Deployable Package for Enhanced Power and Deorbit Capabilities in CubeSat Satellites

Ian Bournelis

Matthew D'Arcy

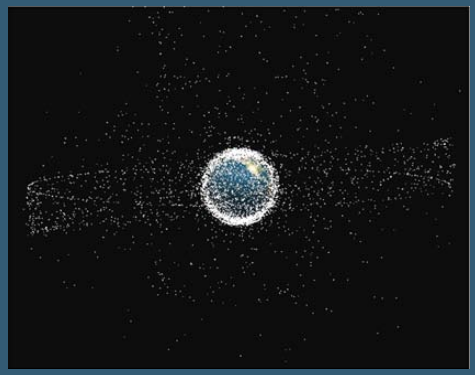
Anthony Iacono

Matthew Mazur

Faculty Advisors: Dr. Ajmal Yousuff, Dr. Jin Kang

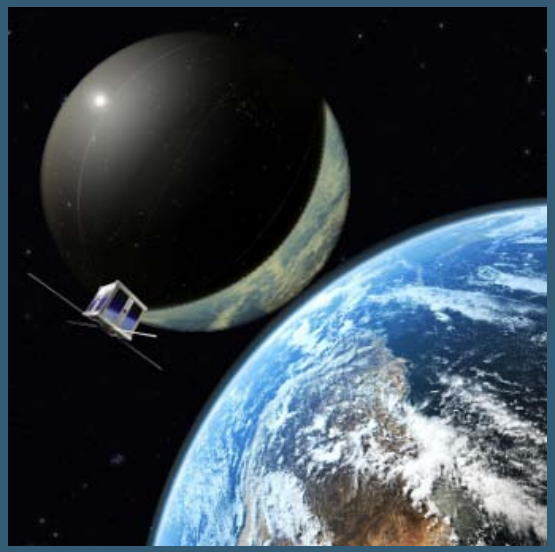
APPLICABLE CUBESAT STANDARDS

- ISO 27852:2010(E)
  - 25 Year Limit
  - Models with error margins
- NASA NPR 8715.6A
  - Corroborates ISO 27852:2010(E)
  - Responsibilities of key NASA personnel
    - Mission Assurance
    - Protection of launch vehicle, payloads, environment, public
    - At worst case, payload is removed from launch manifest

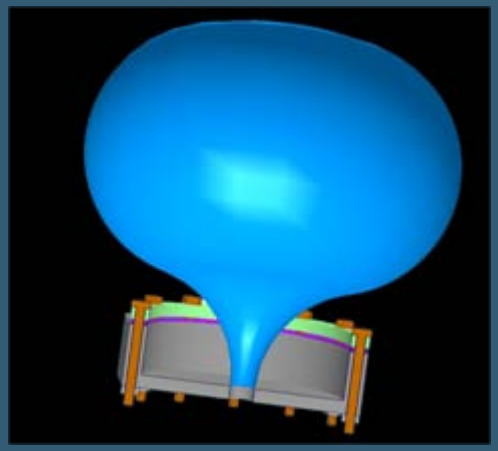


ISO 27852:2010(E): Distribution in Near-Earth Space

DEORBIT AID CONCEPTS



University of Strathclyde
Inflatable Balloon



Old Dominion University
Inflatable Balloon

NASA NanoSail-D
Solar Sail

- Increasing Incident area for hastened deorbit

MISSION STATEMENT

Increase power generation and decrease deorbit time on command without adding significant mass, losing internal volume, or implementing active control systems.

DESIGN PARAMETERS

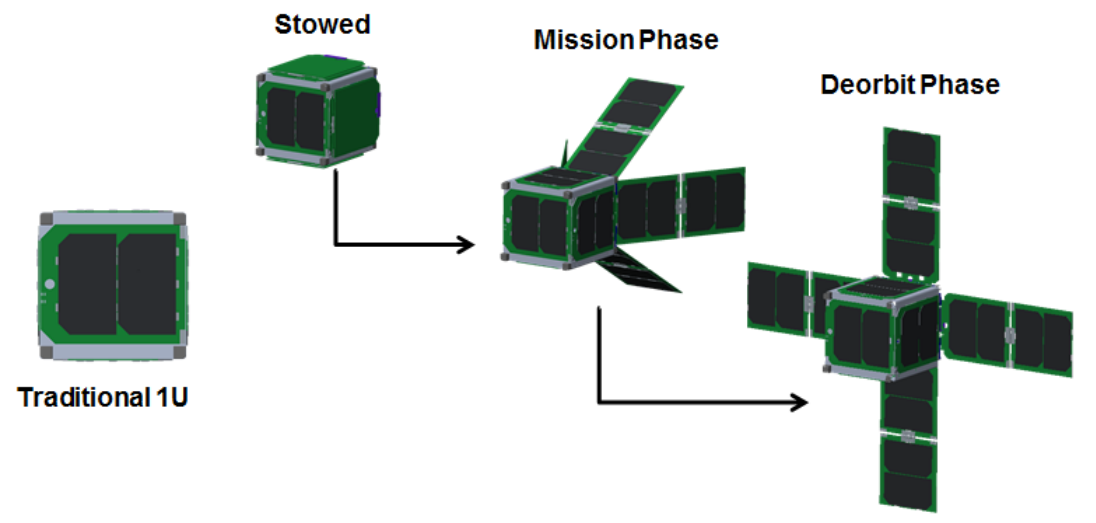
- No use of internal volume
- Minimize number of moving parts (for reliability)
- Maximize cross sectional area during deorbit phase to increase drag
- Increase power generation
- Use passive actuation on command

SUCCESS CRITERIA

Metric	Threshold	Ideal
Increase in power generation	>100%	>200%
Decrease in deorbit time	>20%	>50%
Active control	None	None
Loss of internal volume	<5%	0%
Reliability	>90%	>95%
Cost to manufacture	<$10000	<$5000
Number of Moving parts	<10	<5

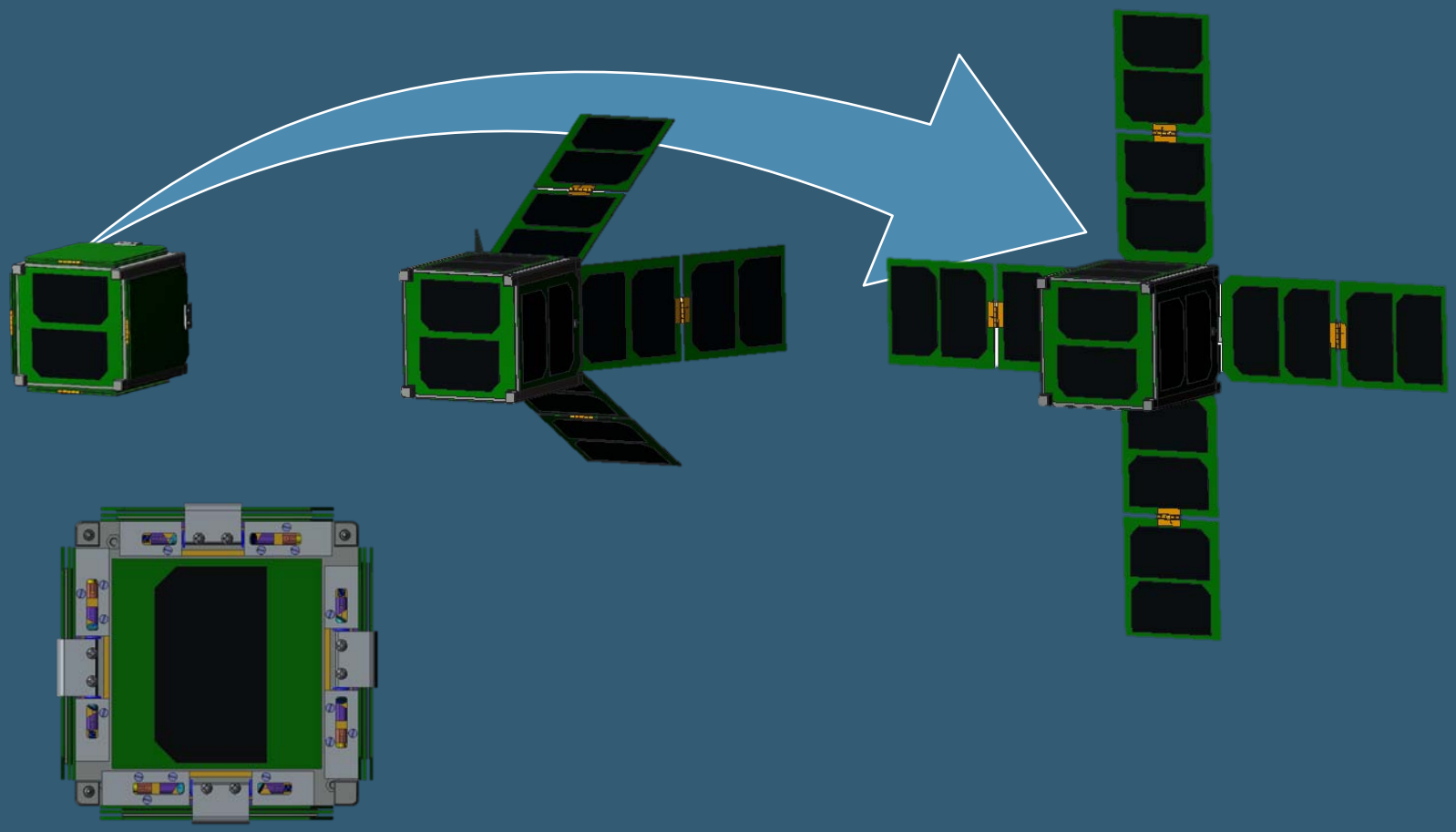
SOLUTION

- Capable of 3.5x power generation of a 1U
- Deorbit efficiency increases with launch altitude
- Passive attitude control in pitch and yaw

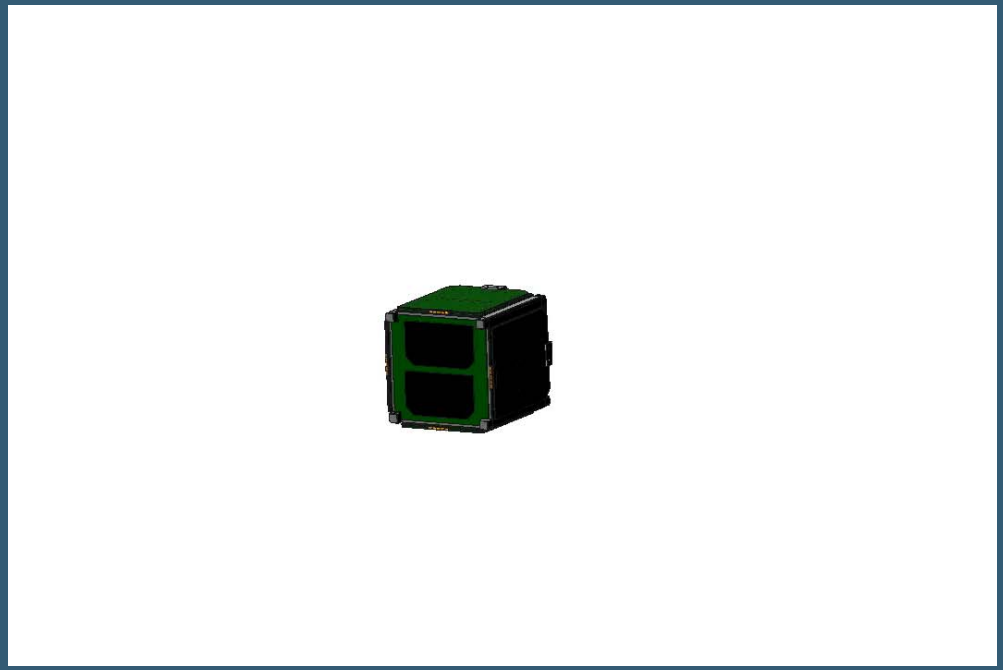


PERFORMANCE ANALYSIS

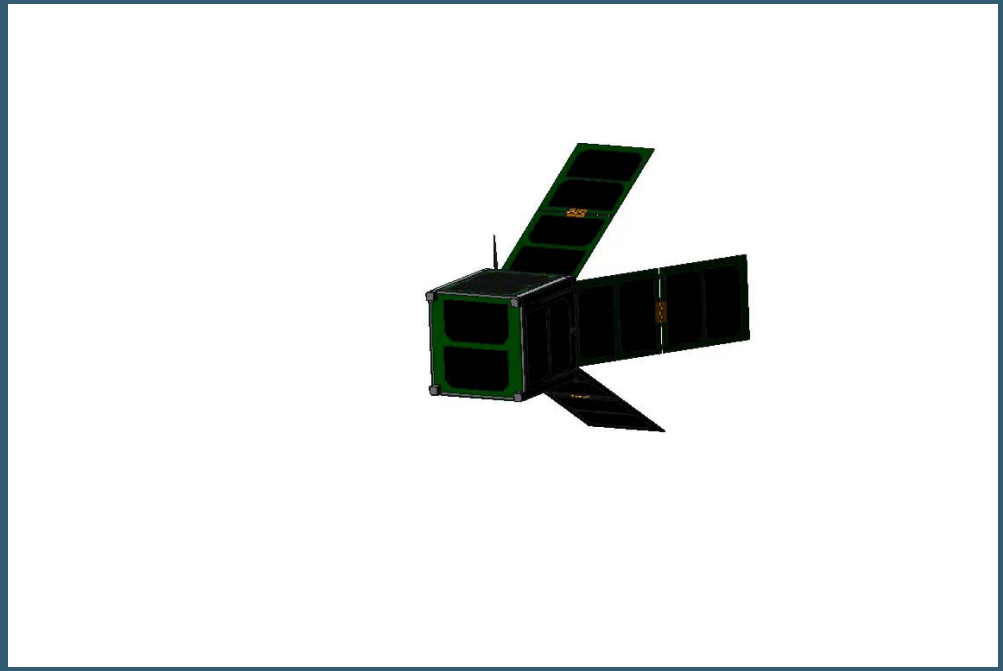
THREE STAGE SHUTTLECOCK



DEPLOYMENT

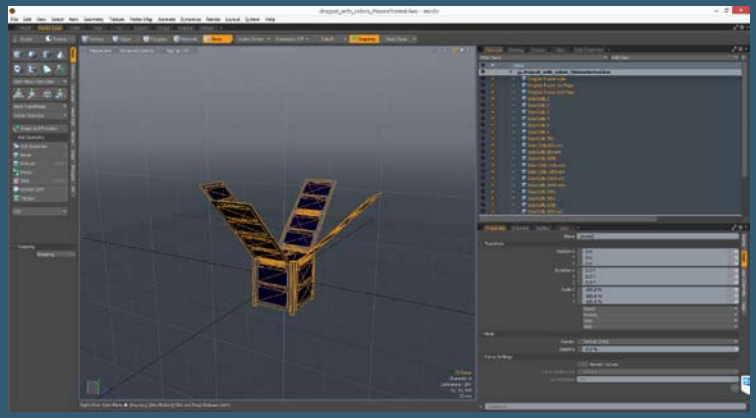


DEORBIT



SIMULATION TOOLS

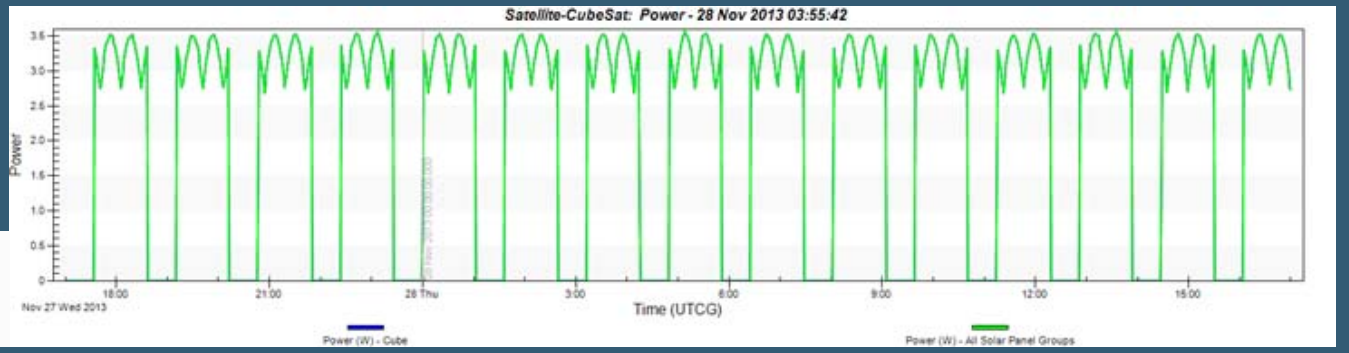
- Creo 2.0
  - Satellite Modeling
- Modo 701
  - Satellite Modeling
  - Preparation for STK Simulation
- STK (Systems Toolkit)
  - Satellite lifetime simulation (SATPro)
  - Satellite power generation
- MATLAB
  - LEO Drag Analysis
  - Data Analysis
  - Concept Verification and Design



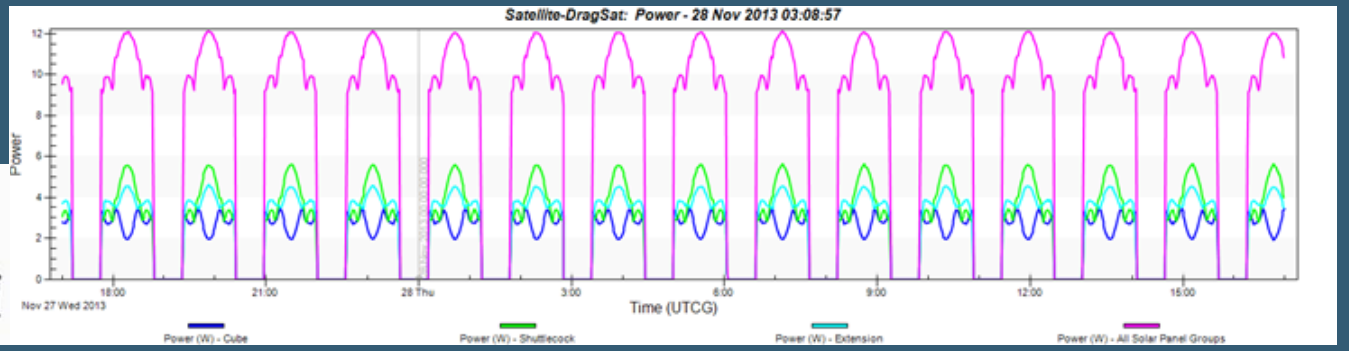
STK PEAK POWER

Power generation for 24 hours

3.47 W

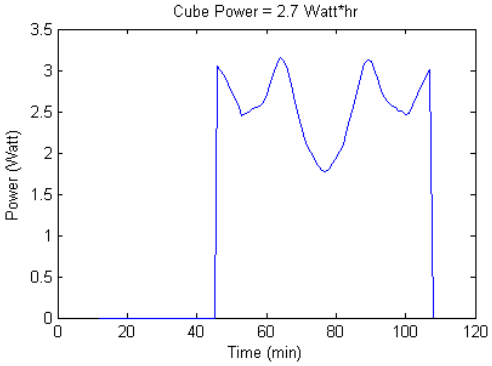


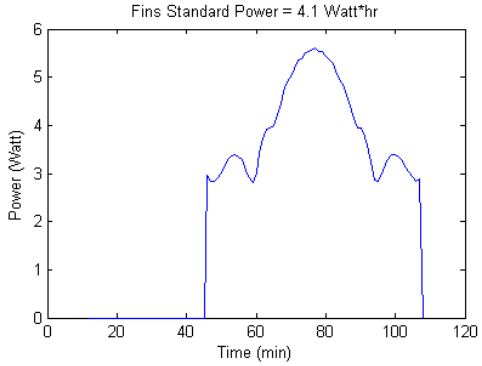
11.96 W



POWER GENERATION

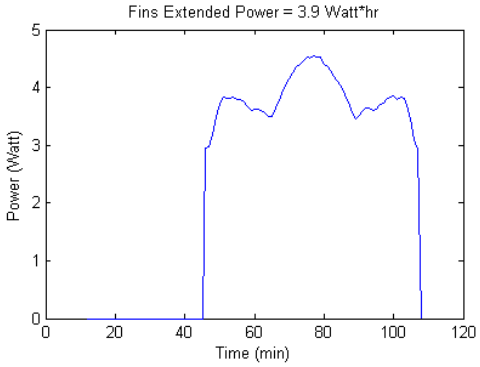
2.7 Watt*hr

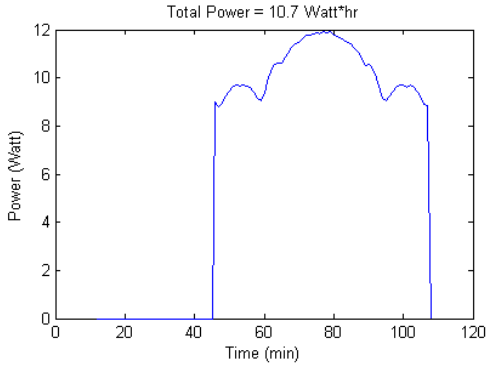




4.1 Watt*hr

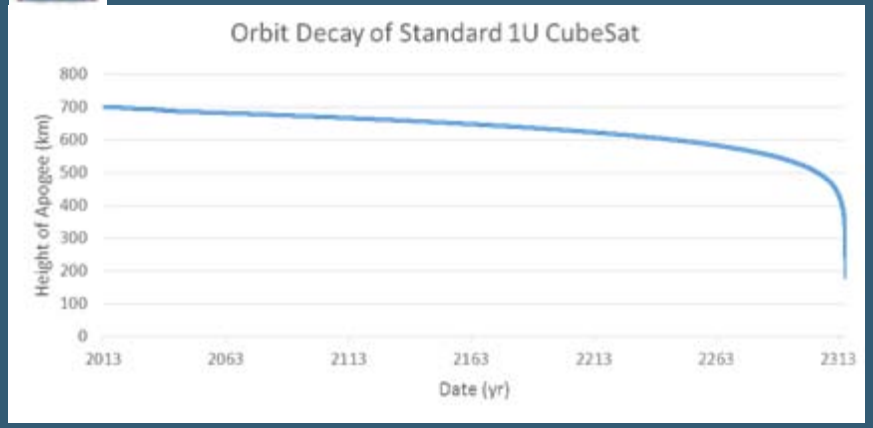
3.9 Watt*hr



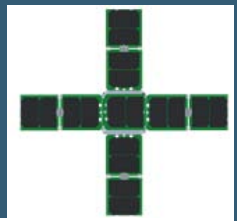


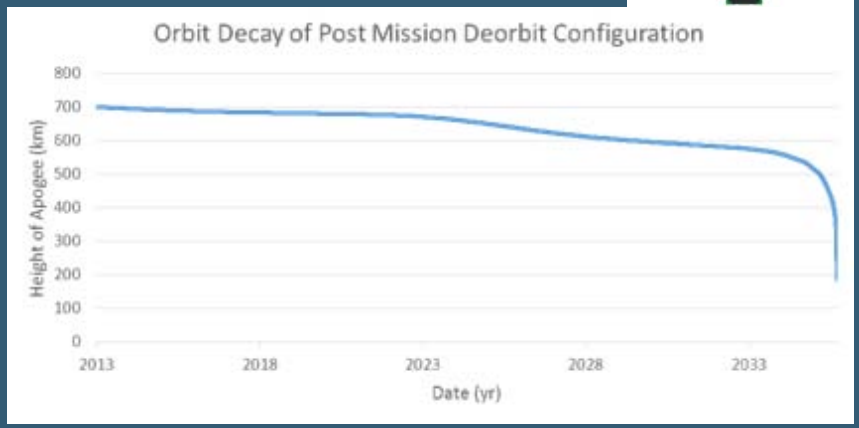
10.7 Watt*hr

ORBIT LIFE COMPARISON (STK)



Standard CubeSat 300+ Years





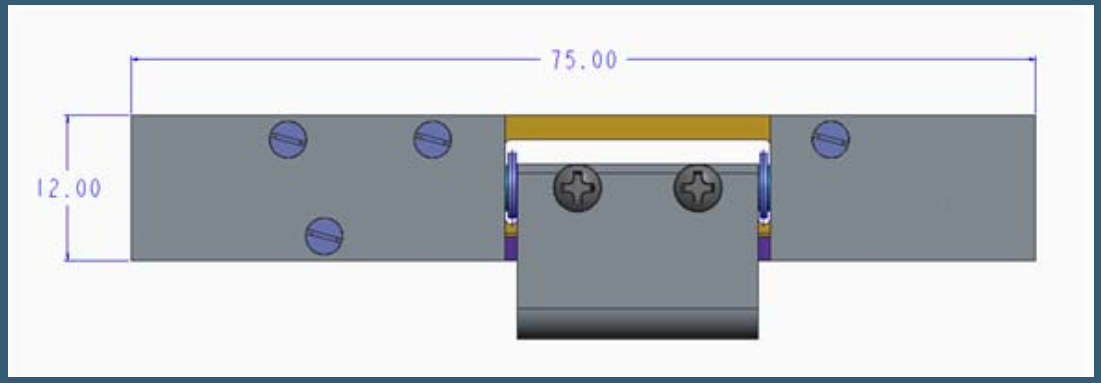
Deorbit Configuration with ~9X incident area: 22 Years

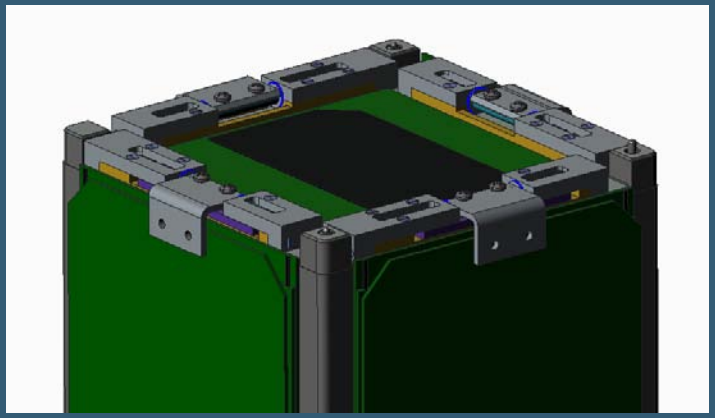
- Maximization of incident surface area
- For a 25 Year deorbit:
  - Ceiling of 540 km 1U standard CubeSat
  - Ceiling of 700 km for 1U shuttlecock formation

ACTUATOR DESIGN

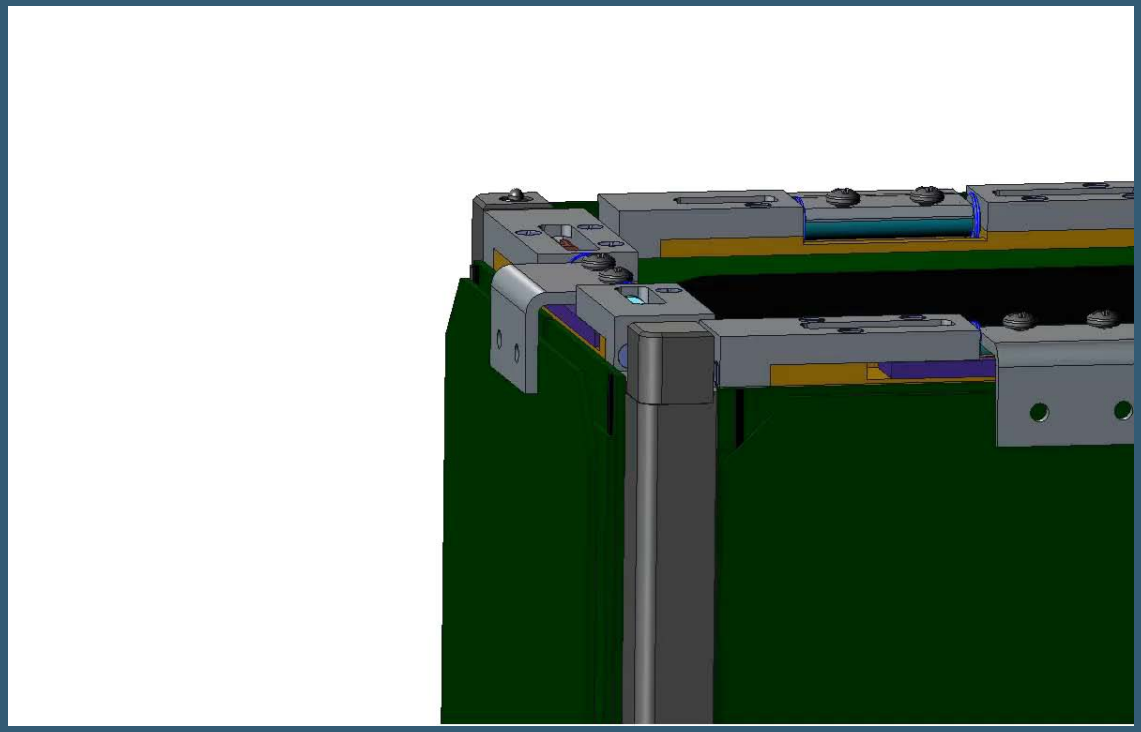
HINGE DESIGN OVERVIEW

- Dimensions: 75 mm (L) x 12mm (D) x 6.5mm (H)
- Mass: ~15 g
- Fastened to CubeSat surface





HINGE ACTUATION

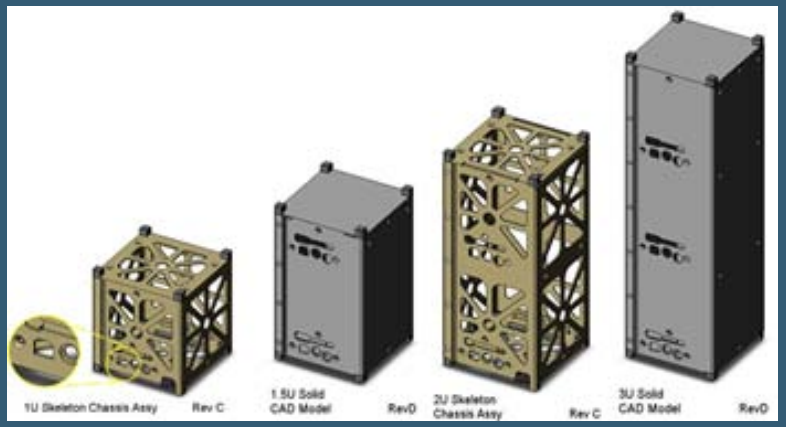


IMPLEMENTATION – KEY FEATURES

- Three stage hinge with passive actuation
  - Burn wire release
- Actuation to any two angles between 0 and 180 degrees
- Net torque: ~4 N-mm
- Compatible with standard CubeSat frame
- Activated electrically with burn circuit
- Low profile and minimum volume interference

DESIGN CHARACTERISTICS

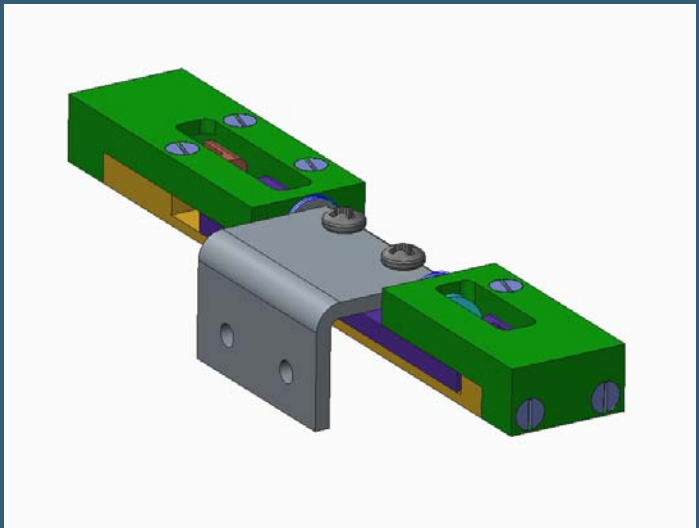
- Modular – applications for 2U, 3U
- Scalable - larger hinge could be used for larger satellites
- Capable of increasing the CubeSat's altitude while still deorbiting within 25 years



Pumpkin CubeSat Frames

FUTURE WORK

- Prototype under fabrication
- Environmental testing in May 2014
- Will be implemented on next CubeSat that we develop



CONCLUSION

Metric	Threshold	Ideal
Increase in power generation	>100%	>200% ✓
Decrease in deorbit time	>20% ✓	>50%
Active control	None	None ✓
Loss of internal volume	<5%	0% ✓
Reliability	>90%	>95%
Cost to manufacture	<$10000	<$5000 ✓
Number of Moving parts	<10	<5 ✓

REFERENCES

- [1] Maslova, A.I.; Pirozhenko, A.V., " Modeling of the Aerodynamic Moment Acting upon a Satellite," Cosmic Research, vol. 48, no. 4, pp. 362-370, August 2010.
- [2] Moe, K. Moe, M.M., " Gas-surface Interactions in Low-earth Orbit," AIP Conference Proceedings, vol. 1333, pp. 1313-1318, July 10-15 2010.
- [3] Walker, A C; Koller, J; Mehta, P M, " Comparison of Different Implementations of Diffuse Reflection with Incomplete Accommodation for Satellite Drag Coefficient Modeling," Planetary and Space Science.
- [4] King-Hele, D.G., " The upper atmosphere as sensed by satellite orbits," Planetary and Space Science, vol. 40, no. 2-3, pp. 223-233, Feb.-March 1992.
- [5] Moe, K.; Moe, M.M., " Gas-surface interactions and satellite drag coefficients," Planetary and Space Science, vol. 53, no. 8, pp. 793-801, July 2005.
- [6] Crowther, R.; Stark, J, " The determination of the gas-surface interaction from satellite orbit analysis as applied to ANS-1 (1975-70A)," Planetary and Space Science, vol. 39, no. 5, pp. 729-736, May 1991.
- [7] Bowman, B R; Moe, K, " Drag Coefficient Variability at 175-500 Km from the Orbit Decay Analyses of Spheres,"US/Russian Space Surveillance Workshop, vol. 6, August 22-26, 2005.
- [8] Wade, M. (n.d.). Encyclopedia Astronautica KH-11. *KH-11*. Retrieved November 30, 2013, from http://www.astronautix.com/craft/kh11.htm
- [9] "Some Useful Information About CubeSats," Clyde-Space.com, [online] 2013, http://www.clyde-space.com/cubesat/som_useful_info_about_cubesats (11/25/2013)
- [10] The CubeSat Program - Cal Poly SLO, United States of America. "CubeSat Design Specification Rev. 13," Aug. 19, 2013.
- [11] "Space Systems - Estimation of Orbit Lifetime." Draft International Standard ISO/IADC 27852:2010(E). November 22, 2013. http://aiaa.kavi.com/apps/group_public/download.php/3159/ISO_27852_(E)4.pdf
- [12] SpaceWorks Enterprises, Inc. "Nano/Microsatellite Market Assessment." February, 2013. http://www.sei.aero/eng/papers/uploads/archive/SpaceWorks_NanoMicrosat_Market_Feb2013.pdf
- [13] "NASA Procedural Requirements for Limiting Orbital Debris," NPR 8715.6A, May 14, 2009

QUESTIONS

Ian Bournelis
- ib57@drexel.edu

Matthew D'Arcy
- mmd79@drexel.edu

Anthony Iacono
- aji26@drexel.edu

Matthew Mazur
- mrm322@drexel.edu