

Mechanical Engineering with SSEL

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Space Science and Engineering Laboratory
Montana State University

- FIREBIRD Separation System
- CubeSat Stand

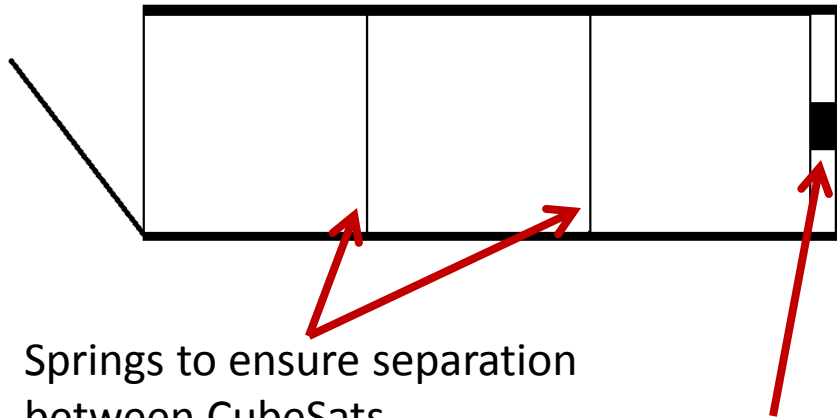


FIREBIRD SEPARATION SYSTEM

Usually
3 1U
>0

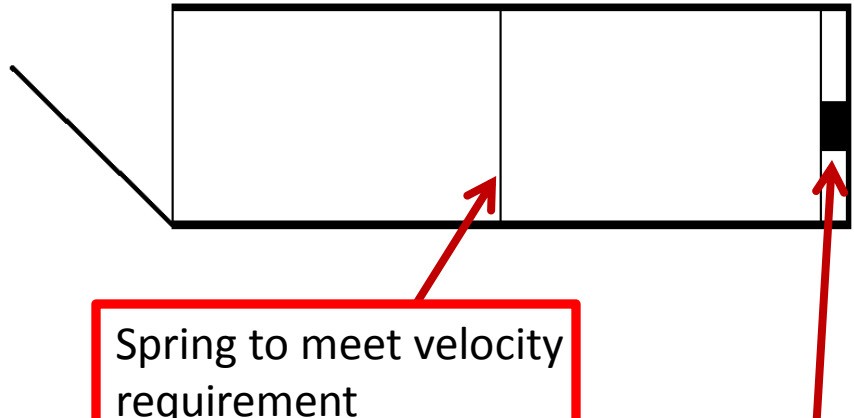
FIREBIRD
2 1.5U
0.7-1.5 cm/s

Separation velocity:



Springs to ensure separation between CubeSats

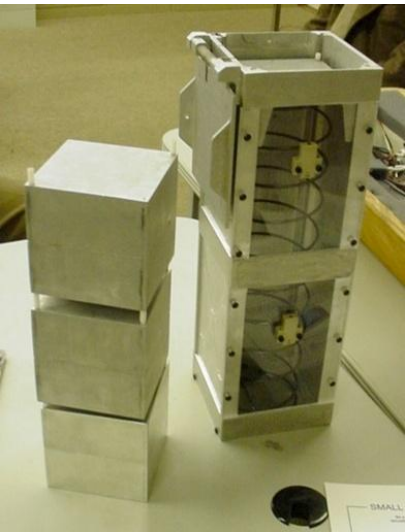
Spring to eject CubeSats from P-Pod



Spring to meet velocity requirement

Separation System

Spring to eject CubeSats from P-Pod



FIREBIRD Separation System

- Mission Requirement: separation velocity must be 0.7-1.5 cm/s

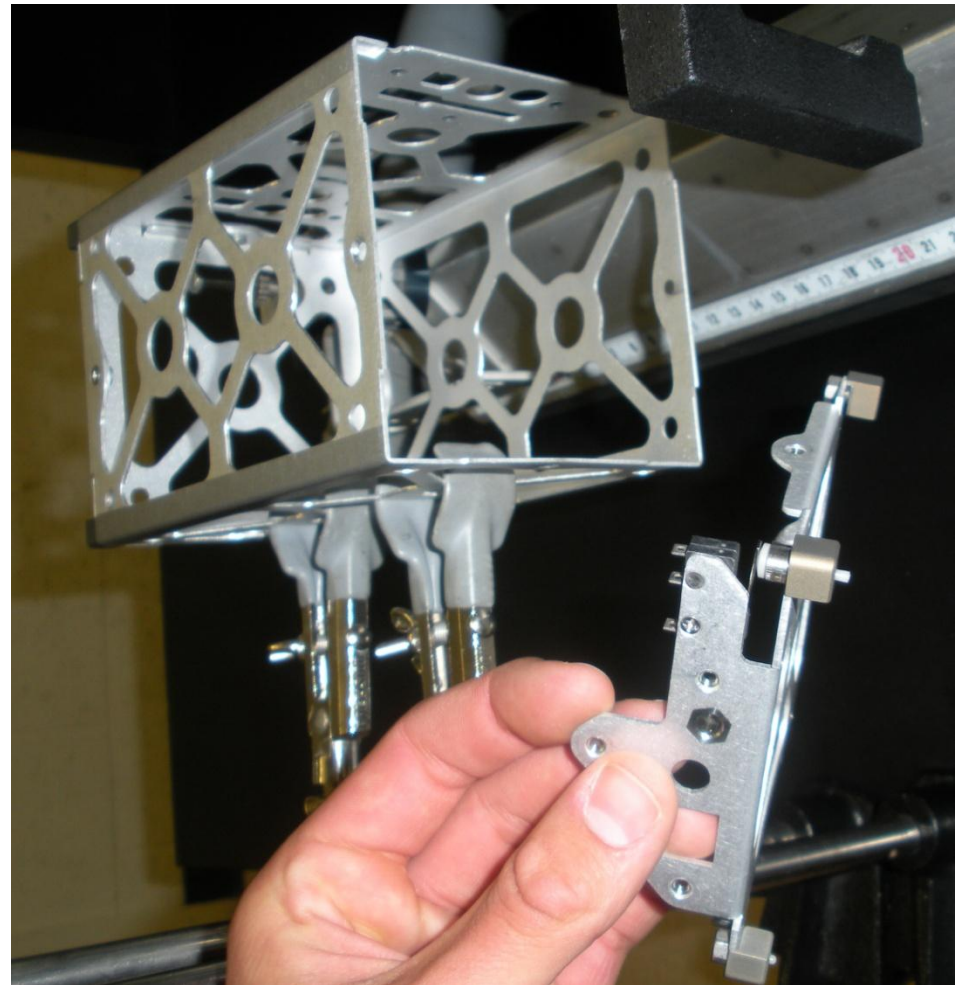
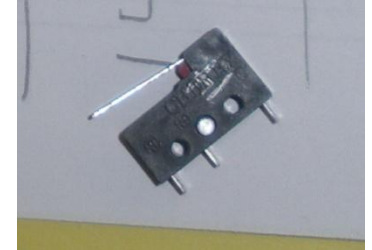
Before I got here:

- Custom spring plunger was made and met mission requirement

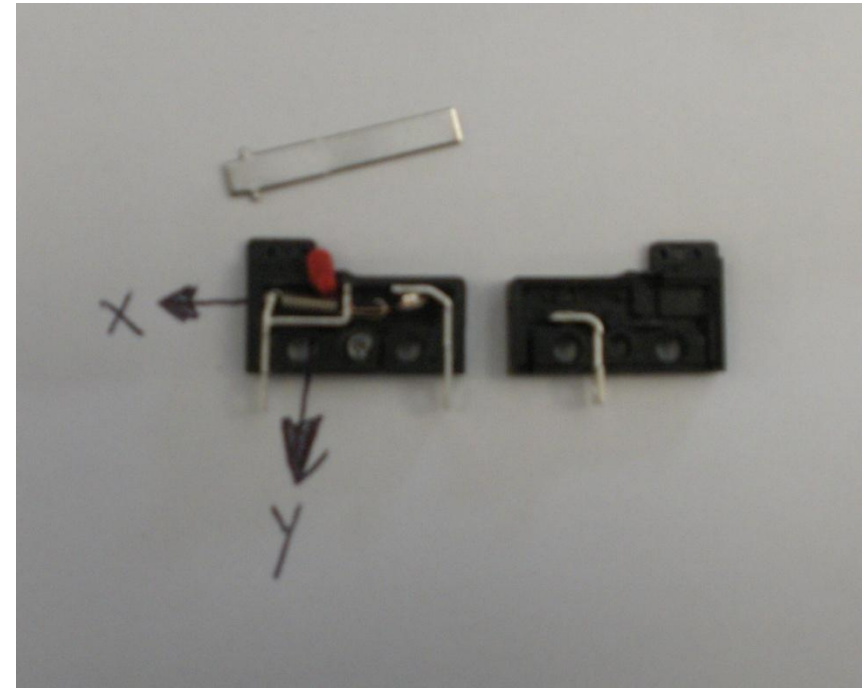
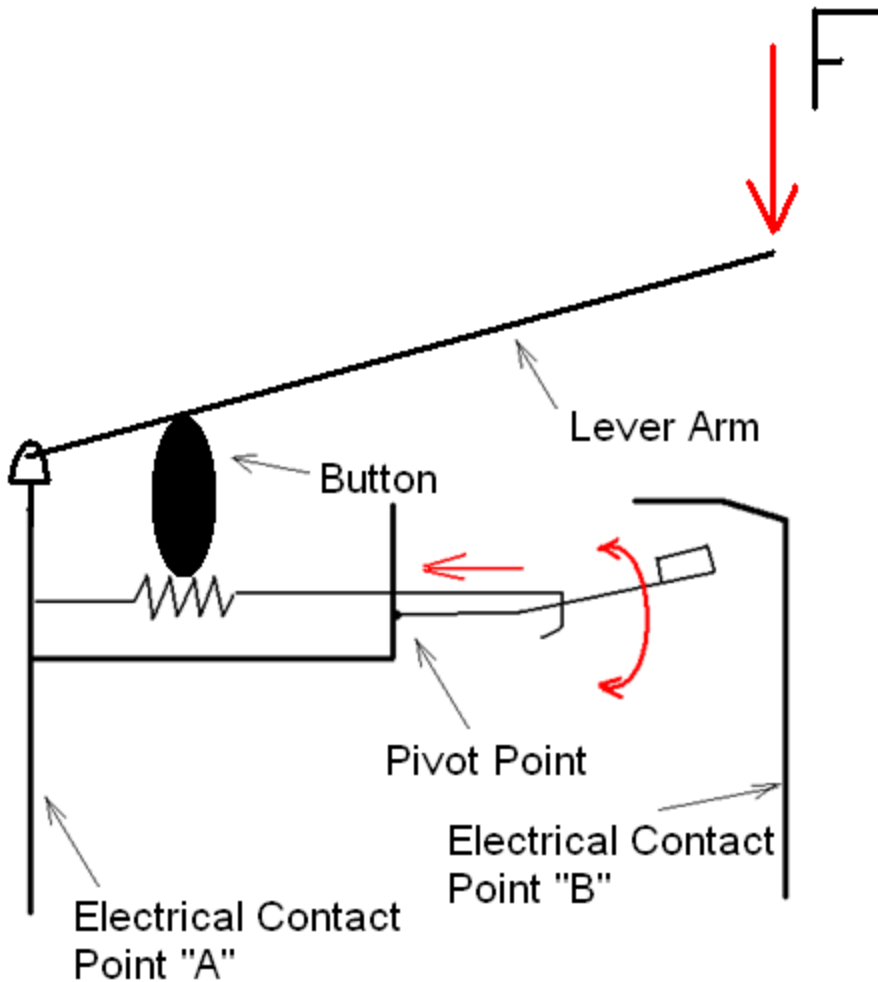
But wait...

Separation Switch

- Purpose- tells whether satellites are together or separated and turns satellites on once separated
- During final custom spring plunger testing it was found that switch adds enough energy to the system that it does not need the custom spring plunger

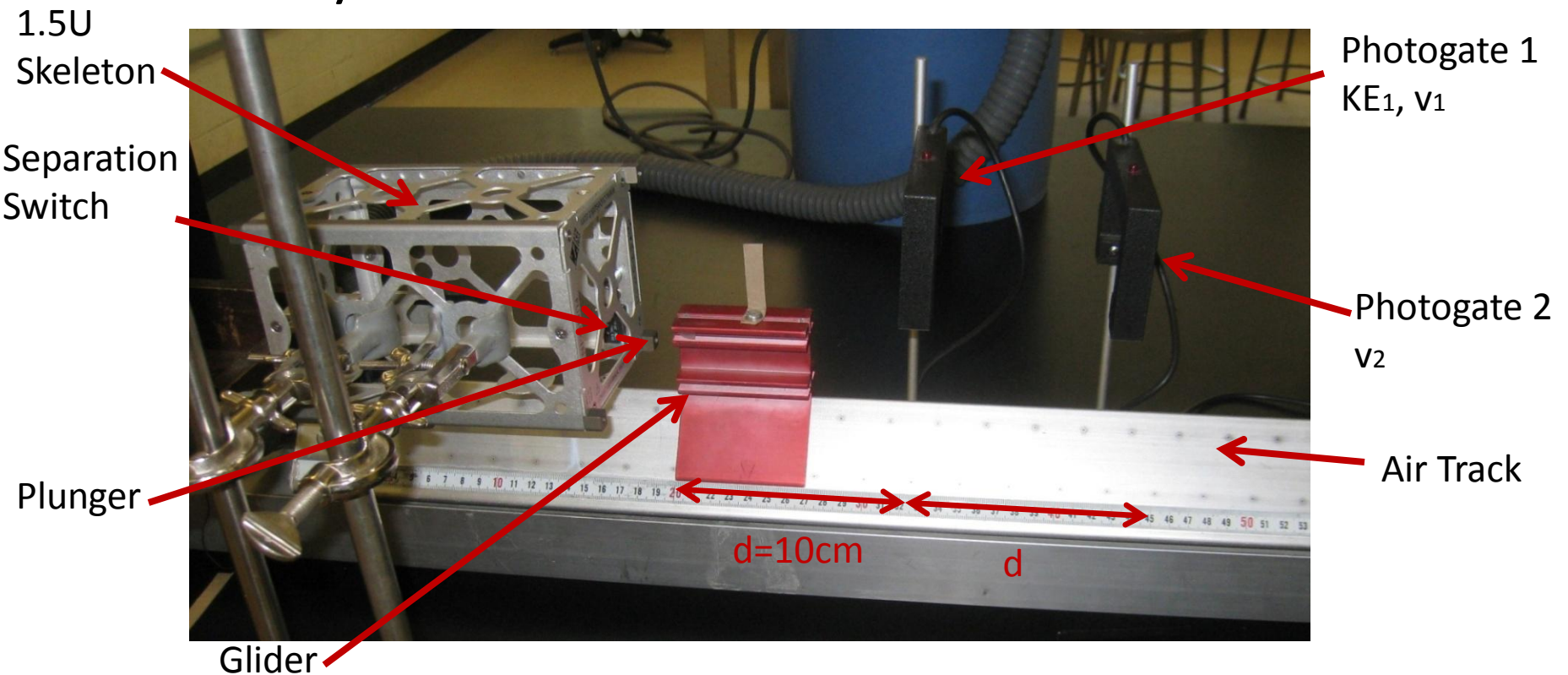


Separation Switch Reverse Engineered (Break S#&@)



Air Track Testing

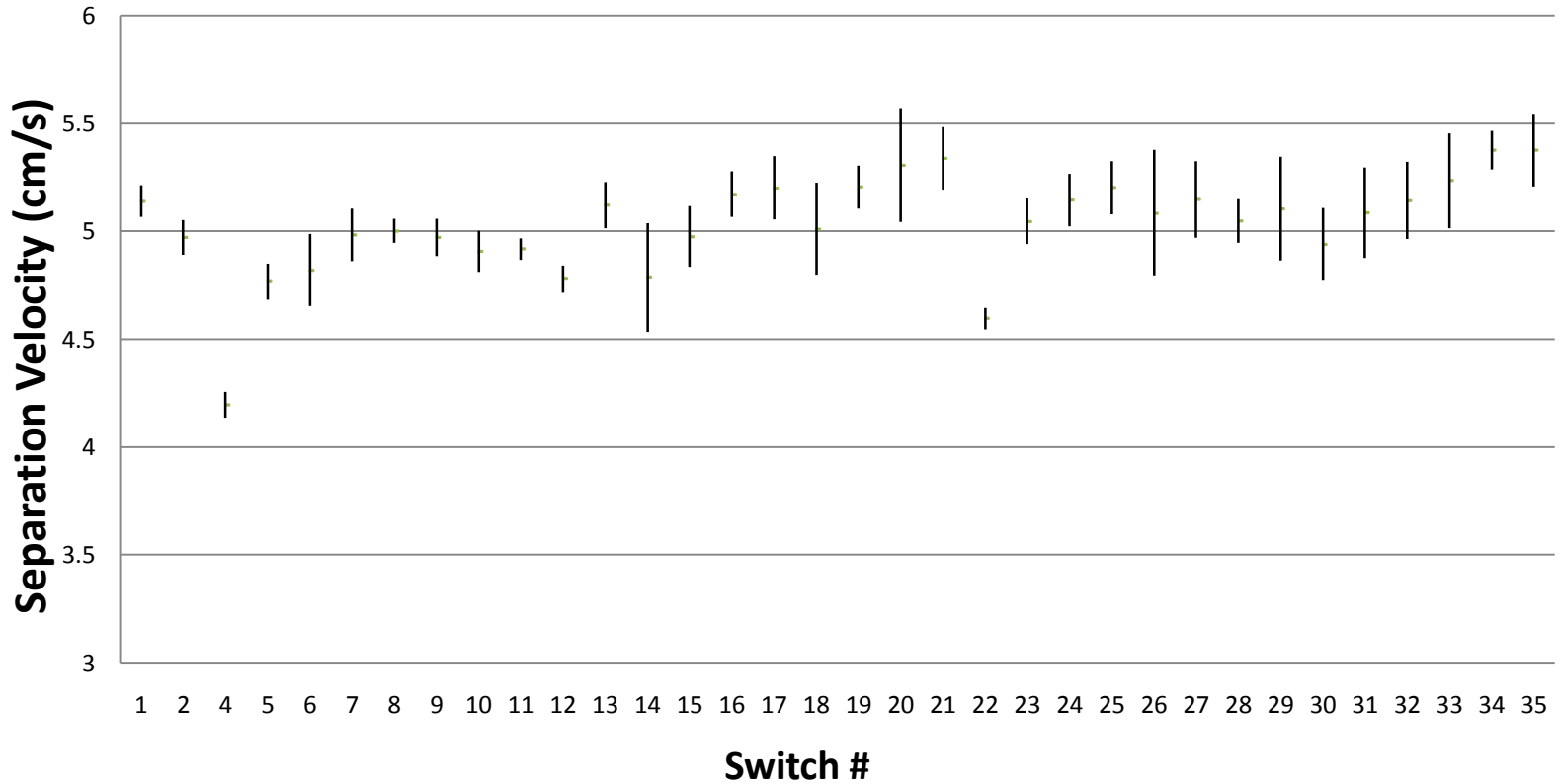
- Purpose: Find potential energy of switches
- Use this energy to calculate expected separation velocity of satellites



Air Track Calculations

- KE at 1st Photogate: $KE_1 = \frac{1}{2} m_{glider} v_1^2$
- Friction loss between photogates: $E_{friction} = m_{glider} * \frac{(v_1^2 - v_2^2)}{2}$
- Potential Energy of switch: $PE_{switch} = KE_1 + E_{friction}$
- Satellite separation velocity: $v_{separation} = \sqrt{\frac{PE_{switch}}{m_{satellite}}}$

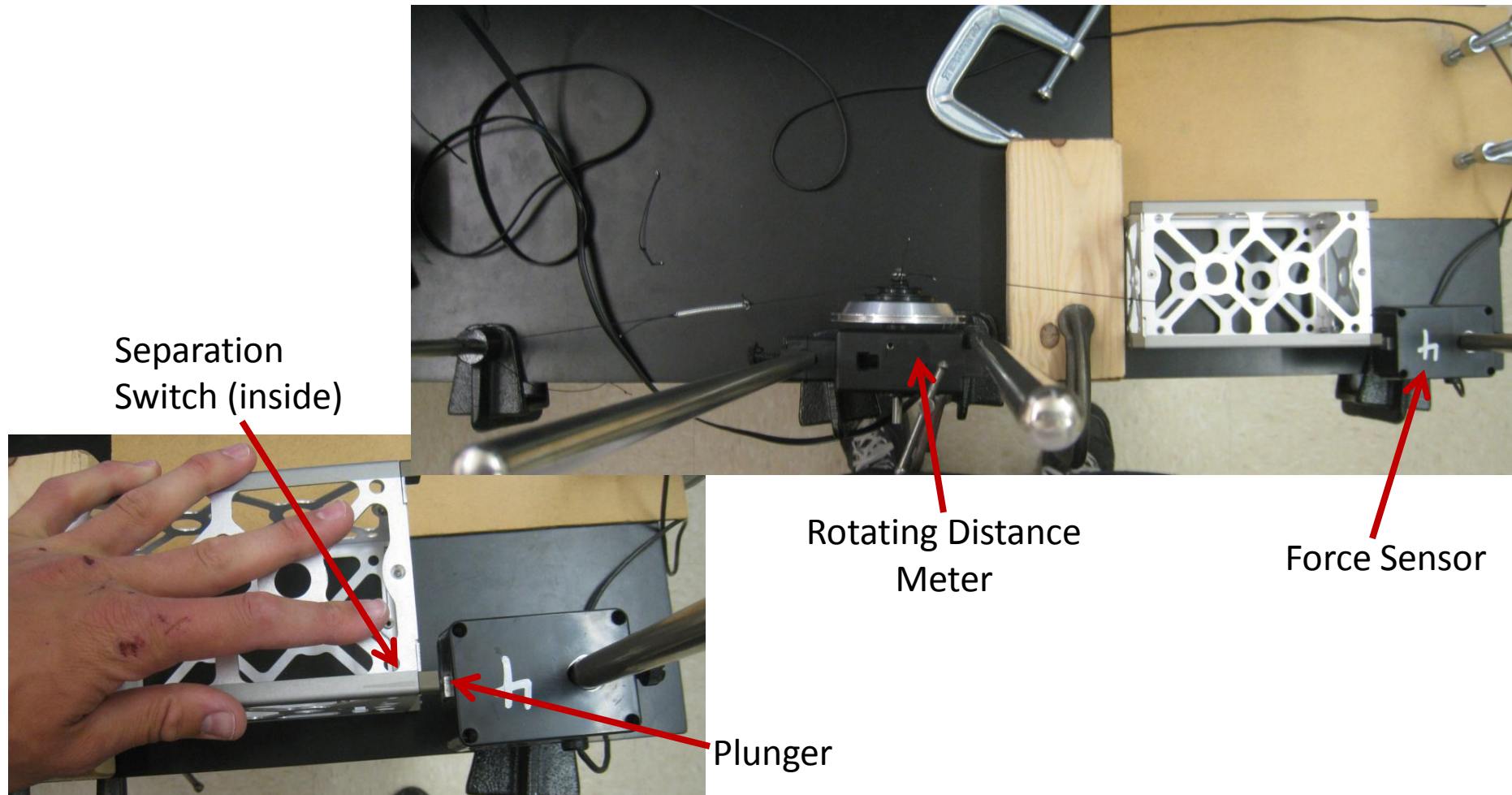
Air Track Results



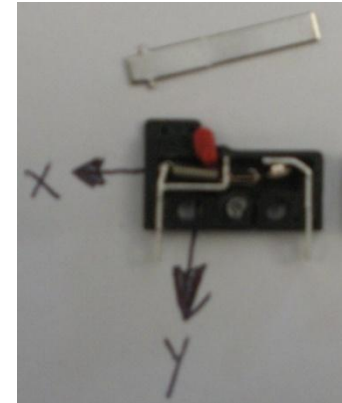
- Lowest velocity = 4.2 cm/s for switch 4
- Velocities are too high!

Force/Position Testing

- Purpose: Find flip points (activation and deactivation points) of switches



Flip Points

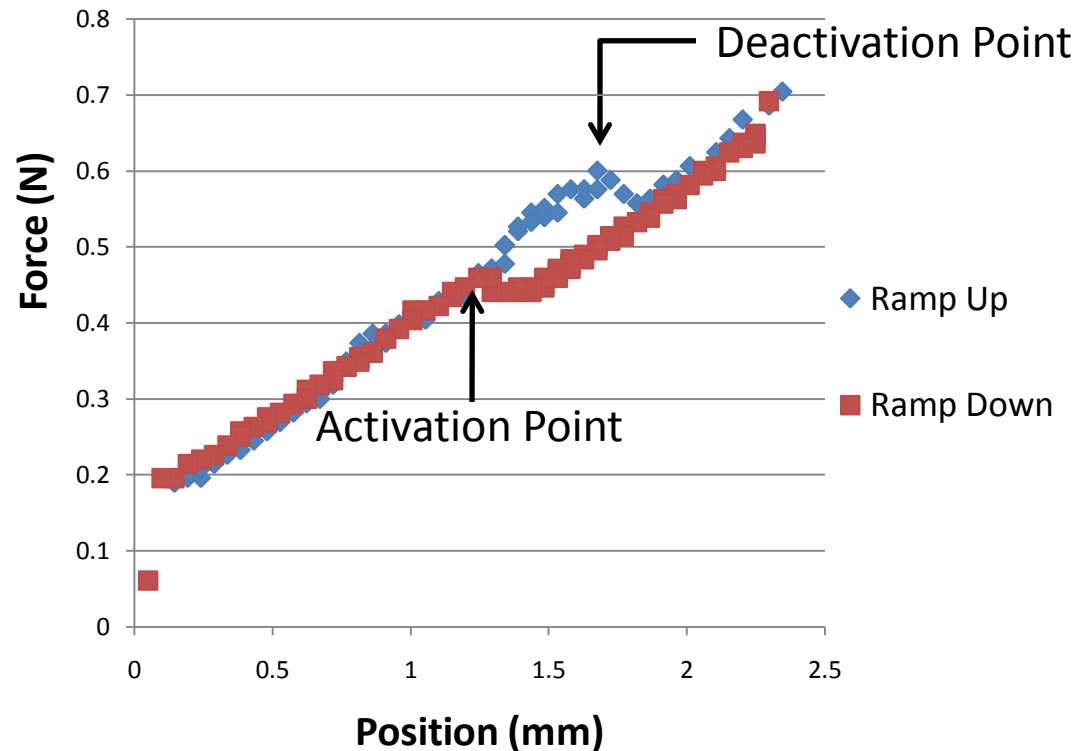


- 2 Flip points
 - Where cam flips

- Activation Point:
 - During ramp down
 - Where switch turns from off to on

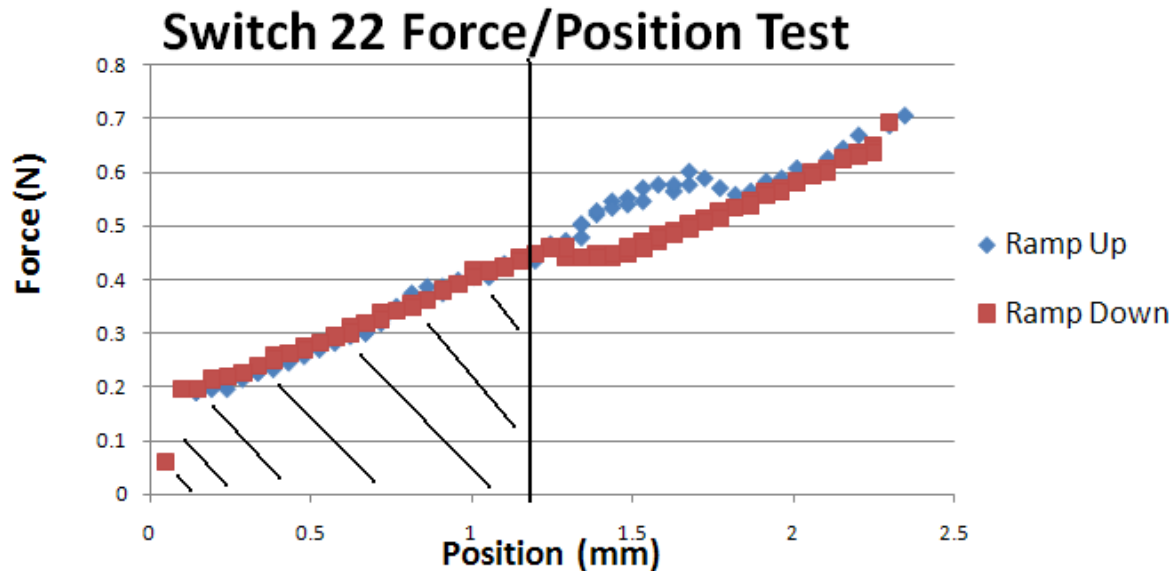
- Deactivation Point:
 - During ramp up
 - Where switch turns from on to off

Switch 22 Force/Position Test



Reduce Energy

- Area under ramp down curve is separation potential energy
- Distances less than activation point are not necessary for proper operation
- Shaded region is potential energy that can be removed

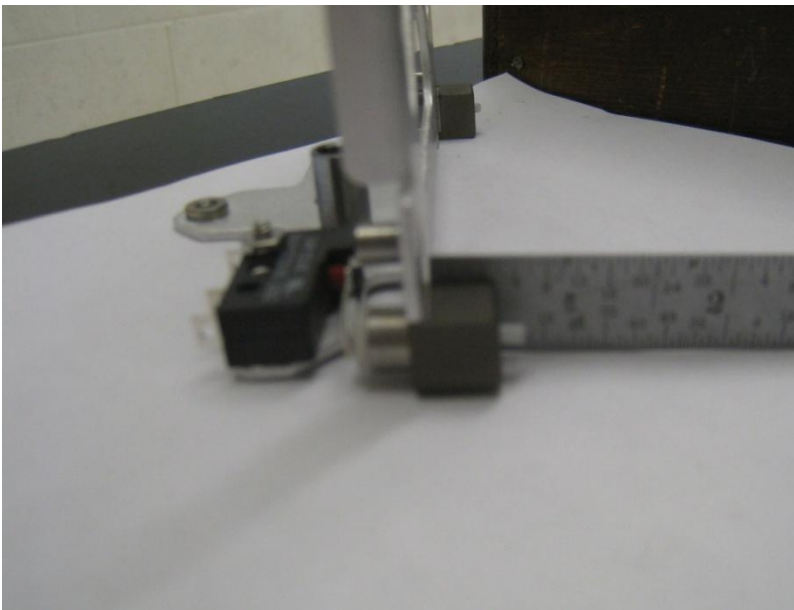


- Limit lower range of motion... But how?

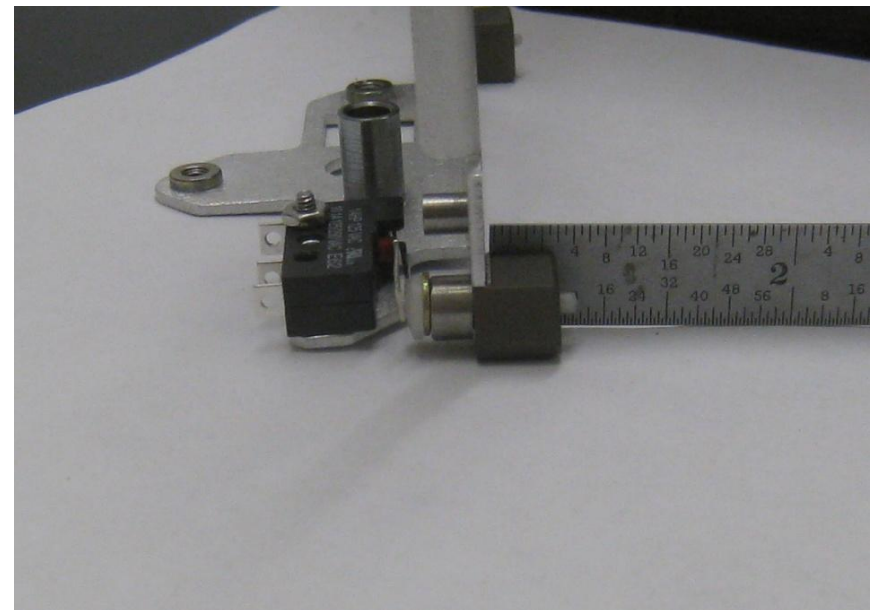
Spacer

- Spacer does not allow plunger to fully extend so not all of the energy from the spring is imparted to the system
- Maximum spacer height: distance from zero to the activation point

No spacer



Spacer



Note difference in plunger length extending from foot

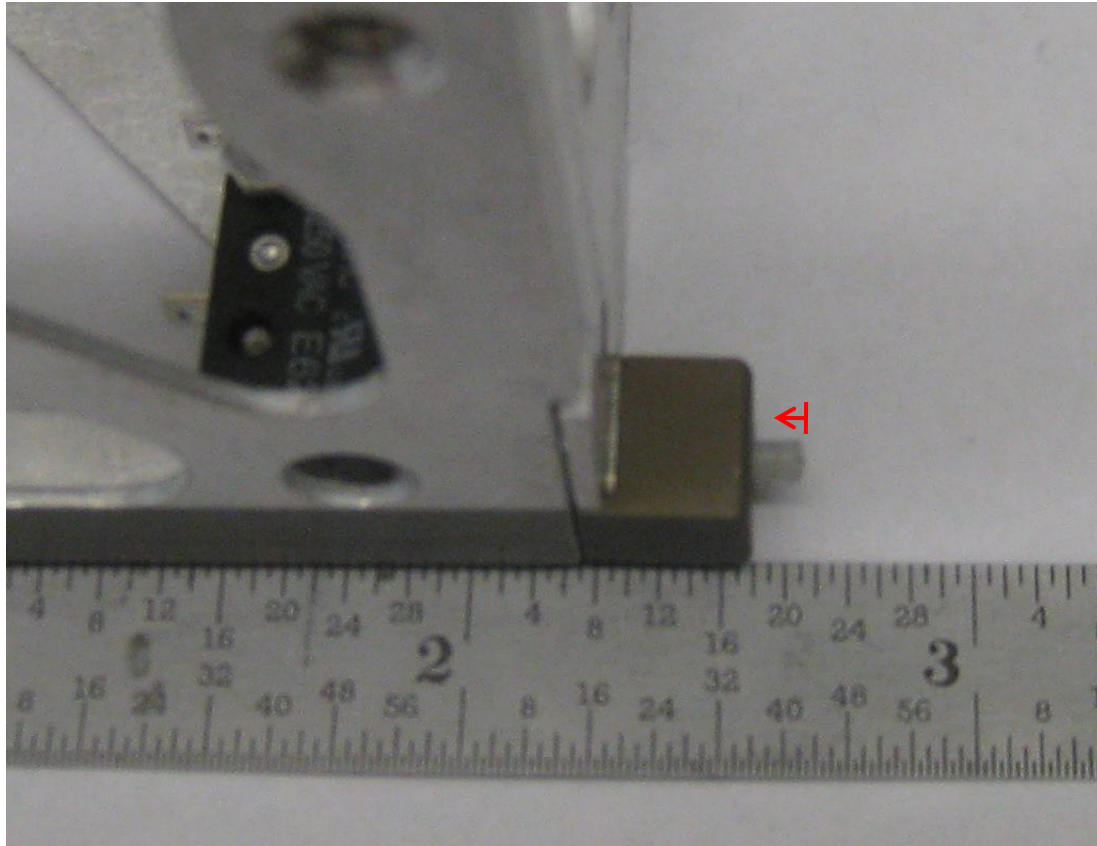
Reduce Energy

- Distances greater than deactivation point are not necessary for proper operation
- Shaded region is potential energy that can be removed

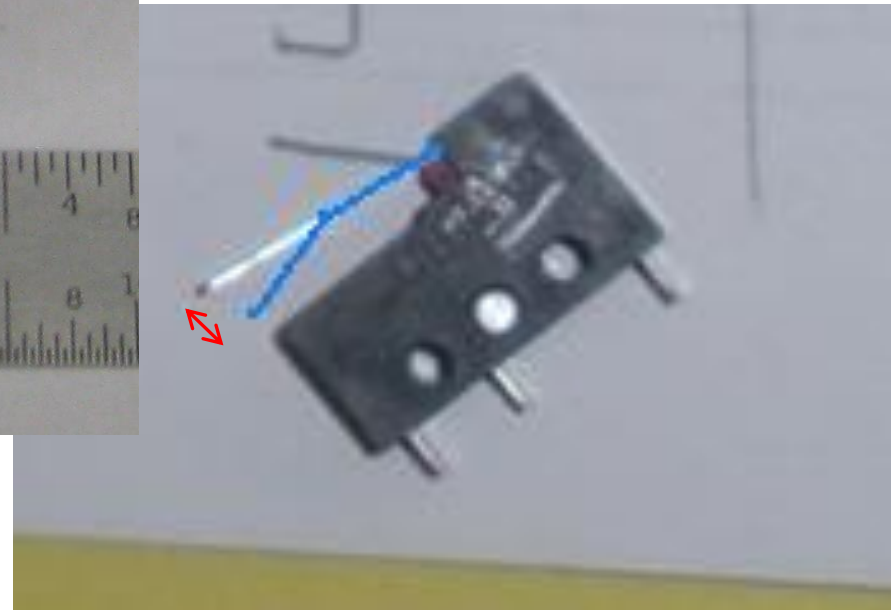


- Limit farther range of motion... But how?

Shave Plunger/Bend Lever Arm



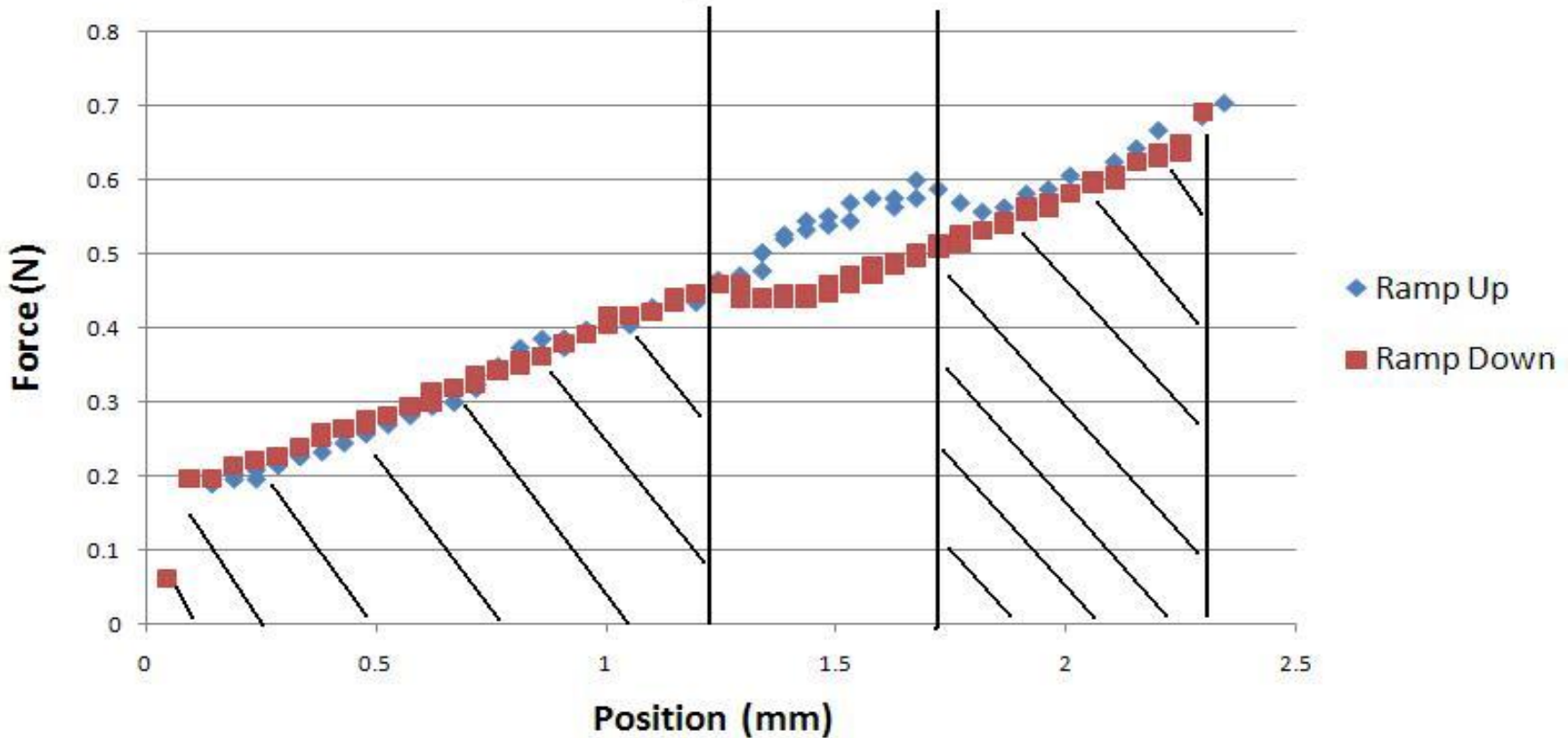
Using this technique, once switch has reached deactivation point the plunger is flush with the foot- plunger is fully depressed without the extra displacement previously necessary



Maximum shave length/lever arm bending loss: distance from the deactivation point to the end of the plunger

Total Possible PE Losses

Switch 22 Force/Position Test



Possible PE Losses of switch are functions of: distance between and distance to activation and deactivation points and spring constant

Data Analysis/Expected Results

Expected results using numerical integration and factors of safety:

Removed distances: zero to $\min_{actdist} - (\text{avg}_{actdist} - \min_{actdist}) * 10\%$

$\max_{deactdist} + (\max_{deactdist} - \text{avg}_{deactdist}) * 10\%$ to end

Switch #	Total PE (mJ)	PE Shave Loss (mJ)	PE Spacer Loss (mJ)	Min Total PE (mJ)	Velocity (cm/s)
4	0.754	0.065	0.254	0.435	1.475
5	0.989	0.348	0.311	0.330	1.284
6	0.907	0.380	0.231	0.296	1.217
9	0.866	0.262	0.309	0.294	1.212
22	0.938	0.210	0.280	0.451	1.501
35	1.001	0.502	0.218	0.279	1.181

- Velocity requirement theoretically met!
- Time for more testing

Future Testing

- Add a washer and do force/position testing to make sure switch is flipping and do air track testing to calculate expected separation velocity
- Shave plunger or bend lever arm and repeat tests
- Combine both techniques, repeat tests, and hope for the best!

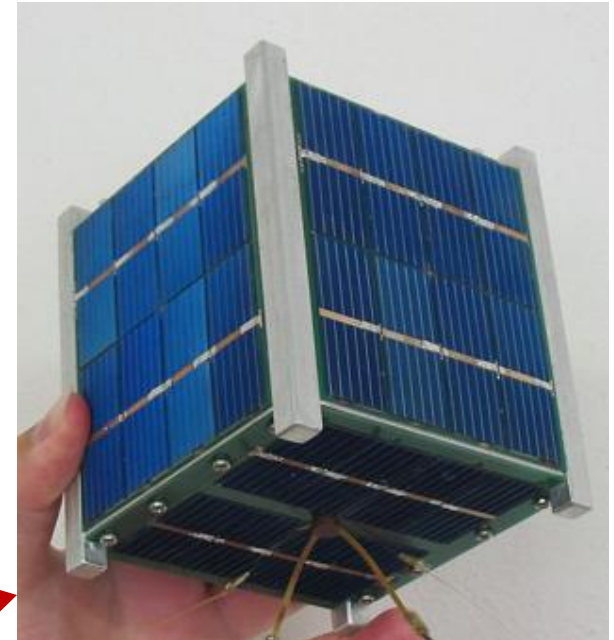


CUBESAT STAND

CubeSat Stand

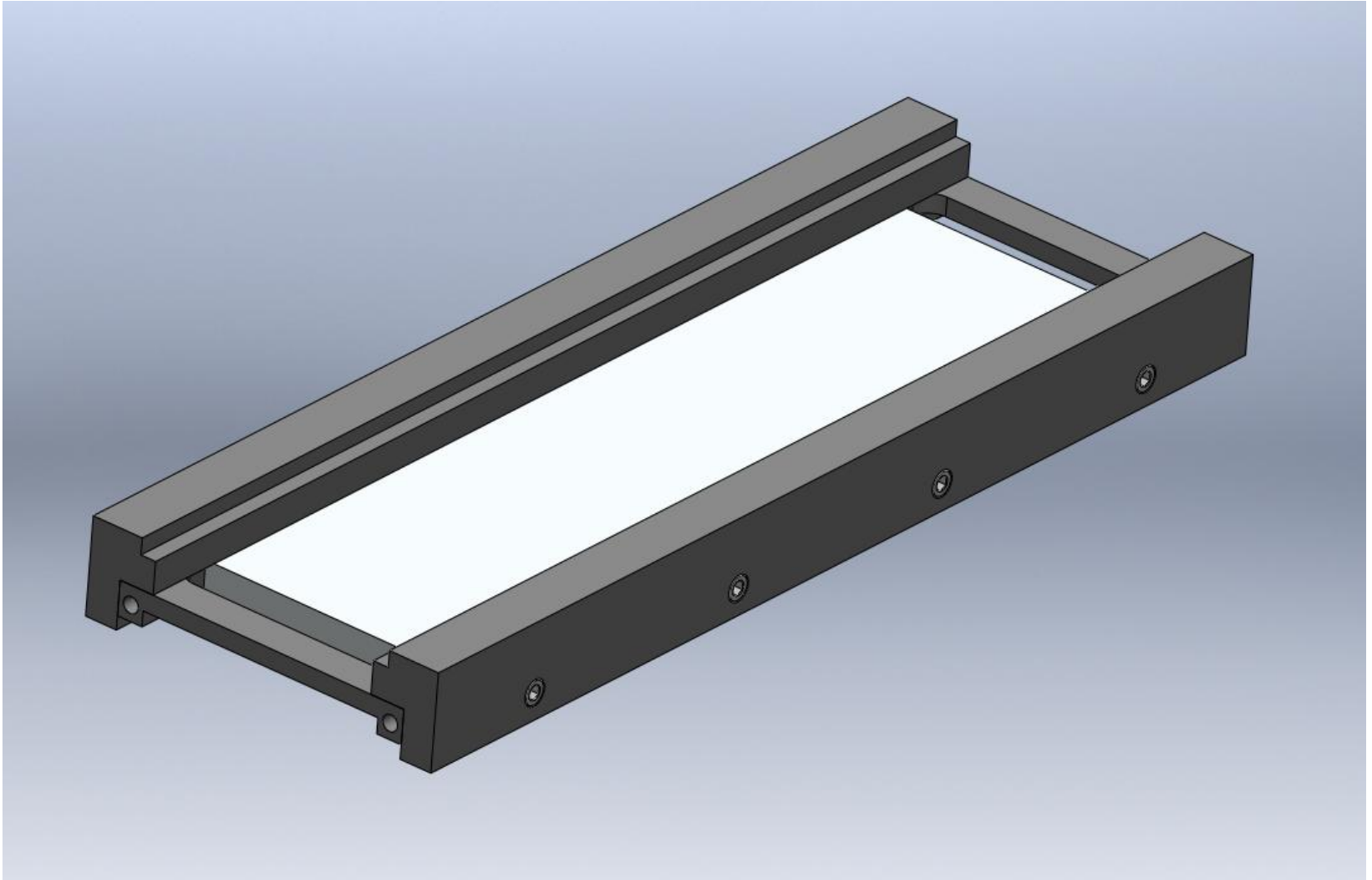
Problem:

- CubeSats cannot be placed on sides without causing damage to solar panels
- These positions are optimal for assembly integration and testing
- Problem encountered in FIREBIRD mission and will recur in future CubeSat missions
- What do we do?



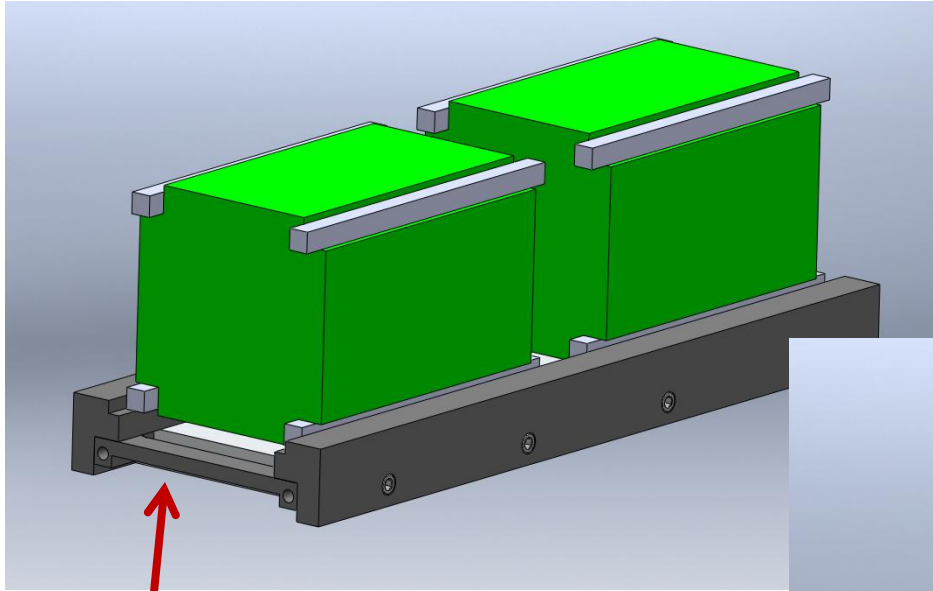
Old System

TA DA!



Can fit up to two 1.5 U
CubeSats at a time

Heavy aluminum base
makes it stable

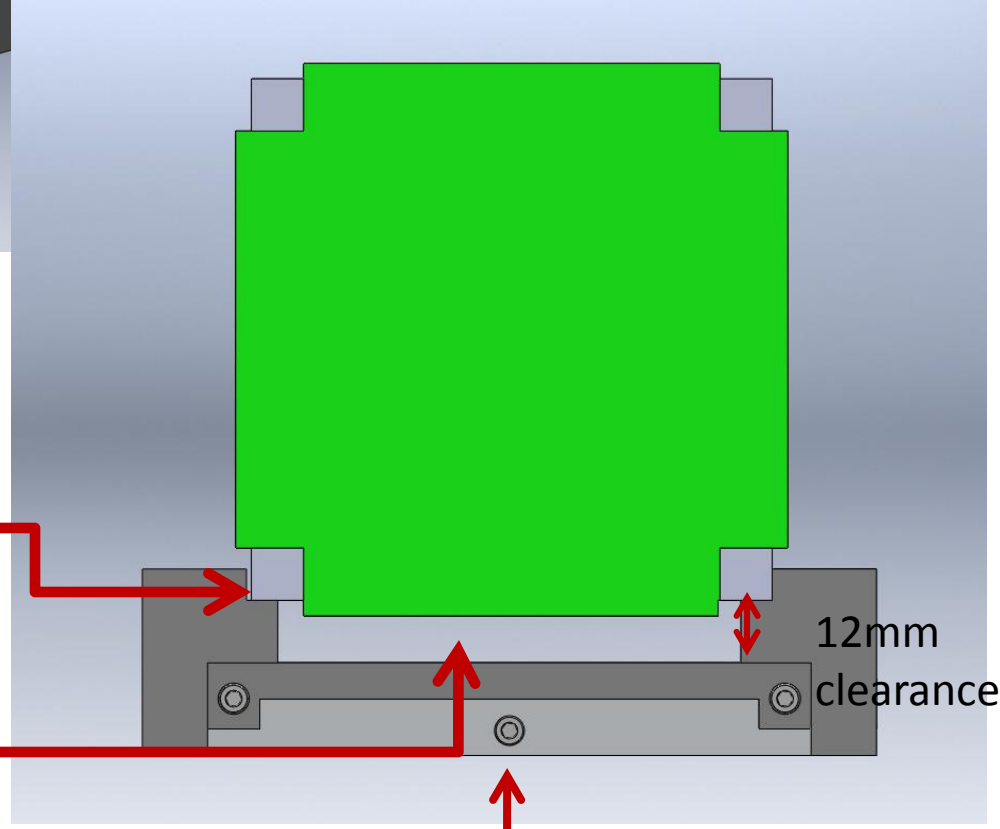


Handles

Holder only contacts rails of
CubeSat

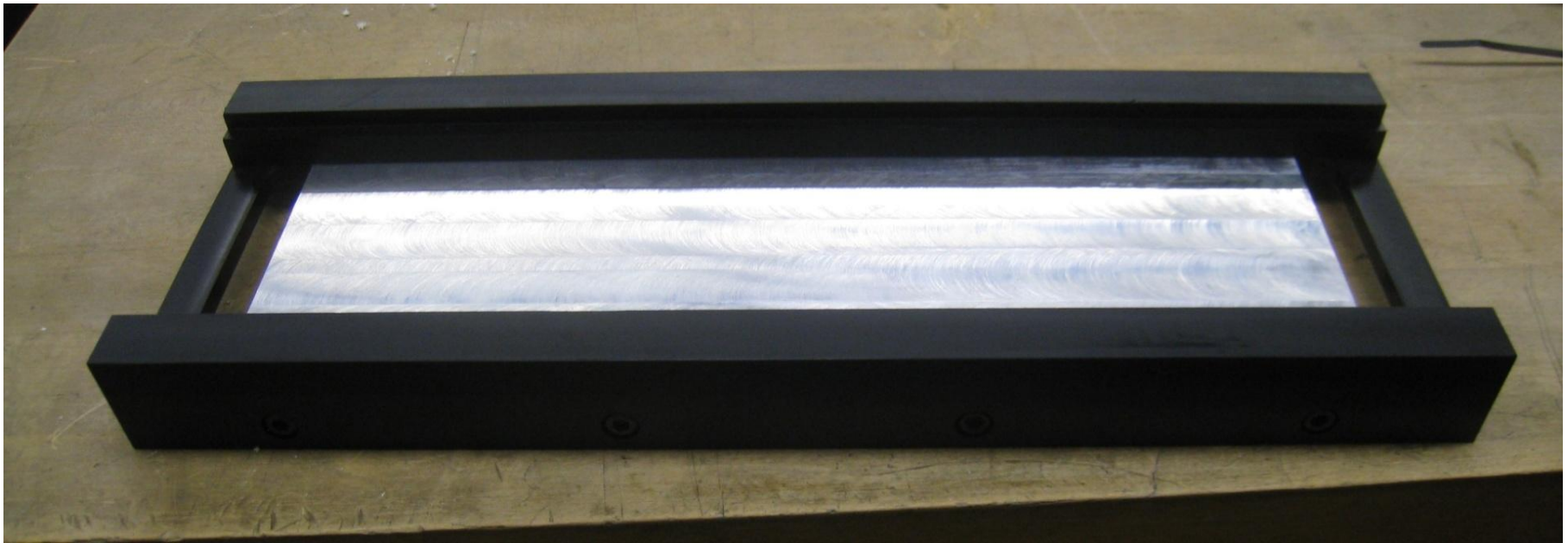
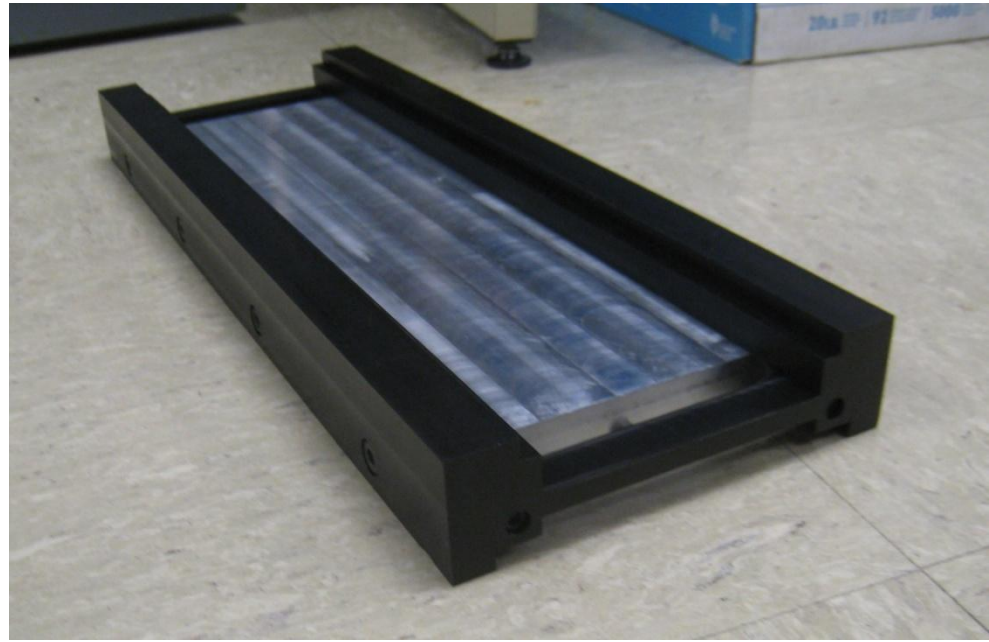
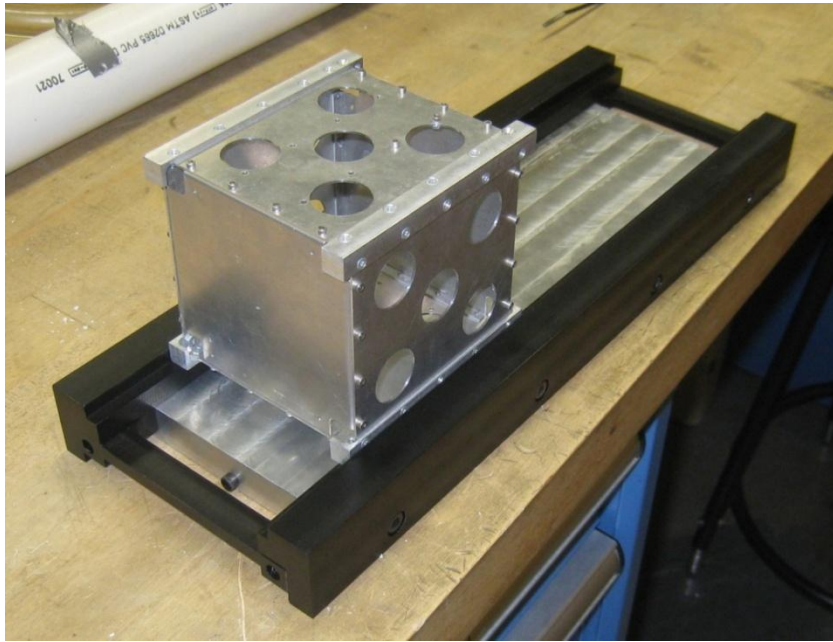
Bottom solar panel is floating

Easy repositioning

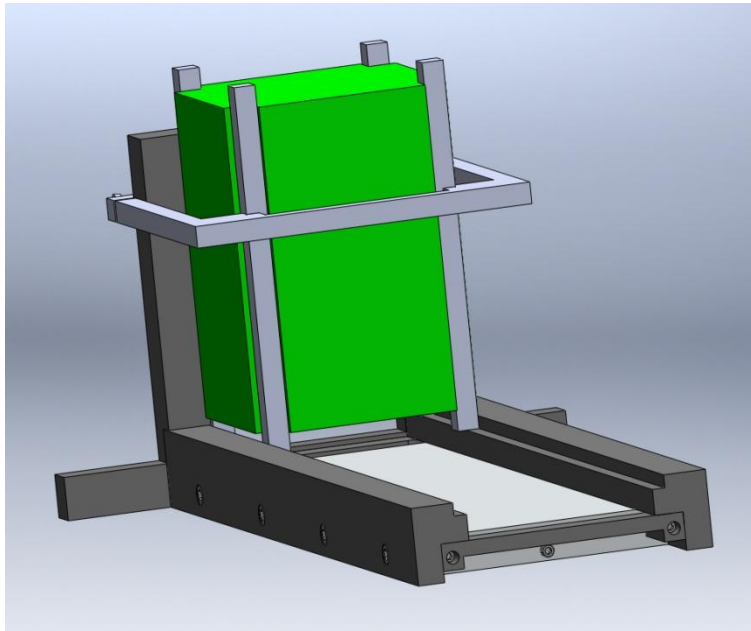


12mm
clearance

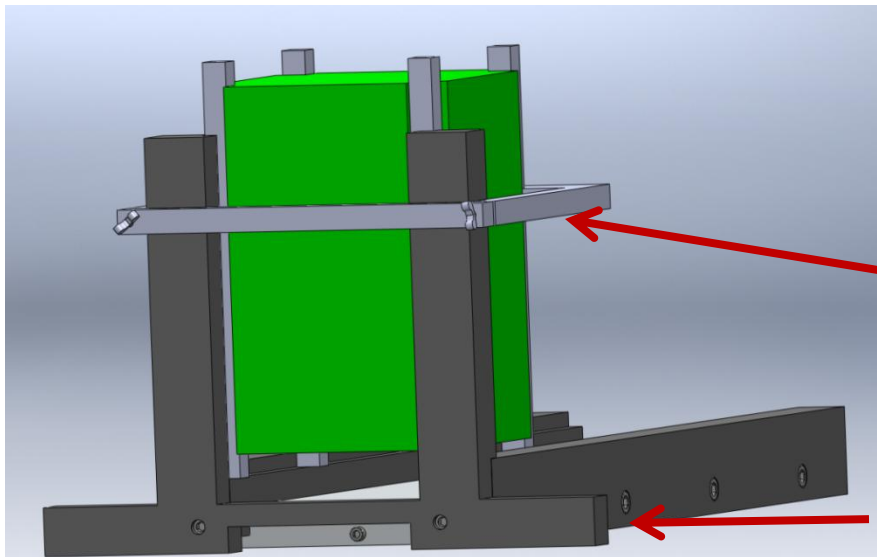
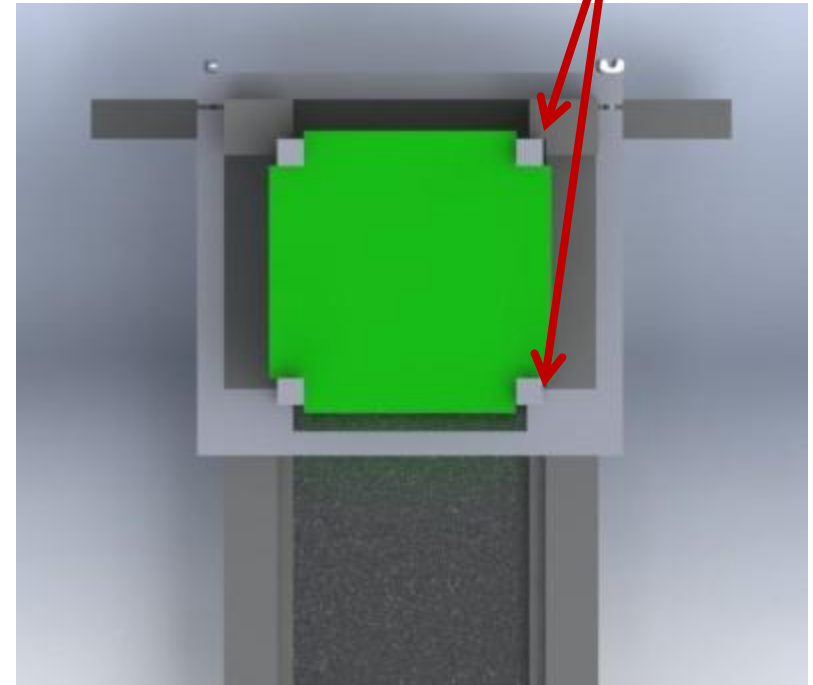
Ground screw



Future Modifications



Only rails are contacted



Easy to adjust slide grip

Can fit up to 3U

Legs make stand stable so won't tip over

Conclusions

- FIREBIRD Separation System
 - Separation velocity requirement should be met by implementing energy reducing techniques- limit range of motion
 - Actual velocity can be up to 27% greater than expected from numerical integration and still be within range
- CubeSat Stand
 - CubeSat stand works well and can be easily modified for other orientations in the future

Thanks for having me here this summer!

