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Differential Drag for Collision Avoidance

Cal Poly CubeSat Workshop 2017

Brian Cooper

Orbital Debris

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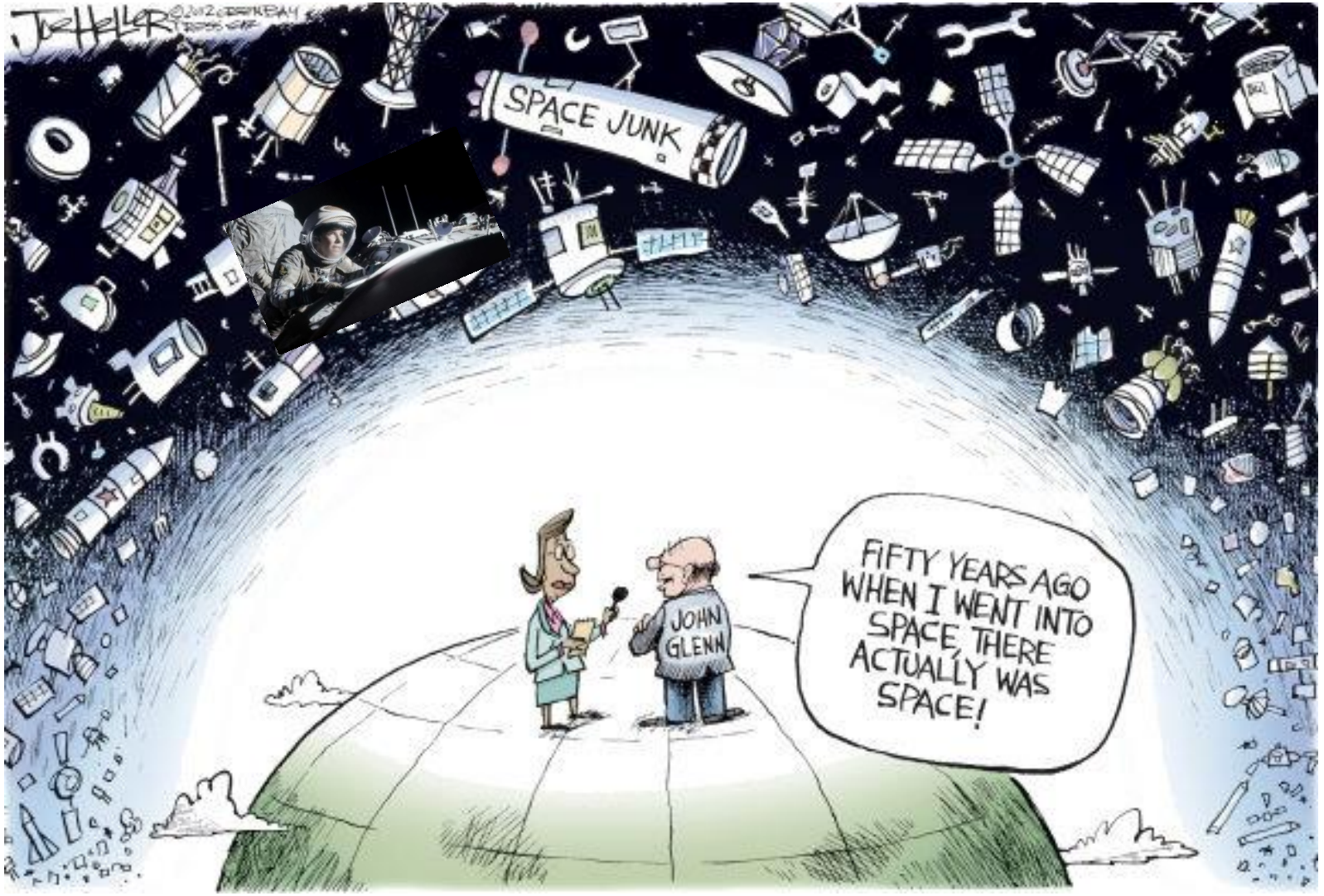
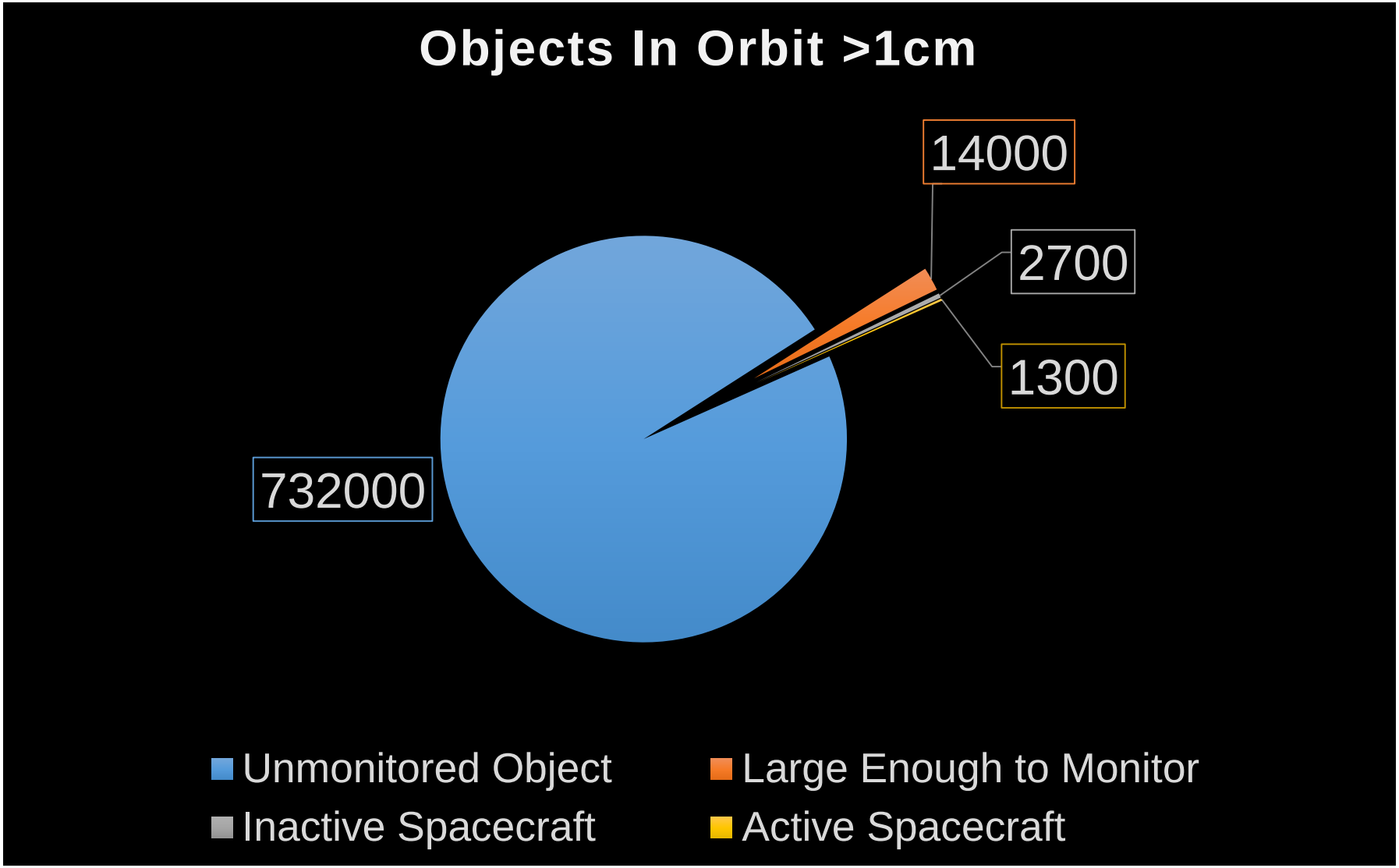


Current State



Current State

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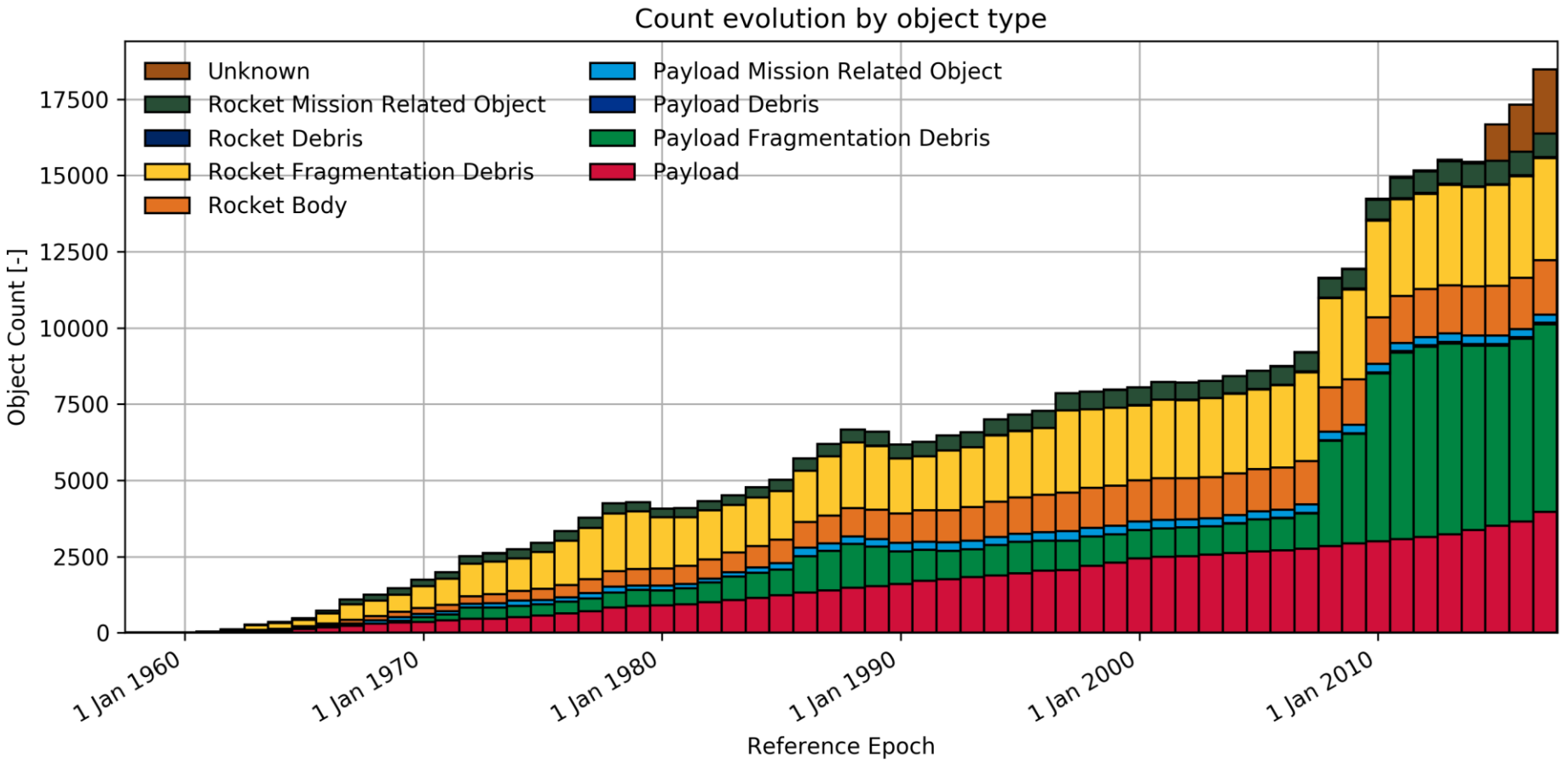

The Future - Megaconstellations

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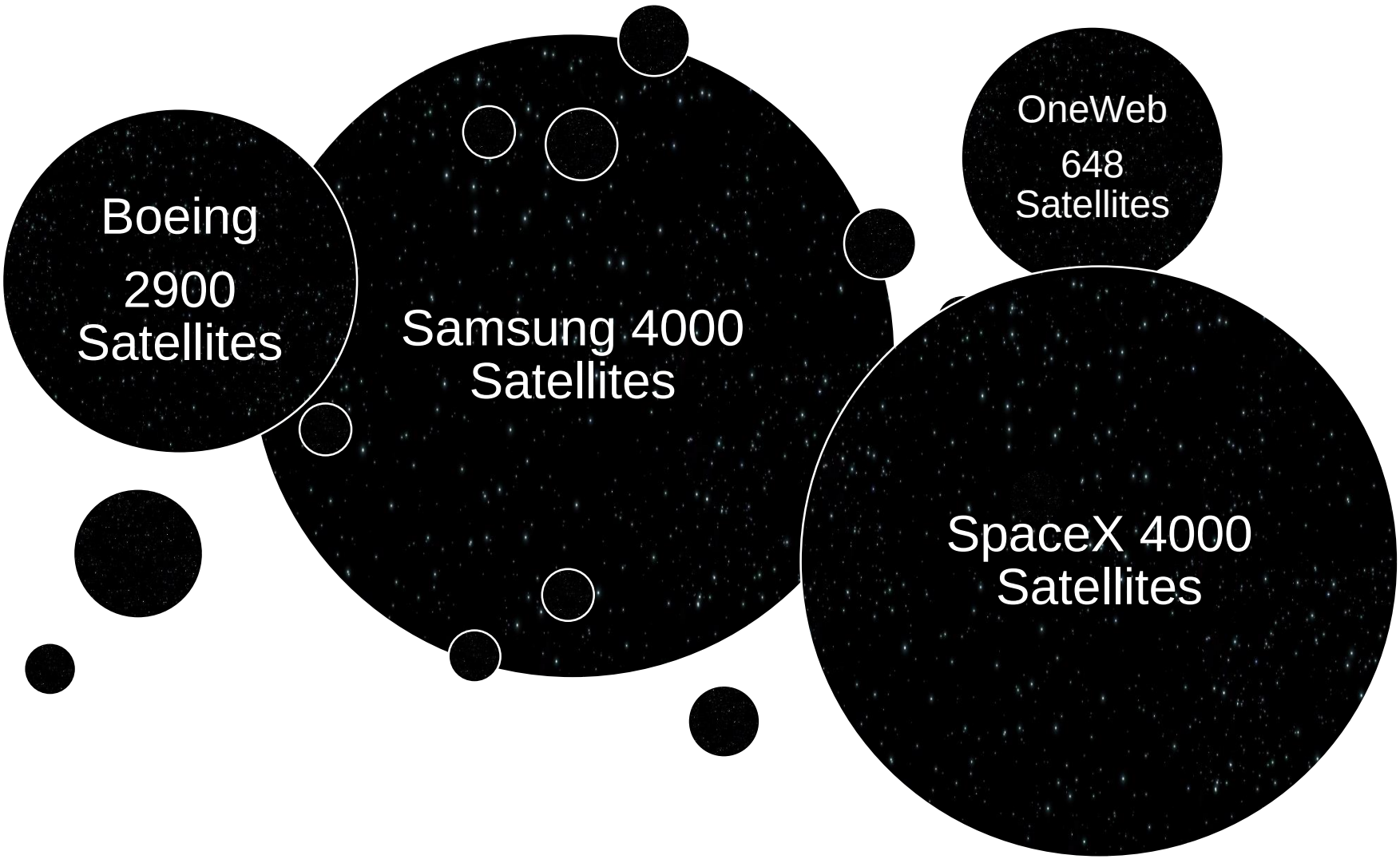

Why We Should Care

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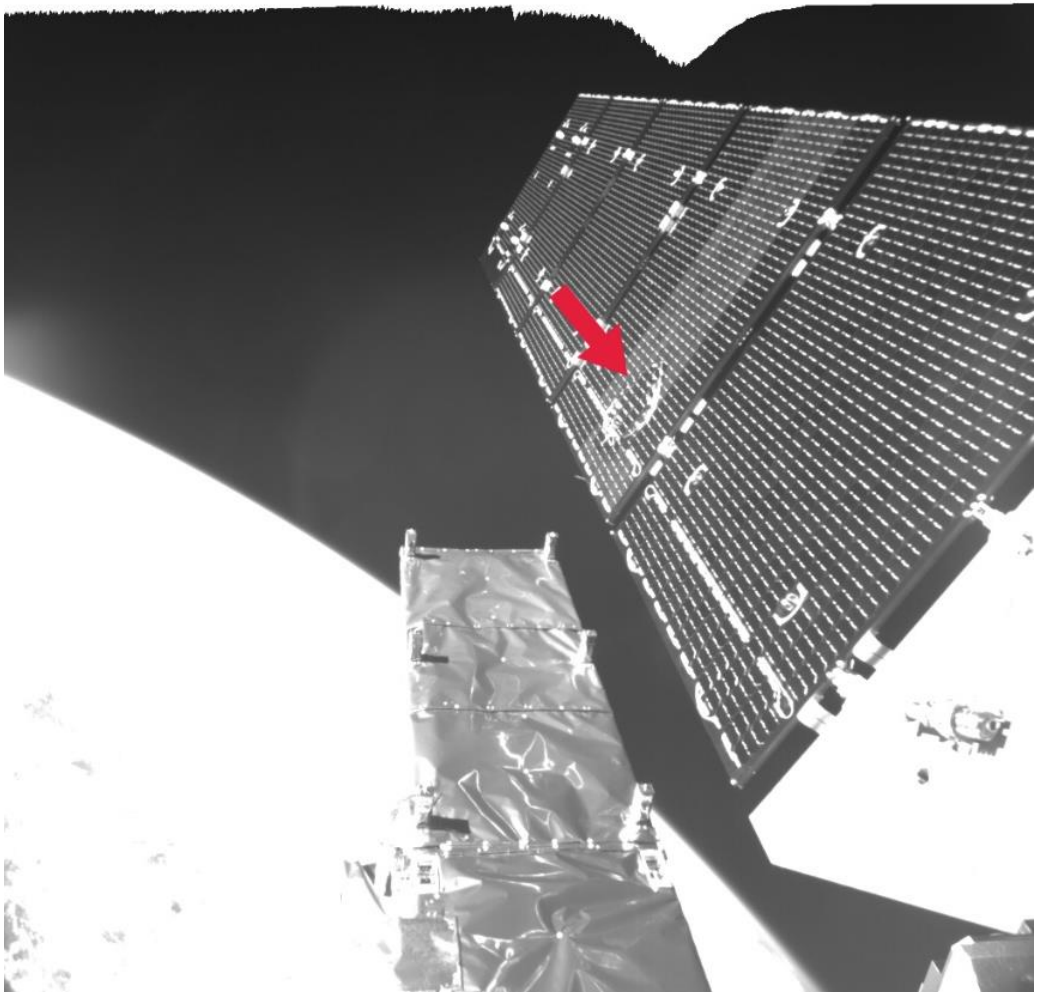
Increased Risk Over Time

More Rules



Sentinel-1a debris impact damage

Cubesat Response – We Need One

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Already Lots of Debris in Orbit	→	Doesn't Address the Whole Problem
CubeSats are so small though	→	But There are a Lot!
Large Satellites are the Real Problem	→	True…but we should do our part
Deorbit Devices	→	Helpful, but still collision risk during operations
We Have Propulsion on our Cubesat	→	Great, but that won't work for everyone ($)
Our Cubesat Has Attitude Control	→	Good, and it's cheap!

Differential Drag

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Velocity

High drag

Low drag

Form Factor Effectiveness

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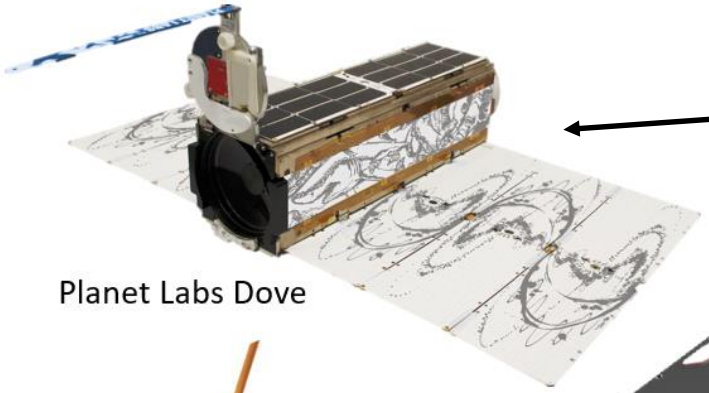
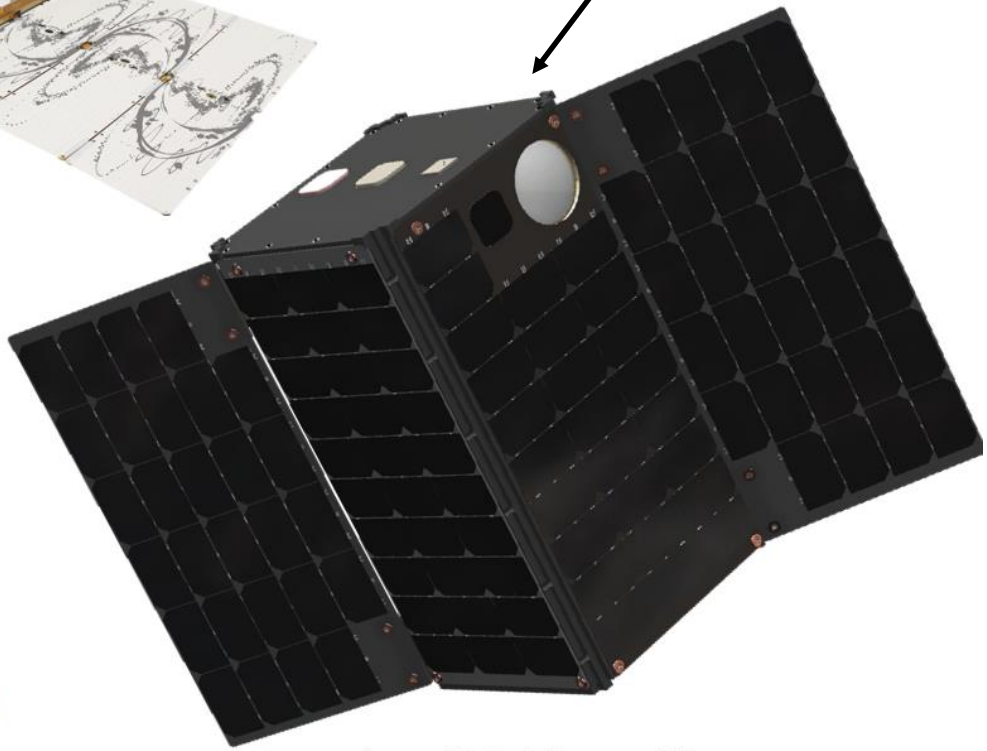
1U (Tyvak)

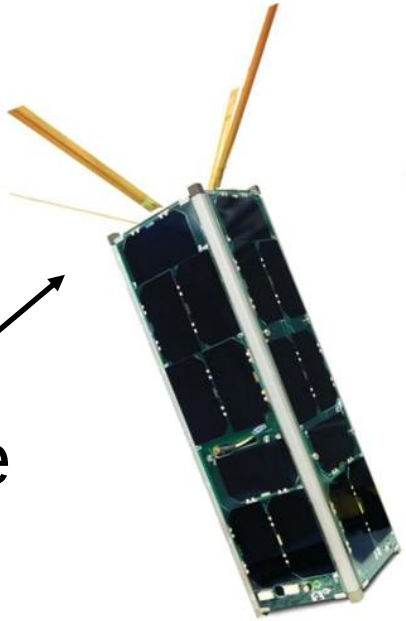


Planet Labs Dove

More effective



Astro Digital Corvus-HD



3U (RAX)

Less effective

Avoidance Maneuvers

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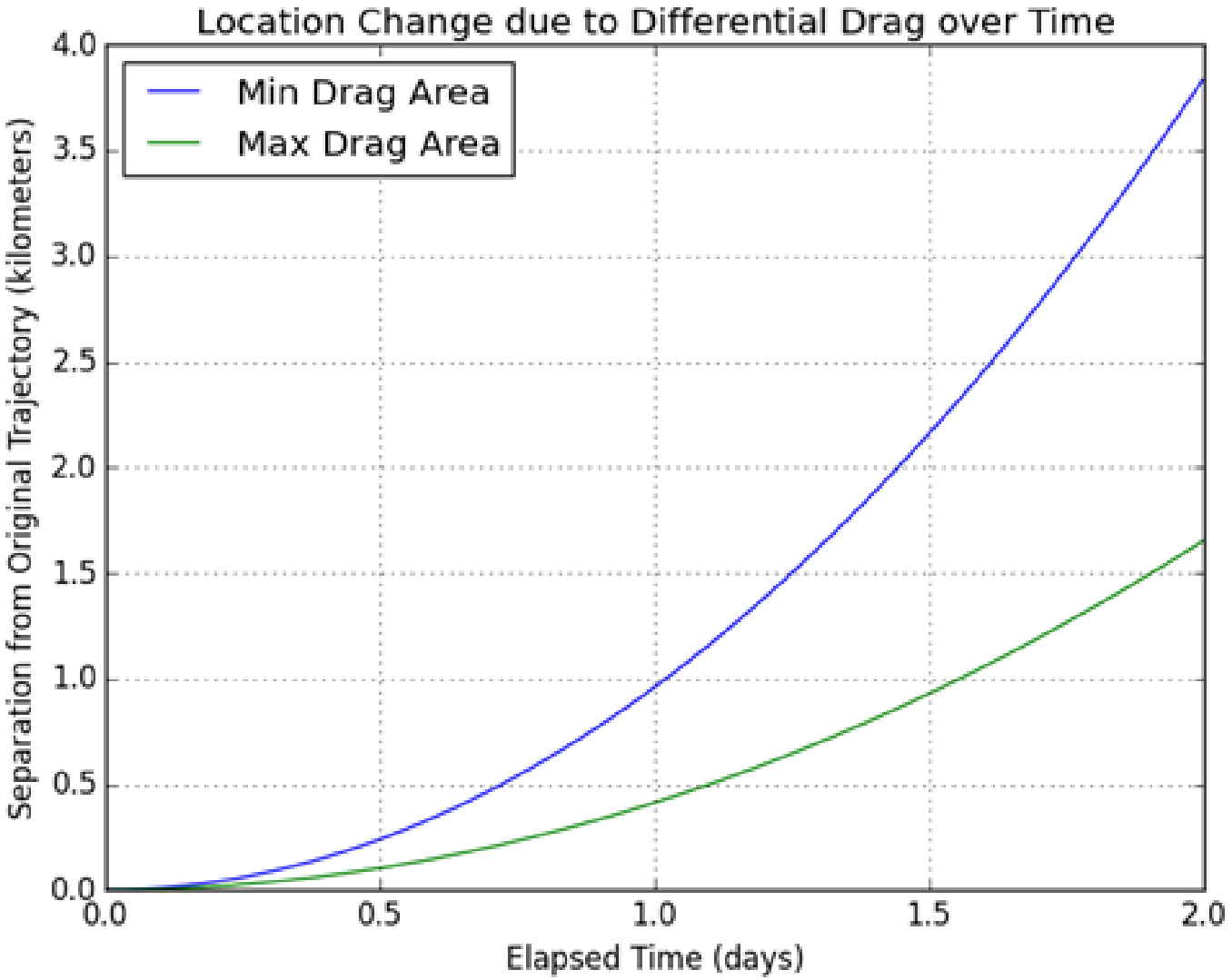
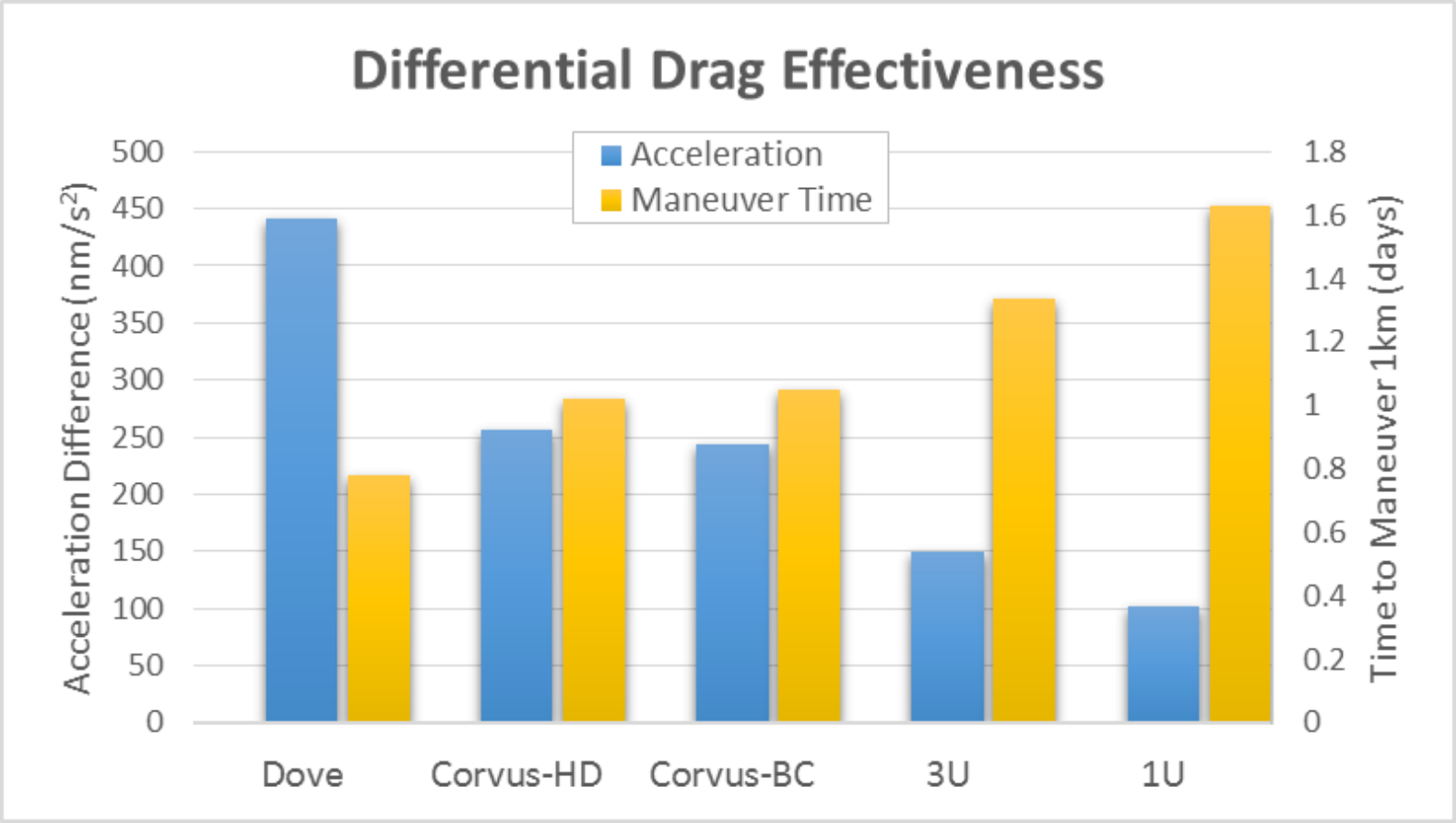


Avoidance Maneuvers



Simultaneous Constellation Maneuvering (SCM)

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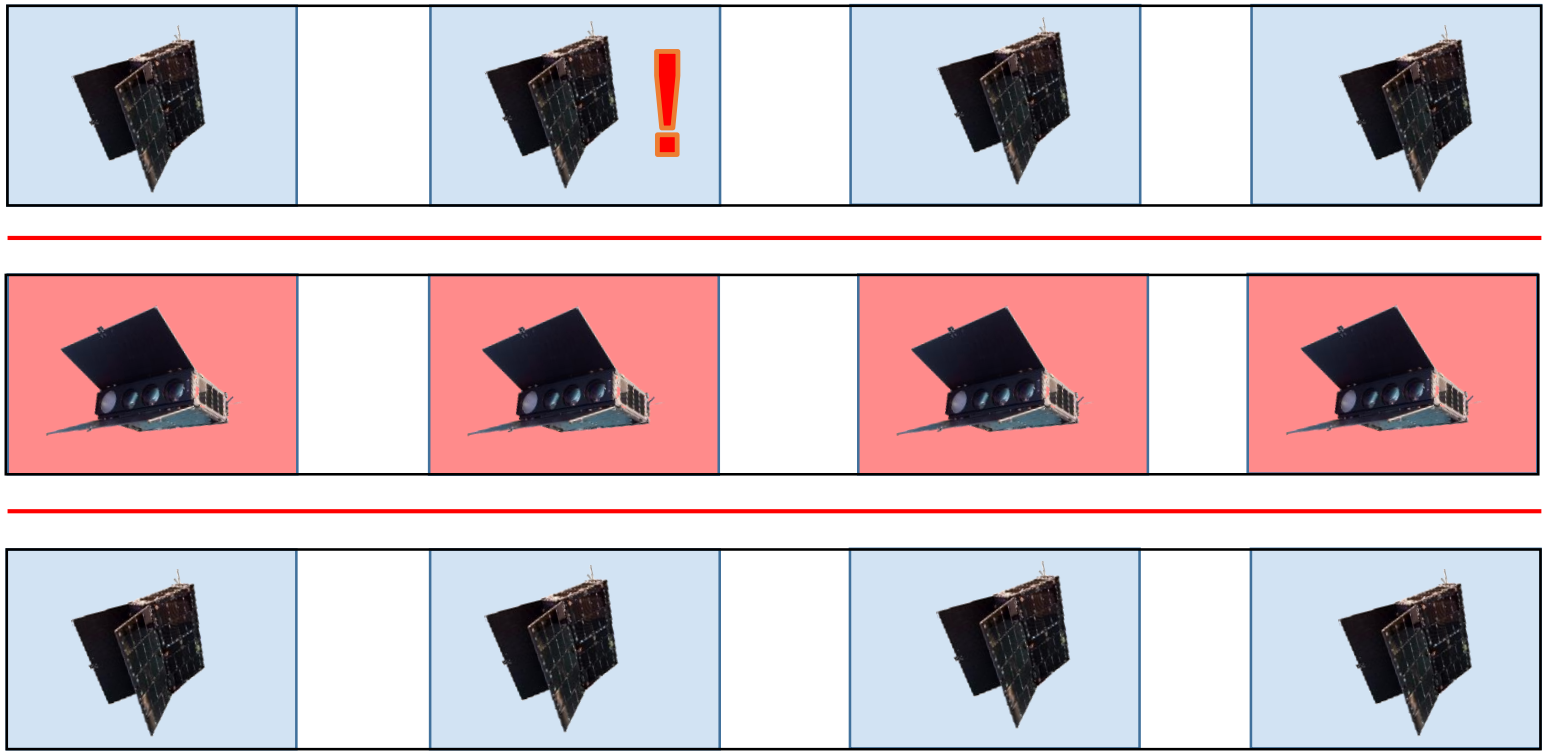
Normal Operations

Warning Received

All SC Maneuver

Collision Avoided

Resume Operations



Velocity

Single Satellite Maneuvering (SSM)

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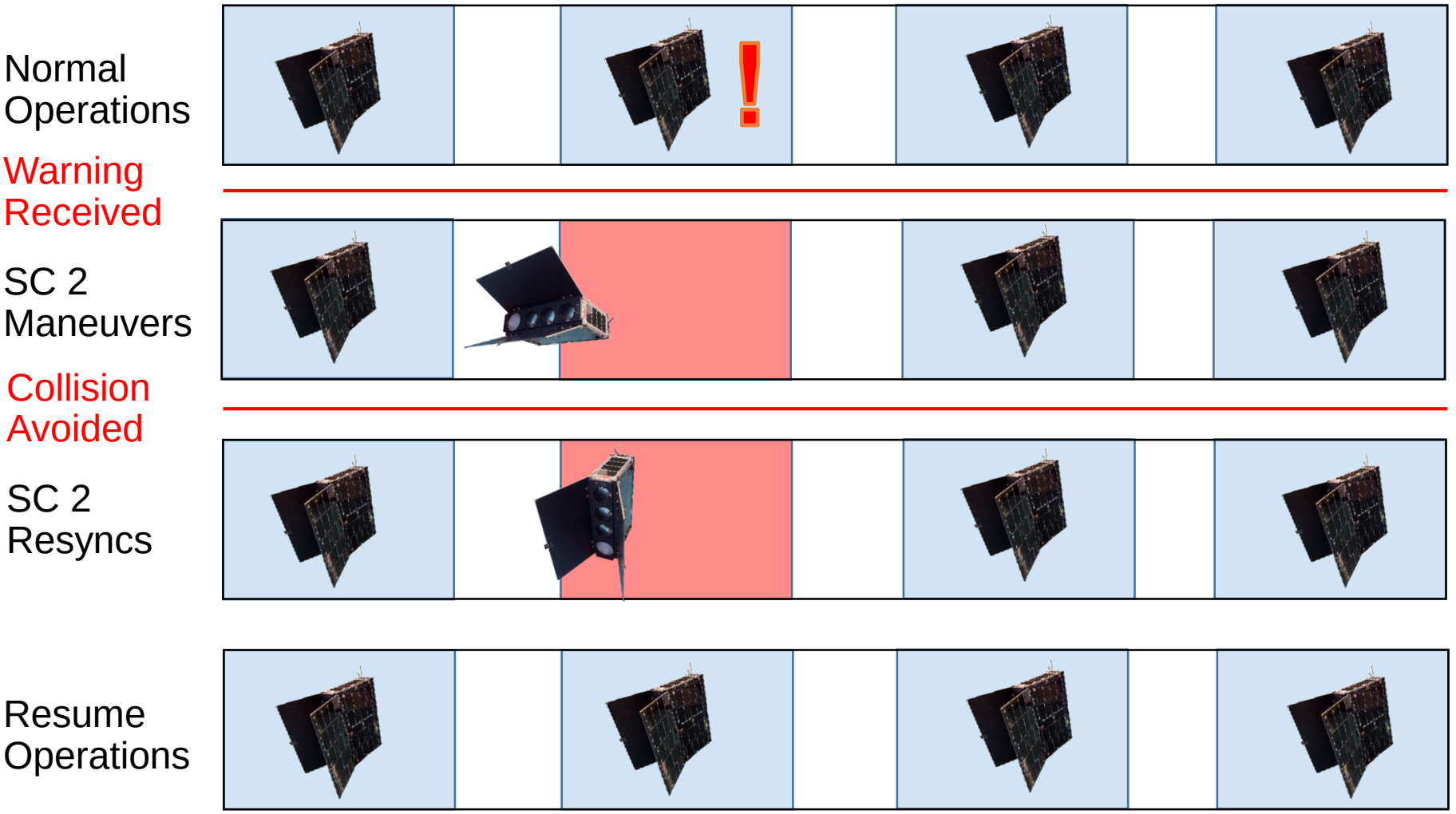
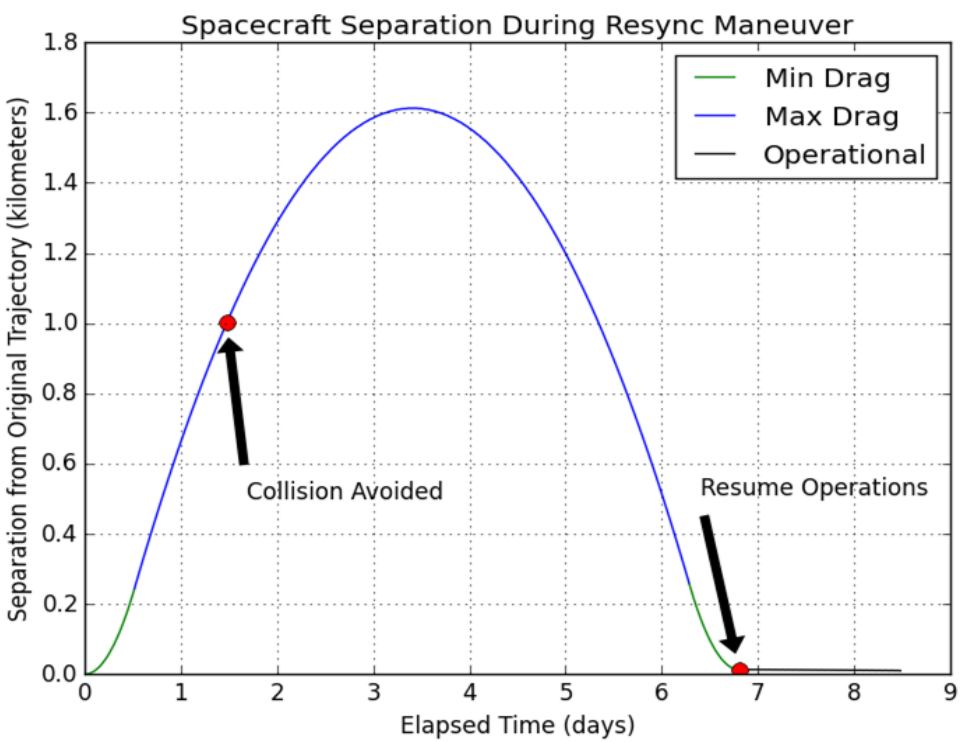


Constellation Resync



Single Satellite Maneuvering Example

Conjunction Frequency

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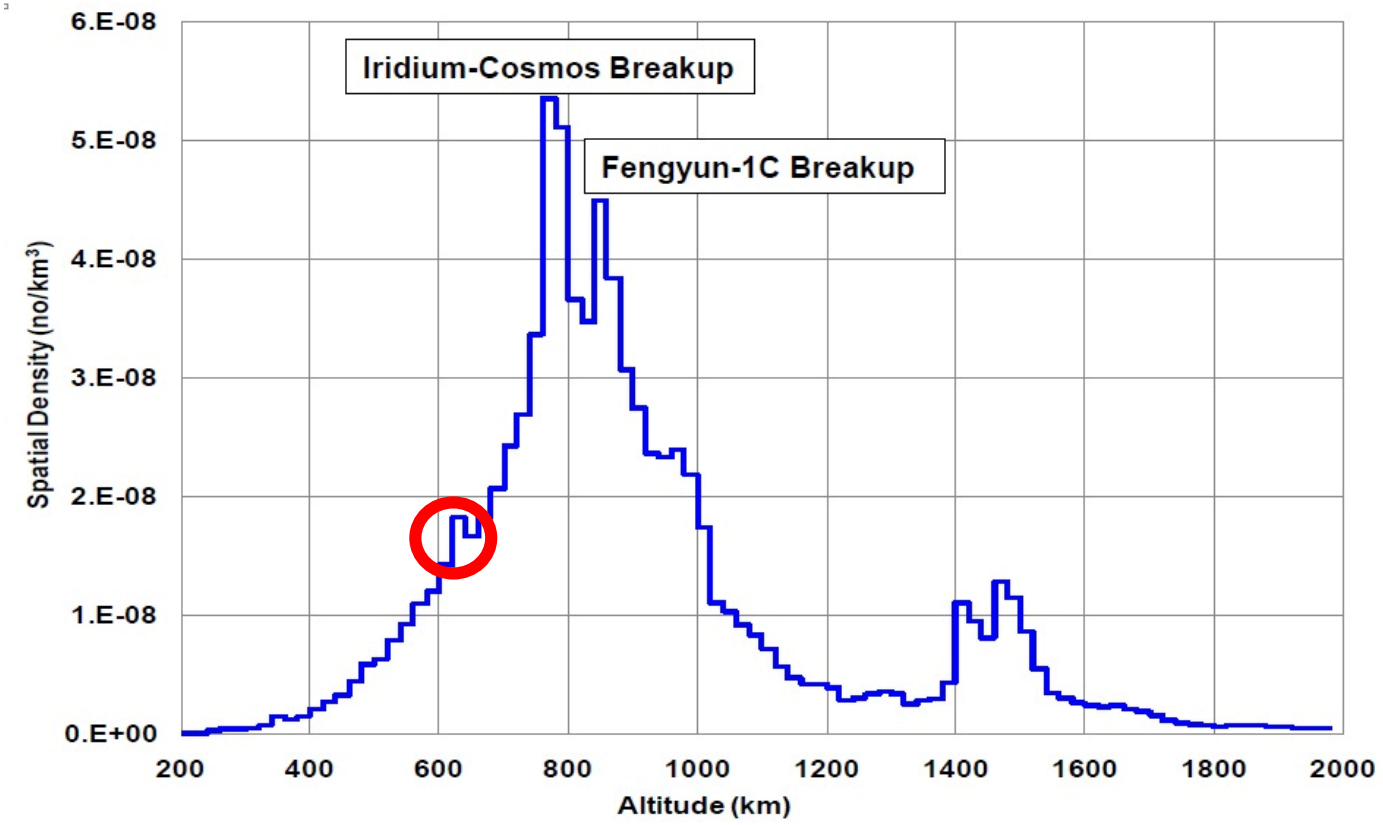
Using data from Perseus-M (620 km):

- 1.89 conjunctions of 300 meters or less per year
- 3.78 conjunctions of 500 meters or less per year
- 7.87 conjunctions of 1000 meters or less per year



Operational Consequences

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Spacecraft	Altitude	Maneuver Method	Conjunctions per Spacecraft per Year	Time to Maneuver	Number of Spacecraft in Constellation	Total Constellation Operational Time per Year	Operational Time Lost per Year	Operational Time Loss
Any	600 km	Propulsion	.78	0.13 days	10 Spacecraft	3650 sat-days	5.1 sat-days	0.1%
Any	600 km	Propulsion	.78	0.13 days	Any			0.1%
Any	450 km	Propulsion	.95	0.13 days	10 Spacecraft	3650 sat-days	1.2 sat-days	0.03%
Any	450 km	Propulsion	.95	0.13 days	Any			0.03%
Corvus-BC	600 km	SCM (Diff Drag)	3.78	1.04 days	1 Spacecraft	365 sat-days	3.9 sat-days	1.1%
Corvus-BC	600 km	SCM (Diff Drag)	.78	1.04 days	10 Spacecraft	3650 sat-days	378 sat-days	10.4%
Corvus-BC	450 km	SCM (Diff Drag)	.95	0.31 days	10 Spacecraft	3650 sat-days	29.5 sat-days	0.8%
Dove	600 km	SCM (Diff Drag)	.78	0.78 days	10 Spacecraft	3650 sat-days	294 sat-days	8.0%
Dove	600 km	SCM (Diff Drag)	.78	0.78 days	100 Spacecraft	36500 sat-days	29400 sat-day	80.8%
Dove	450 km	SCM (Diff Drag)	.95	0.24 days	10 Spacecraft	3650 sat-days	22.7 sat-days	0.6%
Dove	450 km	SCM (Diff Drag)	.95	0.24 days	100 Spacecraft	36500 sat-days	2270 sat-days	6.2%
Corvus-BC	600 km	SSM (Diff Drag)	3.78	6.80 days	Any			7.0%
Corvus-BC	450 km	SSM (Diff Drag)	0.95	1.70 days	Any			0.4%
Dove	600 km	SSM (Diff Drag)	3.78	2.40 days	Any			2.5%
Dove	450 km	SSM (Diff Drag)	0.95	0.78 days	Any			0.2%

Final Words

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Differential drag is a viable opportunity for collision avoidance

(as long as the attitude can be controlled)

Operational constraints on a large constellation may force operators to use propulsion or just accept collision warnings as a risk

A **coherent strategy** for Cubesat collision avoidance needs to be decided on soon, before regulators decide it for us

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Together, we can make sure Sandra Bullock isn't threatened by high speed orbital debris impacts ever again

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