Spacer Development and Analysis

Polar Orbiting Passive Atmospheric Calibration Spheres [POPACS]

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Drexel
UNIVERSITY

Mission Overview

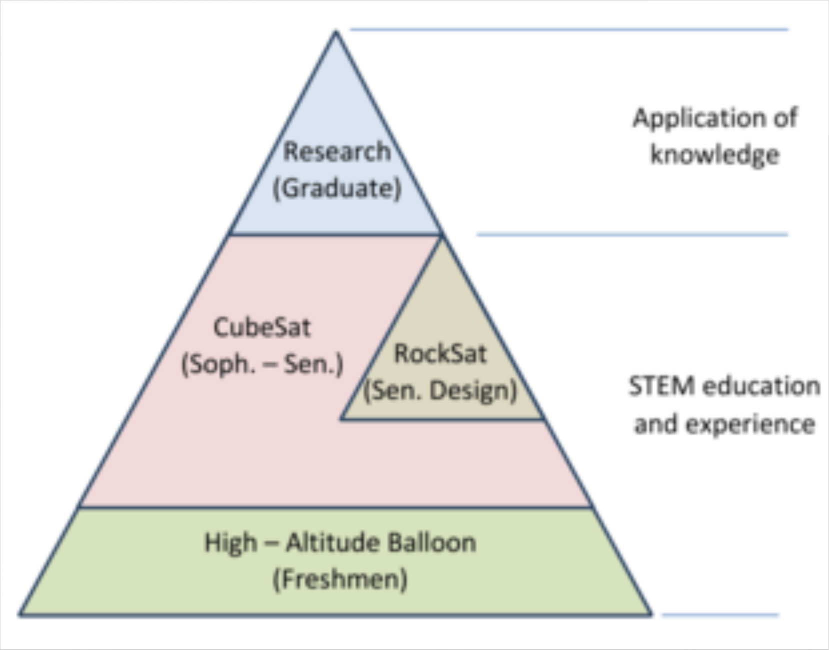
POPACS MISSION

- To measure changes in the density of the auroral zone upper atmosphere in response to various solar stimuli

DREXEL OBJECTIVE

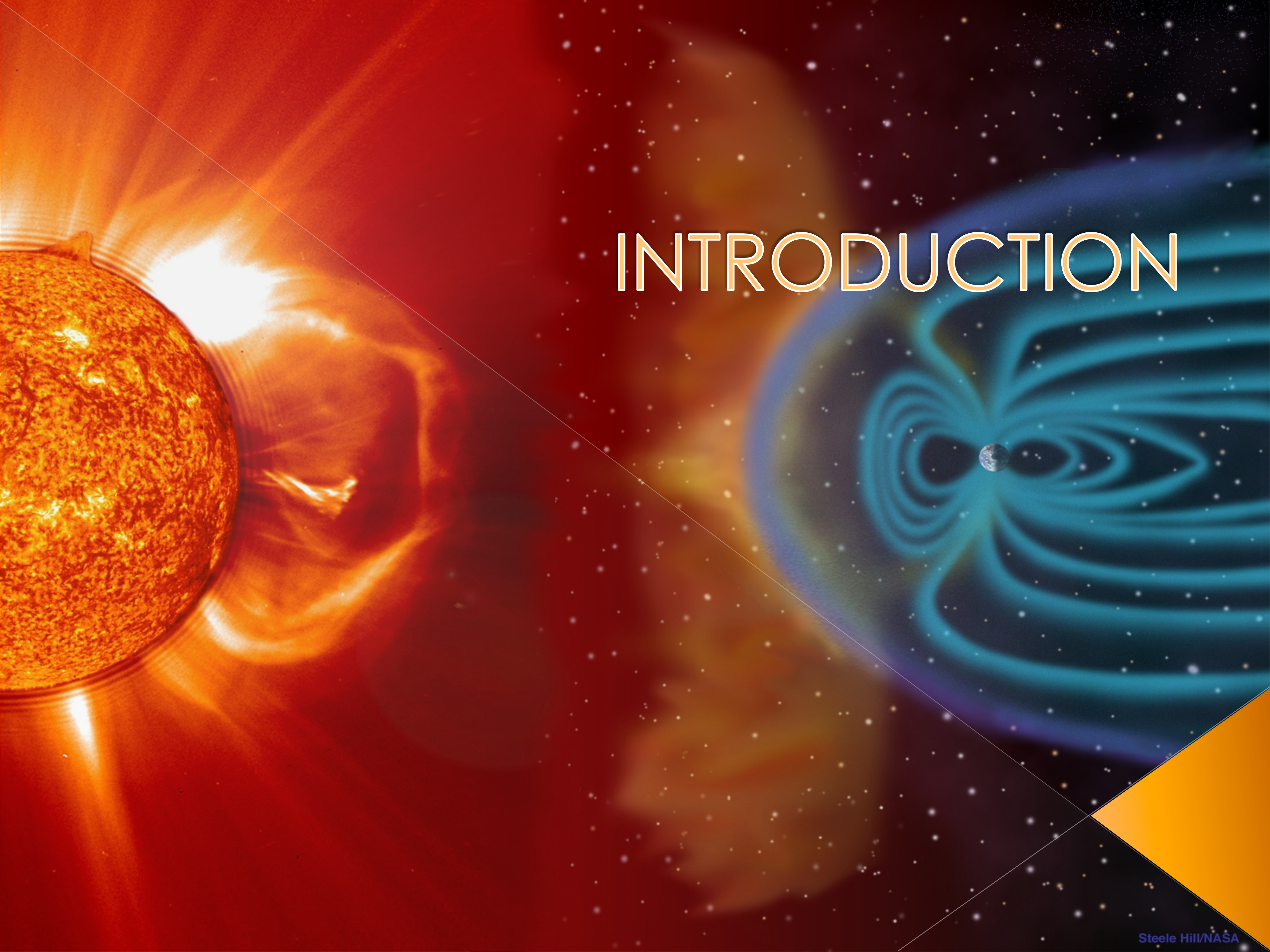
- To design and manufacture a spacer assembly used to support and deploy the spheres

Drexel Space Systems Lab



- Drexel University, Philadelphia, PA
- Started in September 2009
- Part of Mechanical Engineering and Mechanics Department
- Projects include:
  - DragonSat-1 CubeSat
  - RockSat-C Program
  - High Altitude Balloon
  - Graduate Research

INTRODUCTION

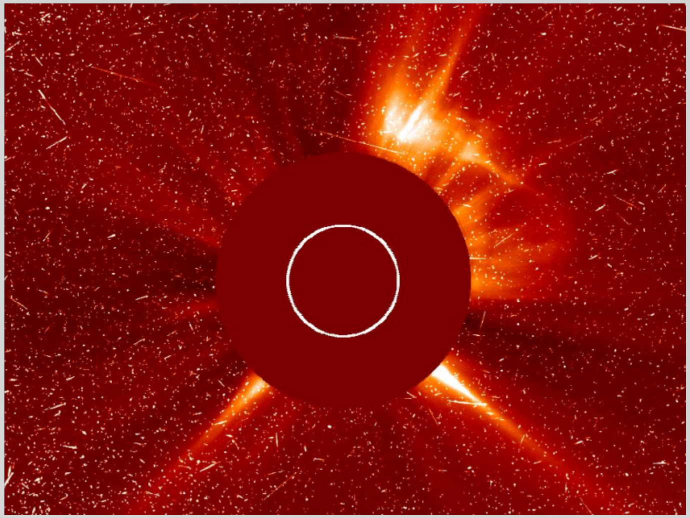


Introduction

- Project spearheaded by Gil Moore, POPACS Project Director
- Collaborative effort amongst many entities including Drexel University Space Systems Lab (DSSL) and Planetary Systems Corporation (PSC)
  - PSC will provide deployment mechanism
    - 3 Unit Canisterized Satellite Dispenser (CSD)
  - DSSL to design spacer structure

Introduction

- Solar Maximum 24 begins early next year
  - 3 years worth of heightened activity
  - Will lead to an increase in particulate matter in upper auroral atmosphere



CME from Sunspot 1429

March 8, 11:38 PM EST to March 9, 12:53 AM EST

Credit: SOHO/ESA & NASA

Introduction

- 3 spheres of 10 cm diameter and different masses will be deployed into highly elliptical orbit
  - 1, 1.5, 2 kg
  - Variations in atmospheric density will change orbit characteristics
  - Understanding these changes will lead to better understanding of upper atmosphere
- Near Polar Orbit
  - 80 degree inclination
  - 325/1500km

Mission Statement

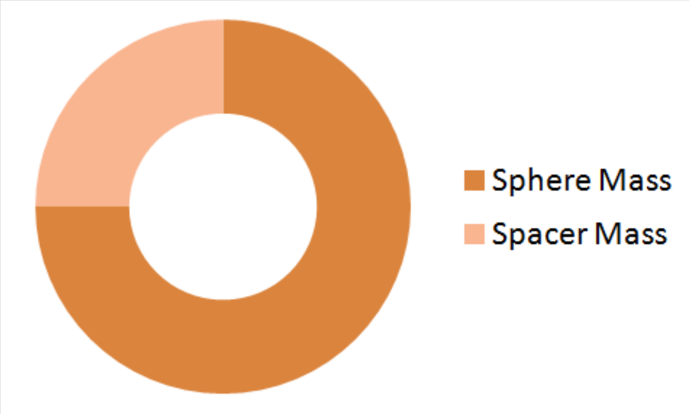
- Assembly must be designed to PSC 3U CSD dimensions and specifications
  - Treat as dynamic envelope
- Manufacturing
  - Gil to make final spheres, also to be used for testing
  - Drexel team to design spacers

6 U CSD designed by PSC.

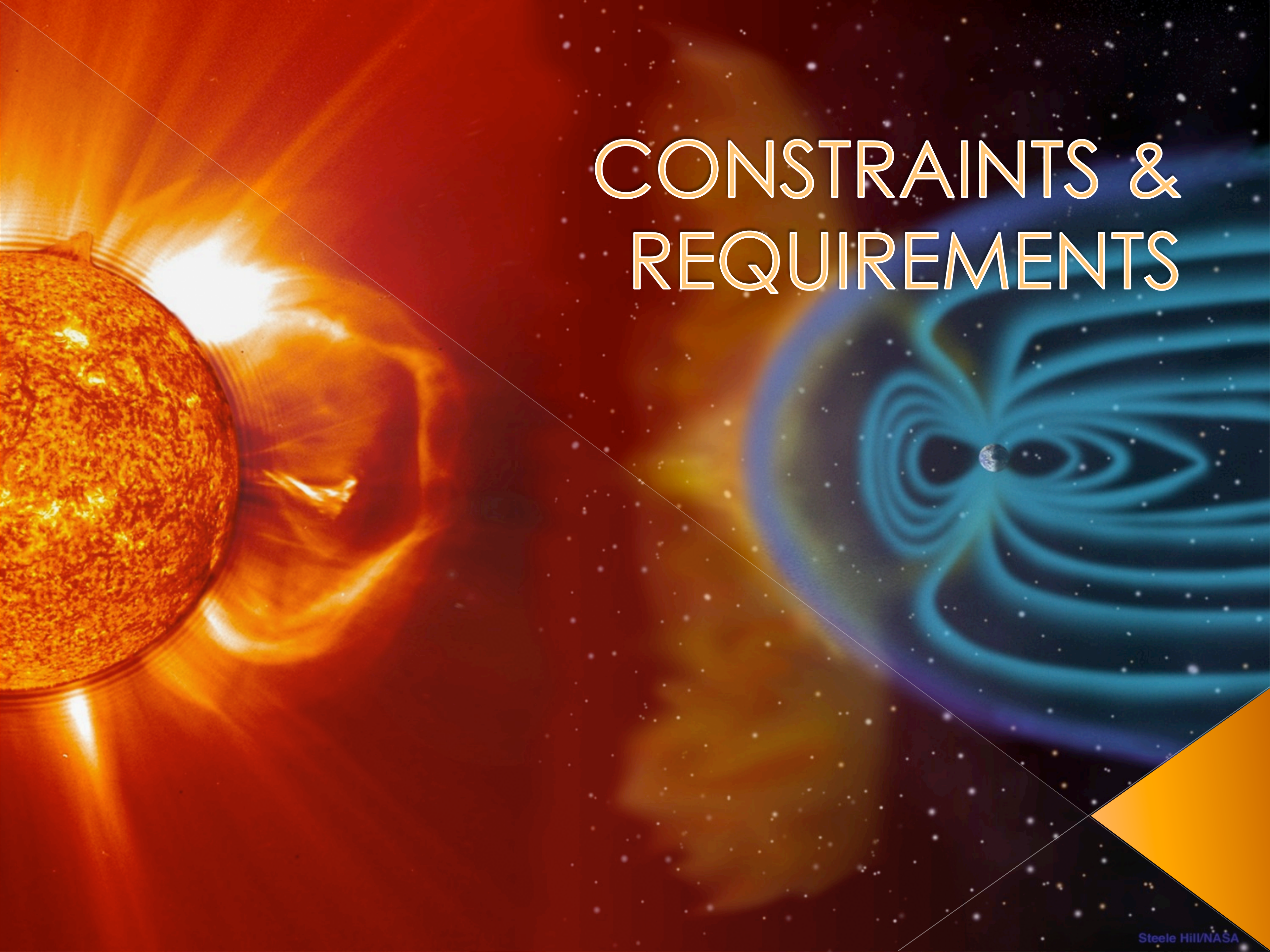
http://www.planetarysystemscorp.com/

Main Challenges

- Low mass
- Stay within volume constraints
- Must cradle the spheres firmly enough to withstand launch conditions but gently enough to not damage the sphere surface
- Manufacturability
- Rigidity of structure



CONSTRAINTS & REQUIREMENTS



Mission Requirements

Number	Requirement
MIS-REQ-1000	**Delivered to launch service by 4th Qtr 2012**
MIS-REQ-2000	**Shall abide by PSC 3U Payload Specifications**
MIS-REQ-3000	**Spacers shall minimize motion of spheres while stowed in launcher**
MIS-REQ-4000	**Spacers shall be able to deploy three spherical structures upon command**
MIS-REQ-5000	**Spacers shall not interfere with path of spheres**
MIS-REQ-6000	Orbital debris shall be minimized
MIS-REQ-7000	Shall pass all pre-launch testing

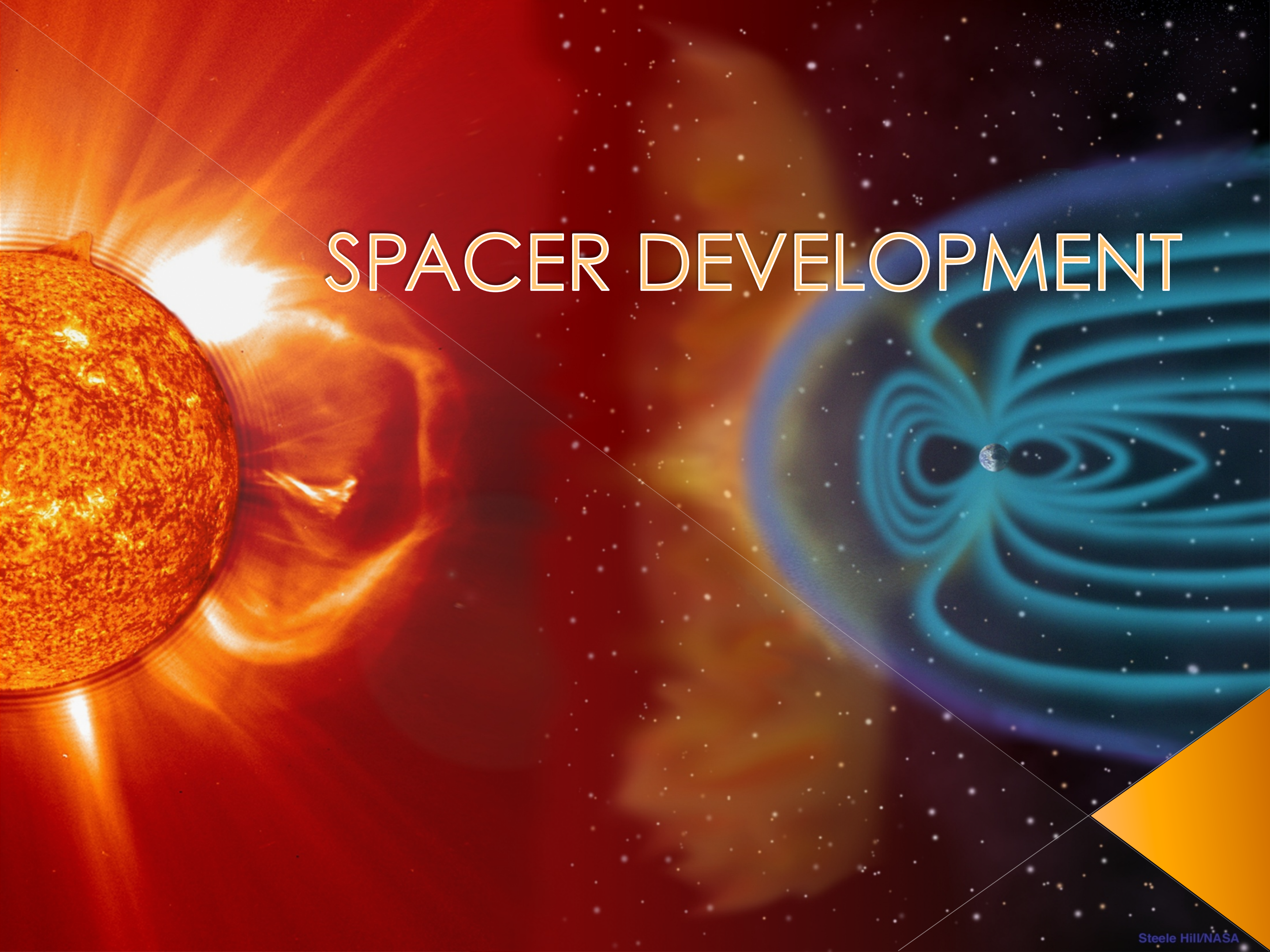
System Requirements

Number	Requirement
SYS-REQ-2010	**Spheres shall be made out of 6061 T-6 aluminum**
SYS-REQ-2020	**Mass of total system ≤ 6 kg**
SYS-REQ-2030	**Masses of 3 Spheres = 2.0kg, 1.5kg, 1.0kg ± 0.1kg**
SYS-REQ-2040	**Sphere Diameter = 10cm ± 0.013cm**
SYS-REQ-2050	**Sphere Center of Mass Variation = Center ± 0.0025cm**
SYS-REQ-2060	Sphere Surface Smoothness = Ra < 1
SYS-REQ-2070	Sphere External Surface Treatment
SYS-REQ-2080	Sphere hemispheres shall be detachable
SYS-REQ-2090	Spacers shall have full tab contact
SYS-REQ-2100	No sharp edges

System Requirements

Number	Requirement
SYS-REQ-3010	**Spacers shall withstand effects of vibrational forces on spheres**
SYS-REQ-3020	**Spacers shall withstand effects of acceleration forces on spheres**
SYS-REQ-4010	**Spacers shall not damage surface treatment**
SYS-REQ-4020	Spheres shall not touch any part of PSC's deployment mechanism or each other
SYS-REQ-6010	Back spacer shall remain behind
SYS-REQ-6020	Spacers shall de-orbit as soon as possible
SYS-REQ-7010	Thermal vacuum testing (8 cycles from -34°C to +80°C at pressure less than 10-4 torr)
SYS-REQ-7020	Vibrational testing: Default MIL-STD 1540 (14.1Grms in each of three mutually orthogonal axes, non-simultaneous)
SYS-REQ-7030	Quasi-static acceleration testing (50g in each of three mutually orthogonal axes, non-simultaneous)

SPACER DEVELOPMENT



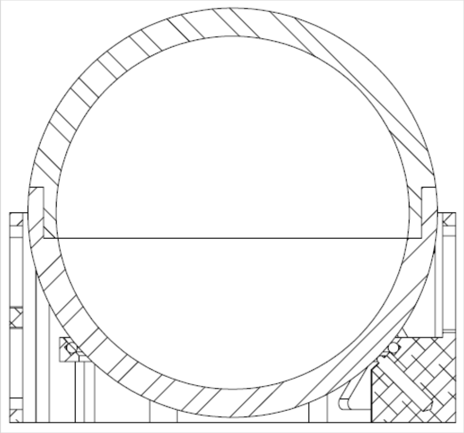
Steele Hill/NASA

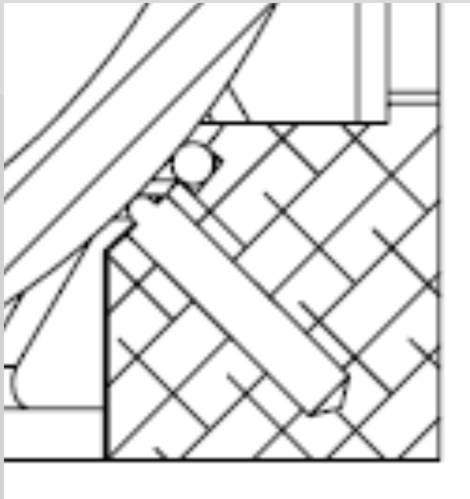
Solutions to Main Challenges

Challenge	Solution
Mass	Make cuts in spacer frame where possible
Stay within volume constraints	Created a dynamic envelop to allow for small displacement
Firm but gentle on spheres	Incorporated a viton o-ring and delrin-tipped spring plungers
Manufacturability	Did not over complicated features of spacers
Rigidity of frame	Stay within dynamic envelop – not allow sphere to come into contact with other components

Concept Design Decisions

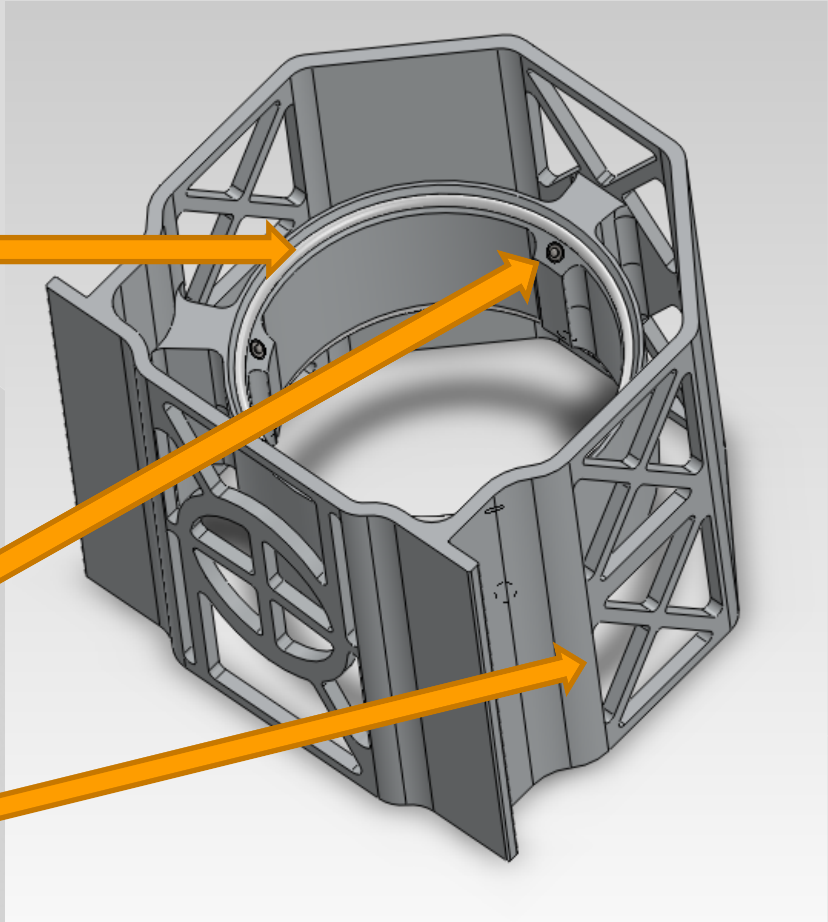
- Spring plunger
  - ensure the sphere separates from o-ring
  - Position them close to o-ring
- Viton o-ring
  - Needed the o-ring to be positioned correctly on the sphere to prevent rubbing against the spacer
- Spacer mass reduction cut outs
  - Shed extra mass without compromising shear strength using x style cut outs





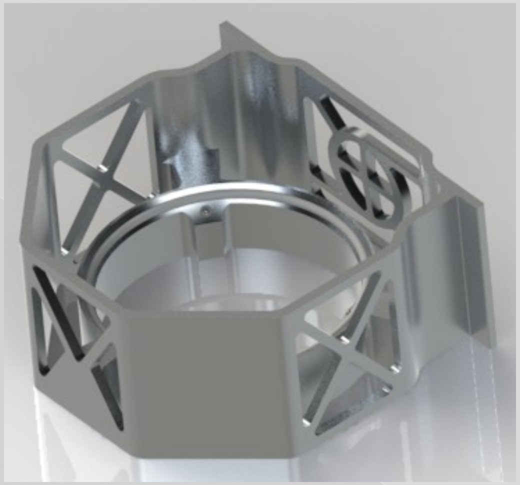
Concept

- Lightweight spacer
  - Use Viton o-ring to ensure sphere surfaces are not scratched
  - Incorporate acetal tipped spring plungers so spheres can exit the spacers without getting stuck to the o-ring
  - Spacer frame cut outs

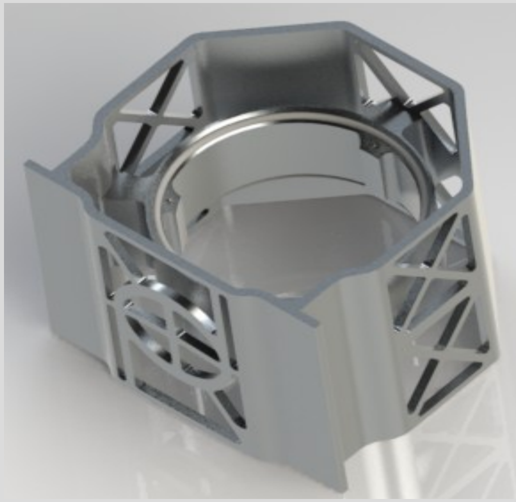


Concept Model

Assembly



Top/Bottom Spacer

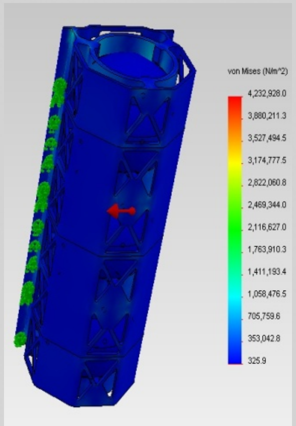


Mid Spacer

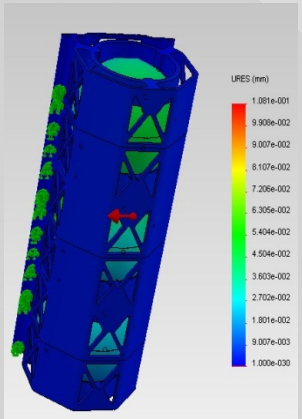
Primary Model Test

Actual Mass = 5794.53g

X Direction



Stress Plot

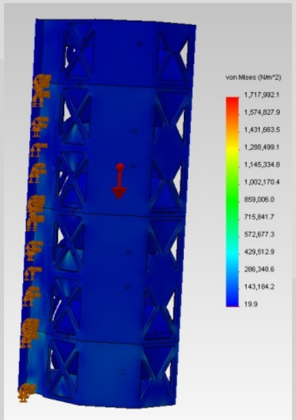


Displacement Plot

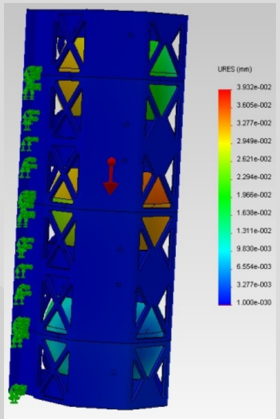
Result Force = -57.912N

Theo. Mass = 5903.4 g

Y Direction



Stress Plot

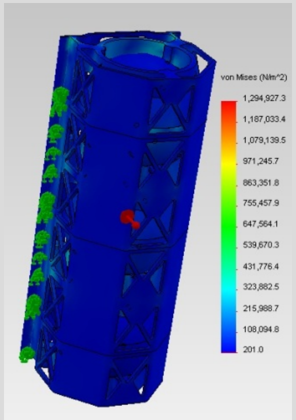


Displacement Plot

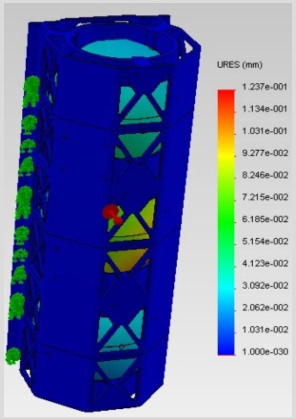
Result Force = 58.602N

Theo. Mass = 5973.7 g

Z Direction



Stress Plot



Displacement Plot

Result Force = -57.912N

Theo. Mass = 5903.4 g

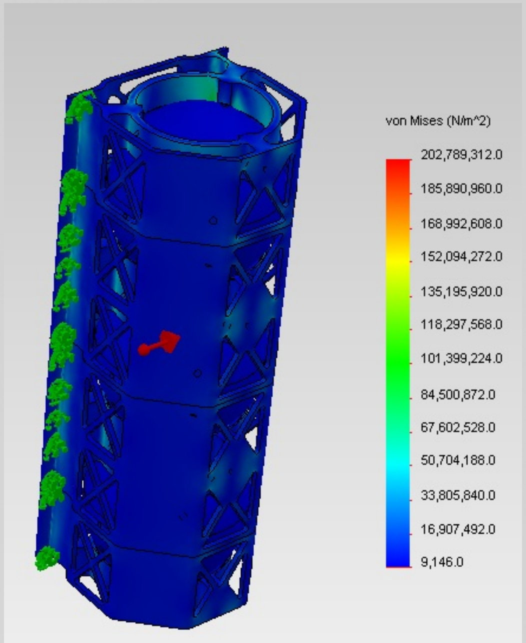
Assumptions:

- Tabs were fixed
- Connections were contact sets
- Solid mesh type

Stress Analysis

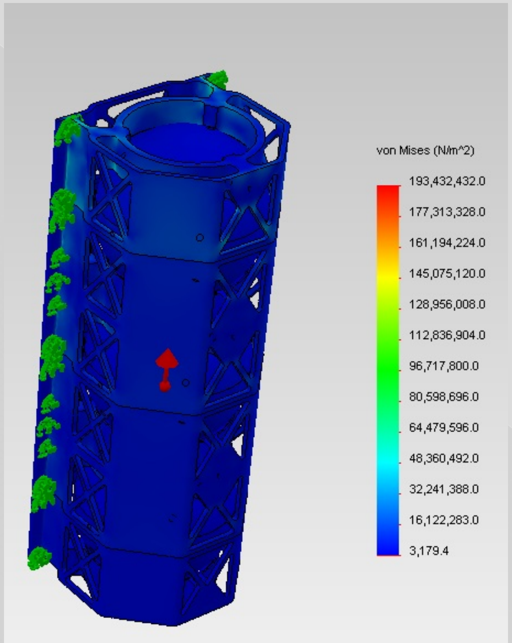
- 80g Load in X, Y, and Z Axis

X Direction



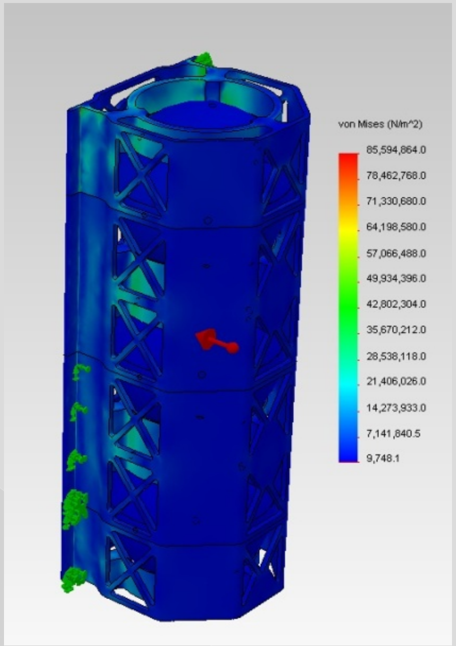
Max Stress: 29.4 ksi

Y Direction



Max Stress: 28.0 ksi

Z Direction



Max Stress: 12.4 ksi

6061 T-6 Aluminum Max Stress: 45.0 ksi

Testing Plan

- Testing to be done at PSC in September
  - Thermal vacuum
  - Vibration
  - Quasi-static loading
- MicroGrav
  - Looking to purchase a flight

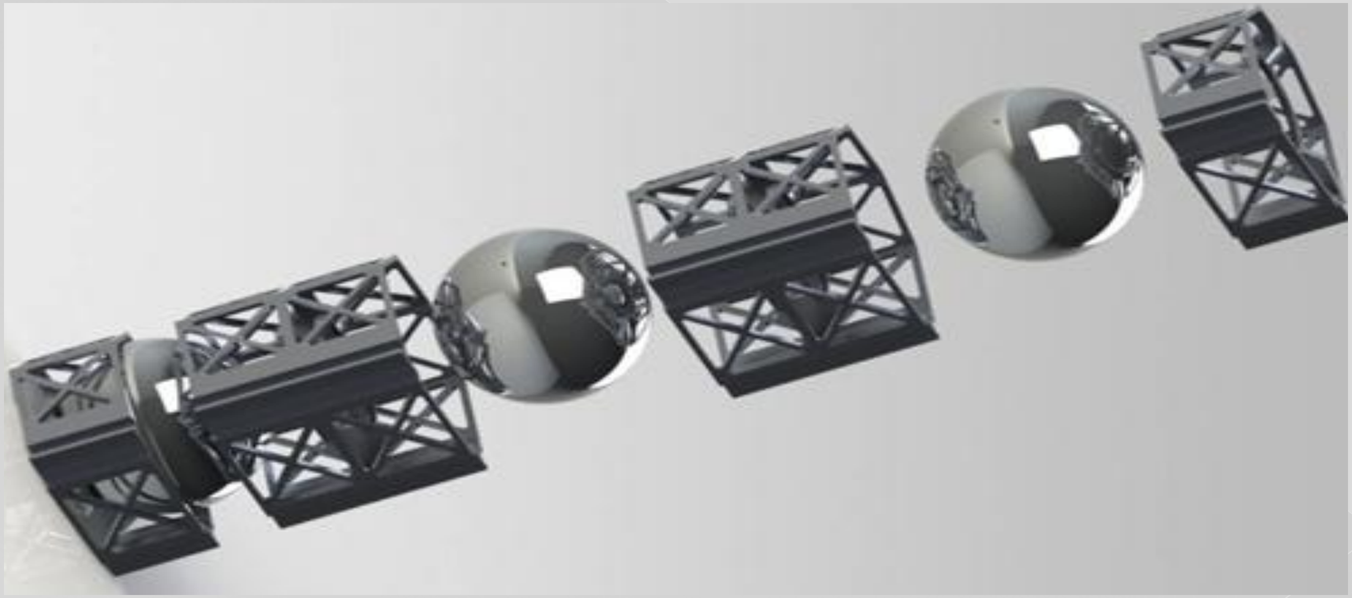
NEXT STEPS & CONCLUSIONS

Concurrent Effort

- Modeling in STK
  - Determination of spacer orbit life (if applicable)
  - Determination of sphere / spacer interference
- Deployment
  - Test deployment from CSD
- Orbital Debris
  - De-orbit quickly and burn up during re-entry

Conclusion

- Gil is coordinating a launch
- Testing is needed before the Solar Max
- Will be on display at SmallSat!



Thank you!

Questions?

Please feel free to email us with additional questions!

- **Tim Wilwert** tjw44@drexel.edu