CubeSat Design

May 15-12

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Problem

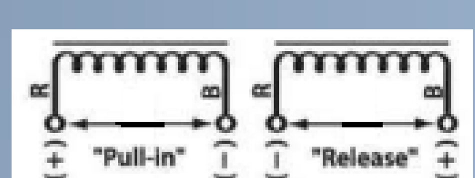
Our group is tasked with designing and implementing a repeatedly deployable and retractable solar cell system that is to be launched into Low Earth Orbit. The system must fit within a 1U CubeSat (10cm x 10cm x 10cm satellite). Flexible solar arrays shall be used that have a minimum bend radius of 2.5cm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

Solution

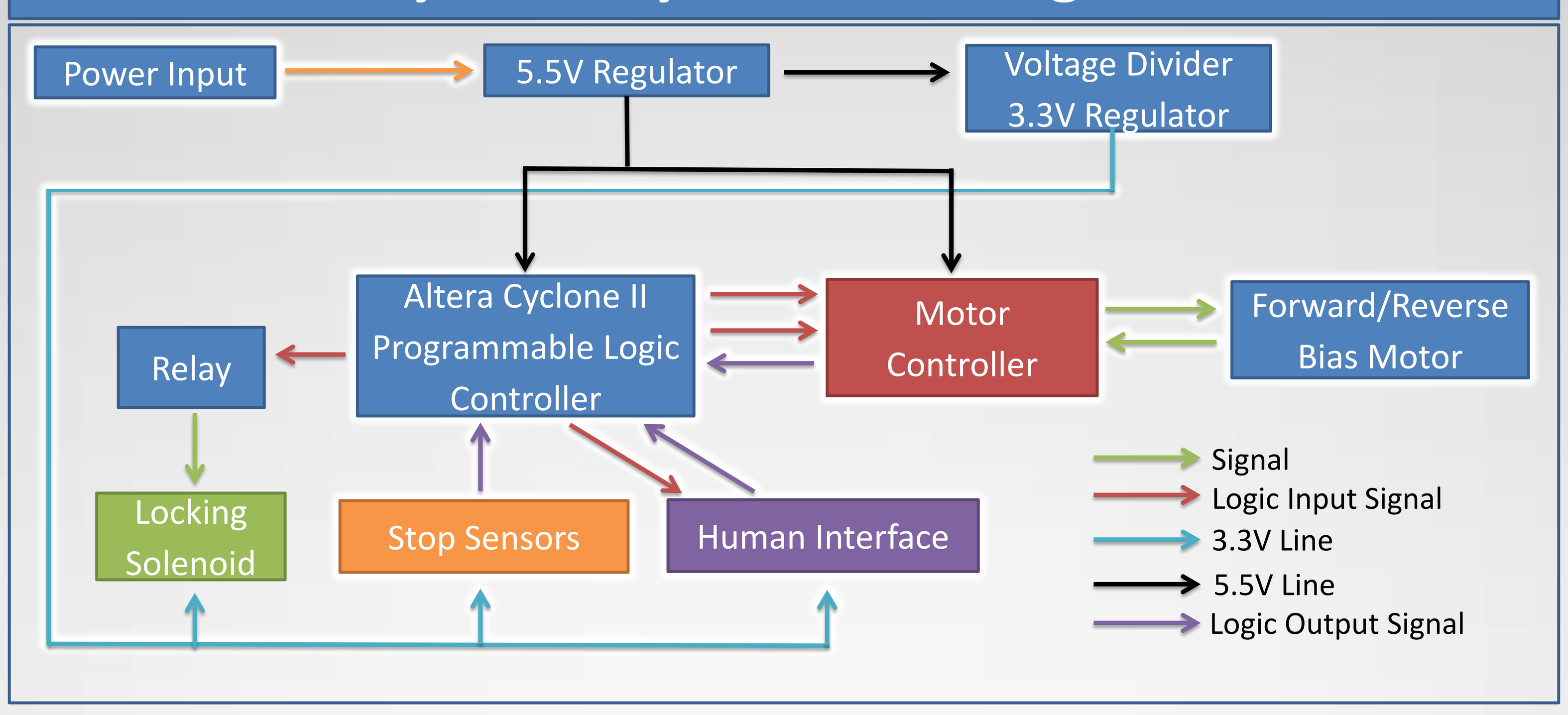
Our final solution utilizes a TRAC style boom to extend the flexible solar panel to a final length of 426.72cm long by 9.5cm wide, for a total area of 4053.84cm^2. Solenoids lock the mechanism in place to prevent it from retracting by accident and the system is spring loaded to ensure smooth and consistent operation while retracting. A small but powerful motor connected to an FPGA through a motor driver drives the unit.

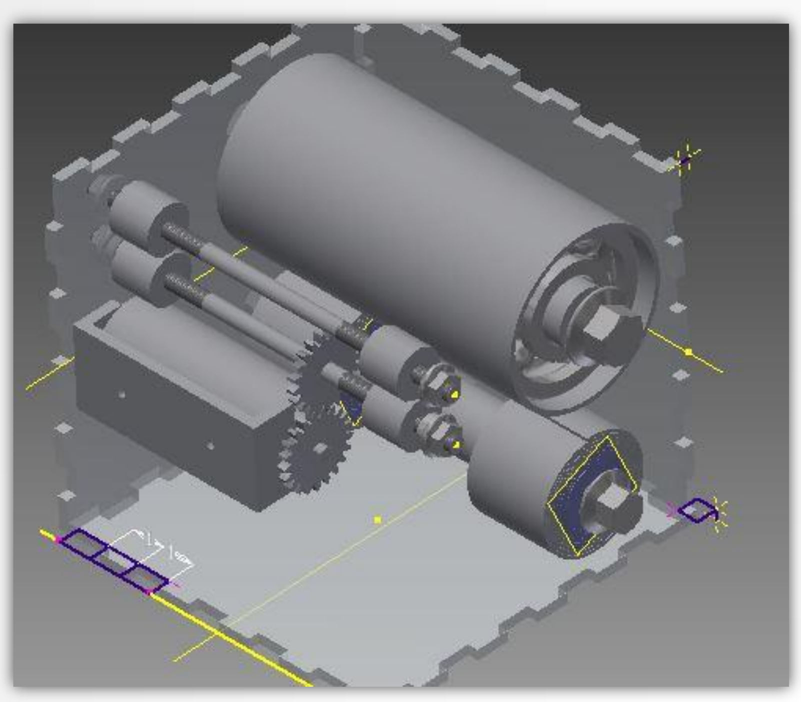
Solenoids

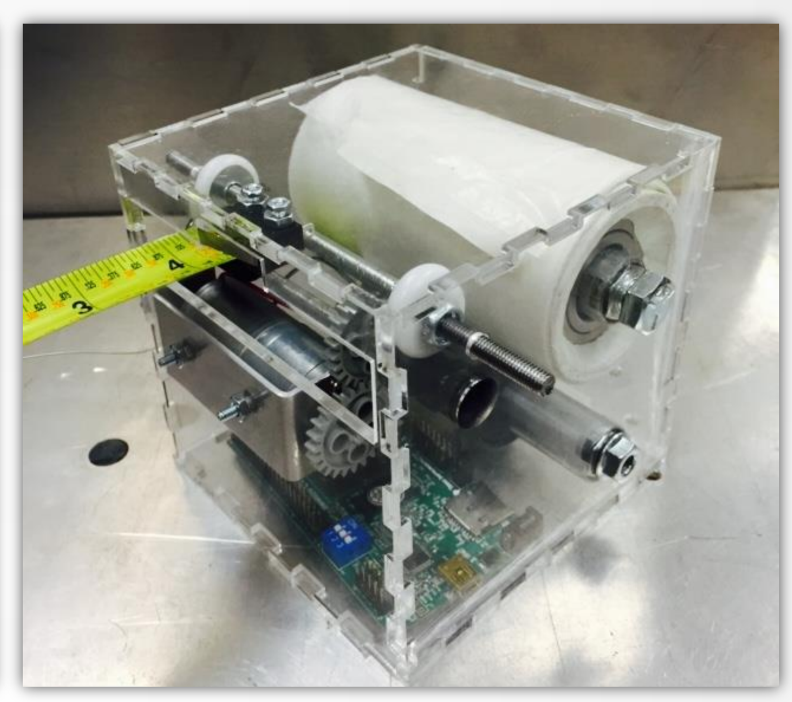
Latch boom at full extension
Reducing power consumption
Zero-power-to-hold magnetic latching system
- Held out by a spring
- Held in by a magnet



System Layout Block Diagram

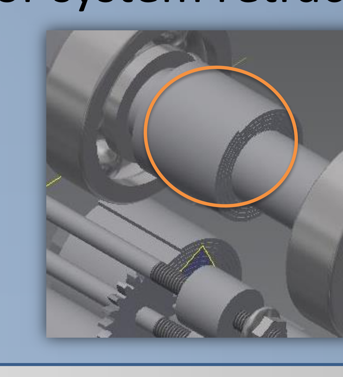






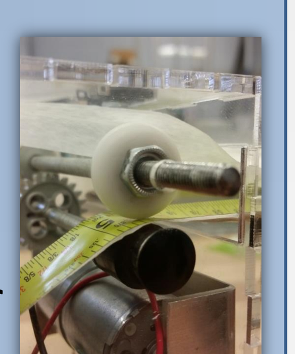
Springs

The spring is a medium-carbon steel spring found in a tape measure. This ensures tension is kept on the solar cells and boom and acts as the force for system retraction.
- Constant-force
- 30 oz-in of force



Wheels

The wheels are made of silicone rubber which is known for its elasticity as well as resilience in adverse conditions. Often silicone is made to with-stand extreme temperatures up to 300C while the lower temper-ature extreme for silicone rubber can be found as low as -100C.



Bearings

The bearings we used have a single row and a deep groove which helps with self-alignment. Self-aligning races decrease binding and allows for smoother motion. They also come pre-greased so we do not need to lubricate them ourselves. These bearings can withstand a wide range of temperatures and will not allow debris to be caught inside do to the single cage design.

TRAC Boom

Triangular Roll able and Collapsible boom
- Developed by the Air Force Research Laboratory
- Implemented on NASA's Nanosail-D

Furled to save space while awaiting deployment
Forms a triangular shape when unfurled
- Increased Strength
- Increased Rigidity
- Material used is Elgiloy, developed specifically for the TRAC system

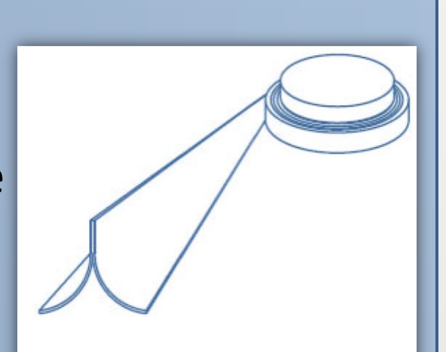
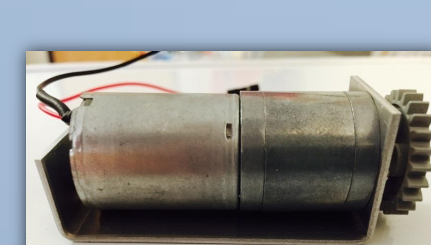
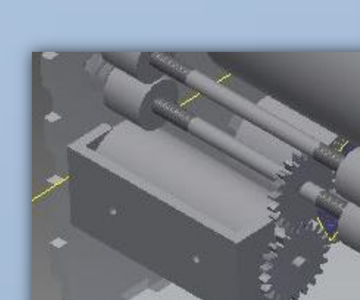


Figure 18. TRAC Boom Stowage Concept(Banik J., 2008)

Motor and Motor Driver

- Brushless DC motor with gearbox
- 55-60 rpm
- Small size
- 260 oz·in stall torque
- Large gear reduction allows for increased stall torque
- Operates at 5.5V delivering continuous 12A
- Various built in shutdowns and protections
- Compact Size





Field Programmable Logic Array

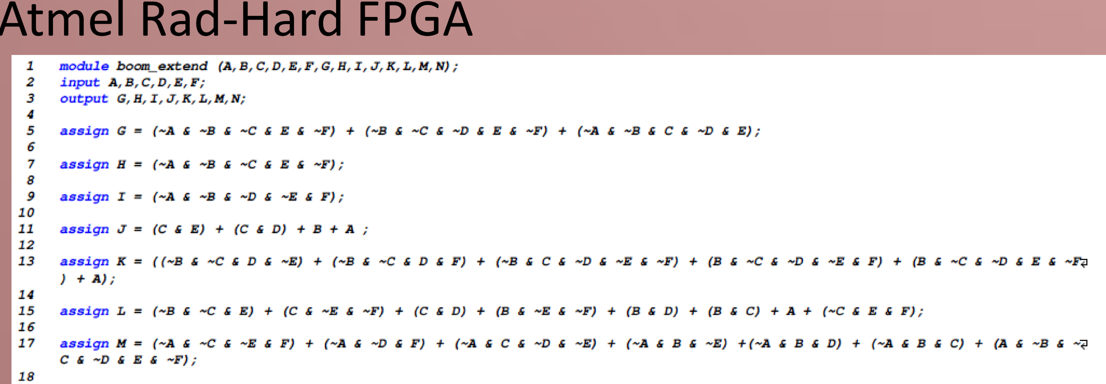
AT40KEL040
- Rad Hard
- 233 I/O Pins
- ATMEL FPGA Designer®
- 3.3V Supply

Reprogrammable
- Quartus II VHDL

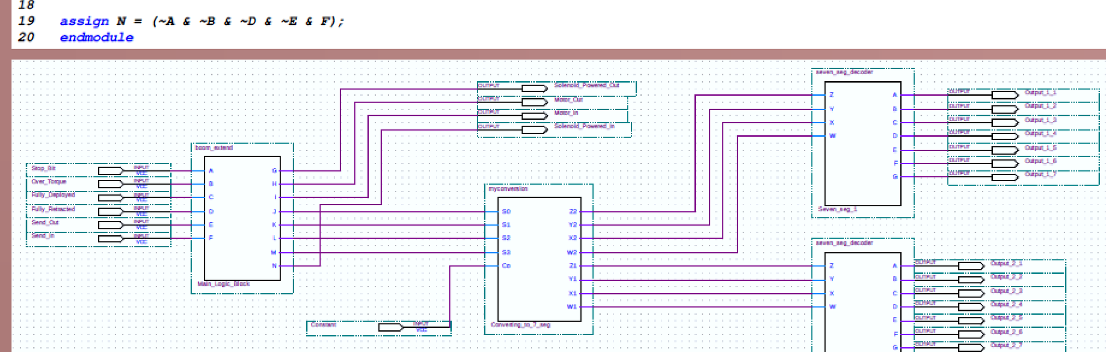
Tested to MIL STD 883 Method 1019.9

Technical Details

- Programed using Quartus II
  - VHDL Design Blocks
  - Sum-of-Products method
- Atmel Rad-Hard FPGA



```
module boom_extend (A,B,C,D,E,F,G,H,I,J,K,L,M,N);
input A,B,C,D,E,F;
output G,H,I,J,K,L,M,N;

assign G = (~A & ~B & ~C & E & ~F) + (~B & ~C & ~D & E & ~F) + (~A & ~B & C & ~D & E);

assign H = (~A & ~B & ~C & E & ~F);

assign I = (~A & ~B & ~D & ~E & F);

assign J = (C & E) + (C & D) + B + A ;

assign K = ((~B & ~C & D & ~E) + (~B & ~C & D & F) + (~B & C & ~D & ~E & ~F) + (B & ~C & ~D & ~E & F) + (B & ~C & ~D & E & ~F
) + A);

assign L = (~B & ~C & E) + (C & ~E & ~F) + (C & D) + (B & ~E & ~F) + (B & D) + (B & C) + A + (~C & E & F);

assign M = (~A & ~C & ~E & F) + (~A & ~D & F) + (~A & C & ~D & ~E) + (~A & B & ~E) +(~A & B & D) + (~A & B & C) + (A & ~B & ~
C & ~D & E & ~F);

assign N = (~A & ~B & ~D & ~E & F);
endmodule
```



Testing

When designing a circuit for Low Earth Orbit (LEO) 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, vacuum conditions and debris, are still important because parts can either float off into space or collide with debris potentially causing damage. In space there is far less room for error demanding a robust and reliable system that can overcome these atypical constraints.

Uses

Comparable Cost: $10,000

Purpose:
- Space research
- Provide power to satellites

Users:
- NASA
- Universities
- Private Corporations

Cost

Materials	Prototype Manufacture	PrototypePrice	Final Manufacture	Final Price
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

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Acknowledgments
John Carr, NASA
Client
Gary Tuttle, ISU
Faculty Advisor