NASA Solar Panel Design

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Design Document
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Contents

Executive Summary

Software based

Our project has a PLC that will be mounted on the inside and will control the operations needed in order to deploy the boom. This consists of a motor that will deploy and retract a scissor boom and a roll of solar cells. The PLC will also control multiple sensors and possibly a torque sensor. The PLC will also be able to interpret the signal it is sent that says weather we want the boom deployed, retracted or held in place in what we call a stop function. This PLC will be the only control center we need because it has the capability to control so much more than even what we need it for.

Hardware based

The hardware used on this design consists of a scissor boom that will give a steady support to the solar cells that we deploy. This design is very compact and will allow for the smallest amount of storage space while also giving us the greatest amount of extended reach when fully deployed.

Next we have the roll of solar cells that will be geared with the boom to ensure they deploy and retract at the same speed so we can lower the chance of damaging the solar cells once in space.

Now to tell the motor when to stop deploying or retracting we have two sensors that will be contact switches and these will make contact either when the boom is fully deployed or when the boom is fully retracted.

Next there is the torque sensor which will tell us if the motor is binding up anywhere and will allow us to stop the motor from continuing its operation and save the cells from damage. This sensor may be replaced with a controller at a future date due to the small size of a controller. The controller can measure the amount of current needed to operate the motor and if the current spikes then we know it is binding up somewhere. This option would also save us space and be more versatile.

Lastly we have the cube set which is the box in which all of these components are stored in during launch. This box is either going to be 10cm x 10cm x 10cm or 10cm x 20cm x 10cm, limiting the amount of room we have and the amount of ways we will be able to configure how components fit and will work together.

System Design

System Description

Our goal with this project was to be able to deploy a certain area of flexible solar panels with a system that would also be as compact and lightweight as possible when retracted. How we were to accomplish this was left entirely up to us.

We considered a few different types of designs, but ended up going with a scissor-jack type boom. Compared to other designs we looked at, it will allow the biggest change in size between its retracted and extended states. This is important since on a spacecraft, small size and low weight is always a plus, and with solar panels, having a large surface area is important since the more area exposed to the sun, the more power generated. We were initially told we would need to create a boom that could support between 4 and 9 square feet of solar panels, but that has now been reduced to 1 square foot. That goes along with a reduction in the area we have to store the boom in, but our design is flexible enough to work with that change.

The current design itself is visually and mechanically similar to a scissor lift jack that would be used in a warehouse or anywhere people or equipment need to be lifted or lowered. The number of "legs" we will use is currently unknown pending clarification on exactly how small we need to build the system, but since this type of design has such a big difference between its closed and extended size, we can be flexible with that in our design. Based on a physical prototype one of our group members built over a weekend and Solidworks simulations, we've found this type of design can have an extended length of over 5 times its compressed length. Corresponding to the bucket on the top of an industrial scissor jack, we have a lightweight bar that the flexible solar panel will be attached to, so that it is unrolled across the length of the boom and held at a fixed width. At the base we have the motor, screw and hinge that will connect the boom to the satellite. One leg on the end is fixed directly to the satellite with a hinge and the other is attached to a nut around the screw, so that as the screw turns it moved closer and farther from the other end, thereby enlarging or retracting the boom. There is also a cylinder at the base which will house the rolled up solar panel with the boom is retracted for safety during launch and while in flight.

The boom is only one aspect of the project however. We also had to design the controls for it. This involved even deciding whether or not we wanted to use analog or digital controls. After weighting the pros and cons of each, we decided on using a digital PLC due to its greater durability and flexibility. This means that we had to figure out how many inputs and outputs we would have on the system so that we could design the software needed to run the PLC. By making a truth table with all the possible outcomes and what should be done when they arise we've done just that, and now the boom can report its position and any errors to the computer while it's in use.

Being in space, this project has to deal with certain problems other terrestrial projects won't, namely extreme temperature and pressure swings, radiation, and a period of high G forces during launch. This makes the material selection very important. We've had to look at what will offer a good combination of light weight, durability, radiation hardness and ability to withstand temperature. This means using many materials only common in the aerospace industry including a type of slippery plastic called vespel and aluminum, as well as shielding the electronics.

All of these aspects have been carefully considered and weight against all the alternatives we could find. Our design won't be flown by NASA into space, but it will serve as a preliminary design for NASA engineers to work off of, so hopefully one day a satellite with parts of our design will be in orbit.

Operating Environment

In our project the team is faced with the task of designing and creating a circuit that will work in space. With that there are several considerations that need to be taken into account including: temperature, radiation, vacuum conditions, and debris.

For our project we are specifically working in Low Earth Orbit (LEO), which helps us to determine what kind of temperature range we are to expect. LEO is approximately 99 miles to 1,200 miles above the Earth's surface. To determine the temperature in LEO we must know the height at which we will be operating. Being that NASA would like to launch the CubeSat we are mounting our circuit into from the International Space Station (ISS) we expect the conditions our circuit will face would be similar to that of the ISS. It is known that the ISS maintains an orbit at an altitude between 205 miles and 270 miles above Earth's surface. According to NASA the ISS sun-facing side experiences a temperature of approximately 250 degrees Fahrenheit while the dark side experiences approximately -250 degrees Fahrenheit. Given NASA's information of the different temperatures the ISS experiences we can assume that we will face the same conditions. The given temperature range described above is the range for the outer surface of the ISS. This wide range of temperature is not feasible for today's electronic components so they must be protected from varying temperatures. We expect that our circuit will be protected or shielded inside the CubeSat from this great range of temperature thus reducing the range. It is still not know exactly what temperature range we can expect, so when considering parts we must select the most temperature-durable parts for a long lasting system.

Our second consideration is radiation. Being that LEO is not protected by the Earth's atmosphere the radiation from space can directly affect our electronic components. Radiation is an important factor, because over time it will degrade electronic components ultimately causing failure. An example of a failure may just be our programmable logic controller (PLC) sending a 1 instead of a 0 which can be very detrimental to our system, because it will no longer function as needed. Radiation in LEO is dependent on the orbital inclination around the earth. At low inclinations (I < 28 degrees) a typical dose rate would be from 100-1000 rad (Si)/year. In a high inclination (20 < I < 85) the typical dose rate can be from 1000-10,000 rad (Si)/year. It can be seen that inclination is an important factor in determining the amount of radiation to expect. It is known that the ISS has an orbital inclination of about 51.65 degrees thus for our circuit we can expect radiation in the high inclination range. Fixing components in space is cumbersome and comes at extreme costs, so we must select components that will not require constant maintenance due to radiation. To overcome this radiation challenge we plan to select Rad Hard components with the desired radiation tolerance as well as the circuit being protected by the outer shell of the CubeSat.

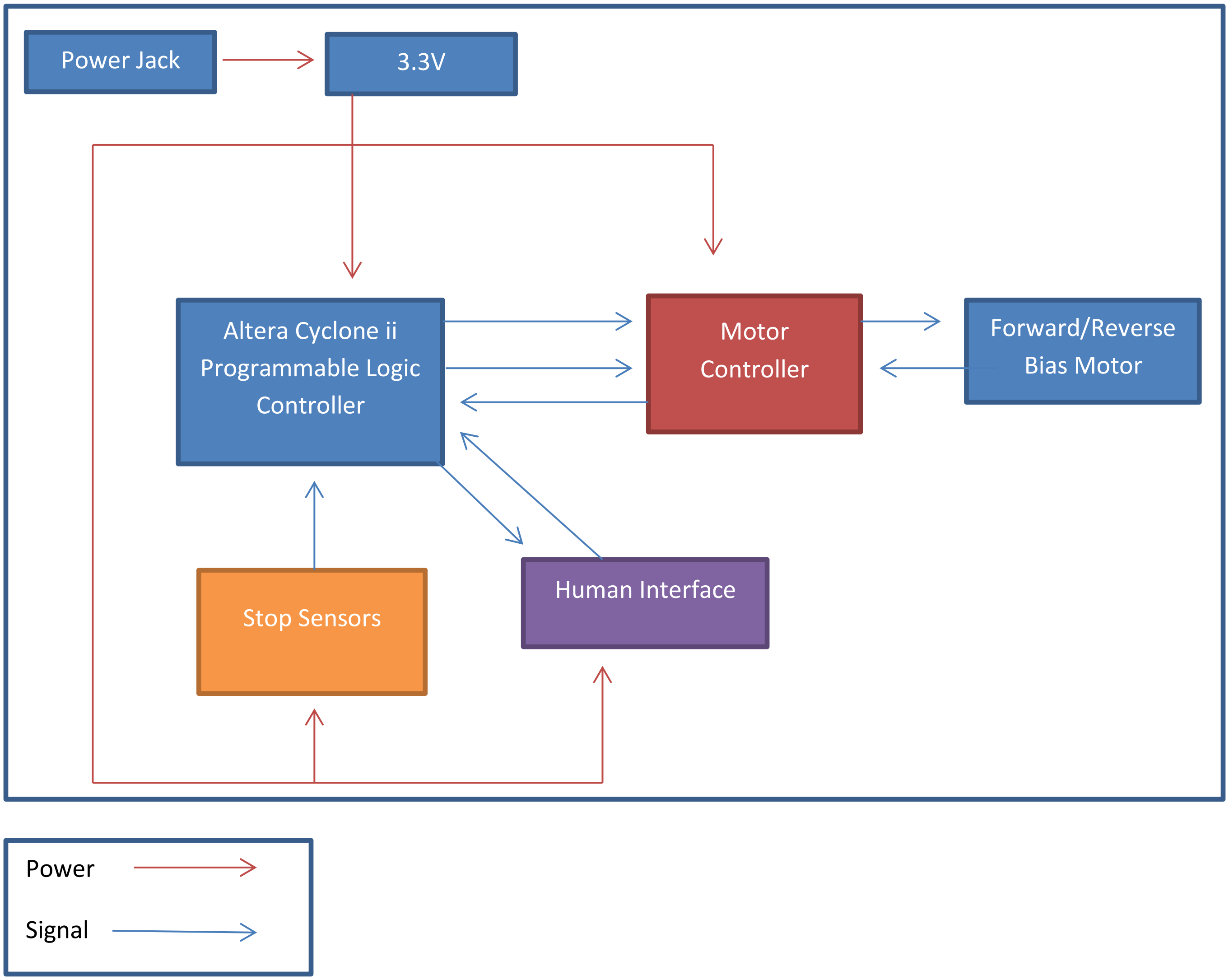
Another consideration of ours is the vacuum conditions of space. Vacuum in space is a condition well below normal atmospheric pressure where pressure is being measured in pressure units (Pascal). At sea level pressure is 101 kilopascals (kPa) and the atmospheric pressure in LEO is known to be about 10^-8 Pa. Though pressure is significantly lower in LEO as compared to Earth there is still some orbital decay due to atmospheric drag. In our project it is not our task to counteract this orbital decay; however, it is our task to keep our circuit intact while in orbit. Due to this low pressure it is possible our components can detach over time, so we have decided to use a PLC with surface mount components to prevent loss of components.

Our last consideration is debris. This, again, is not a challenge that we are tasked to address, but we must at least consider it. Debris in space can either be natural or man-made. Natural debris can be in the form of meteoroids whereas man-made may be shrapnel from previous collisions. It is expected that NASA will provide protection for our circuit from any sort of space debris when retracted. Unfortunately our system cannot be protected at all times such as when it is deployed. It is planned to implement fail-safes into our circuitry to work out any malfunctions of the system due to debris.

When designing a circuit for space conditions there are many considerations that we do not face on a daily basis. Temperature and radiation are the two major considerations in designing a circuit for space, because either of these will degrade the circuitry. The two lesser considerations of vacuum conditions and debris are still important, because parts can either float off into space or collide with debris damaging the point of impact. In space there is far less room for error demanding a robust and reliable system that can overcome these atypical constraints.

Detailed Design

Hardware Specification

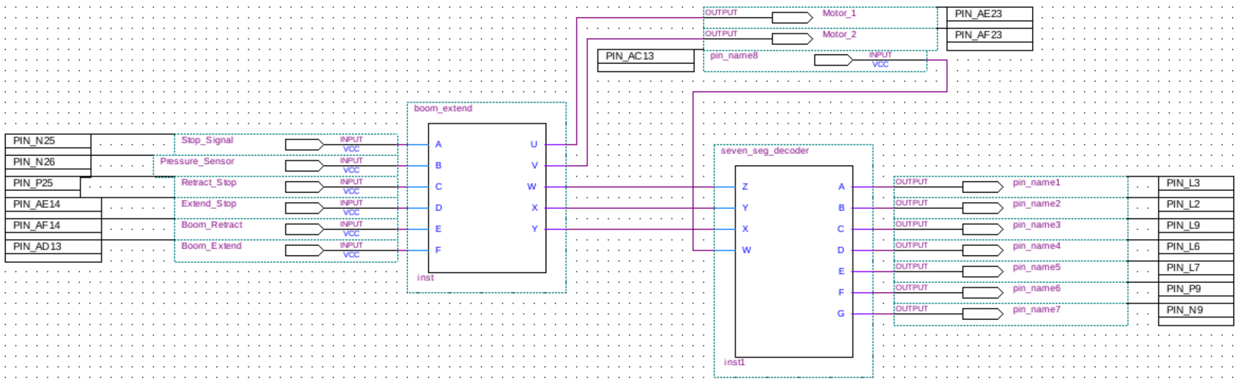


Programmable Logic Controller

For our design we are using an Altera Cyclone II Programmable Logic Controller. This PLC can simulate a wide array of logic systems but uses solid state components instead of relying on several physical logic gates. Overall all this will increase the reliability of the system and allows minor changes to several systems to occur without changing the building process. In our system the PLC will:

- Conduct all of the logic processes
- Accept inputs from sensors to determine the state of the system
- Send/Receive information to the end user to make further decisions
- Send start/stop signal to the motor controller

This acts as the main controller for the entire system. All inputs and outputs are run through our PLC for processing before being sent to another part of the system. This ensures that the entire system is acting in unison and nothing is being over looked. The PLC has been programed to the specifications as outlined below.




```
module boom_extend (A,B,C,D,E,F,U,V,W,X,Y);
input A,B,C,D,E,F;
output U,V,W,X,Y;
        assign U = (~A&~B&~D&~E&F);
        assign V = (~A&~B&~C&E&~F);
        assign W = (B);
        assign X = (~A&((~B&(F&((~C&~E)|(D&E))|(C&(~D|~F))))|(B&(C|D|(E&~F)))));
        assign Y = ~A&((~B&((C&(E|F))|(E&~F)|(~C&D&F)))|(B&(C|D|(~E&F))));
endmodule
```

```
module seven_seg_decoder (A,B,C,D,E,F,G,Z,Y,X,W);
input Z,Y,X,W;
output A,B,C,D,E,F,G;
        assign A=((~Z&~Y&~X&W)|(~Z&Y&~X&~W)|(Z&~Y&X&W)|(Z&Y&~X&W));
        assign B=((~Z&Y&~X&W)|(~Z&Y&X&~W)|(Z&~Y&X&W)|(Z&Y&~X&~W)|(Z&Y&X&~W)|(Z&Y&X&W));
        assign C=((~Z&~Y&X&~W)|(Z&Y&~X&~W)|(Z&Y&X&~W)|(Z&Y&X&W));
        assign D=((~Z&~Y&~X&W)|(~Z&Y&~X&~W)|(~Z&Y&X&W)|(Z&~Y&X&~W)|(Z&Y&X&W)|(Z&~Y&X&~W));
        assign E=((~Z&~Y&~X&W)|(~Z&~Y&X&W)|(~Z&Y&~X&~W)|(~Z&Y&~X&W)|(~Z&Y&X&W)|(Z&~Y&~X&W));
        assign F=((~Z&~Y&~X&W)|(~Z&~Y&X&~W)|(~Z&~Y&X&W)|(~Z&Y&X&W)|(Z&Y&~X&W));
        assign G=((~Z&~Y&~X&~W)|(~Z&~Y&~X&W)|(~Z&Y&X&W)|(Z&Y&~X&~W));
endmodule
```

Motor Controller

The motor controller has been added to the system to allow the motor the appropriate voltage needed to power the boom while still being able to accept 3.3V signals from the PLC. This also allows a secondary system to interpret the torque sensor from the motor before that information is sent to the PLC. The motor controller is programed to send a single once the torque goes outside set bounds. The torque sensor is built into the motor controller which adds an additional layer of protection. The activation of this sensor will automatically send a stop signal to the motor and sends a warning signal that over torque to the end user through the human interface.

Forward/Reverse Bias Motor

For our system we are using a forward and reverse bias electric motor capable of at least 30 inch-pounds of torque. This will give sufficient power to extend and reverse the boom in the near-zero gravity environment. We have also included a buffer zone of 50% torque to ensure the motor will have sufficient torque. The motor chosen must also lock in place when power is not applied. This will decrease the power consumption of the system and ensure the boom stays in the extended or retracted position.

Human Interface

The human interface portion of our system consists of five 7-segment LCD displays and five 2-position switches. Three of the 7-segment displays will relay the torque values in inch-pounds back to the end user while the other two displays relay position information. The position information values will correspond to a set table of values where each value corresponds to different situations as shown below. All of these components are powered off of the 3.3V power supply.

Displayed Value	Meaning
01	Clear, ready for command
02	Boom is retracting normally
03	Boom is extending normally
04	Boom stop has been activated-manual stop set
05	Torque stop has been activated-movement ceased
06	Torque stop has been activated during retraction-movement ceased
07	Torque stop has been activated during extension-movement ceased
08	Torque stop & boom stop both activated
09	Boom Extension OverRide has been activated-boom extending
10	Boom Retraction OverRide has been activated-boom retracting
11	Receiving Signal to both Extend and Retract-boom movement ceased
12	Multiple Contracting Signals-Movement ceased

Stop Sensors

At each end of the screw that moves the boom there are contact sensors. When the boom reaches these sensors a signal is sent to the PLC that stops the motors and sends this information back to the end user through the human interface. These normally open contacts close then activated sending a 3.3V signal.

Node Name	Direction	Location	I/O Bank	Fitter Location	I/O Status	Current Strength
Boom Extend	Input	PIN_AD13	8	PIN_AD13	3.3 V	24mA
Boom Retract	Input	PIN_AF14	7	PIN_AF14	3.3 V	24Ma
Motor Forward	Output	PIN_AE23	7	PIN_AE23	3.3 V	24mA
Motor Reverse	Output	PIN_AF23	7	PIN_AF23	3.3 V	24mA
Pressure Sensor	Input	PIN_N26	5	PIN_N26	3.3 V	24mA

Stop Signal	Input	PIN_N25	5	PIN_N25	3.3 V	24mA
Retract Stop	Input	PIN_P25	6	PIN_P25	3.3 V	24mA
Extend Stop	Input	PIN_AE14	7	PIN_AE14	3.3 V	24mA
LCD_1	Output	PIN_L3	2	PIN_L3	3.3 V	24mA
LCD_2	Output	PIN_L2	2	PIN_L2	3.3 V	24mA
LCD_3	Output	PIN_L9	2	PIN_L9	3.3 V	24mA
LCD_4	Output	PIN_L6	2	PIN_L6	3.3 V	24mA
LCD_5	Output	PIN_L7	2	PIN_L7	3.3 V	24mA
LCD_6	Output	PIN_P9	2	PIN_P9	3.3 V	24mA
LCD_7	Output	PIN_N9	2	PIN_N9	3.3 V	24mA

Software Specification

We will be using a PLC to operate all controls in the design. The PLC will be programmed with Altera Quartus II software, using code written in Verilog. A signal will be received from the operator, then interpreted by the PLC, which will execute the command while monitoring for problems.

Basic Operations:

PLC

- The system must be able to receive a deployment signal from the operator.
- The system must be able to interpret the received extension signal.
- The system must be able to execute the deployment command.
- The system must be able to receive an error for excessive boom tension, indicating a problem with deployment.
- The system must be able to automatically stop deployment at full extension.
- The system must be able to return a signal that the boom successfully extended.
- The system must be able to receive a retraction signal from the operator.
- The system must be able to interpret the received retraction signal.
- The system must be able to execute the retraction command.
- The system must be able to receive an error for excessive boom tension, indicating a problem with retraction.
- The system must be able to automatically stop retraction at full retraction.
- The system must be able to return a signal that the boom successfully retracted.
- The system must be able to receive a stop signal to interrupt deployment or retraction during any step of command execution.

Note: The communication between the base station (operator) and the satellite will be taken care of by NASA.

We will be using a motor controller to determine the torque which the motor is exerting on the shaft during operation. By using our knowledge from classes, we know that the harder a motor is working, the electric potential across the input terminals will decrease and the current draw will increase. By monitoring these values in comparison to predetermined threshold values, we can monitor for torque and locked rotor conditions.

Motor Control Circuit

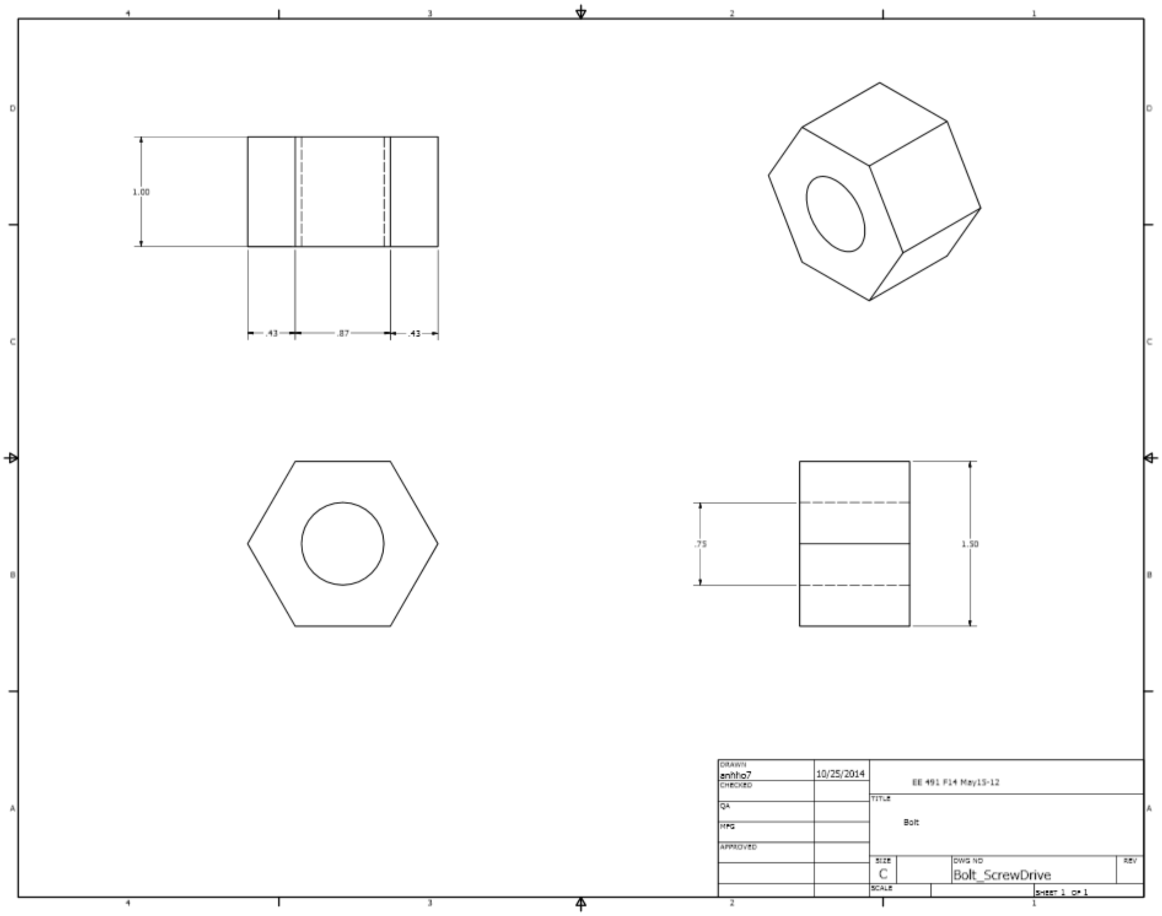
- The system should be able to measure current draw.
- The system should be able to measure electric potential.
- The system should be able to decide which threshold range the values fall into.
- The system should be able to determine what needs to be done within that threshold range.
- The system should be able to return a decision to the PLC.
- The system should be able to constantly iterate these checks and evaluations during boom operation.

Based on the requirements for this motor control circuit, we will most likely need to use a microcontroller to carry out these operations.

Boom Design

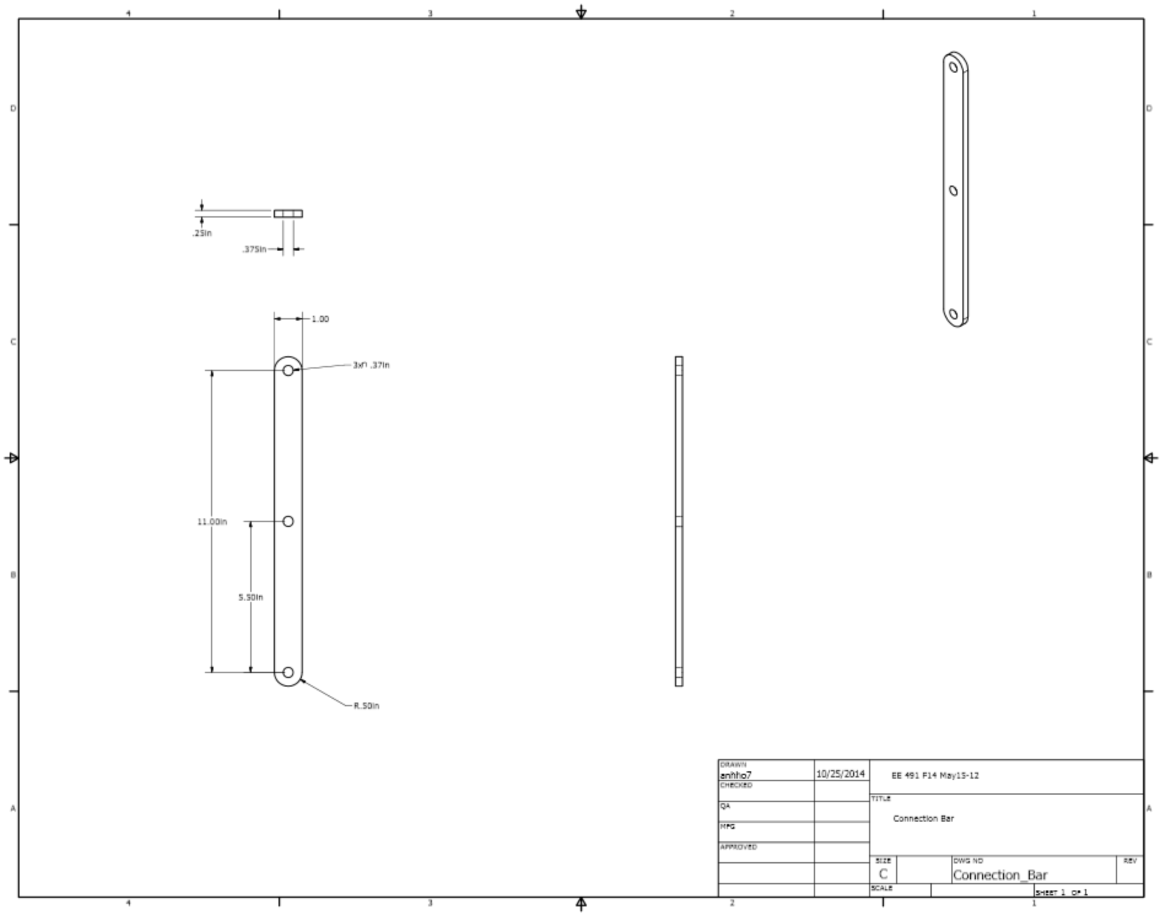
The solar panels will be supported by a scissor type boom. When retracted the boom will fit completely inside of the cube satellite. The individual parts of the boom will be built as shown below.

Bolt Screw



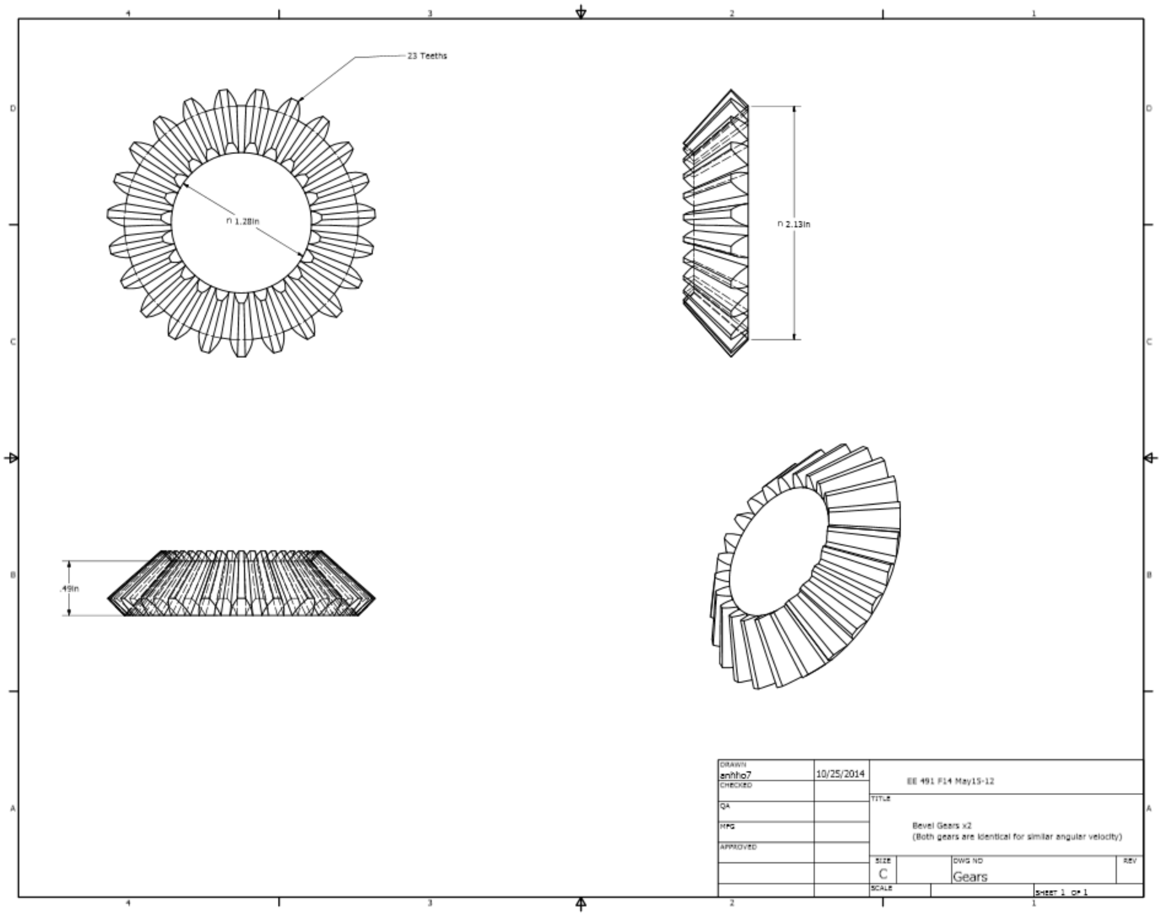
Nut: This piece will move the floating end of the boom for extension and retraction.

Connection Bar



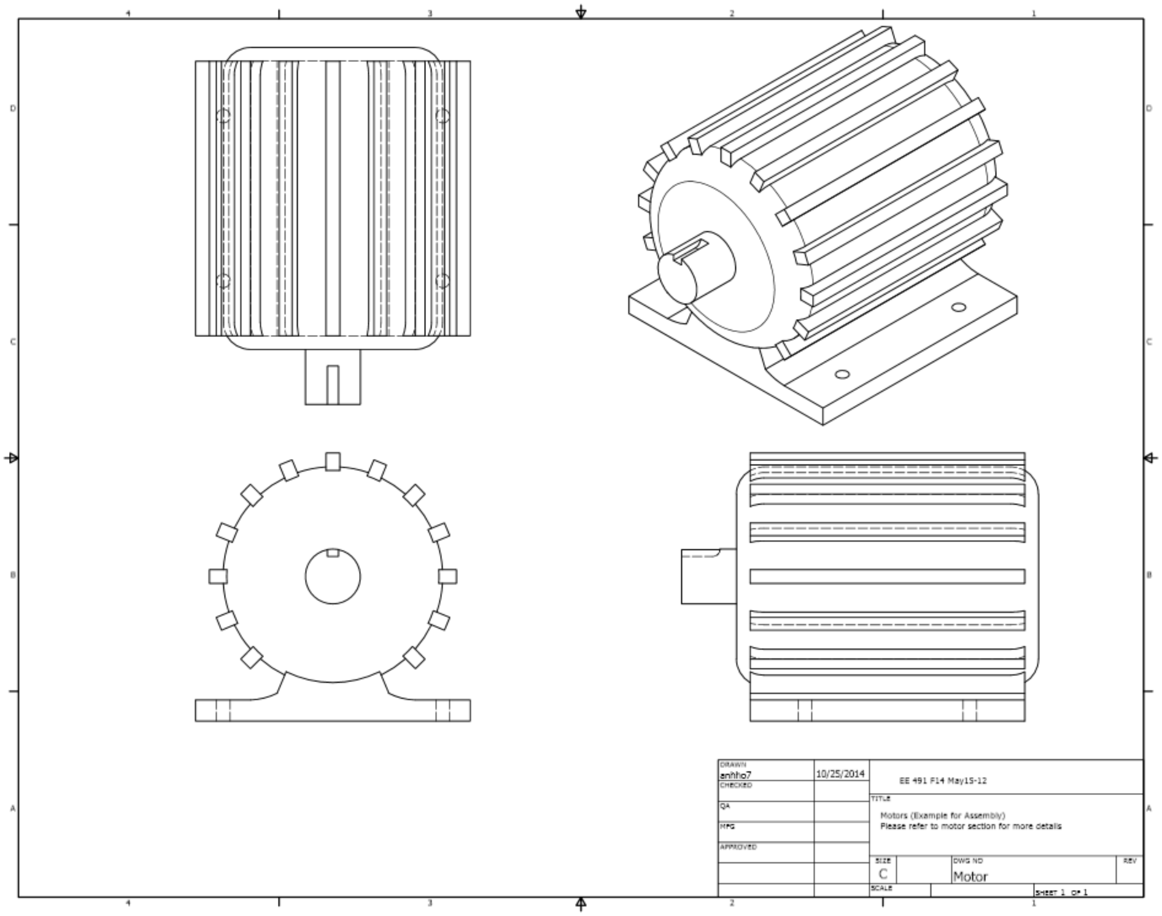
Boom Arms: This piece makes up the boom structure. These pieces will be used in multiples of two to achieve the desired length of the boom.

Gears



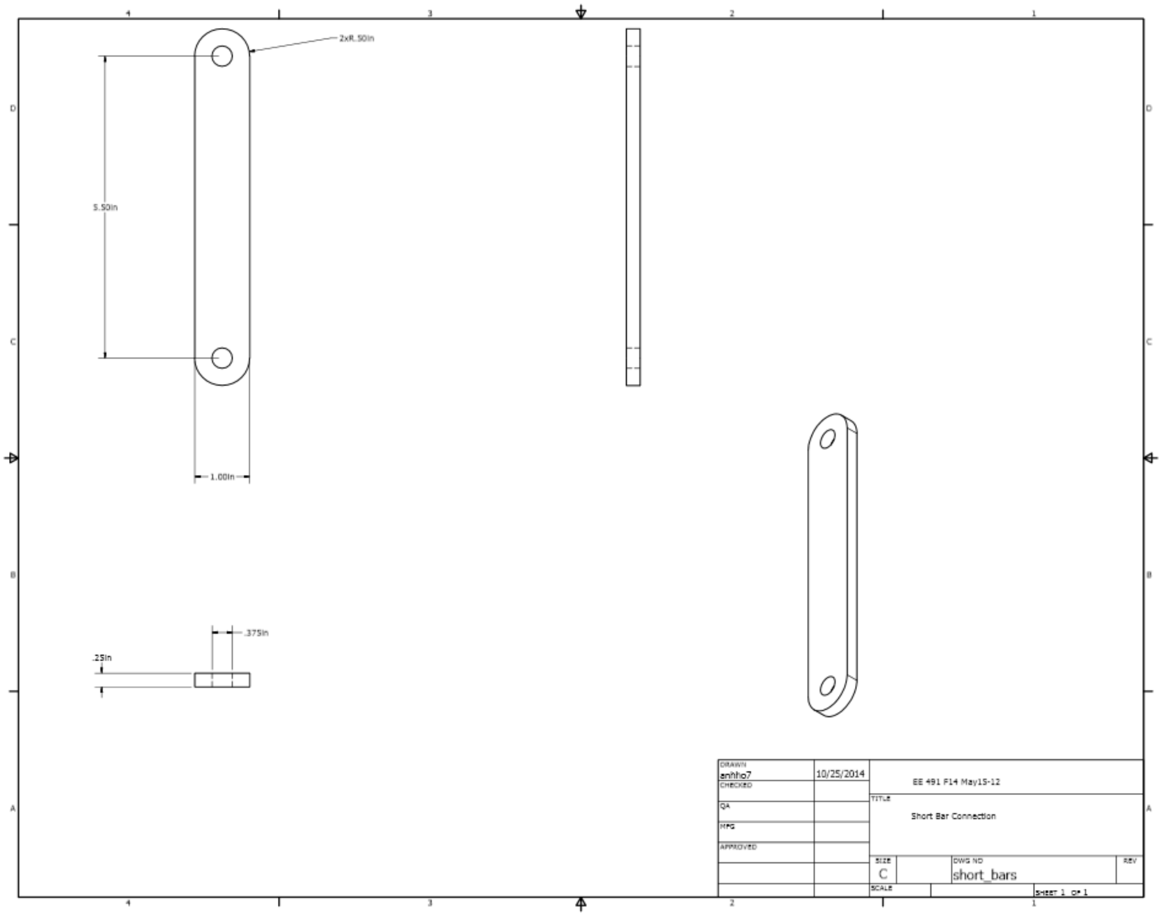
Gears: The gears are responsible for coupling the drive motor to the extension / retraction shaft. By selecting the proper number of teeth for the gears, we can change the rate of deployment and retraction, as well as the mechanical advantage achieved, thus reducing the torque required by the motor.

Motor



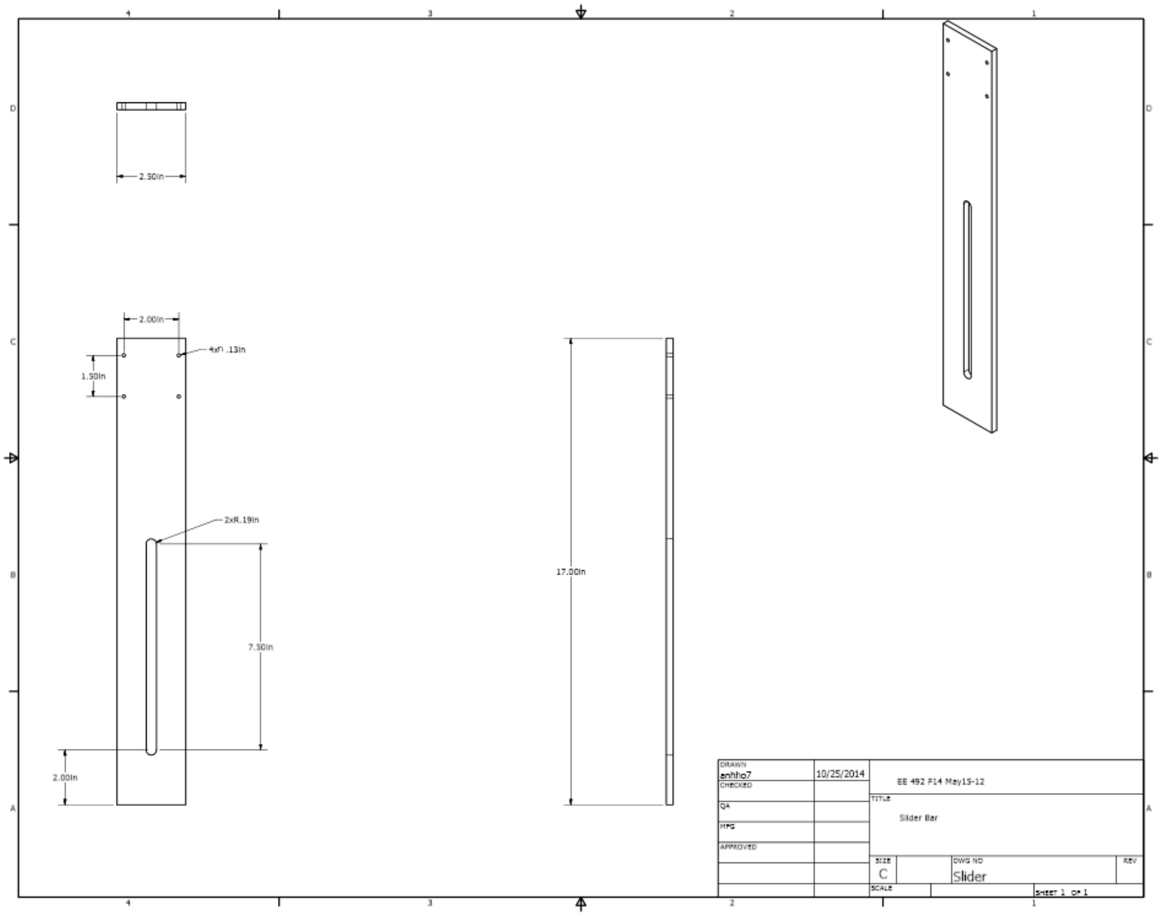
Motor: The motor is responsible for driving the extension / retraction shaft. The proper motor needs to be selected to give us enough torque to deploy the boom.

Short Arms



Half Boom Arms: Depending on the outcome of final testing, we may need to use short arms for the termination point of the boom.

Slider

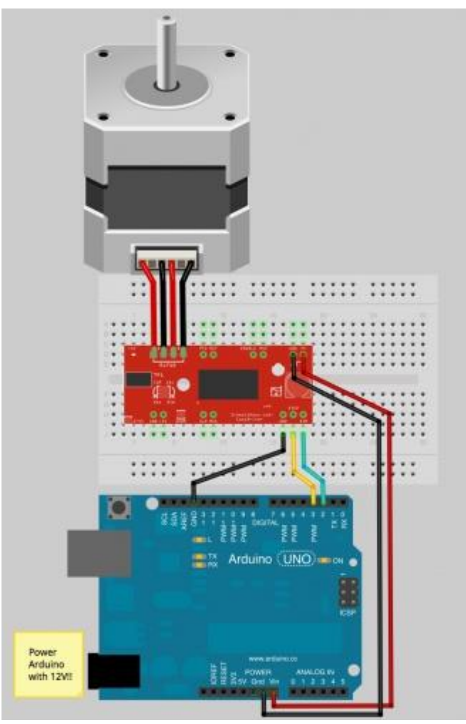


Slide Plate: The slide plate is responsible for guiding the extension and retraction of the boom, as well as removing unnecessary stress on the drive shaft and motor.

Interface

For the interface between our Arduino PLC and our motor that will be turning the screw that extends our boom we will be using a motor driver to help improve our programs abilities. For our motor driver we chose a high-power motor driver which uses a discrete mosfet H-bridge designed to drive large DC brushed motors. The H-bridge uses one N-channel mosfet per leg and these mosfets determine the board's performance. For the model we picked the mosfet's have an absolute maximum voltage rating of 40V and can deliver up to 23A of continuous current with a board size of only 1.8" by 1.2" and no required heat sink. Since optimization of size is very important for our design this driver works perfect.

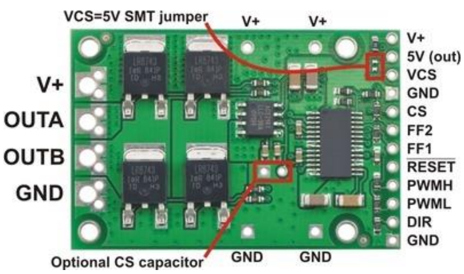
The module offers a simple interface that requires two I/O lines while allowing for both sign-magnitude, locked-antiphase operation, and coasting. Some of its available applications are motor control, load detection and management, switch-mode power supplies, and overcurrent fault protection. This board also features a current-sensing circuit that measures bidirectional motor current with a magnitude up to 30 amperes and outputs an analog voltage. This feature was of grave importance to us since we will be using this as our work around for torque sensors as they were very expensive or impossible to find in motors of our caliber. Also integrated into the circuit is detection of various short-circuit conditions and failure protection which are shown in the table.



Connections

The motor and motor power connections are on the left side of the board, and the control connections are on the ride side. The motor supply will need to be capable of the high current the motor will require. To limit noise we will need to install a capacitor between V+ and ground close to the motor driver. With the two axial capacitors that are included with the driver will be installed by soldering them into the V+ and GND pins along the top and bottom of board. There are two options for connecting to the high-power signals (V+, OUTA, OUTB, GND) but we will use the pairs of 0.1"-spaced holes that can be used with breadboards, and 0.1" connectors.

The logic connections are designed to interface with 5V systems, with a minimum high input signal threshold of 3.5 V. In our configuration, only PWML isn't of worry because we do not need to use coasting but this may change. The two fault flag pins FF1 and FF2 can be monitored to detect problems and will be used for unsafe shutdowns through our program. The RESET pin is pulled up to V+ through a 20 kΩ resistor so when it's held low, it puts the driver into a low-power mode and clears any stuck fault flags. The V+ pin on the logic side of the board gives you access to monitor the motor's power supply or pass it on to low-current devices. The board also provides a regulated 5V pin which can provide a few milliamps which we will short to VCS to power the current sensor. When the current sensor is powered by applying 5 V to VCS, the CS pin outputs 66 mV/A for currents between -30 and 30 A centered at 2.5 V.



PIN	Default State	Description
V+		This is the main 5.5 – 40 V (absolute max) motor power supply connection, which should typically be made to the larger V+ pad. The smaller V+ pads along the long side of the board are intended for power supply capacitors, and the smaller V+ pad on the logic side of the board gives you access to monitor the motor's power supply (it should not be used for high current).
5V (out)		This regulated 5V **output** provides a few milliamps. It can be shorted to VCS to power the current sensor. This output should not be connected to other external power supply lines. **Be careful not to accidentally short this pin to the neighboring V+ pin while power is being supplied** as doing so will instantly destroy the board!
VCS		Connect 5 V to this pin to power the current sensor.
GND		Ground connection for logic and motor power supplies.
CS		ACS714 current sensor output (66 mV/A centered at 2.5 V).
OUTA		A motor output pin.
OUTB		B motor output pin.
PWMH	LOW	Pulse width modulation input: a PWM signal on this pin corresponds to a PWM output on the motor outputs.
PWML	HIGH	Control input that enables coasting when both PWML and PWMH are low. See the "motor control options" section below for more information.
DIR	LOW	Direction input: when DIR is high current will flow from OUTA to OUTB, when it is low current will flow from OUTB to OUTA.
RESET	HIGH	The RESET pin is pulled up to V+ through a 20 kΩ resistor. When held low, it puts the driver into a low-power sleep mode and clears any latched fault flags.
FF1	LOW	Fault flag 1 indicator: FF1 goes high when certain faults have occurred. See table below for details.
FF2	LOW	Fault flag 2 indicator: FF2 goes high when certain faults have occurred. See table below for details.

Materials

Material Selection

A designing process of materials' physical properties.

The main objective of design is to produce an effective, safe product at an acceptable cost. Materials are selected by satisfactorily achieving a range of individual properties. More often, however, materials are selection involves seeking the best materials that are able to achieve multiple constraints.

Methodology

- Translate design requirements into materials specifications. There should be a vast consideration in the design objective, constraints, and free variables.
- Screening out materials that do not meet the criteria.
- Rank materials by their abilities to meet the objectives (Material Indices).
- Determine supporting information for the material candidates.
- Use Ashby chart to for selection.

Defining Design Requirements

- What does the component do?
    - Any engineering component has one or more objectives
- What are the objectives?
    - Designers have certain goals to make the products feasible, light or high safety standards.
- What are the requirements?
    - Objective must be achieved subjected to fixed variables.
- What is the designer free to change?
    - Free variables?

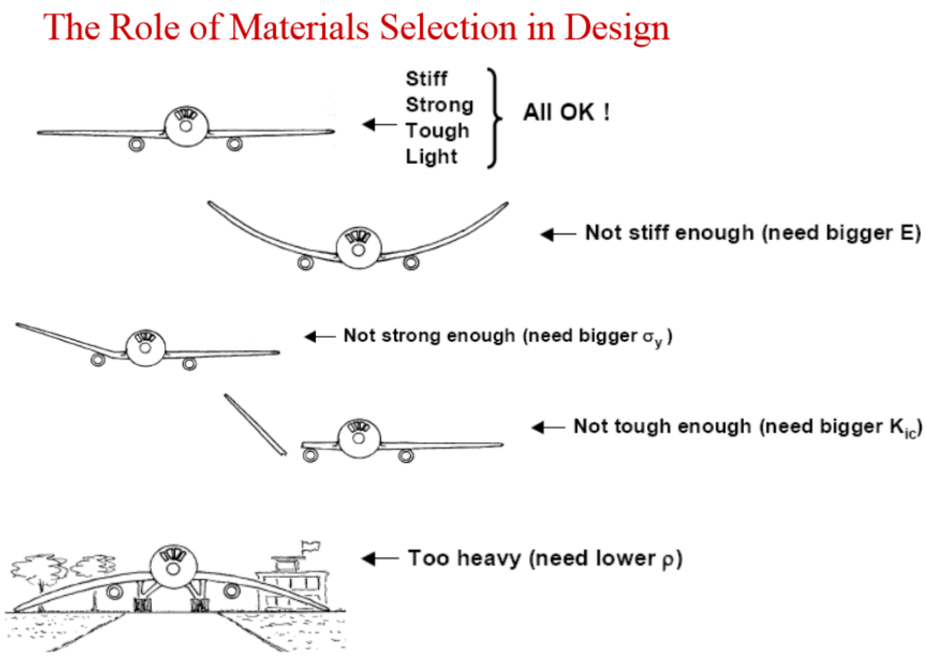


Figure 1 - Ashby - Materials Selection in Mechanical Design (2004)

Figure 1 shows the behavior of the product when certain objectives are not met.

In the case of this project, the main objective is to have a boom to hold solar panels outside of Earth's atmosphere.

The following is research and found from the Course PH 508 Department of Astronomy, University of Kent

Spacecraft structures:

- Minimize mass without compromising reliability.
- Must support itself and its loads through all phases of the mission.
- Environmental protection

Some Suggested Materials – Beryllium, Titanium, Magnesium, Aluminum,

- Beryllium – Stiffest, low density, high specific strength, high temperature tolerance, expensive and difficult to work.
- Titanium – Lightweight with high specific strength, stiff, high temperature capability, less ductile, lower availability.
- Magnesium – High stiffness, good specific strength, workable, but chemically active.

- Aluminum – Low density, good specific strength, easily workable, cheap and widely available, but has low melting point (933K)
- Tungsten - Highest melting point besides diamond.

Thus, component must be lightweight, low thermal coefficient; high specific strength, fracture tough ness and stiffness and the ability to withstand UV radiation and outgassing.

Some Material Properties that are used in this project. Since there is a maximize funding for the project, materials have to be low costs.

Mechanical

- Tensile Strength – Maximum stress that a material can withstand before failing or breaking.
- Specific Strength – Materials tensile strength divided by its density.
- Yield Strength – Stress at which material begins to deform.
- Fracture Toughness – Ability of a material containing a crack to resist fracture.
- Young's Modulus – Stiffness of an elastic material and is a quantity used to characterize materials.

Physical/Thermal/Chemical

- Density – Property to determine the weight of the material. Mass per unit volume.
- Thermal Expansion – Tendency of materials to change through heat transfer (temperature).
- UV Radiation – Due to materials being in vacuum.
- Outgassing – Due to materials being in vacuum.

General

- Cost

The following Ashby charts are generated by CES Edupack 2013 to finalize product design and compares between aluminum, steel, tungsten, and titanium.

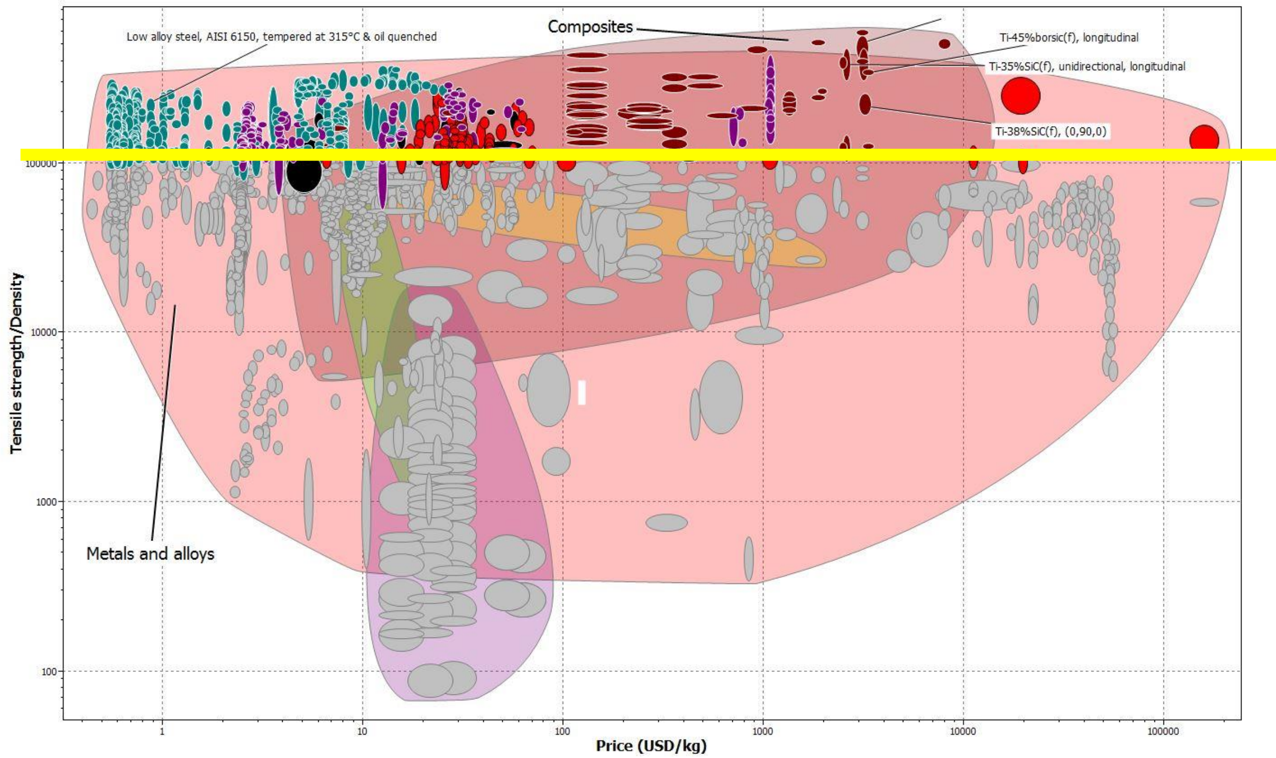


Figure 2 - Cost comparison of the four materials.

The above figure shows that specific strength of each metals are way above 2 MPa of strength, but in comparison with cost Titanium and tungsten are in the hundreds of dollars/kg range, thus way out of the cost constraint for the project.

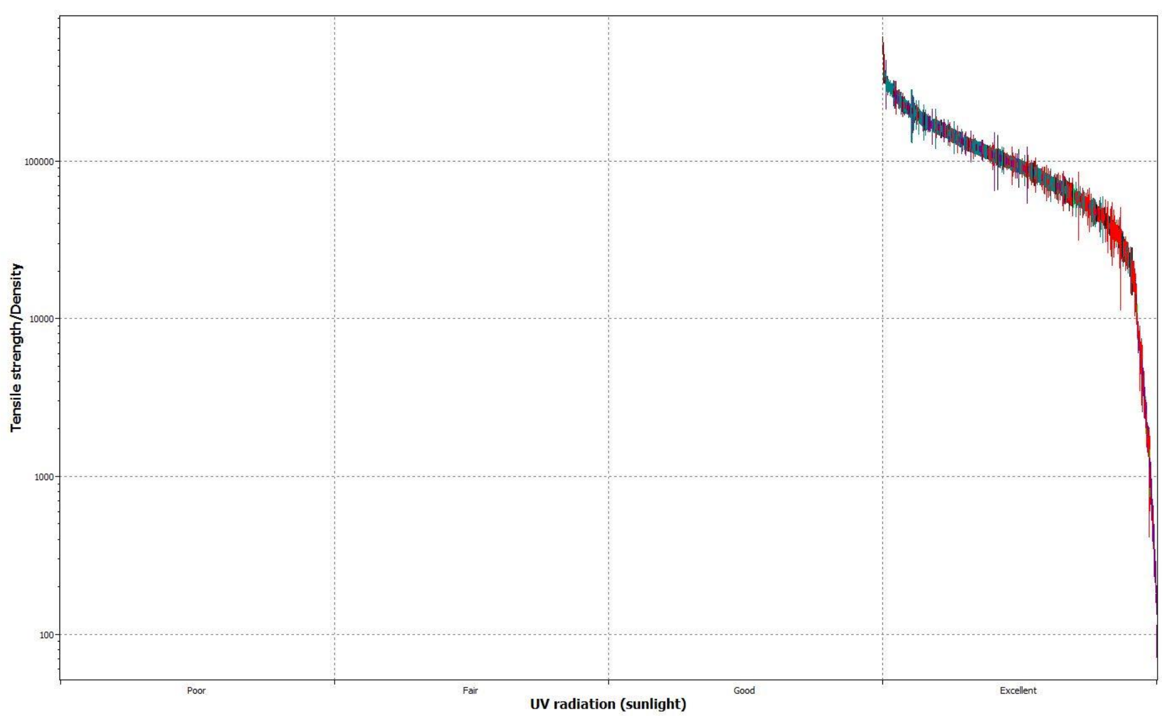


Figure 3 - UV radiation comparison.

Figure 3 shows that most metals are in the excellent range when compare between specific strength and the reliability in atmosphere when dealing with radiation.

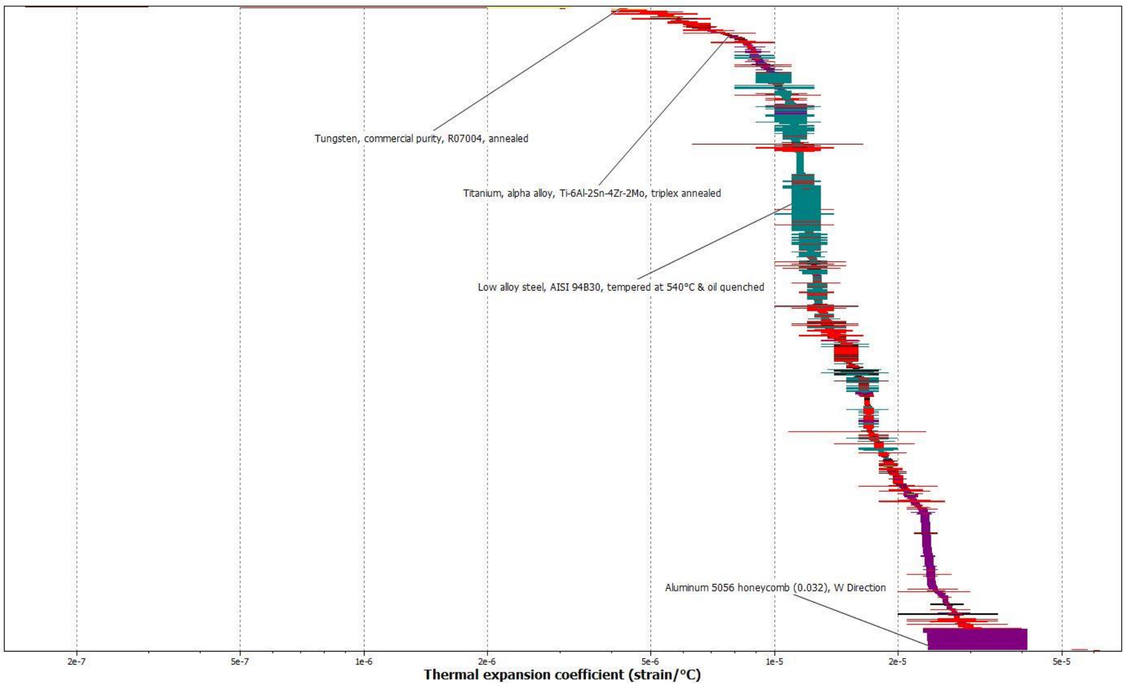


Figure 4 - Thermal coefficient comparison.

As can be seen it is correct that titanium and tungsten have a much higher thermal resistance than both steel and aluminum.

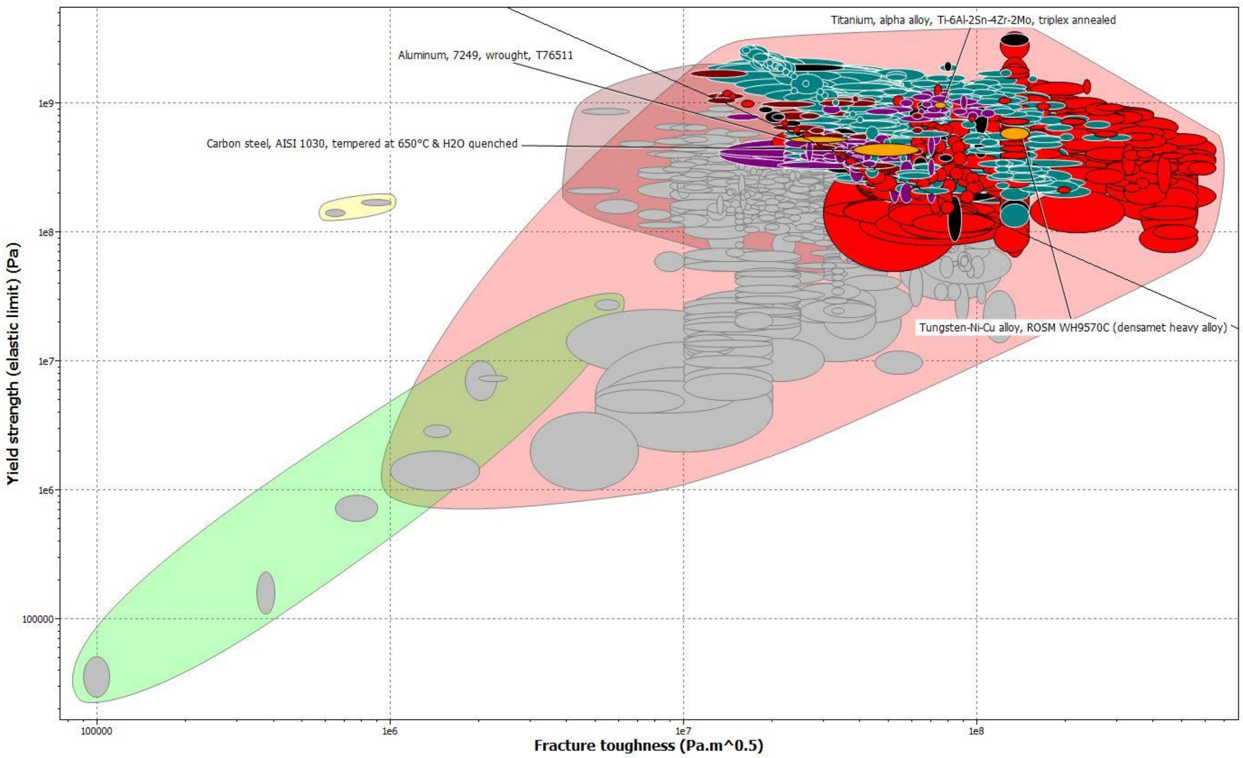


Figure 5 - Stiffness and Fracture toughness.

This graph also shows that all four materials are in the high range of stiffness and fracture toughness.

It would be a great idea to use the best materials for the space expedition, but with small amount of money compare to what NASA use for their project; it would be very difficult to get such materials. Also, the materials that are suggested from University of Kent, they are low availability, and would need a certain machine to work with. Thus, this selection process is to find an (almost) the best material that can at least withstand the environmental condition in the area of Ames, IA.

Schedules

These are the following due dates that we have chosen for major steps in our senior design project.

Due Date	Tasks	Team Assignment
Oct-5-14	**Wired filters or PLC**	
	Design Simplicity	Luke/Dustin
	Size(mass)	Luke/Dustin
	Cost	Tom/Isaac
	Reliability	Tom/Isaac
	Fabrication	Antjuan/Ryan/Anh
	Implementation	Antjuan/Ryan/Anh
	Testing	Antjuan/Ryan/Anh
Oct-31-14	**Circuit Outline/Improvements**	Team
Nov-14-14	**Final Circuit Completion**	Team
	Material Selections	Anh
	Bill of Materials (BOM)	Team
Nov-20-14	**Material Ordering**	Team
Dec-12-14	**Draft Design and BOM send to NASA**	Team
Jan-30-15	**Circuit Assembled**	Team
Feb-6-15	**On surface Testing**	Team
Feb-20-15	**Testing Completion**	Team
	Ship Circuit to NASA	Team
	Boom Design	Team