PCBs
Stage Design (Mechanical)
Micro-Design
Macro-Design