Differential Drag for Collision Avoidance

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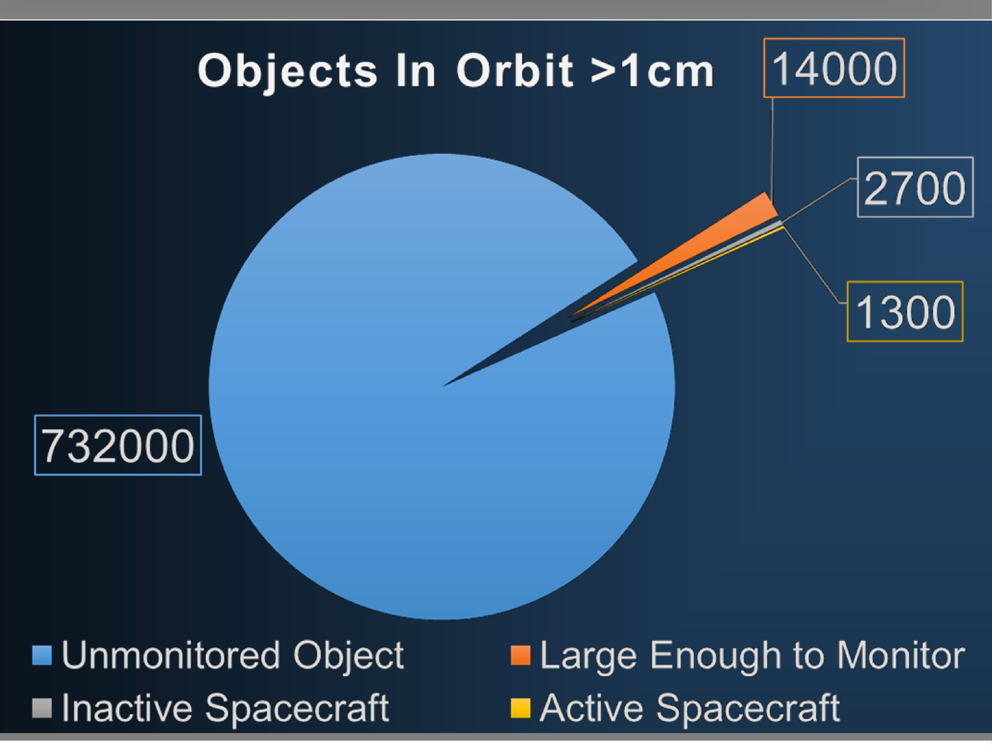
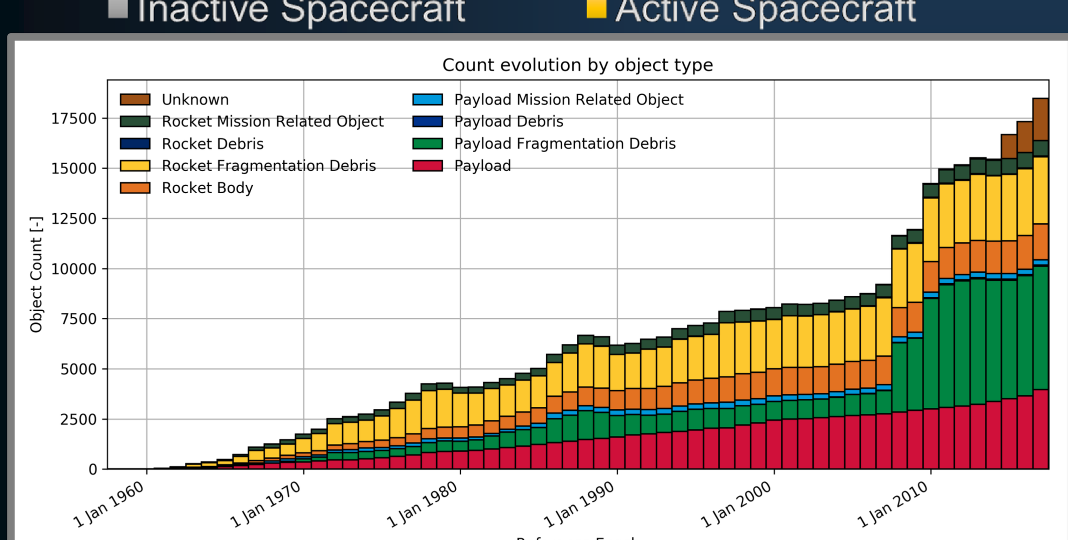
Introduction

Small satellite operators need a coherent response to the question of space debris, and many designers can't afford the volume, weight, and/or cost of a propulsion system.

Small satellites provide the most likely platform to make use of differential drag due to their characteristically high surface-area-to-mass ratio, as well as volume constraints that can preclude the use of an on-board propulsion system. Planet Labs has proven that differential drag can be used for tasks such as constellation phasing[1], and the research presented here demonstrates its use for collision avoidance as well.

Current Debris in Orbit





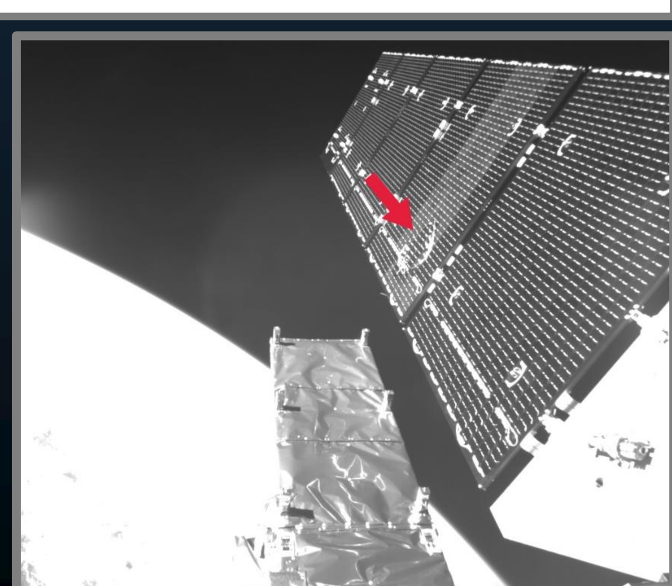
Risks:

•Mission-killing impacts

•Functional degradation from small impacts

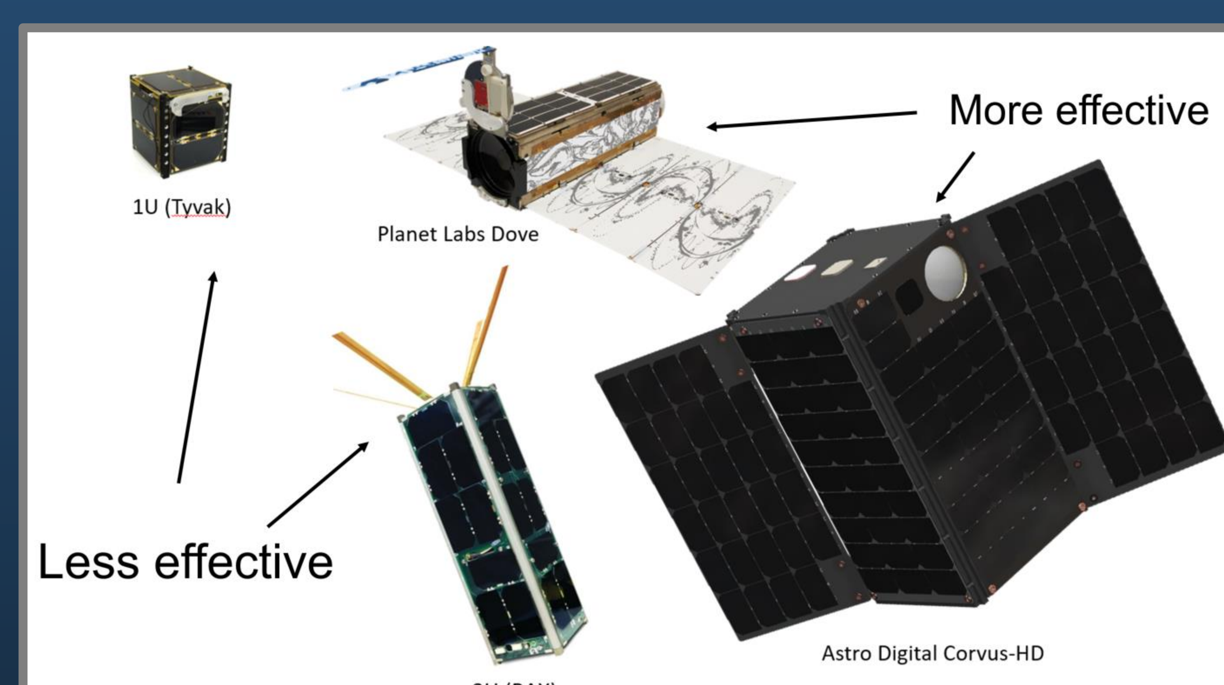
•Increased regulation on satellite launches (More costs!)

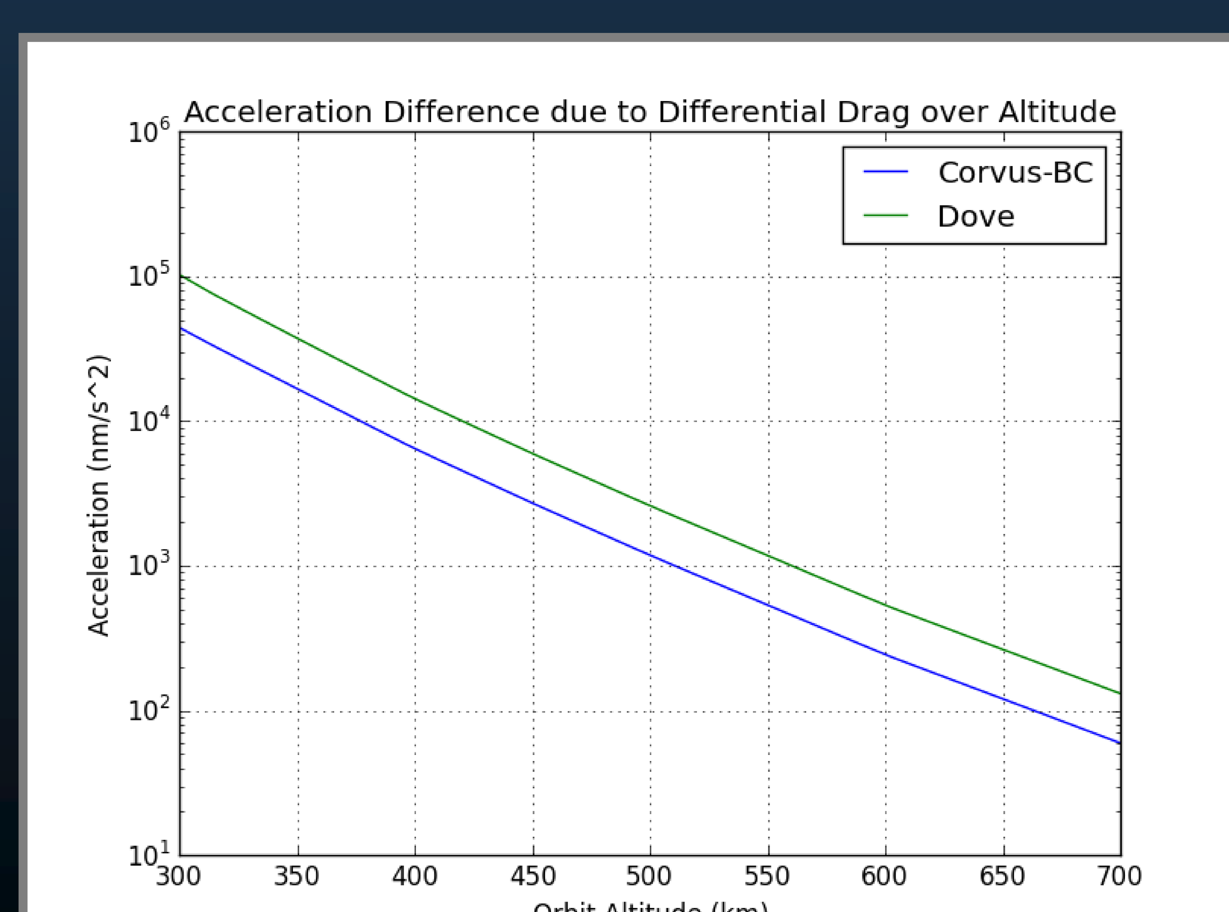
•Worst case: Regulatory refusal to launch objects that can't maneuver



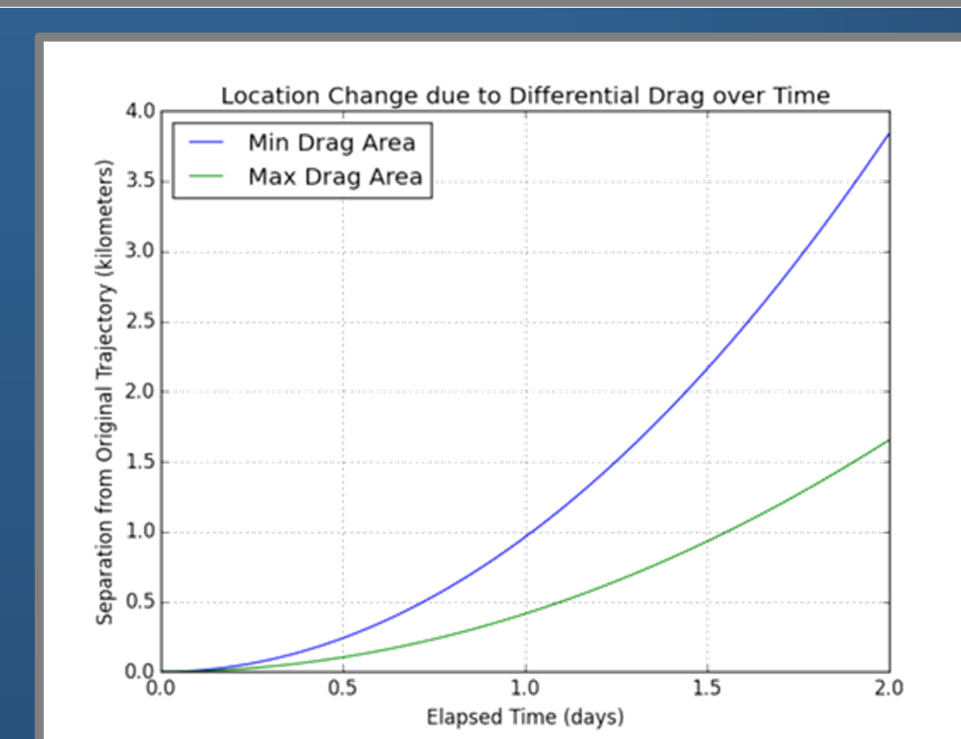
Differential Drag

Form Factor Effectiveness

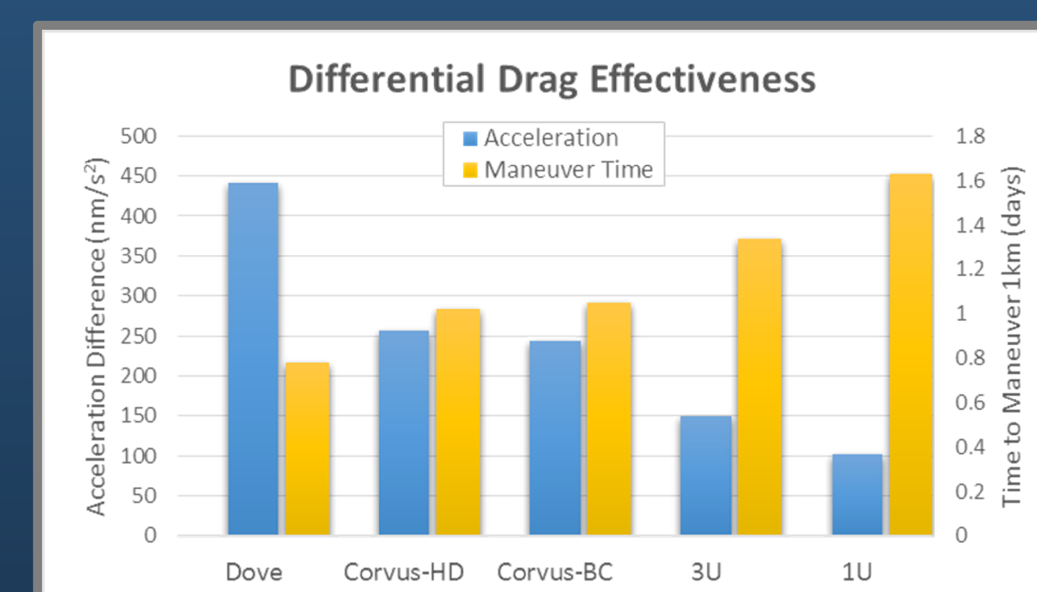




Avoidance Maneuvers

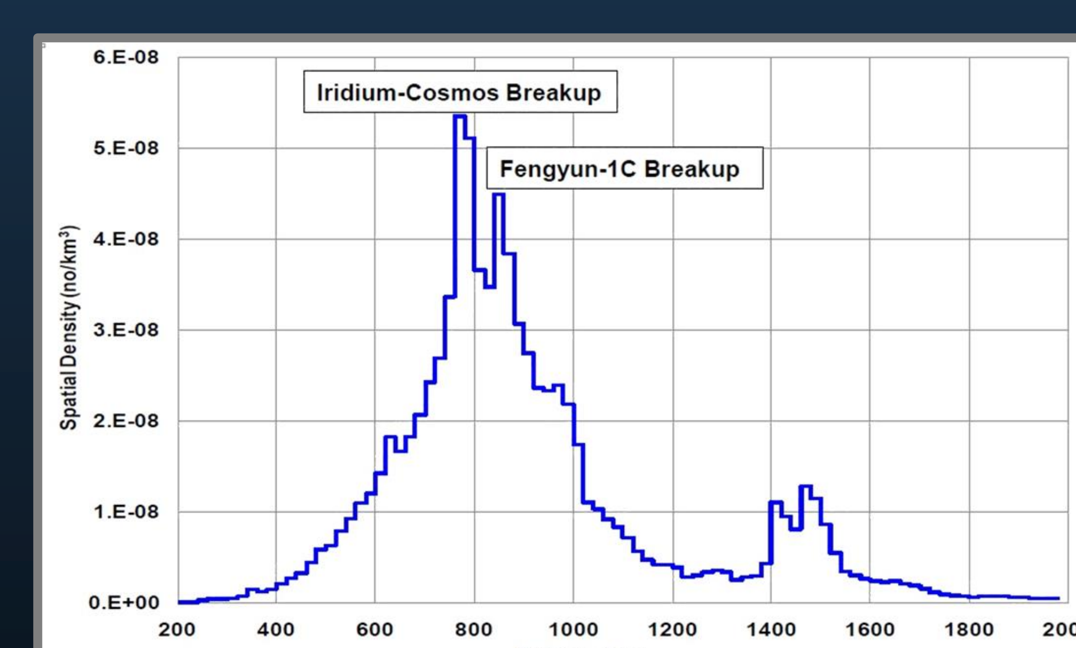


Maneuvering capability for Corvus-BC form factor at 600 km altitude



Time to shift predicted position by 1 kilometer and differential acceleration for various form factors at 600 km altitude

Conjunction Frequency

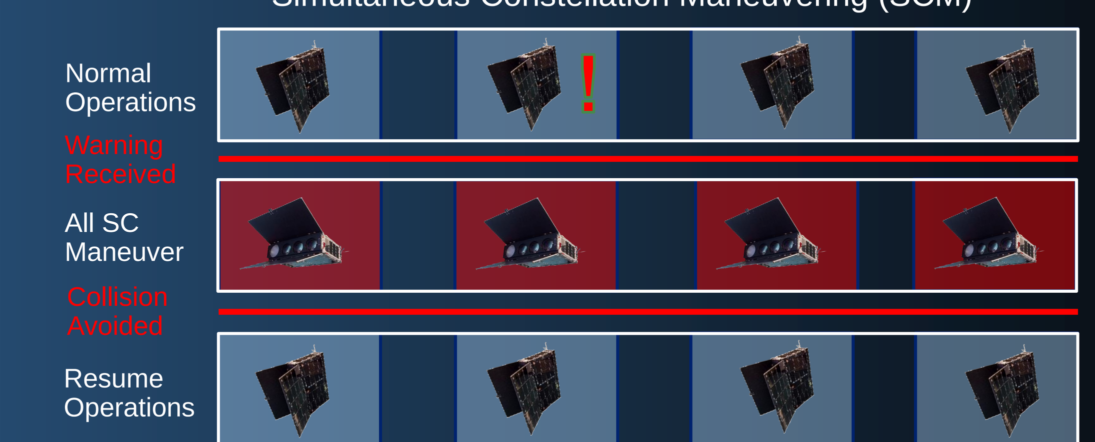


Using data from Perseus-M (620 km orbit), there are:
1.89 conjunctions of 300 meters or less per year
3.78 conjunctions of 500 meters or less per year
7.87 conjunctions of 1000 meters or less per year

Maneuvering Methods

These two methods can be used to maintain relative phasing between spacecraft in a constellation.

Simultaneous Constellation Maneuvering (SCM)



Single Satellite Maneuvering (SSM)

Operational Interruption

A method of collision avoidance that requires the satellite to be constantly maneuvering is not viable. The table below shows the expected loss of operations time various constellation designs would experience using different methods of collision avoidance if all conjunctions under 500 meters were avoided.

As expected, propulsion results in the least lost operations time. However, SSM is fairly reasonable for larger constellation sizes and low altitude orbits. SCM is more effective for small constellations (<4 satellites).

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	3.78	0.13 days	10 Spacecraft	3650 sat-days	5.1 sat-days	0.1%
Any	600 km	Propulsion	3.78	0.13 days	Any			0.1%
Any	450 km	Propulsion	0.95	0.13 days	10 Spacecraft	3650 sat-days	1.2 sat-days	0.03%
Any	450 km	Propulsion	0.95	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)	3.78	1.04 days	10 Spacecraft	3650 sat-days	378 sat-days	10.4%
Corvus-BC	450 km	SCM (Diff Drag)	0.95	0.31 days	10 Spacecraft	3650 sat-days	29.5 sat-days	0.8%
Dove	600 km	SCM (Diff Drag)	3.78	0.78 days	10 Spacecraft	3650 sat-days	294 sat-days	8.0%
Dove	600 km	SCM (Diff Drag)	3.78	0.78 days	100 Spacecraft	36500 sat-days	29400 sat-day	80.8%
Dove	450 km	SCM (Diff Drag)	0.95	0.24 days	10 Spacecraft	3650 sat-days	22.7 sat-days	0.6%
Dove	450 km	SCM (Diff Drag)	0.95	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%

[1] Foster, C., Hallam, H., and Mason, J., "Orbit Determination and Differential-Drag Control of Planet Labs CubeSat Constellations," Planet Labs, Inc., AAS 15-524, Sep. 2015

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