CUBESAT SOLAR PANELS

May15-12

Client: John Carr, NASA

Advisor: Gary Tuttle

PRELIMINARY PROBLEM STATEMENT

Our group is tasked with designing and implementing a deployable and retractable boom that fits inside a 1 cubic foot satellite used to deploy and retract a solar cell array with a minimum area of $9ft^2$.

PRELIMINARY DESIGNS-SCISSOR JACK

- Size Constraint
  - $1ft^3$ cube
  - $9ft^2$ solar panels
- Scissor Design
  - Motor
    - 3 ft-lb
    - 2 phase motor deploy and retract
    - Stepper motor
  - Power Transmission
    - Screw drive

PROBLEM STATEMENT

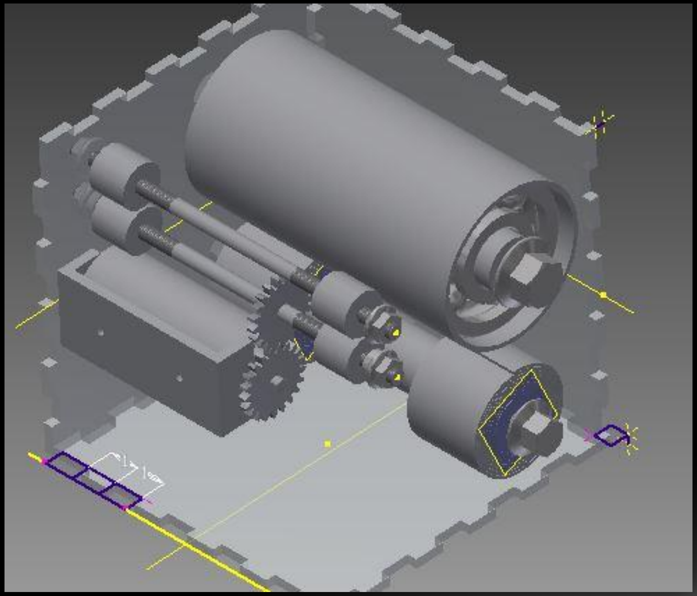
Our group is tasked with designing and implementing a repeatedly deployable and retractable solar cell system that is to be launched into Low Earth Orbit. The system must fit within a 1U CubeSat (10cm x 10cm x 10cm satellite). Flexible solar arrays shall be used that have a minimum bend radius of 2.5cm and must cover at least $3720cm^2$.

PRELIMINARY DESIGNS-FAN

- One dual phase motor
- Multiple servo motors
- Difficult to reach 4 ft^2 solar panels
- Gear Drive
  - At pivot point - 360° rotation
  - One to unfold – achieve more than 1 foot radius
- The Area of this method will never achieve 100% full of solar cells
  - 25mm bending radius
  - $A_{cell,min}$ = 1cm x 1cm $A = \pi R^2$
- Solar Panel Calculation. $R = \frac{4ft^2}{\pi}$

PRELIMINARY DESIGN-TAPE MEASURE

- Size Constraint
  - 1000cm^3 cube-sat
  - 4-9ft^2 solar panels



- Measure tape technique
  - Motor
    - 100+ oz-inch
    - Brushed motor
    - Single phase motor deploy
    - Continuous
  - Power Transmission
    - Spur Gears deploy
    - Retract – spiral coil

FINAL DESIGN DECISION

Design		# Mechanical Components	Size	Solar Area	Motor Torque Require	Prototype cost	Final Grade
1	Fan	Low	1	Limited	High	Medium	11
2	Scissor	Medium	1	Neutral	High	Low	13
3	Tape	High	2	Neutral	Low	Medium	14

Color Code Grading
1
3
5

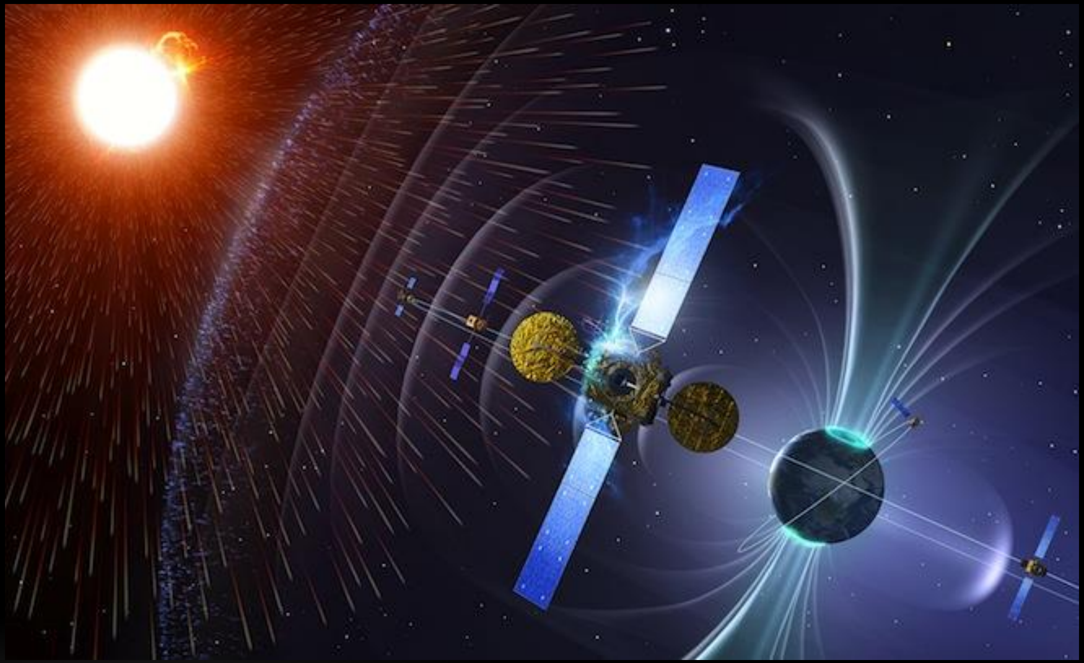
Size Chart	
1	Restricted Size
2	Linient

FUNCTIONAL REQUIREMENTS

- Repeatable operation
- Low power consumption
- Structural rigidity when extended
- Physical Limitations of Materials
- Receive and interpret the signal
- Monitoring boom extension for excessive torque
- Latch at full extension

NON-FUNCTIONAL REQUIREMENTS

- Temperature
- Radiation
- Elasticity
- Reliability/Lifetime
- Fixed components
- Weight
- Size
- Accessibility

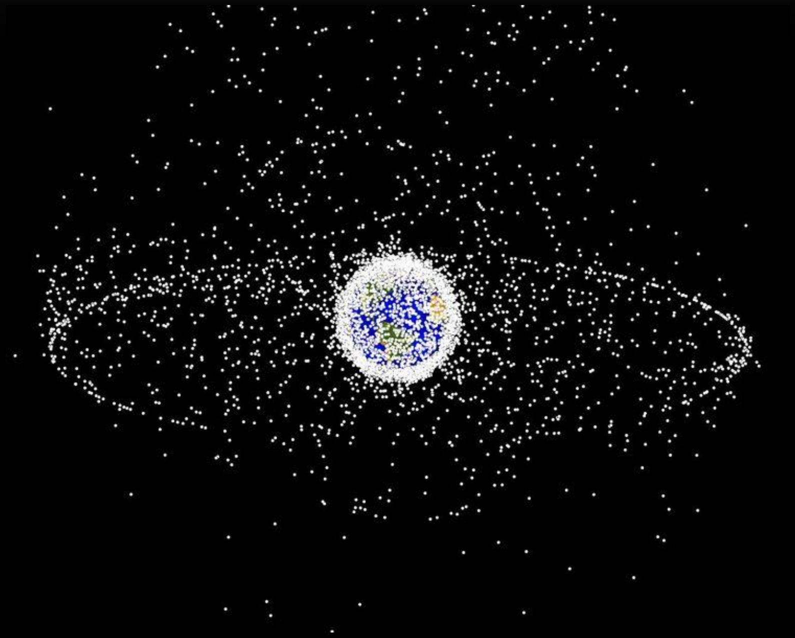


MARKET FOR CUBESATS

- Comparable Cost: $10,000
- Purpose: Space Research
- Users
  - NASA
  - Universities
  - Private Corporations

POTENTIAL RISKS IN LEO

- Temperature swings (-250F to +250F)
- Radiation exposure
- UV exposure
- Extremely low pressure (Vacuum)
- Near zero ease of access



MATERIAL COSTS

Bearing	Fastenal	$1.75	Timken	$99.50
Wheels	Campbell Supply	$7.84	SAE International	$72.00
Motor Driver	Pololu	$22.00	Moog	$100.00
Gear Motor	Pololu	$25.00	Moog	$700.00
Solenoid	Bicron Electronics	$2.00	Ledex	$7.00
Spring	Small Parts	$37.95	Vulcan	$20.00
FPGA	Atmel	$39.47	Atmel	$1,400.00
Total Price		$136.01		$2,398.50

Total Prototype Cost: $136.01

Total Final Cost: $2,398.50

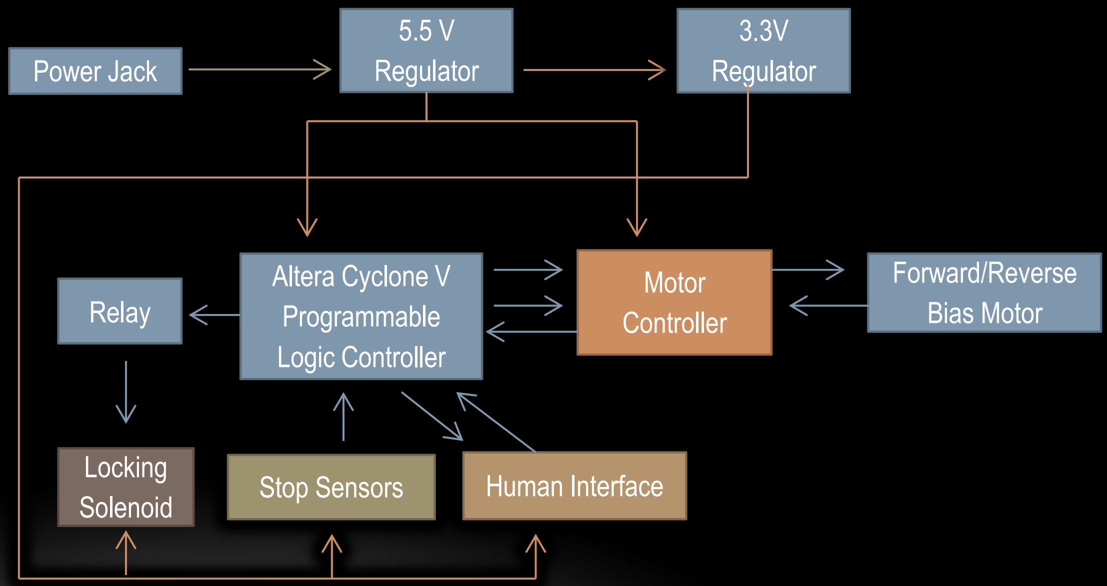
TECHNOLOGY PLATFORM

Hardware

- Atmel Rad-Hard FPGA
- Motor
- Motor controller
- Relays
- Solar array

Software

- VHDL
- A2D conversion



IMPLEMENTING PROTOTYPE

Each individual member researched & selected at least one component of the final design

For each component members were asked to create a test for functionality

Individual Components to be Tested	
FPGA Solenoids Motor Bearings	Motor controller Wheels Springs Tape

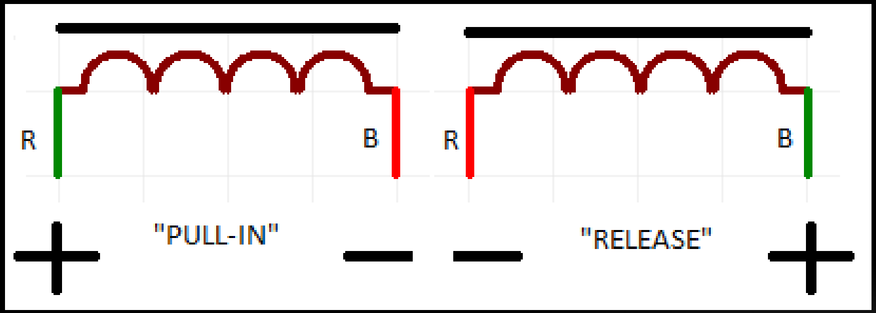
BEARINGS

- Prototype
  - Fastenal
  - 30-35% Greased
- Space Implementation
  - Timken
- Design, Structure and Testing
- Lubrication
  - Prototype
  - NASA test and usage

SOLENOIDS

General

- Used to latch boom
- Reduce power consumption
- Testing



Magnetic Latching System

- Stays in position when voltage is removed
  - Held out by spring
  - Held in by magnet
- Reverse voltage to move core in other direction
- “Zero-Power-to-Hold”

CONSTANT FORCE SPRING

Prototype spring:

- Compact
- Correctly tensioned
- Low cost

For NASA's actual use

- Vulcan Spring's products recommended

HUMAN TO MACHINE INTERFACE

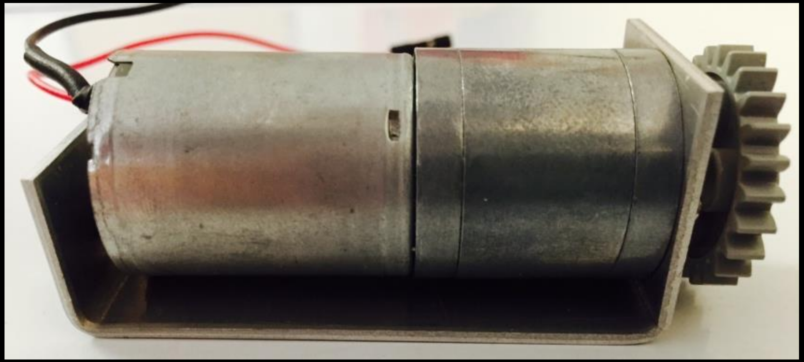
- Test Requirement
- Momentary Push Button
- Three Switches
  - Stop
  - Send Out
  - Send In
- Seven Segment Display

FIELD PROGRAMMABLE LOGIC CONTROLLER

- ALTERA Cyclone V Test
- AT40KEL040
  - Rad Hard
  - 233 I/O Pins
  - ATMEL FPGA Designer®
- 3.3V Supply
- Reprogrammable
  - Quartus II VHDL
- MIL STD 883 Method 1019.9

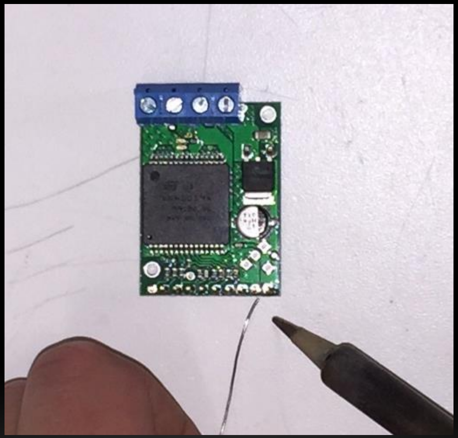
MOTOR

- Brushed DC motor with gearbox
- 57 rpm
- Small size
- 260 oz·in stall torque
- Terminal resistance and torque testing



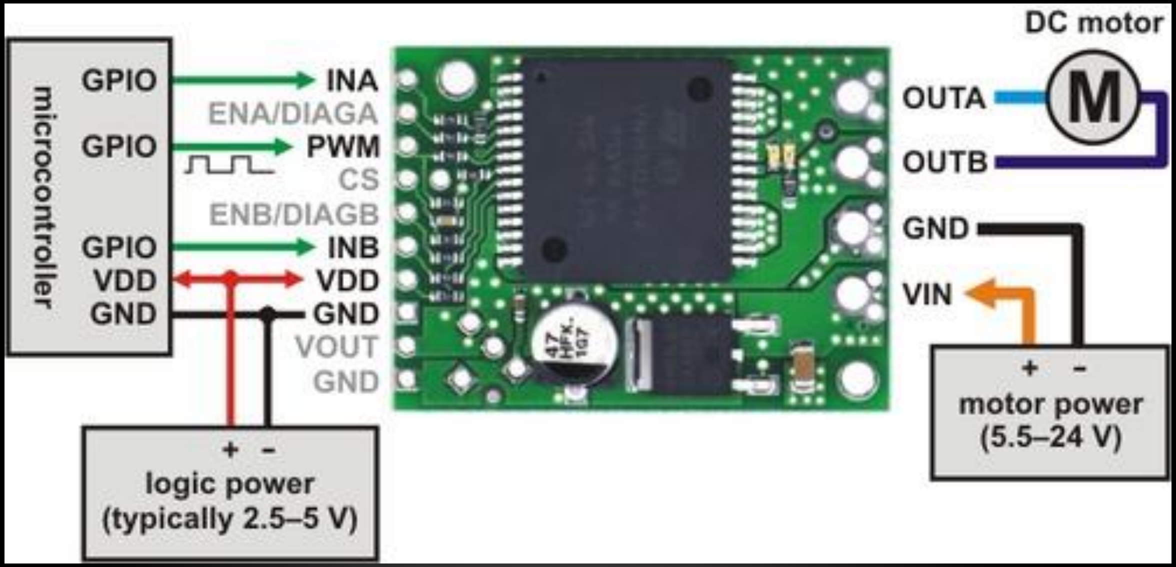
MOTOR DRIVER

- Operates at 5.5V delivering continuous 12 A
- Various built in shutdowns and protections
- Compact Size
- Test current sense ability and LEDs

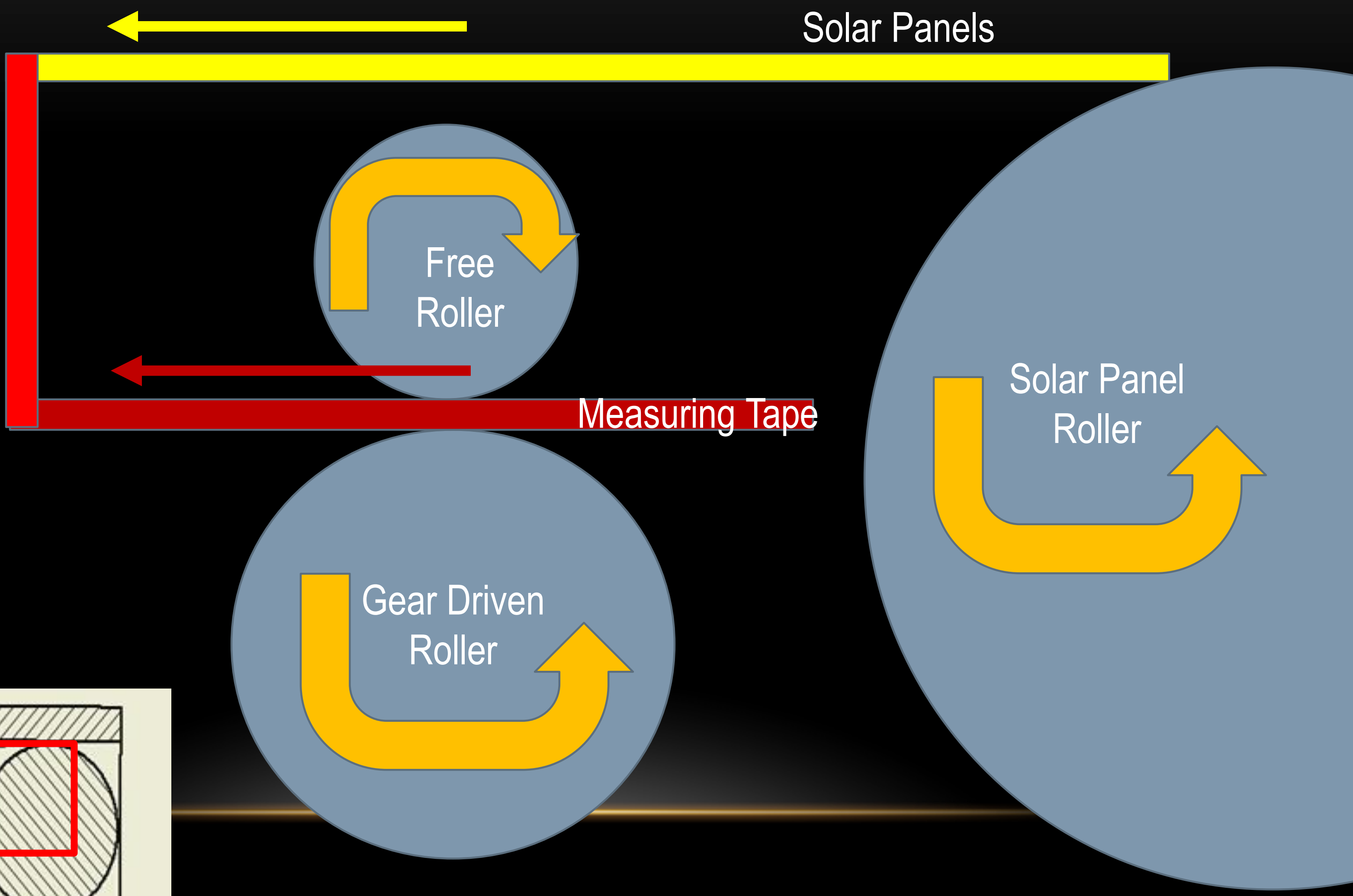


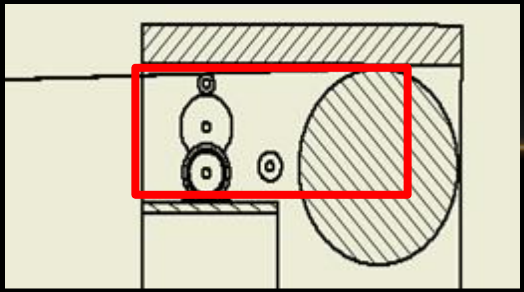
ELECTRICAL INTERFACE

- 172:1 Gearmotor with 260 oz-in stall torque
- Motor Driver
- Atmel Microcontroller

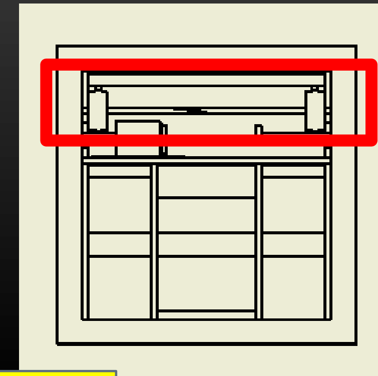


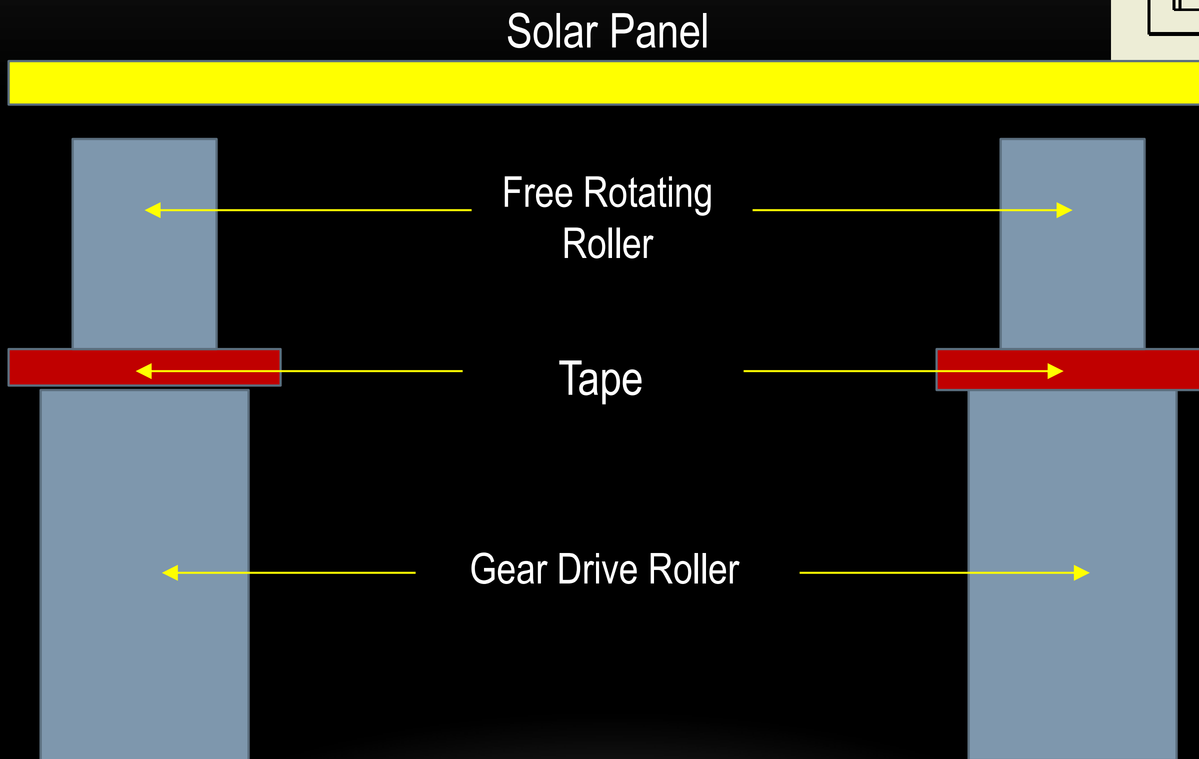
ZOOM-IN SIDE VIEW



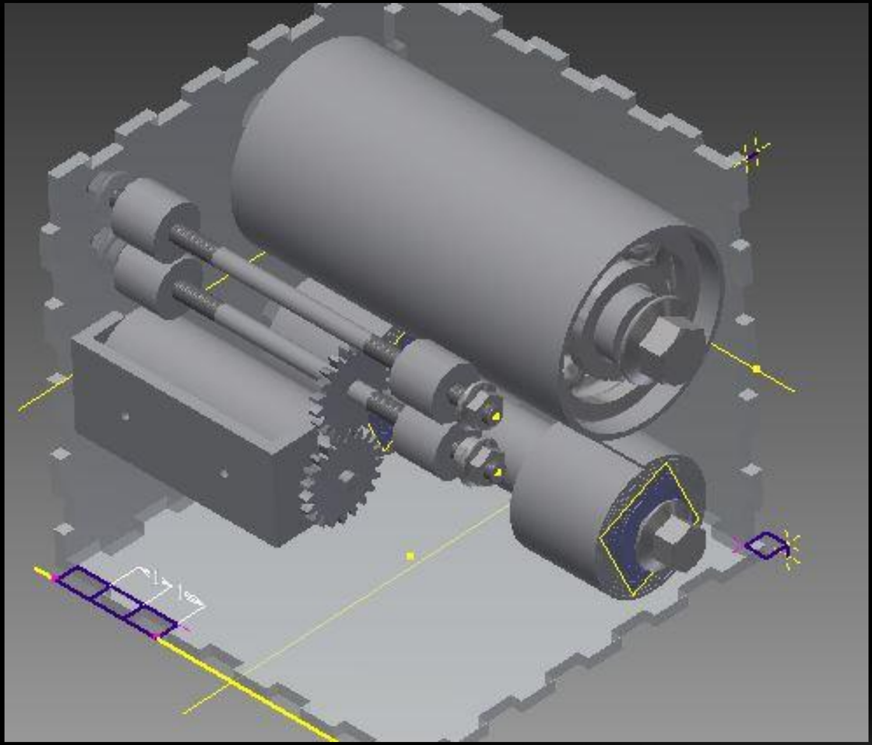


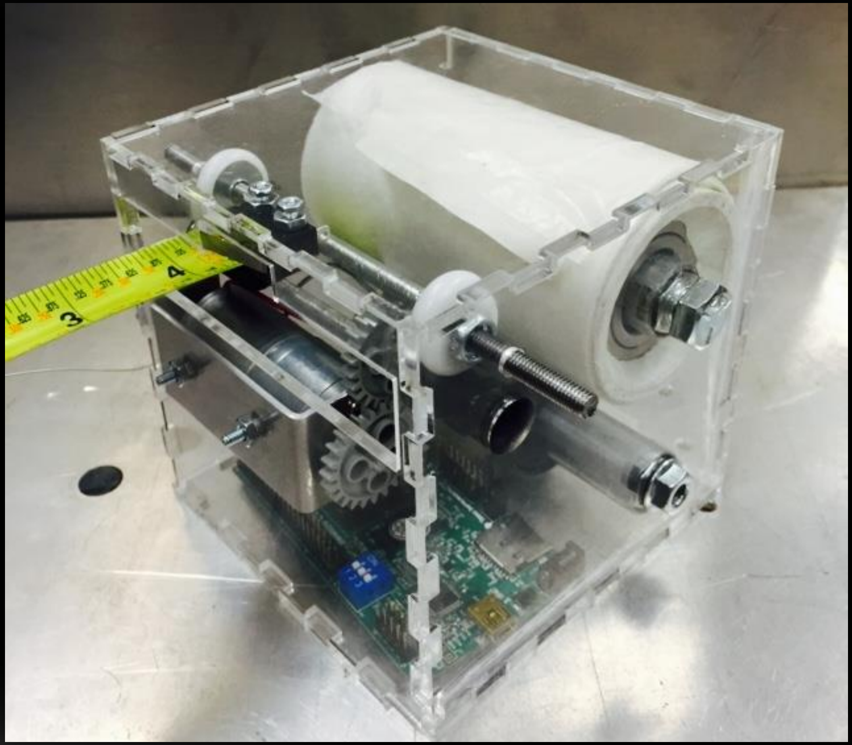
ZOOM-IN FRONT VIEW





FINAL DESIGN





MILESTONES

• Analog or Digital	10/05/2014
• Circuit Outlines and Improvements	10/31/2014
• Our Design Constraints were changed	11/01/2014
• Redesigned our 1U CubeSat	11/12/2014
• Final Circuit Completion	11/26/2014
• Material Selections	12/05/2014
• Draft Design Sent to NASA	12/06/2014
• Bill Of Materials	12/07/2014

SEMESTER SCHEDULE

Material Ordering	01/30/2015
Begin building	02/20/2015
Circuit Assembled	04/08/2015
Complete Local testing	04/17/2015
Submit Final Documentation to NASA	05/04/2015