DEPLOYMENT OF CUBESAT CONSTELLATIONS UTILIZING CURRENT LAUNCH OPPORTUNITIES

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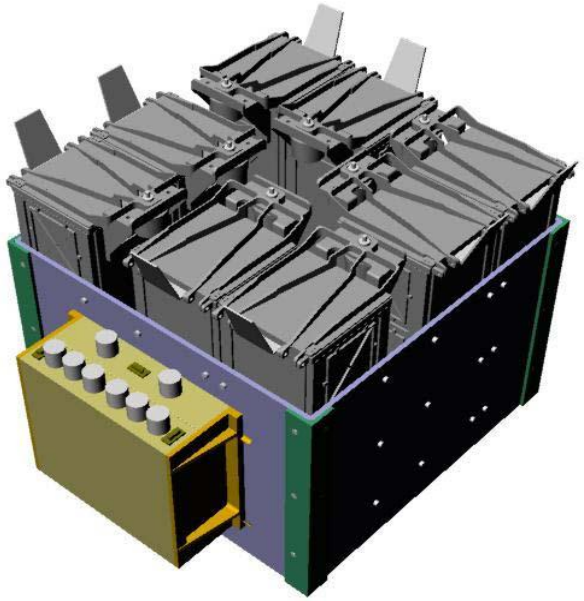
CubeSat Constellations

- Clear Next Step in CubeSat Mission Evolution
- CubeSats Provide Ideal Constellation Platform
  - Low-Cost CubeSats enable large numbers
- New Missions are Enabled by Constellations
  - Fast revisit global coverage
  - Multiple simultaneous measuring points
  - Failure tolerant
- Problem: Require Constellation Deployment
  - Difficult with secondary launch opportunities
  - Maneuvering requirements (propulsion?)

Can We Deploy Constellations Using Current Capability?

Assumptions

- Use only CubeSat separation time and direction to control constellation deployment
- Baseline Launch NPSCuL on Atlas V (L-36)
  - 8 identical 3U CubeSats
  - Identical deployment speed
  - Single orbit plane deployment
  - Separation speed 1.4m/s
- Target Constellation Configuration
  - Uniform distribution along orbit



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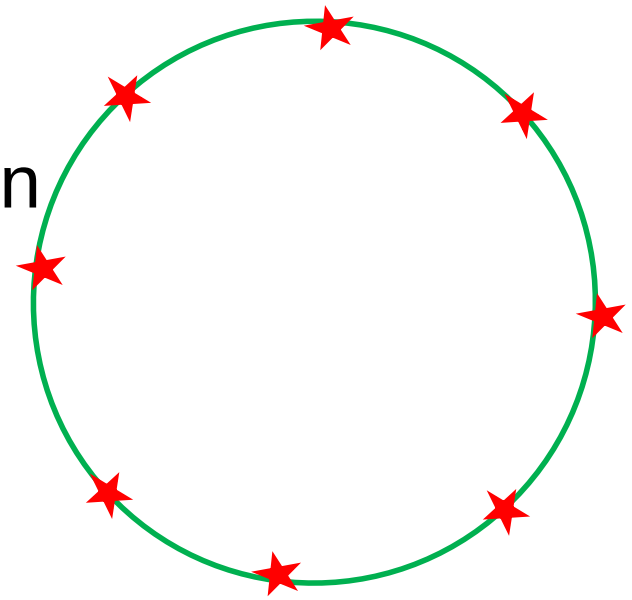
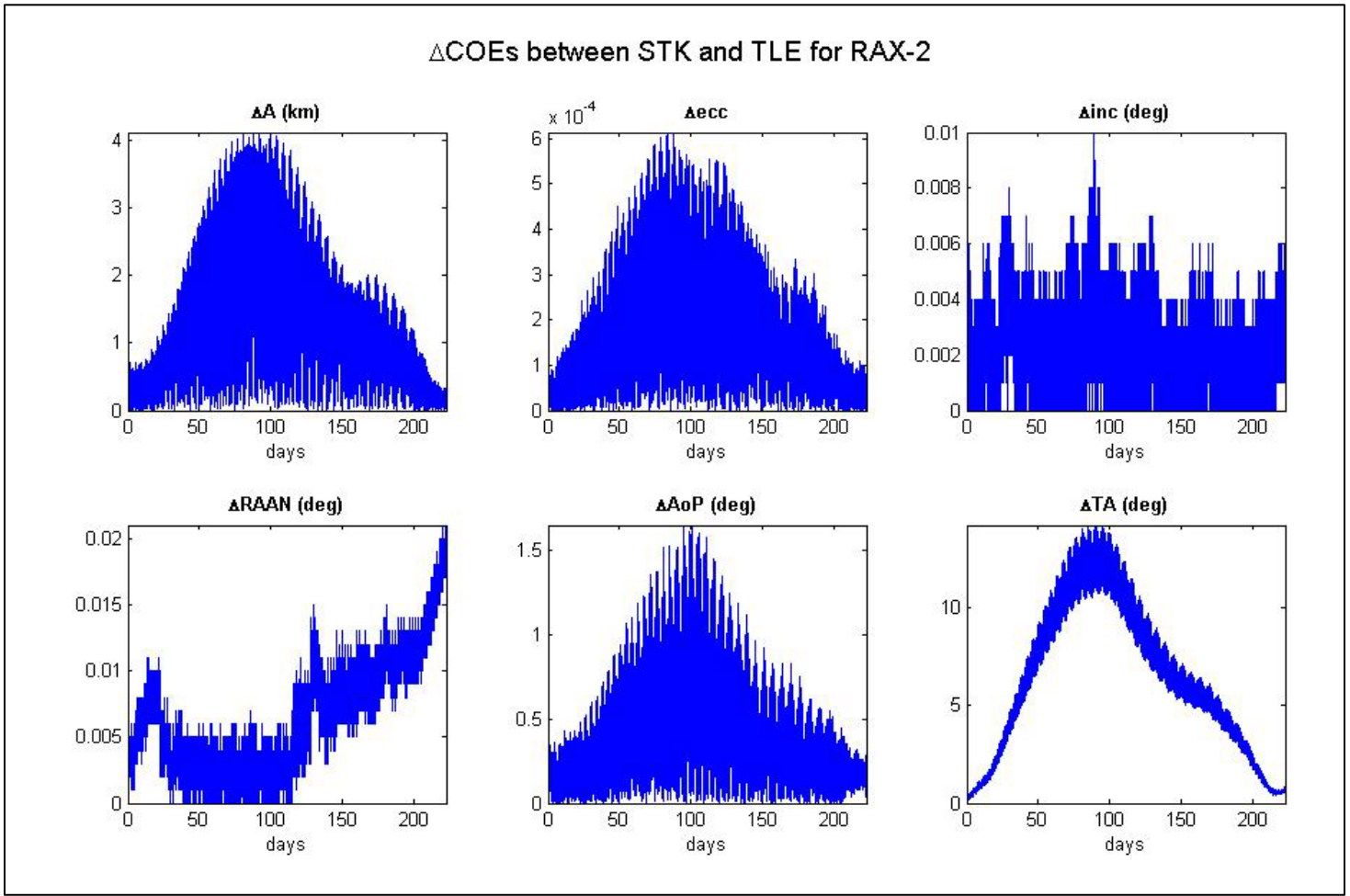


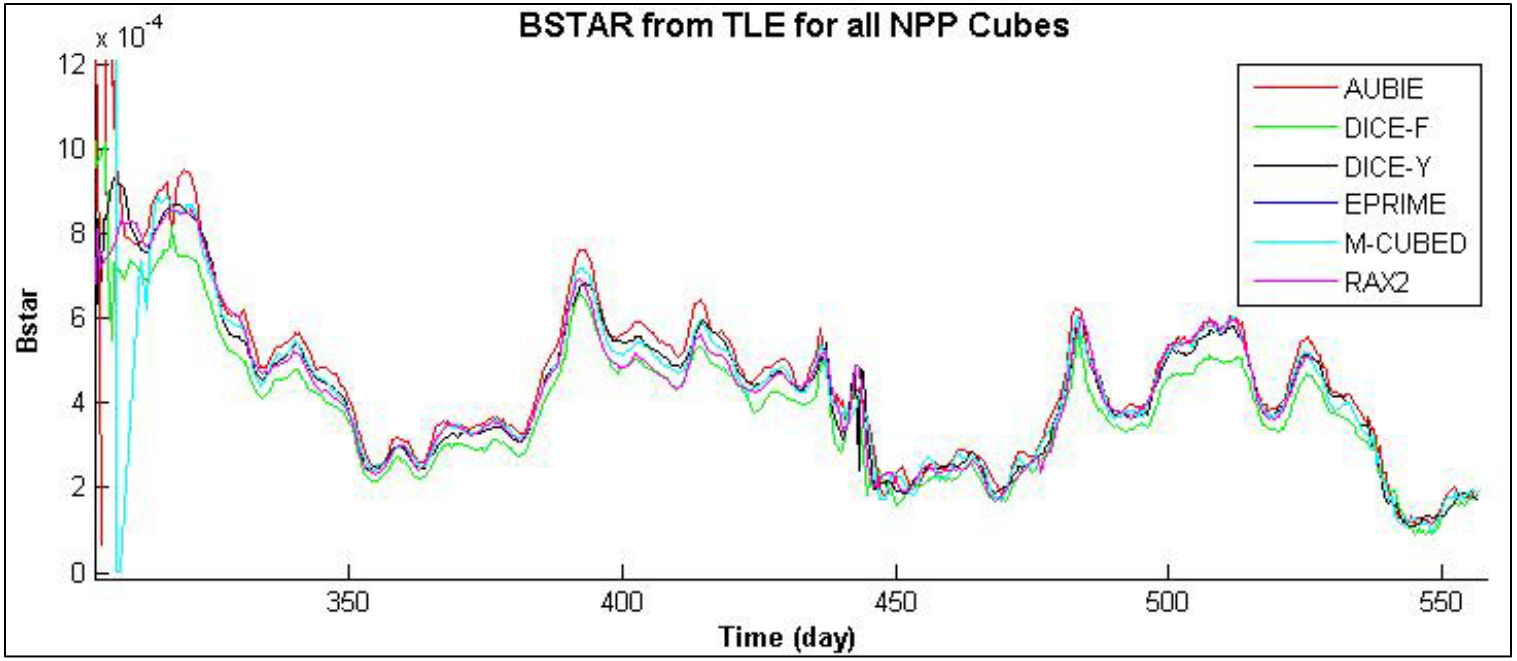
Simulation Accuracy

- Can we accurately simulate long deployment events?
  - RAX-2 launched with NPP in Oct 2011 into 450 x 780 km altitude
  - RAX-2's orbital elements in STK vs. JSpOC TLEs



Drag Variations

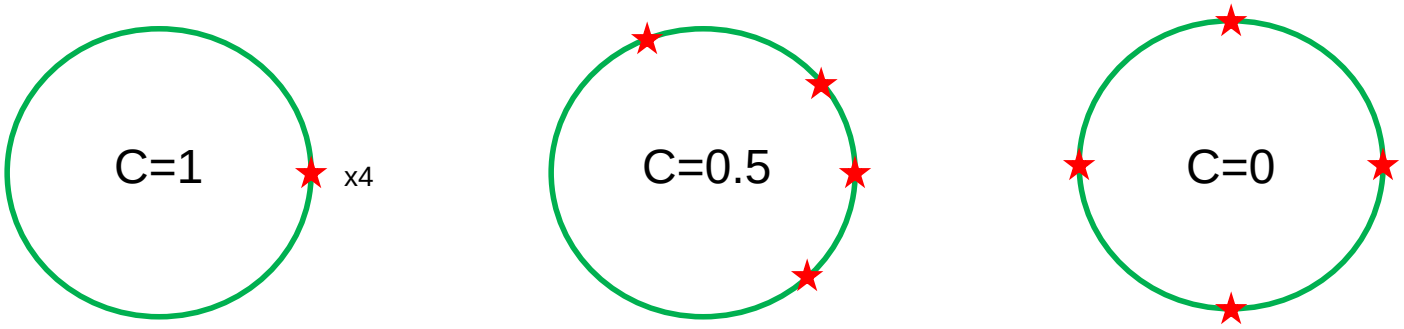
- RAX-2 perturbations dominated by changing drag parameter
- Examining B* term for all CubeSats from the NPP launch



- Uniform Variations for all Spacecraft
- Relative Errors Small for Identical Spacecraft

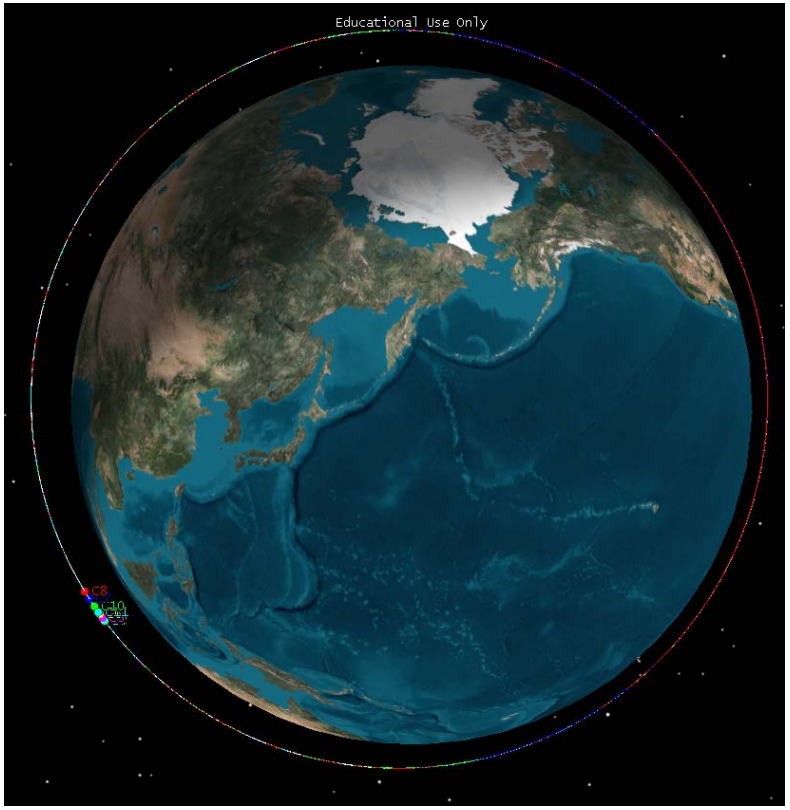
Need Constellation Dispersion Metrics

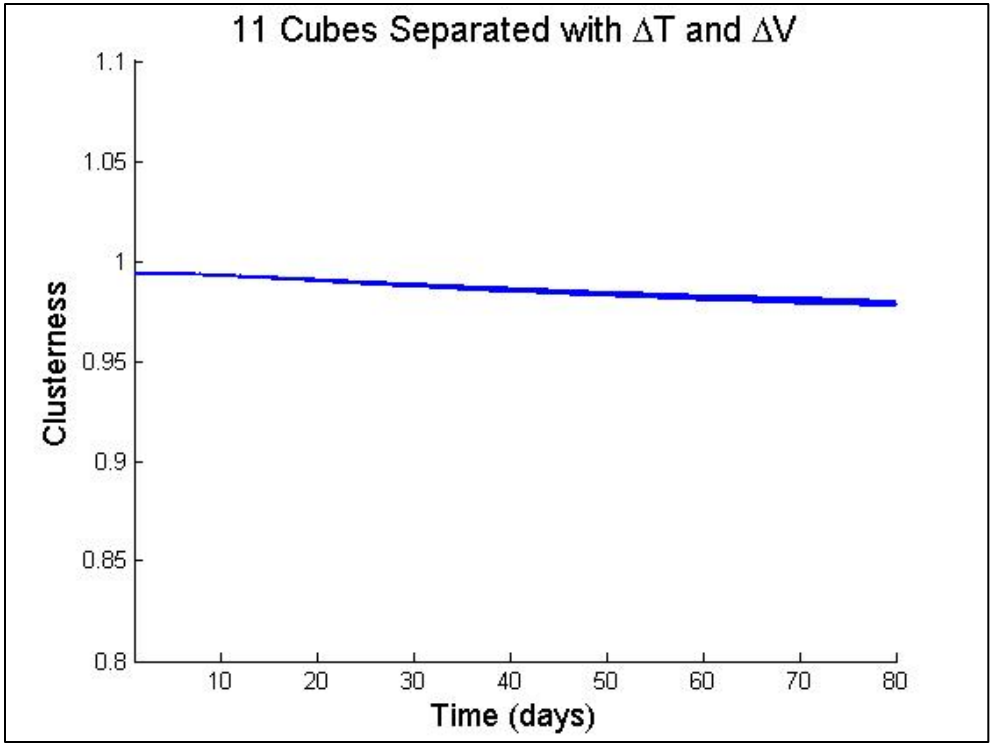
- Define “Clusterness” as level of Satellite dispersion
  - C= 0 => Uniform dispersion
  - C= 1 => Satellites at same location



Standard NPSCuL Deployment

- All Spacecraft deployed in aft direction with time delay

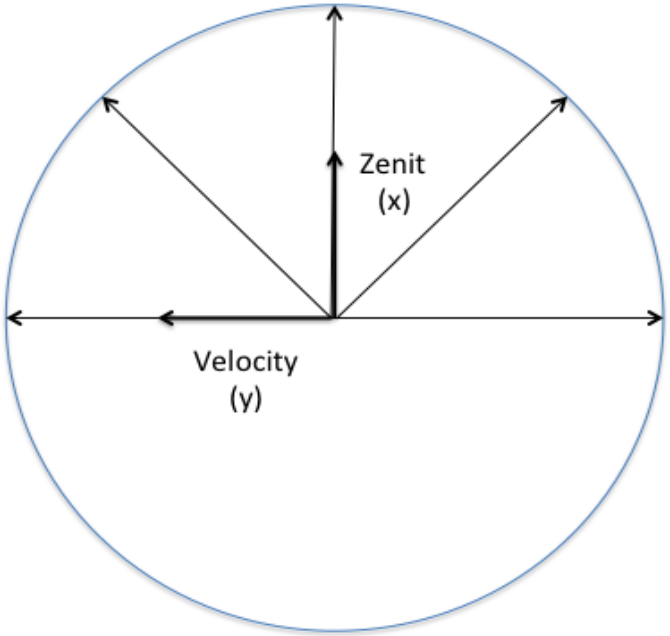




- Expected result: Linear orbit theory predicts separation is a function of speed differential in orbital velocity direction

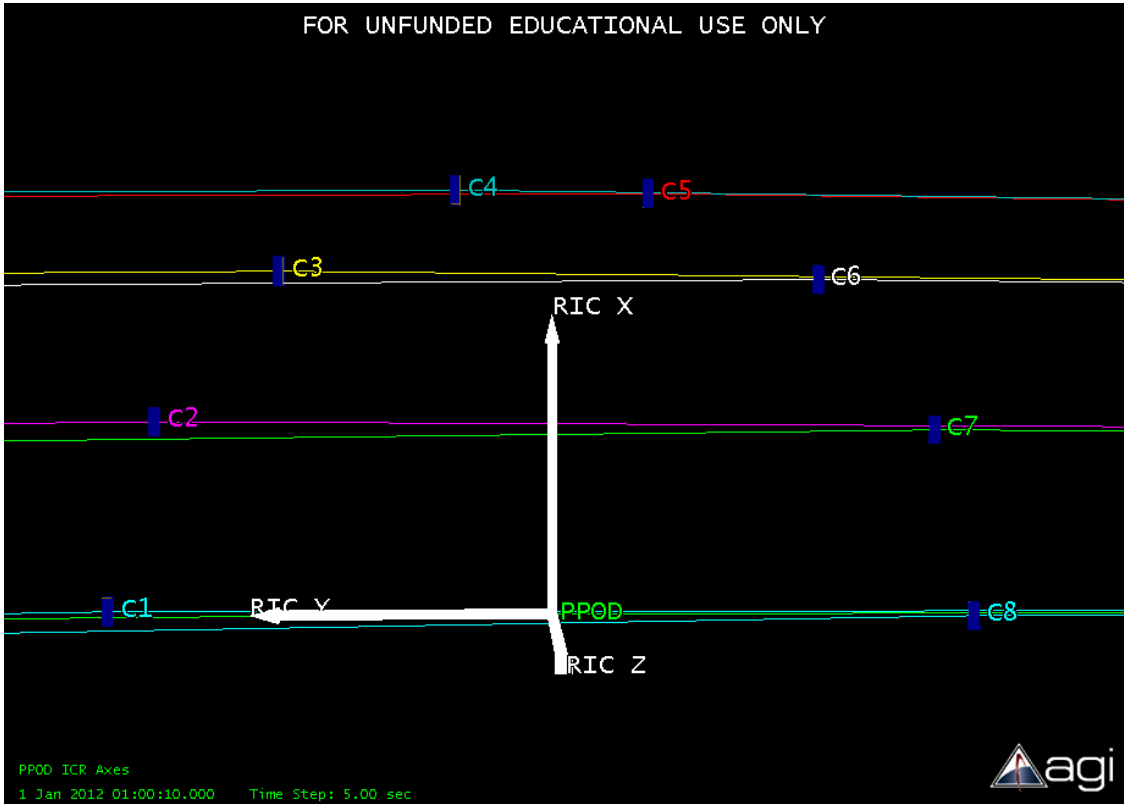
Better Dispersion Solution

- Use Circular Deployment to Vary Separation Speed Component in Velocity Direction



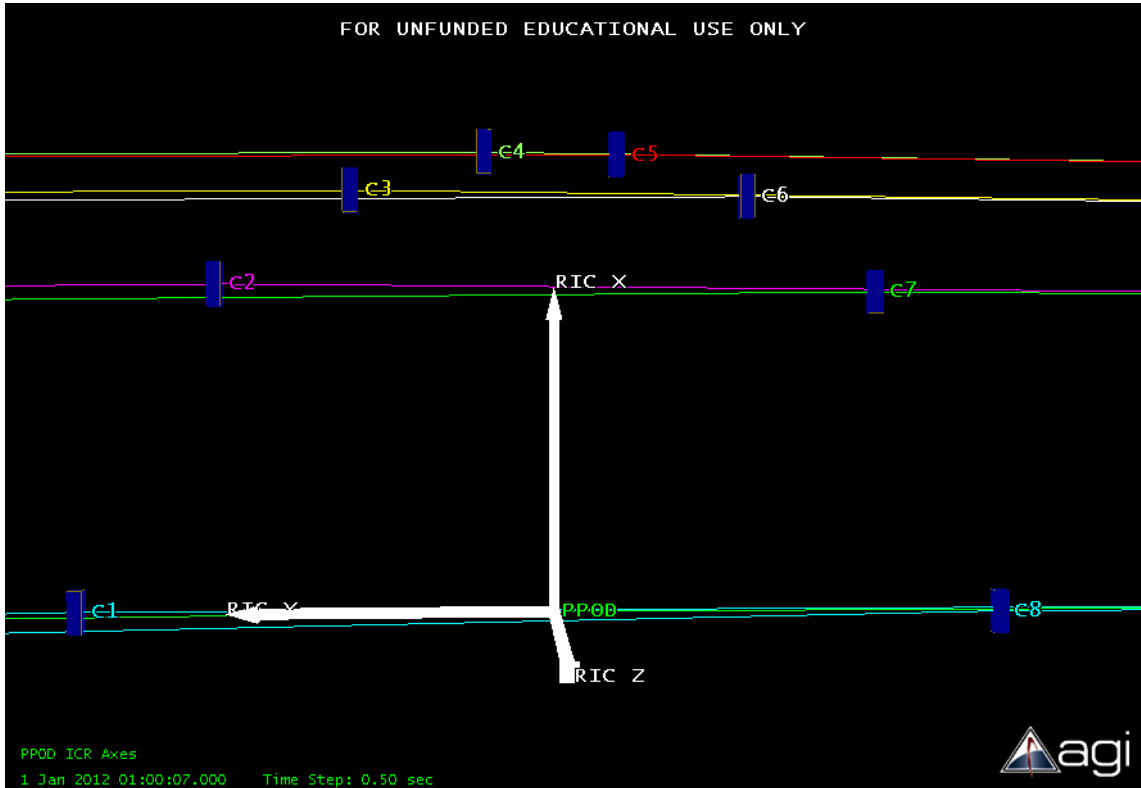
Better Dispersion Solution

- Use Circular Deployment to Vary Separation Speed Component in Velocity Direction
- Two options:
  - Uniform deployment angle
    - Easy implementation



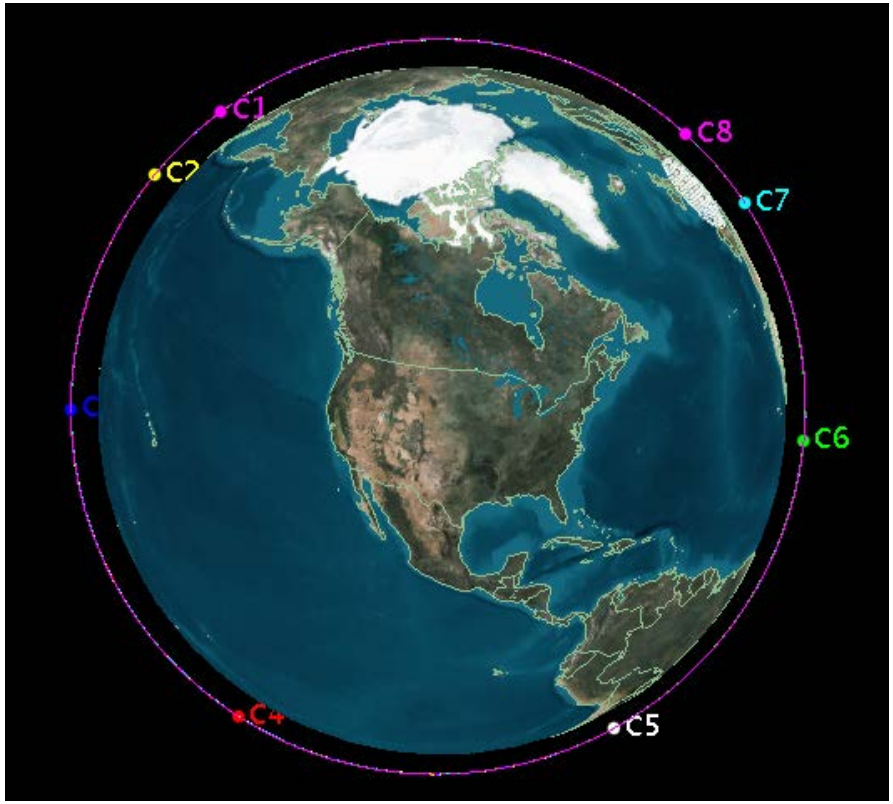
Better Dispersion Solution

- Use Circular Deployment to Vary Separation Speed Component in Velocity Direction
- Two options:
  - Uniform deployment angle
    - Easy implementation
  - Uniform Vy distribution
    - Optimum dispersion

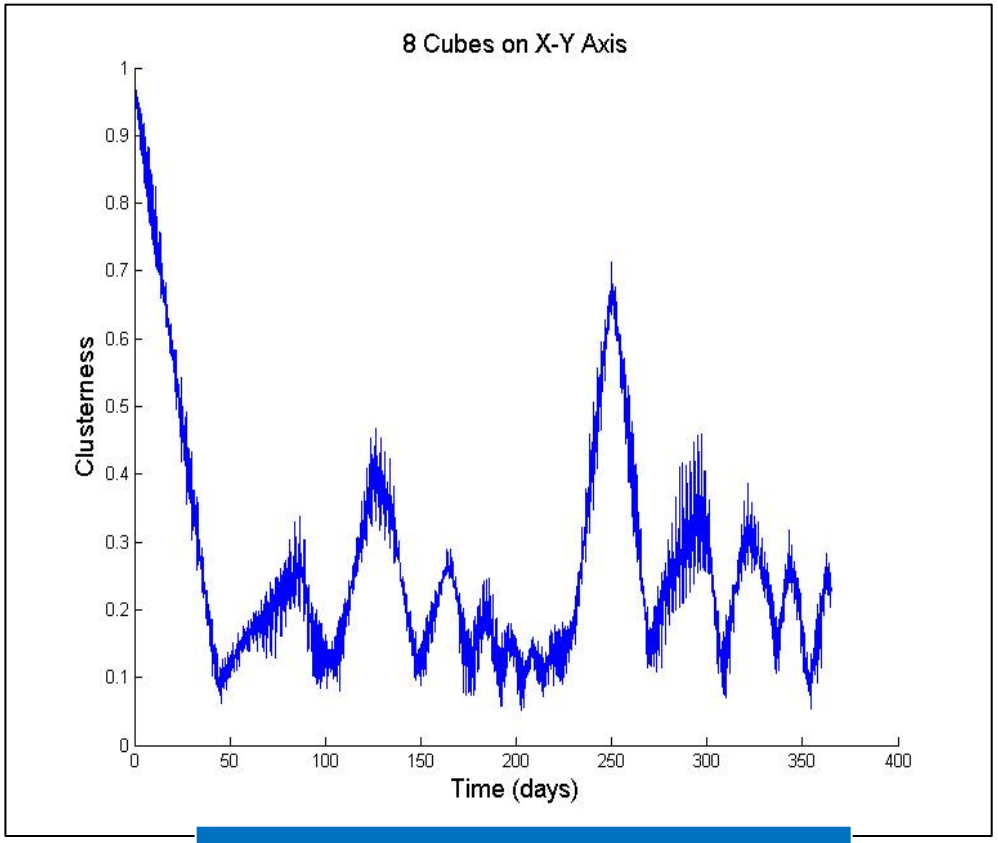


Angle-based Circular Separation

- Large distribution from easy maneuver for LV



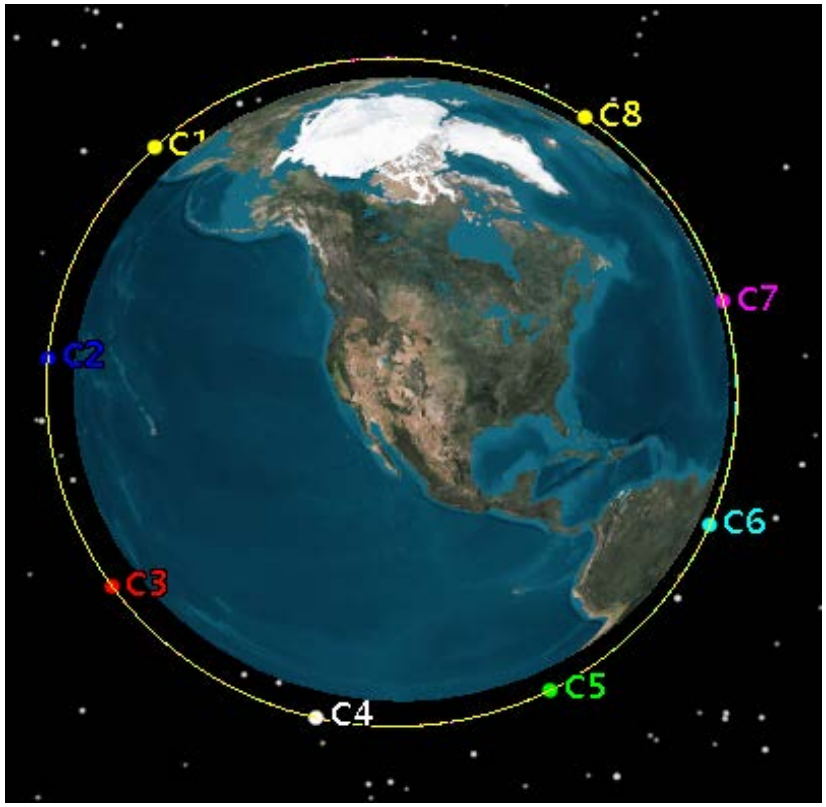
Day 48



Minimum ~ 0.06

Y-vector based Semi-circle Separation

- Equal distribution in Y-vector = equal distribution in orbit
- More complex maneuver for LV



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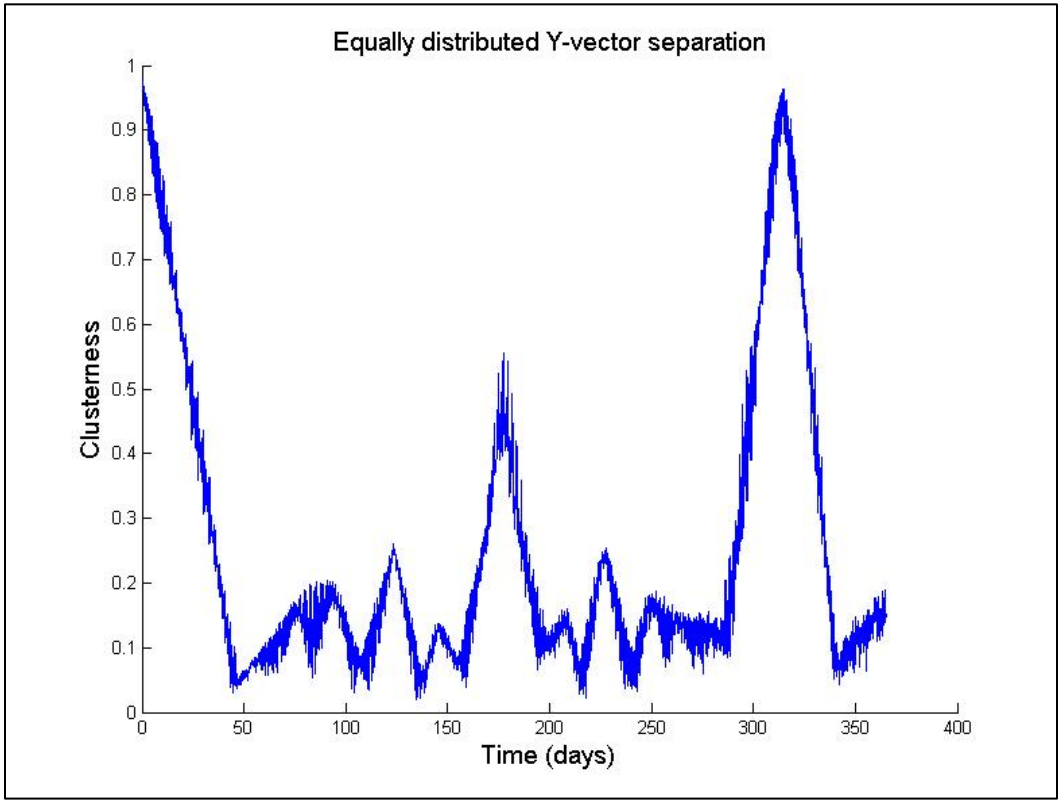
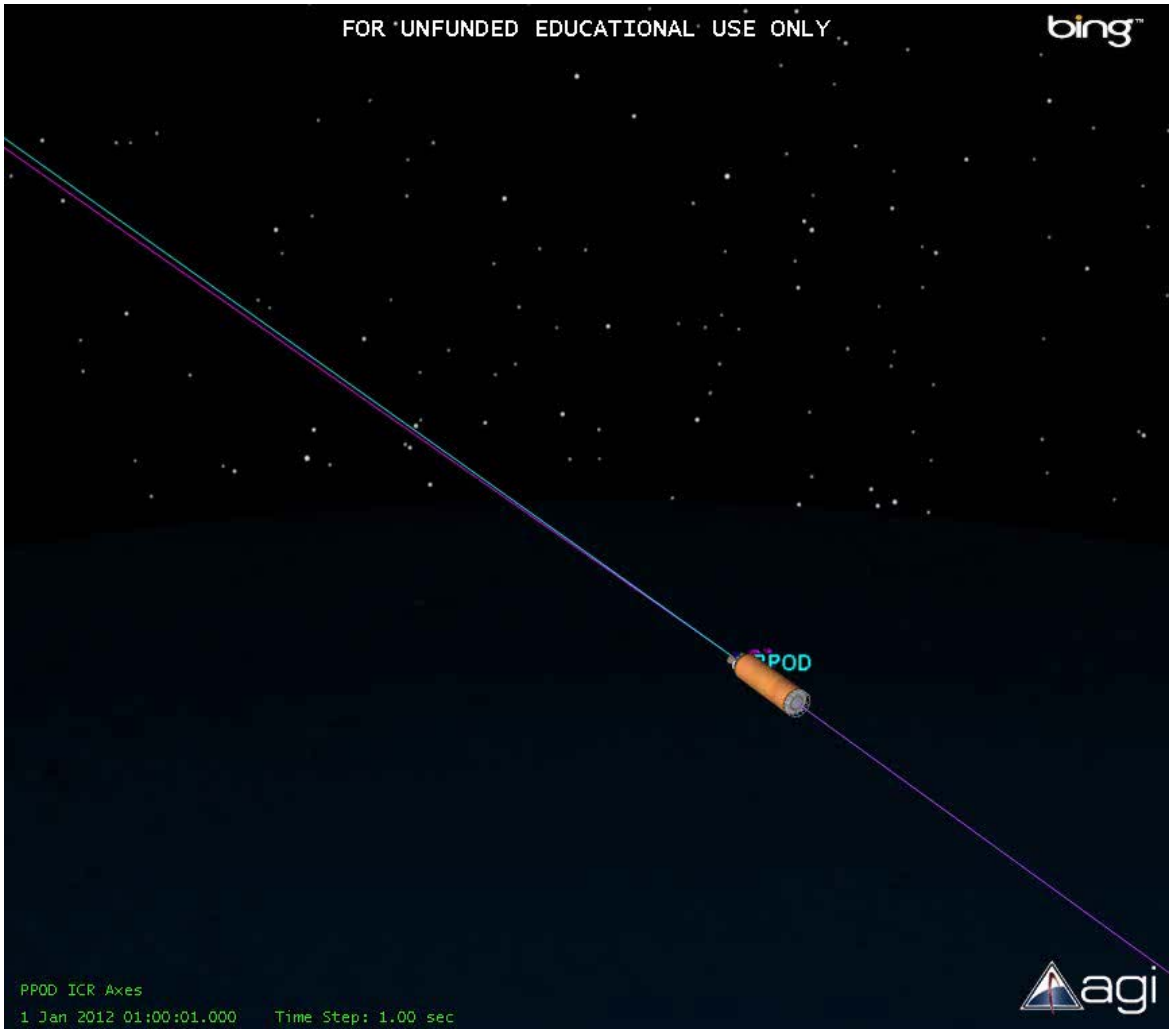


Minimum ~ 0.02

Angle-based Semi-circle Separation



Atlas V jettisoning Cubes

Video

Y-vector based constellation development

Constellation development

Video

Constellation Breakdown

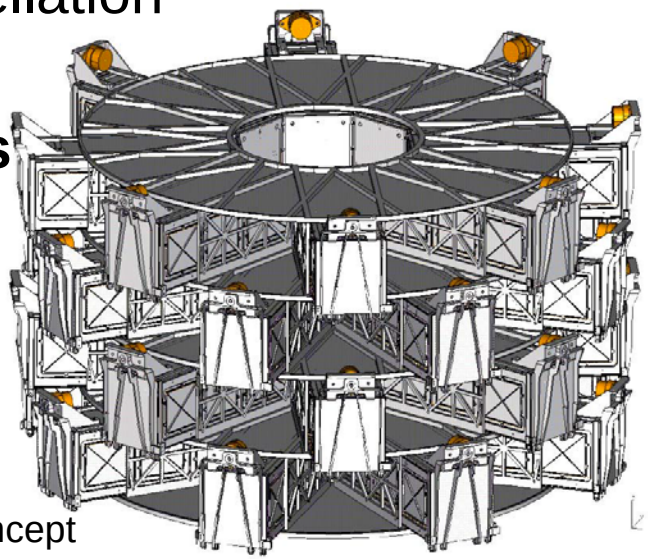
- In order to “freeze” constellation orbital maneuver required.
- Need to change orbital period up to ~ 10 sec per Cube.
- ΔV required:

Cube #	Pre-maneuver Orbital Velocity (km/s)	|ΔV| required (m/s)
Target	7.5751	-
1	7.5758	0.6708
2	7.5714	3.6947
3	7.5678	**7.3733**
4	7.5789	3.7989
5	7.5768	1.6953
6	7.5784	3.2434
7	7.5750	0.1663
8	7.5770	1.8370

- Very Low ΔV: drag differential and small cold gas system are options

Conclusion

- Standard Deployment Strategies do not Ease Dispersion
- Current Launch Systems can better Disperse CubeSats
  - Minimum maneuver requirements for LV
  - No initial propulsion requirement on CubeSats
  - Improved dispersion eases initial acquisition
  - Low ΔV requirements to maintain constellation
  - Reasonable time for full dispersion
  - **We are ready to deploy constellations**
- Alternative Deployer Mounting can Produce Similar Effects



SDL/Cal Poly HIDEF Concept

THANK YOU

Questions?