Insights from the Gannon Geomagnetic Storm on Sustainable Satellite Operations

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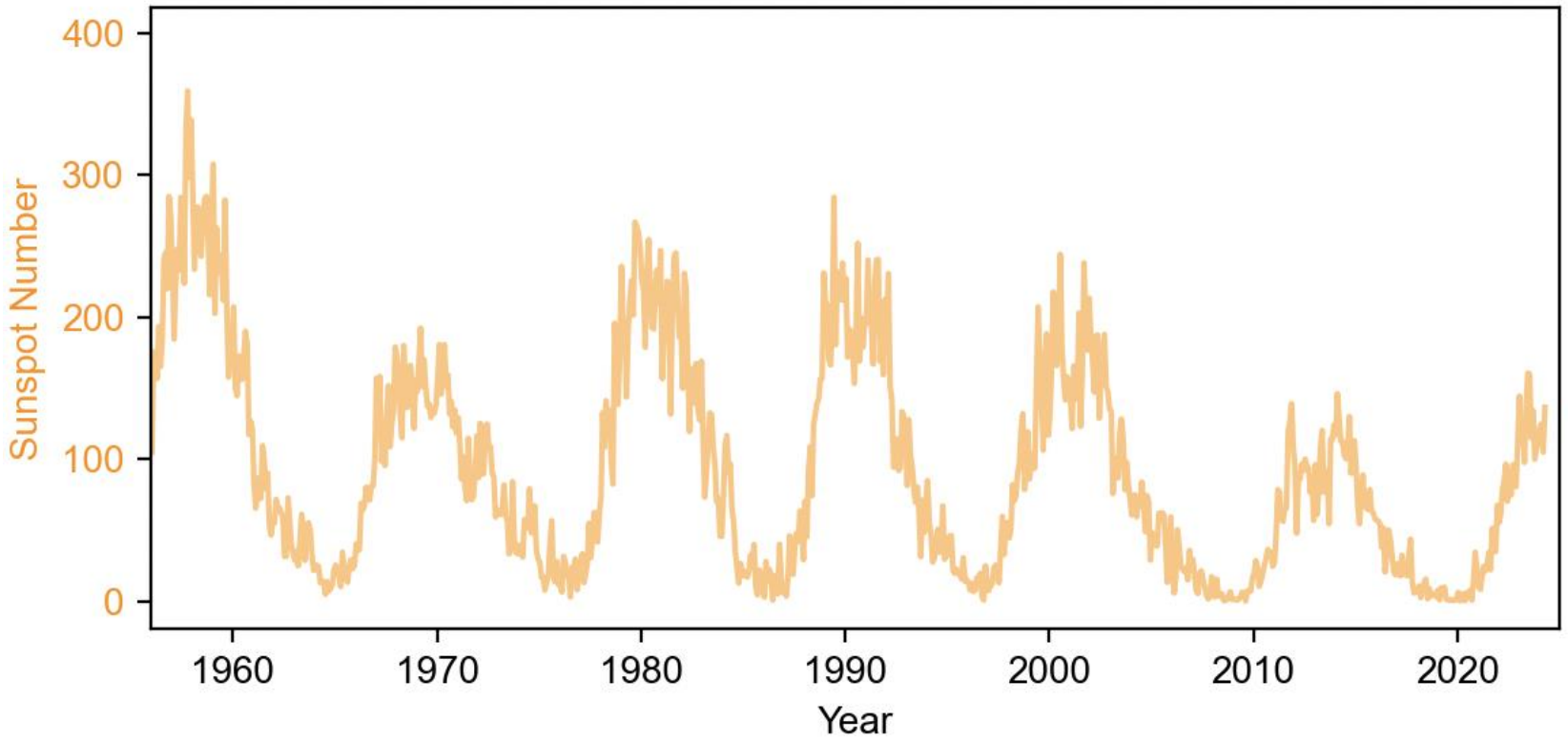
AMS 2025

MIT AEROASTRO

MIT Astrodynamics, Space Robotics, and Controls Laboratory

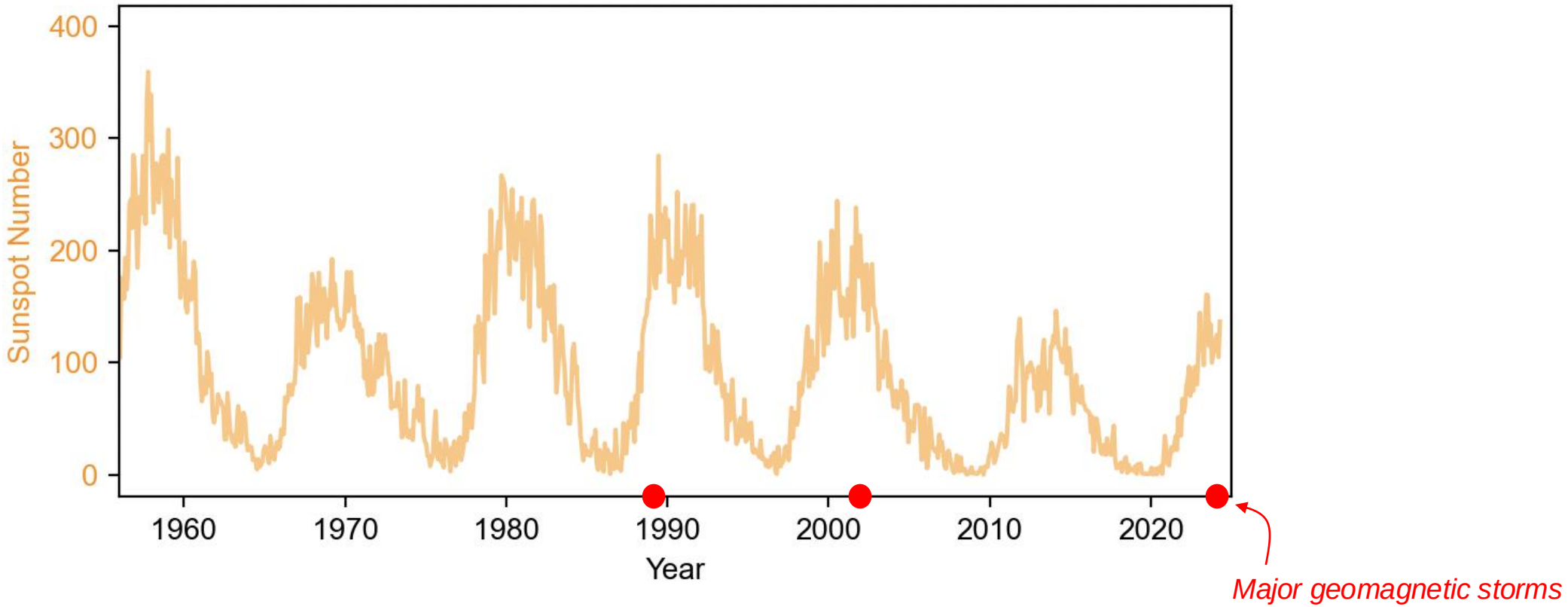
NSF

Gannon Storm: ***What's new?***



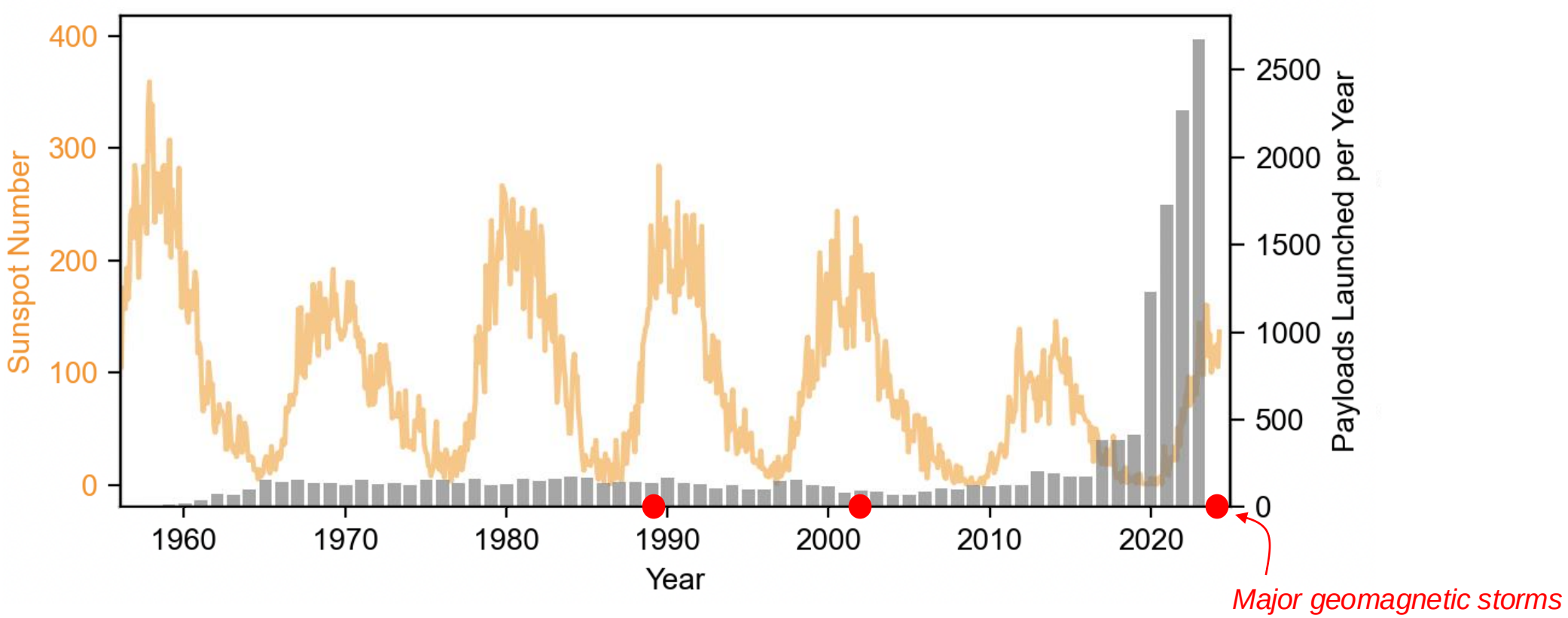
We've seen solar max before…

Gannon Storm: ***What's new?***



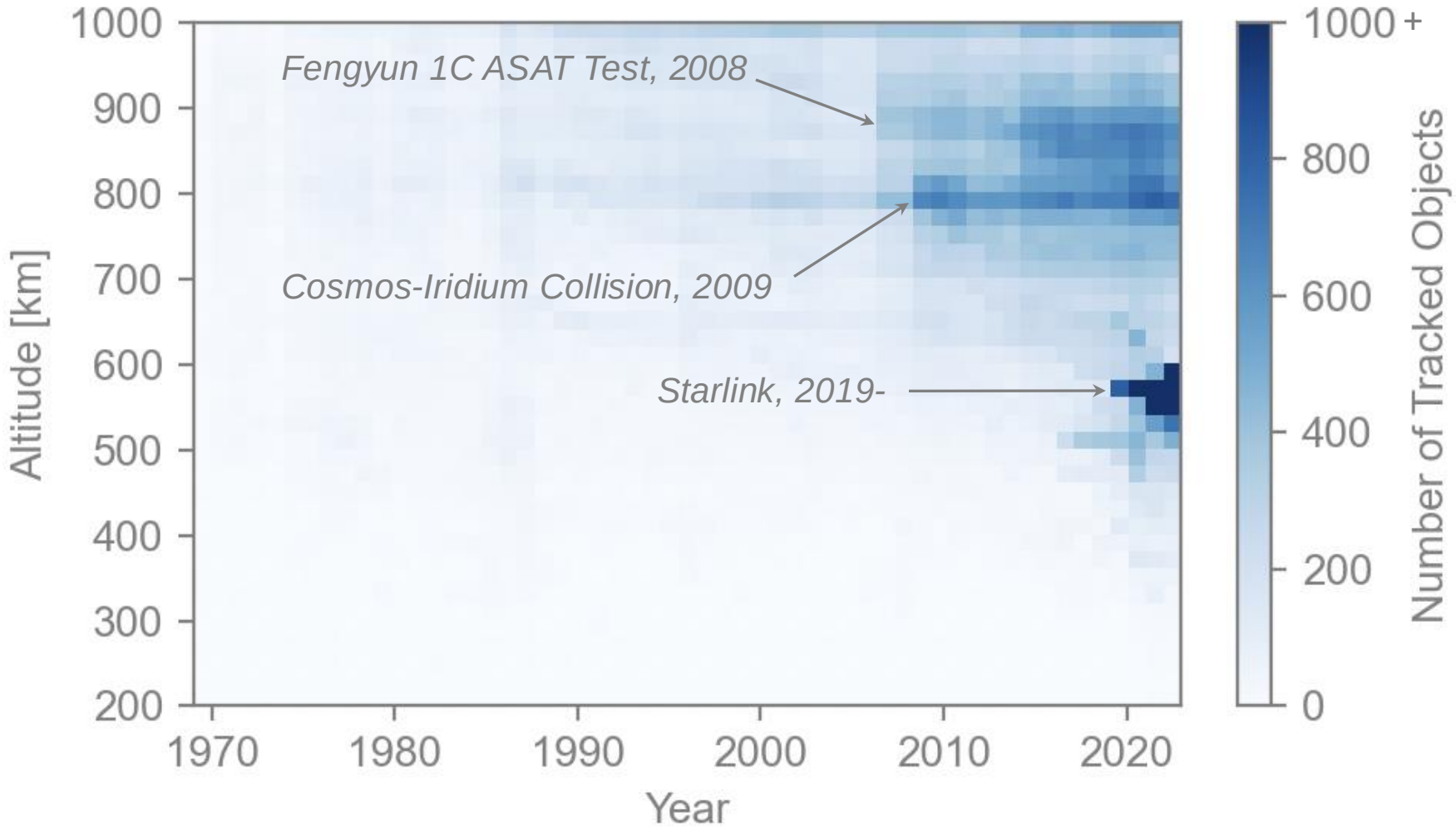
We've seen solar max before… ***We've seen major storms before…***

Gannon Storm: ***What's new?***



We've seen solar max before… *We've seen major storms before…* ***Satellite operations have changed a lot.***

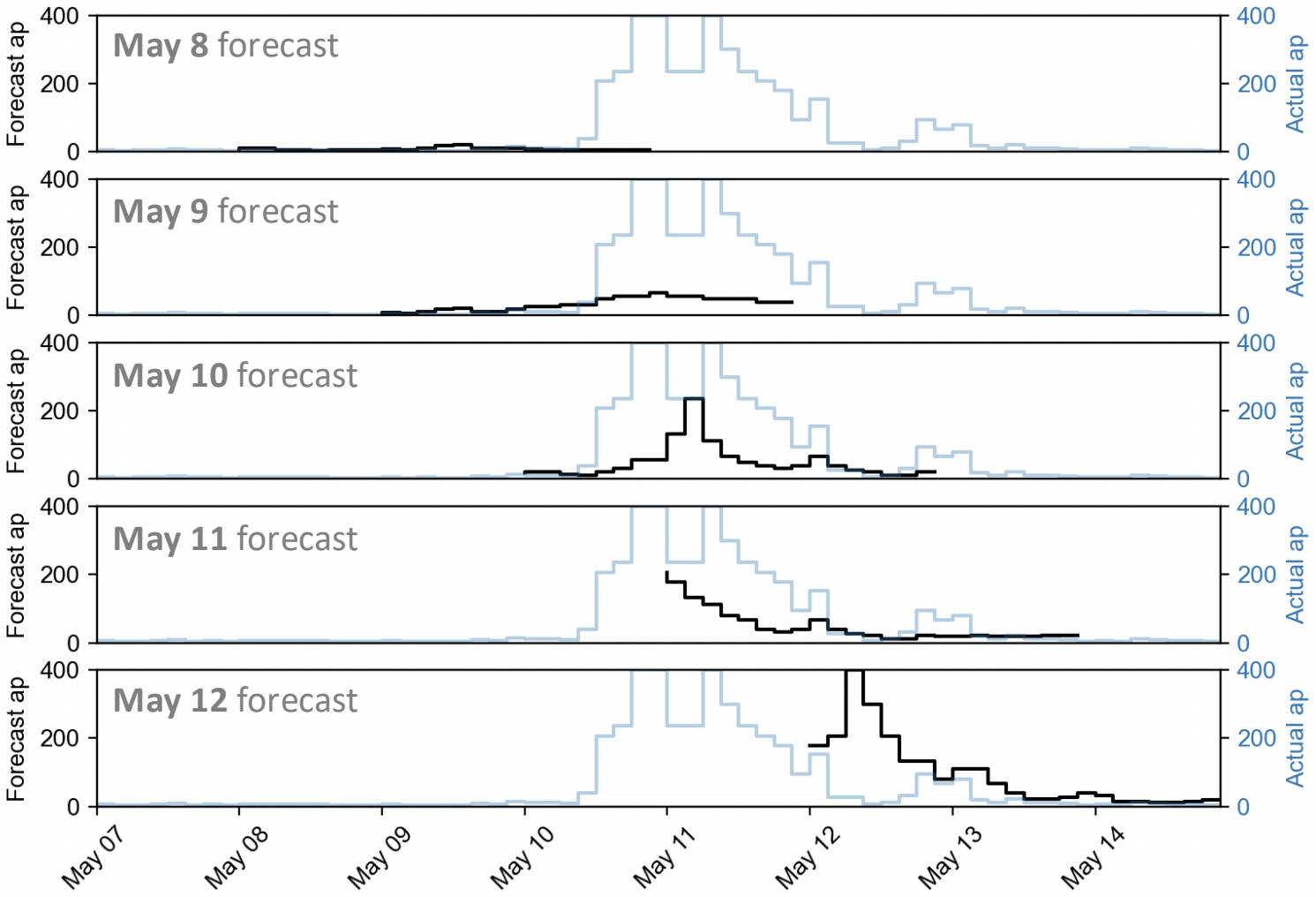
Debris Growth in LEO



SWPC *ap* Forecasts

Gannon Storm

Struggled to forecast the **timing**, **magnitude**, and **duration** of the storm



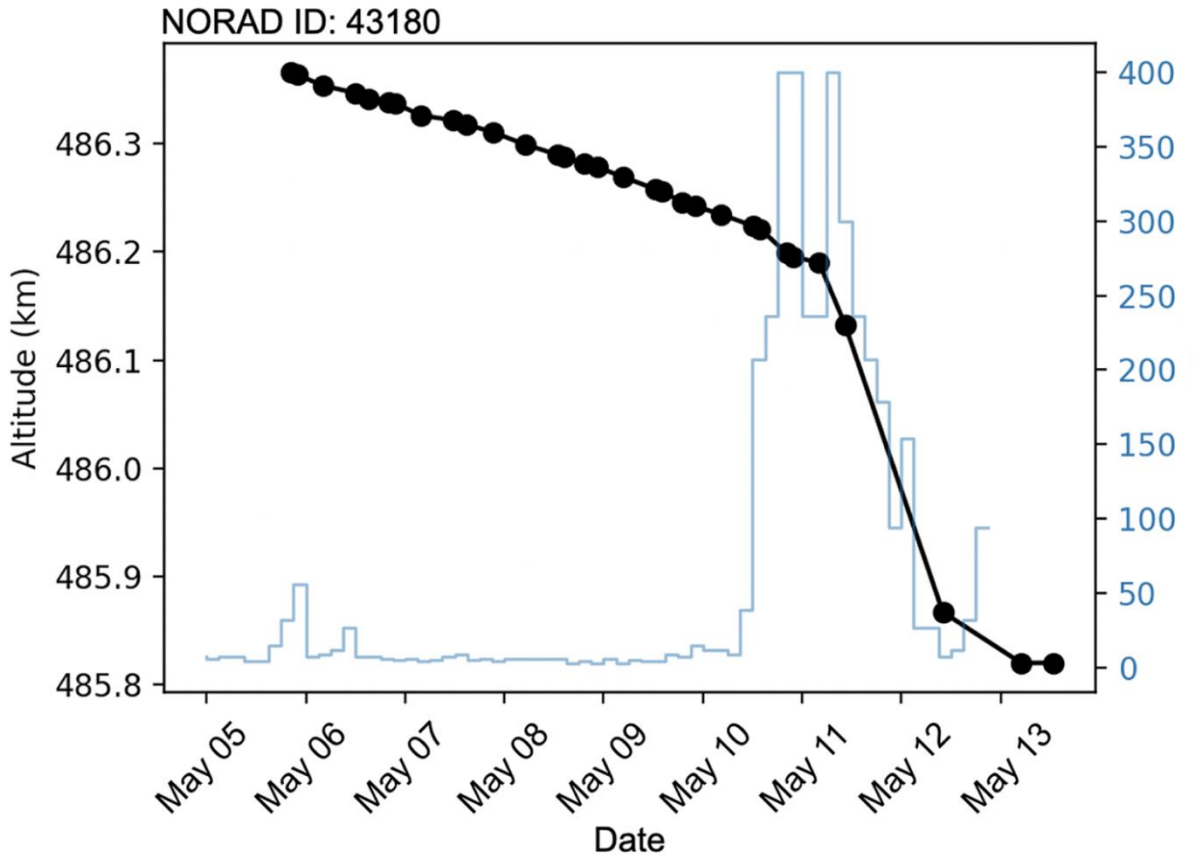
*For a 24-hour propagation, Starlink saw **20 km** position errors!*

(Petrov and Hoot, 2024)

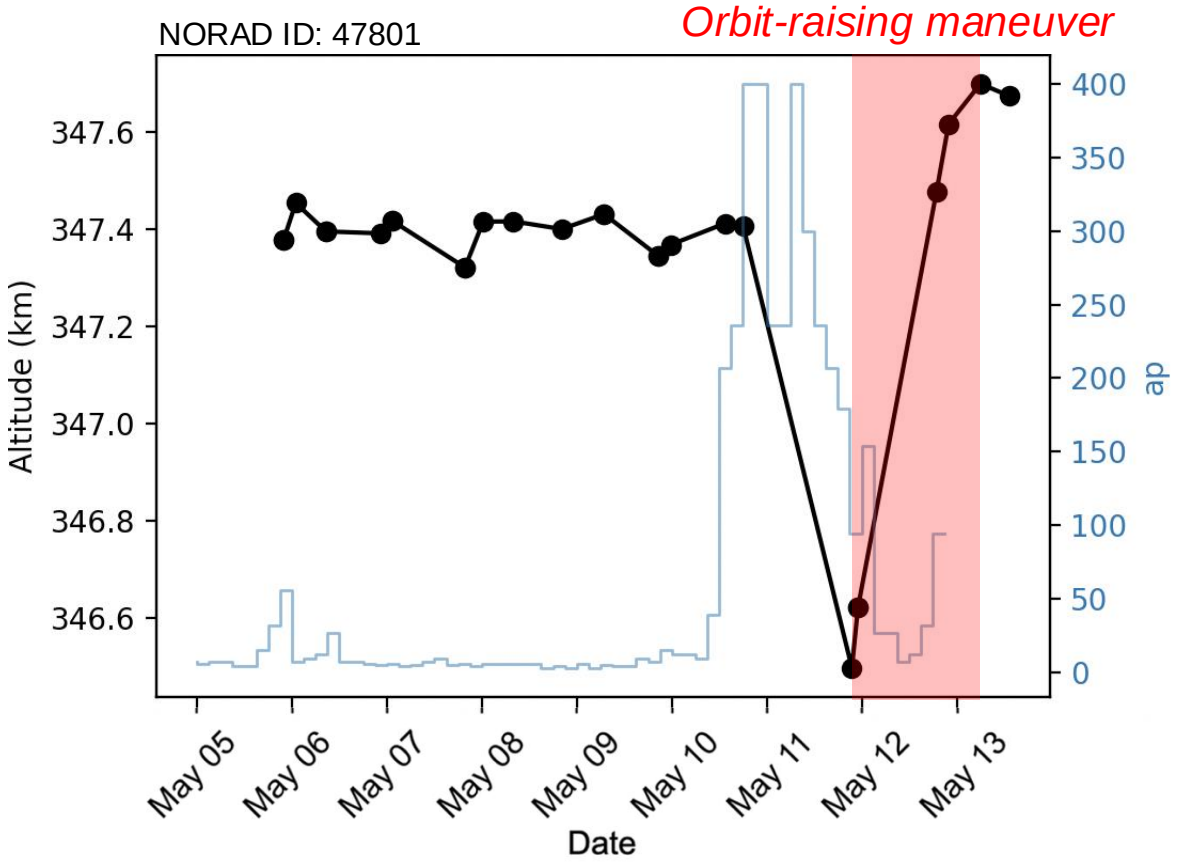


Rapid Drag-induced Satellite Decay

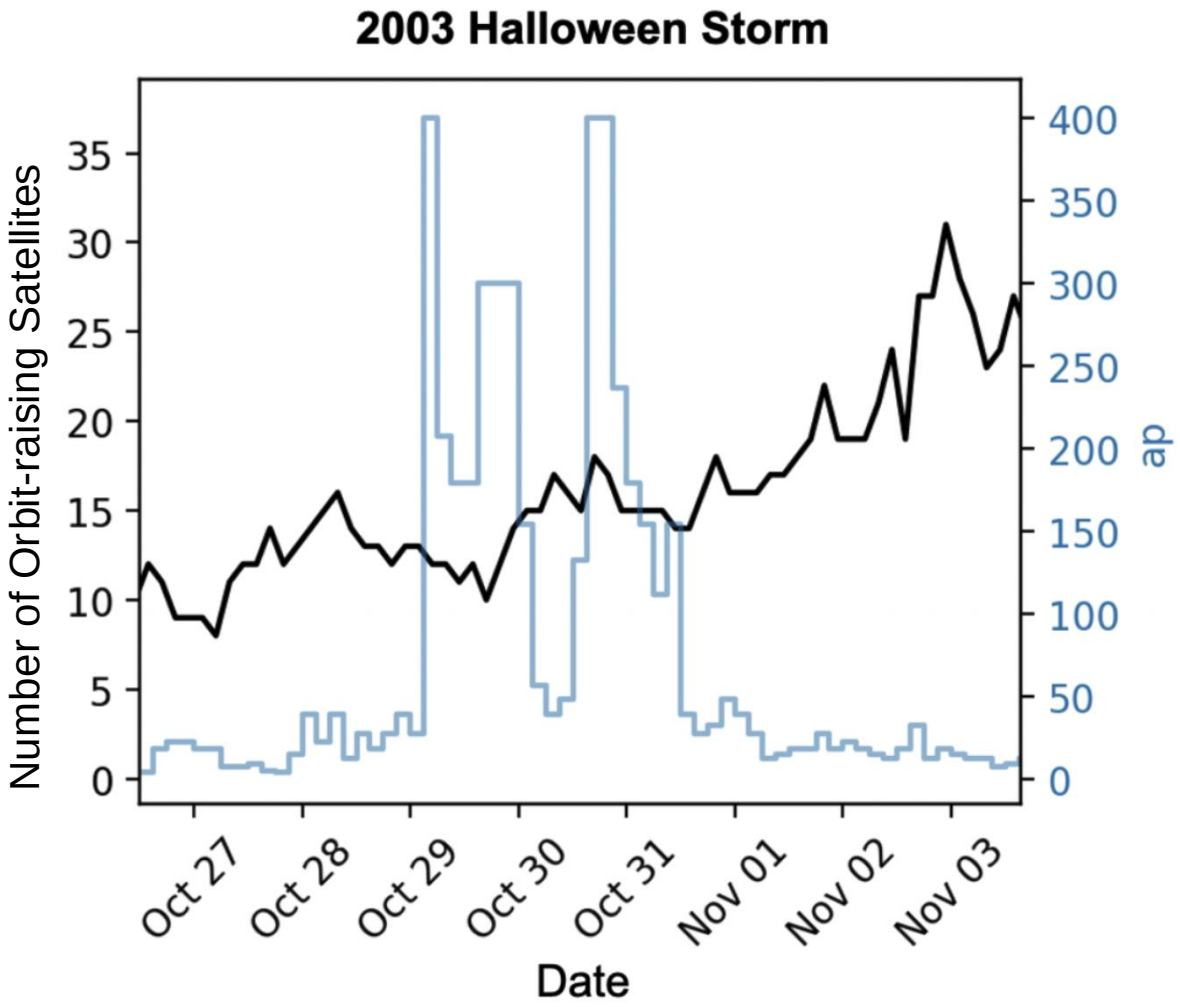
***Passive* response**

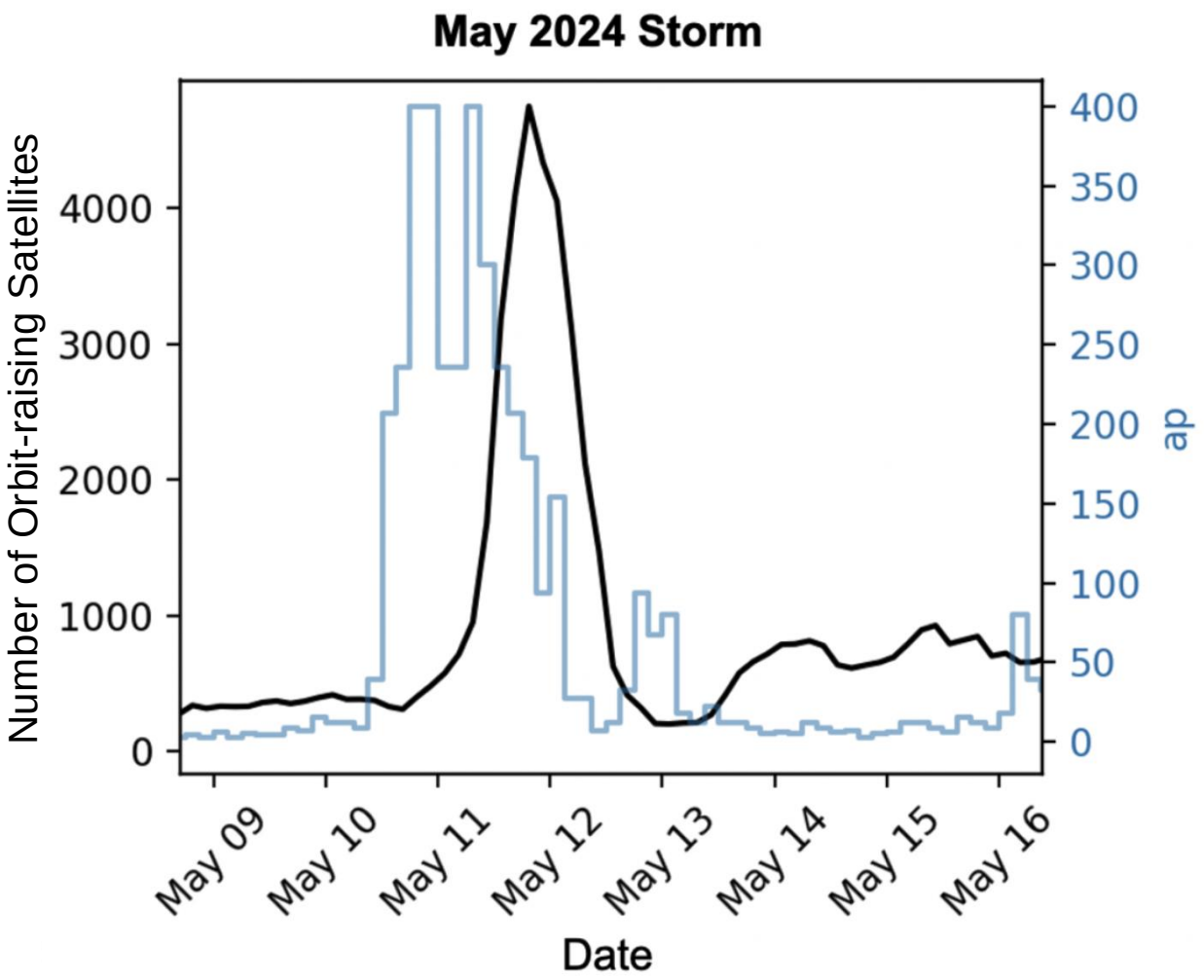


***Active* response**



Orbit Maintenance Maneuvers



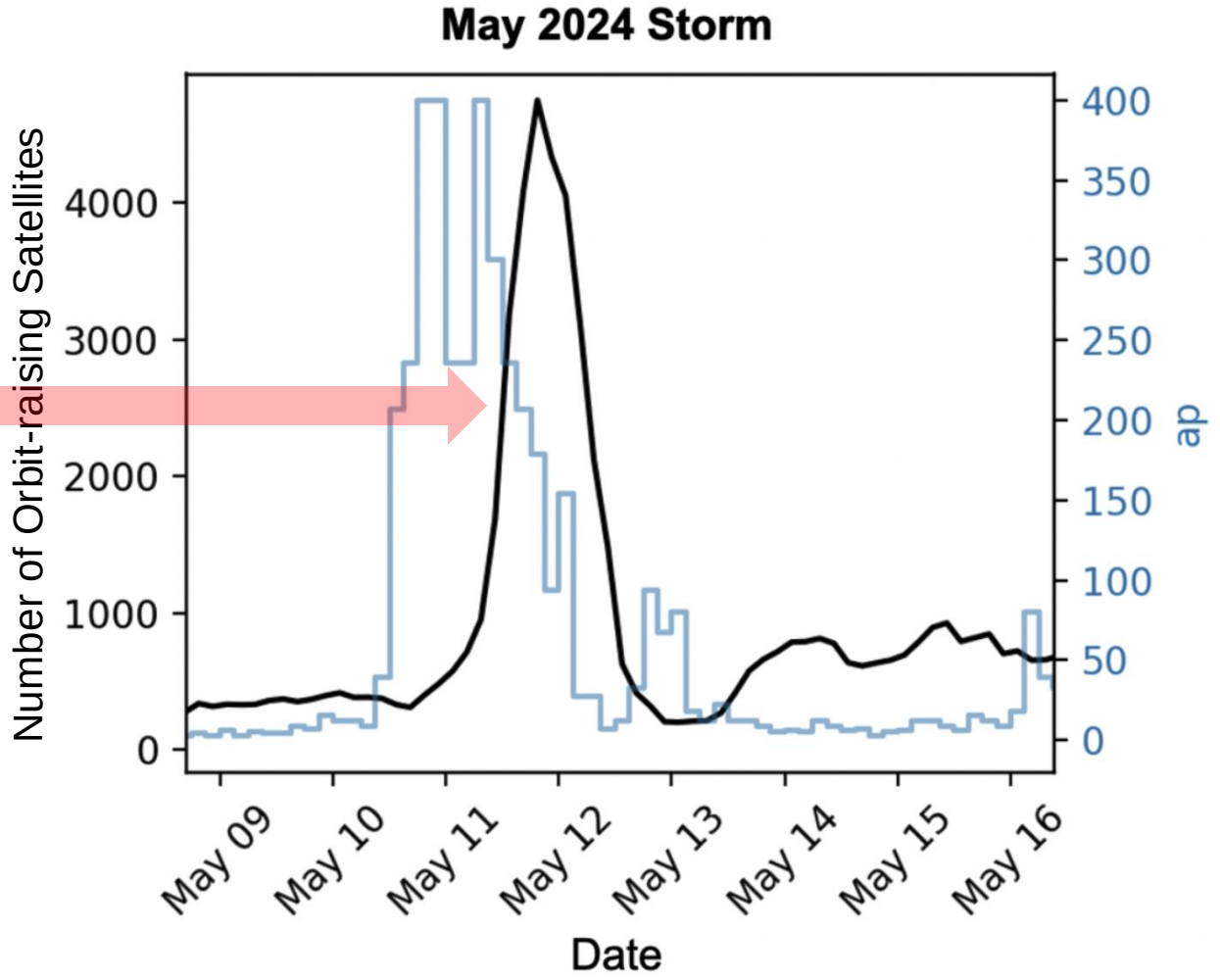


Orbit Maintenance Maneuvers

SPACE.com

May solar superstorm caused largest 'mass migration' of satellites in history

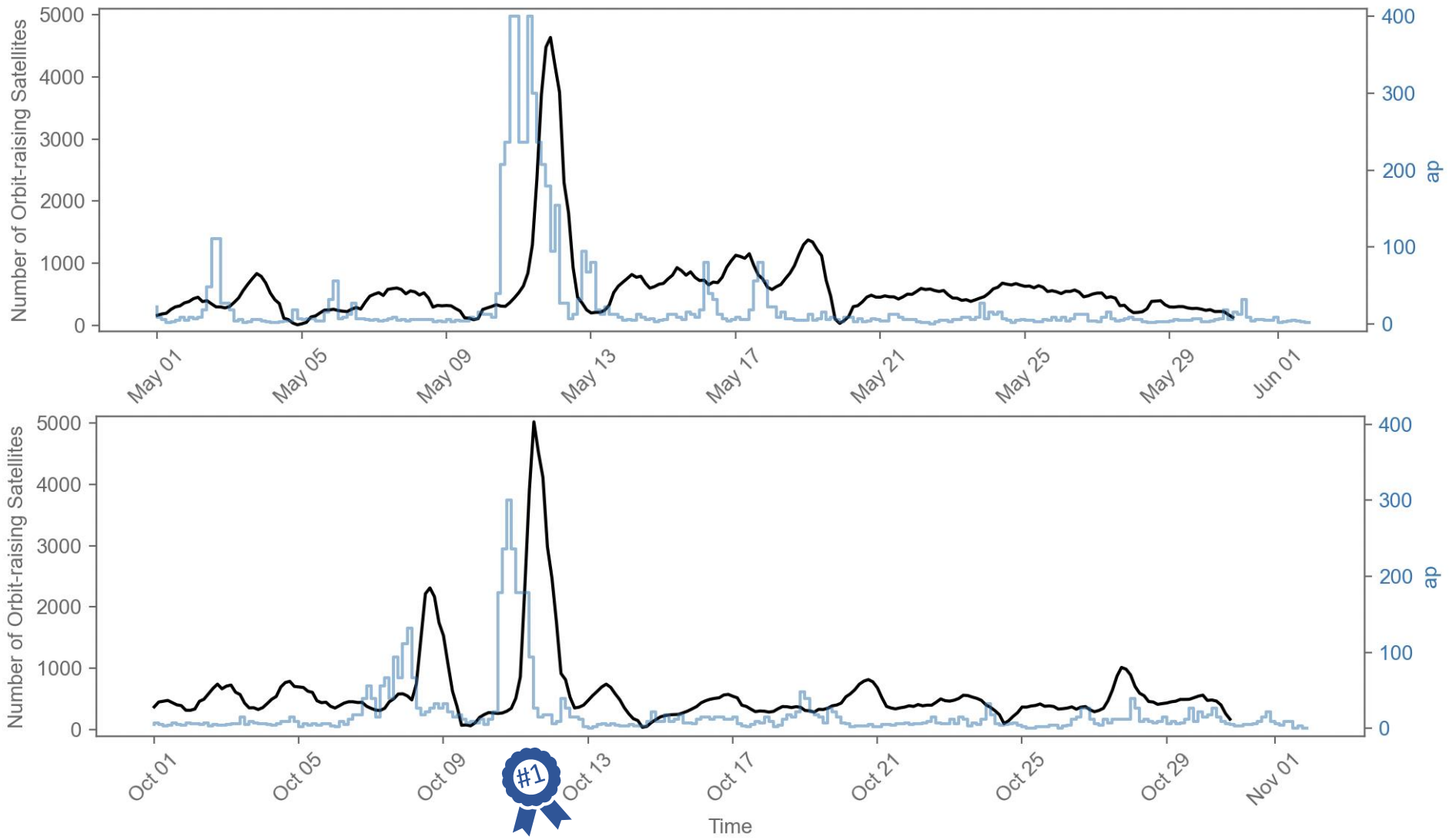
News By Tereza Pultarova published July 19, 2024



Reliable Satellite Mass Migration

May Storm

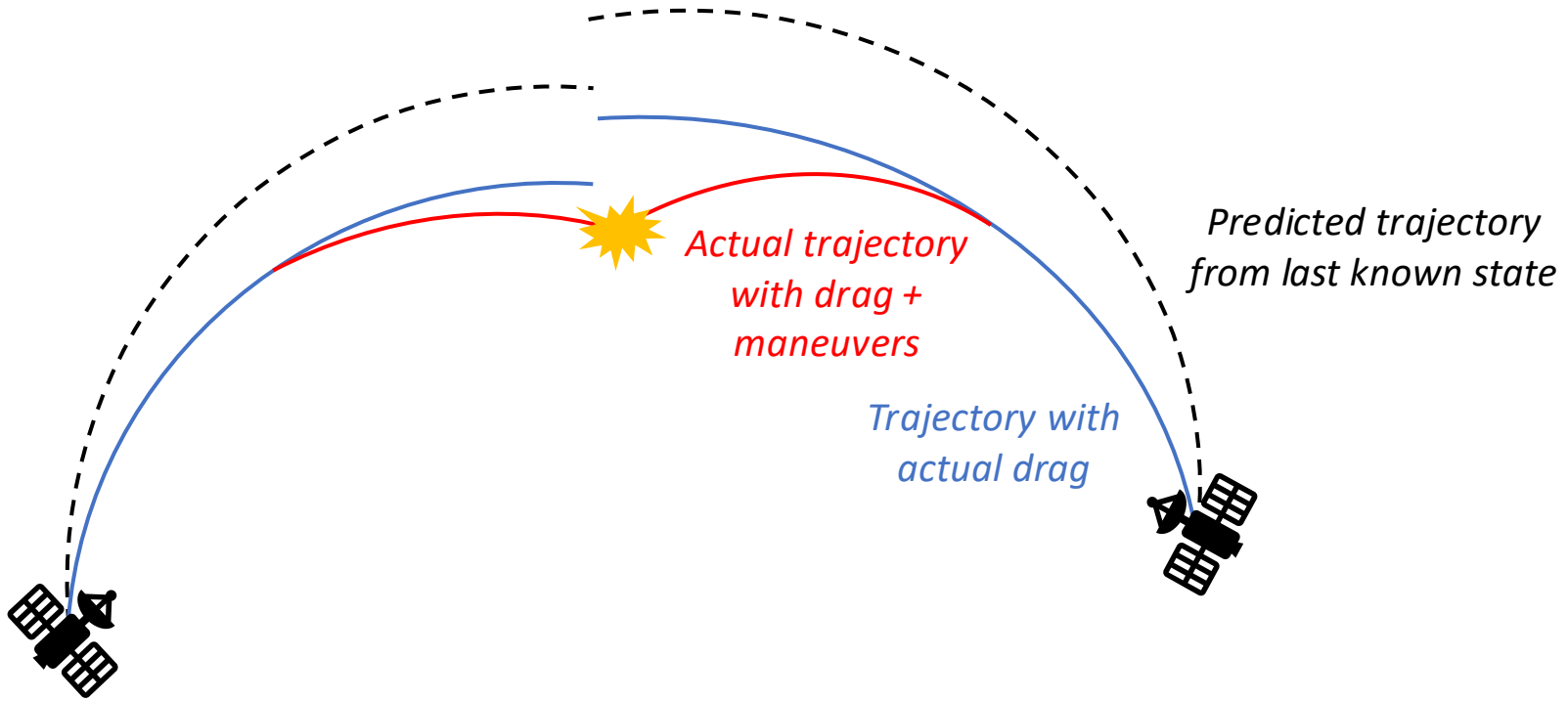
Oct. Storm



Satellite collision avoidance is not robust to storms.

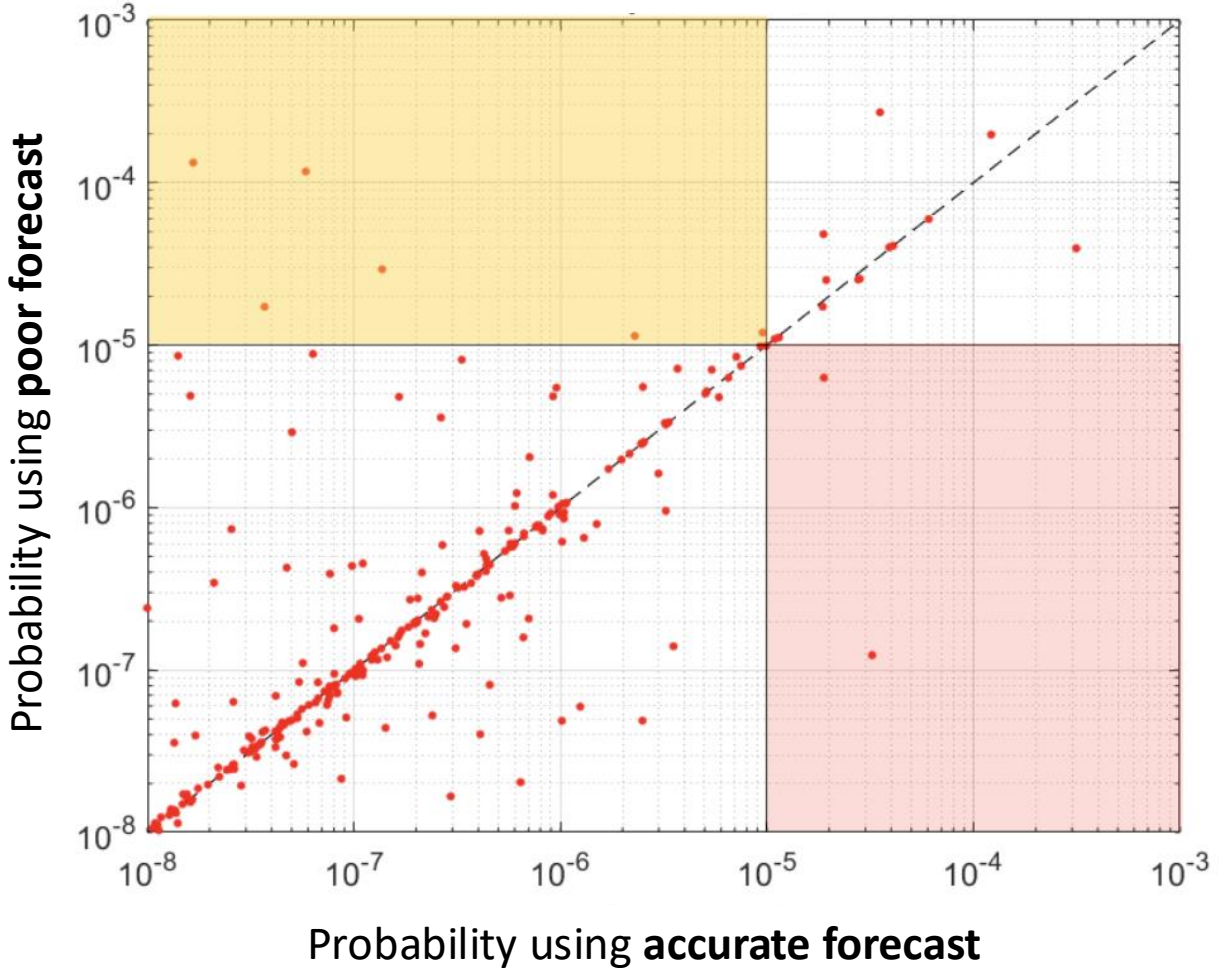
Predicted satellite trajectories are very wrong
(from poor storm forecasts)

Satellites perform unplanned maneuvers *en masse*
(to maintain their orbital slots)

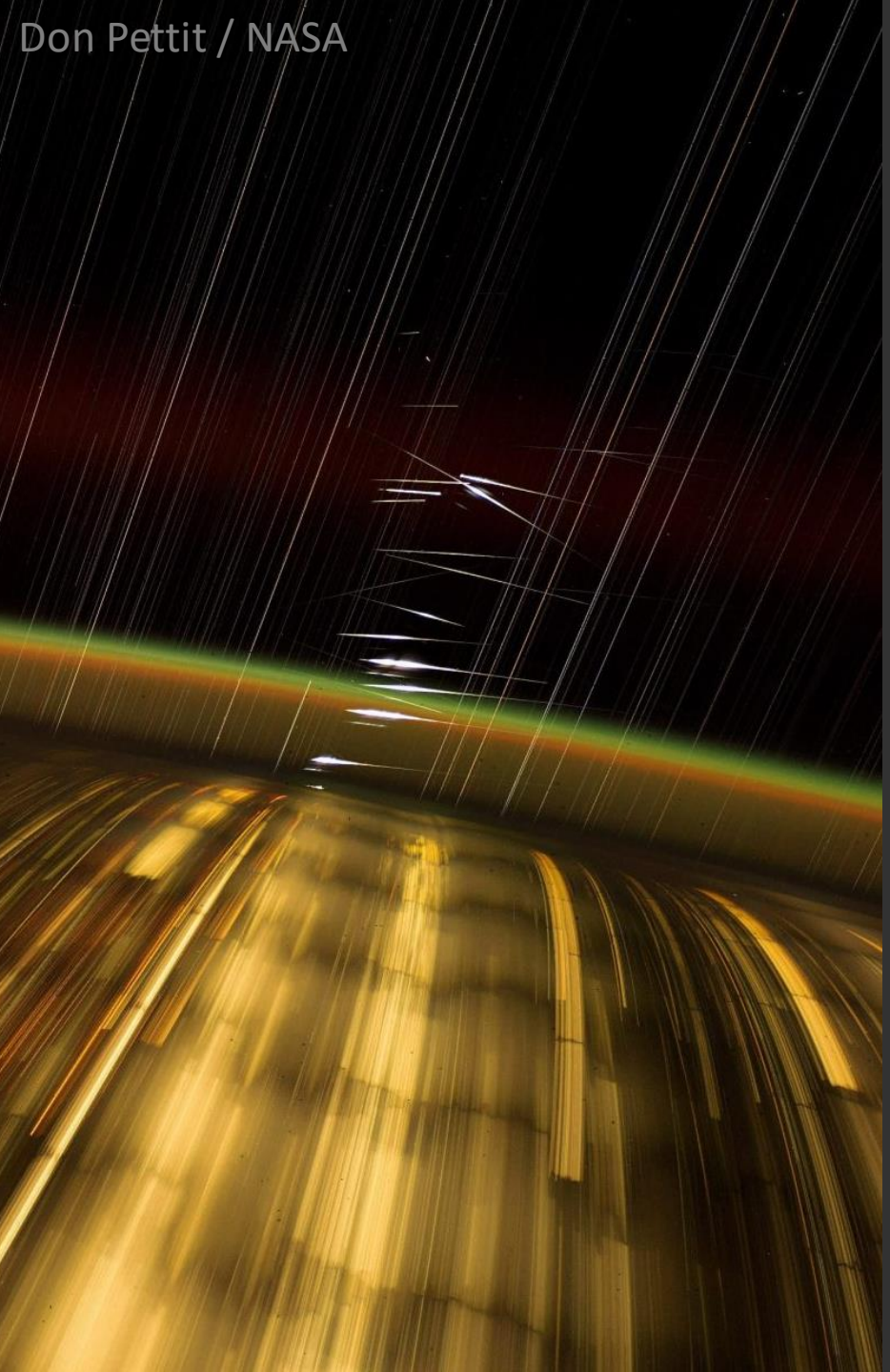


How often would better space weather forecasts change our maneuver decisions?

We **DON'T** need to perform a maneuver, but current Pc says we **DO**



We **DO** need to perform a maneuver, but current Pc says we **DON'T**



Questions?

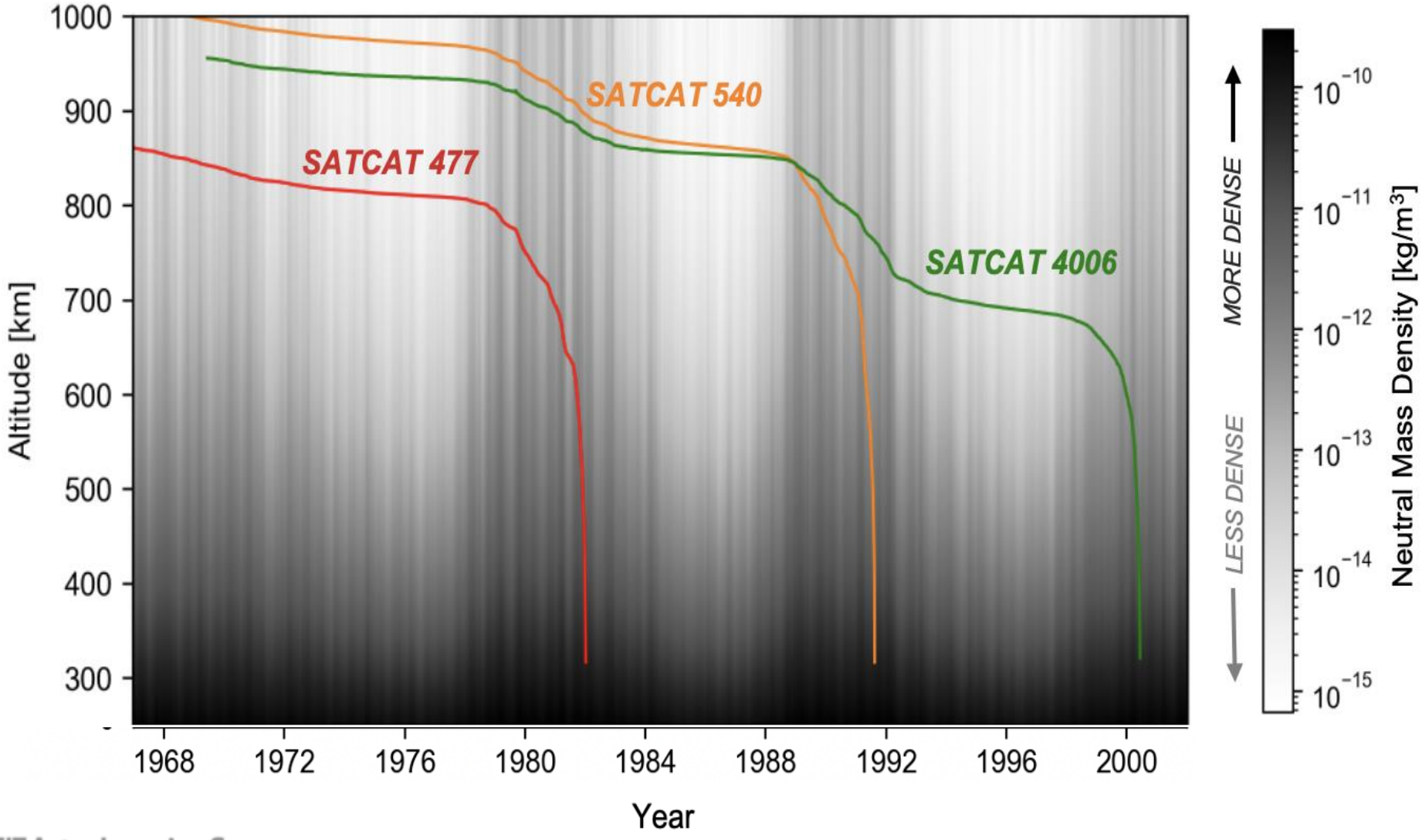
wparker@mit.edu

Relevant papers!

Gannon Storm Satellite Drag

Space Weather & Collision Avoidance

Operating in the Thermosphere (Long-term)



Satellite Drag

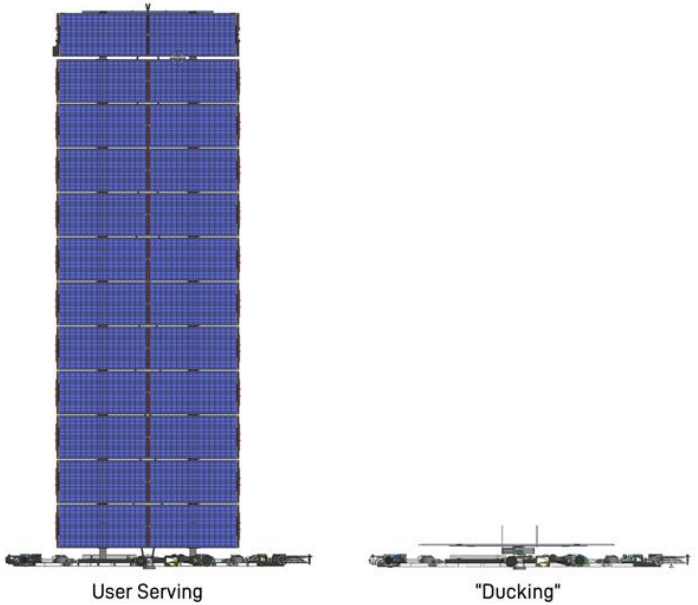
Uncertain shape/attitude (esp. debris)

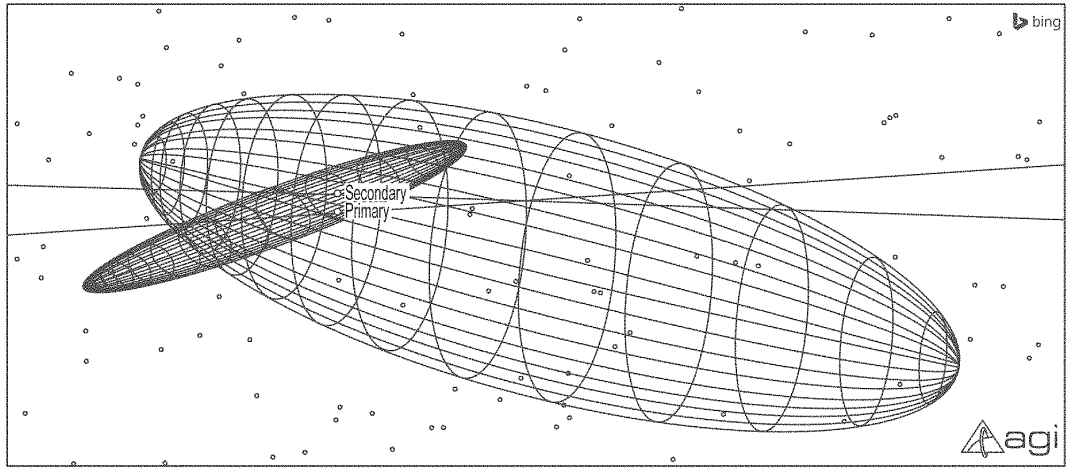
Uncertain neutral density

$$\ddot{\mathbf{r}}_D = -\frac{1}{2}\frac{\rho v_{rel}^2 C_d A}{m}\mathbf{e}_{rel}$$

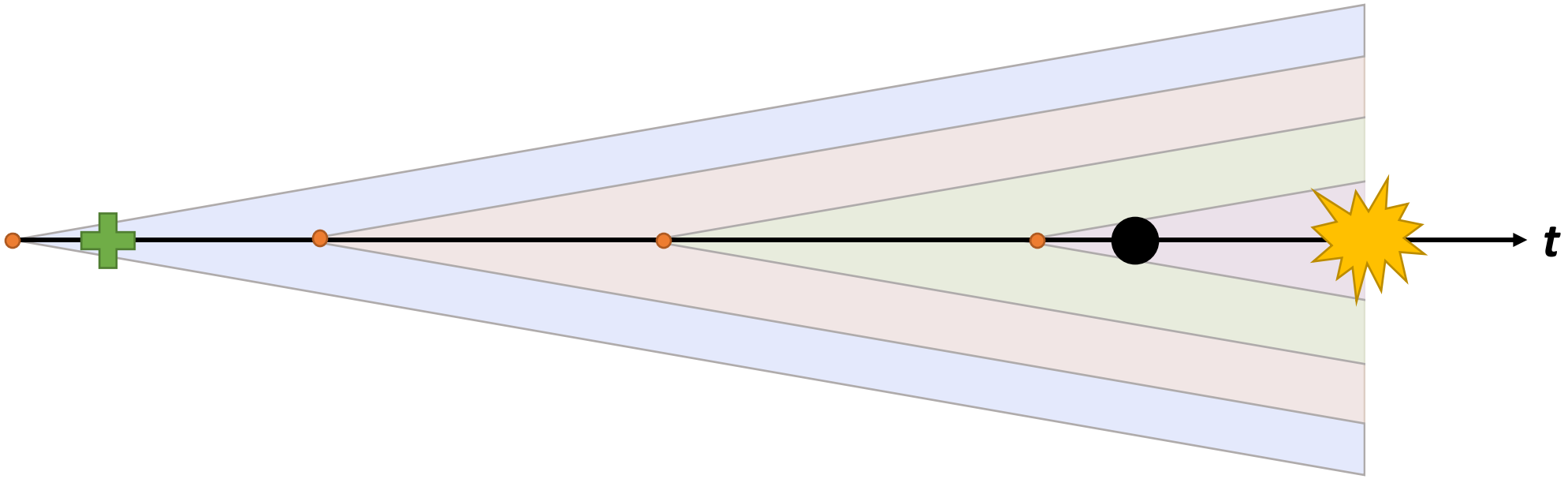
Uncertain launch mass, propellant usage, etc. (esp. debris)

Uncertain thermosphere winds





Conjunction Assessment Timeline



First CDMs are created (screening)

TCA – 7 d

Most Maneuvers

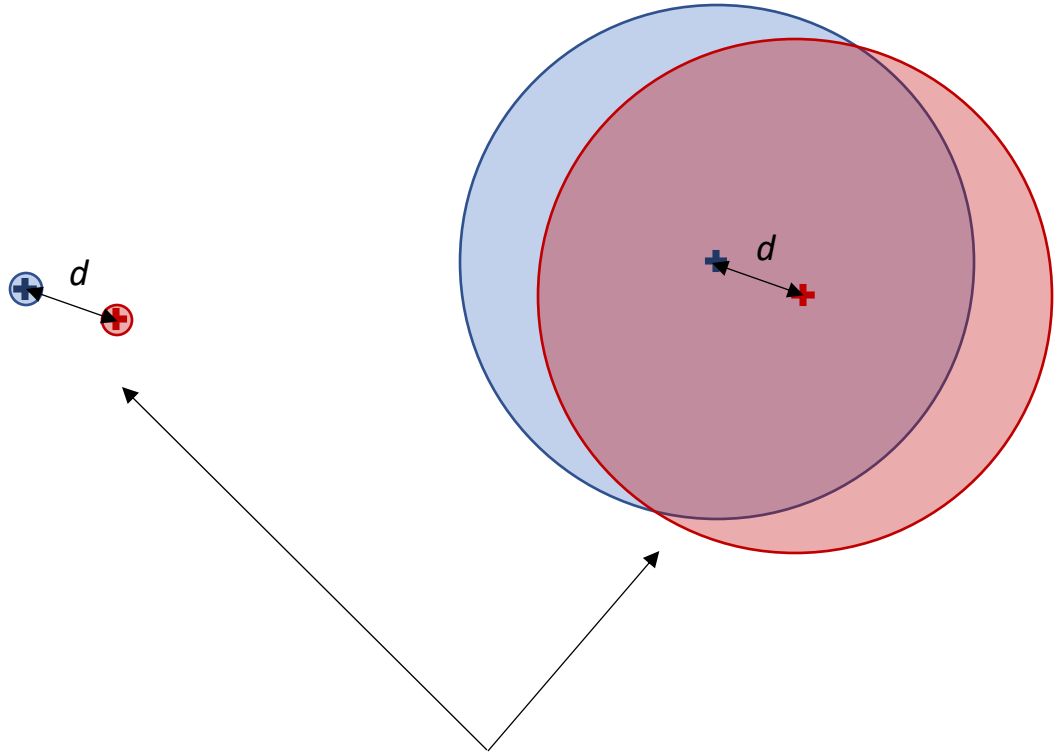
TCA – (12-24h)

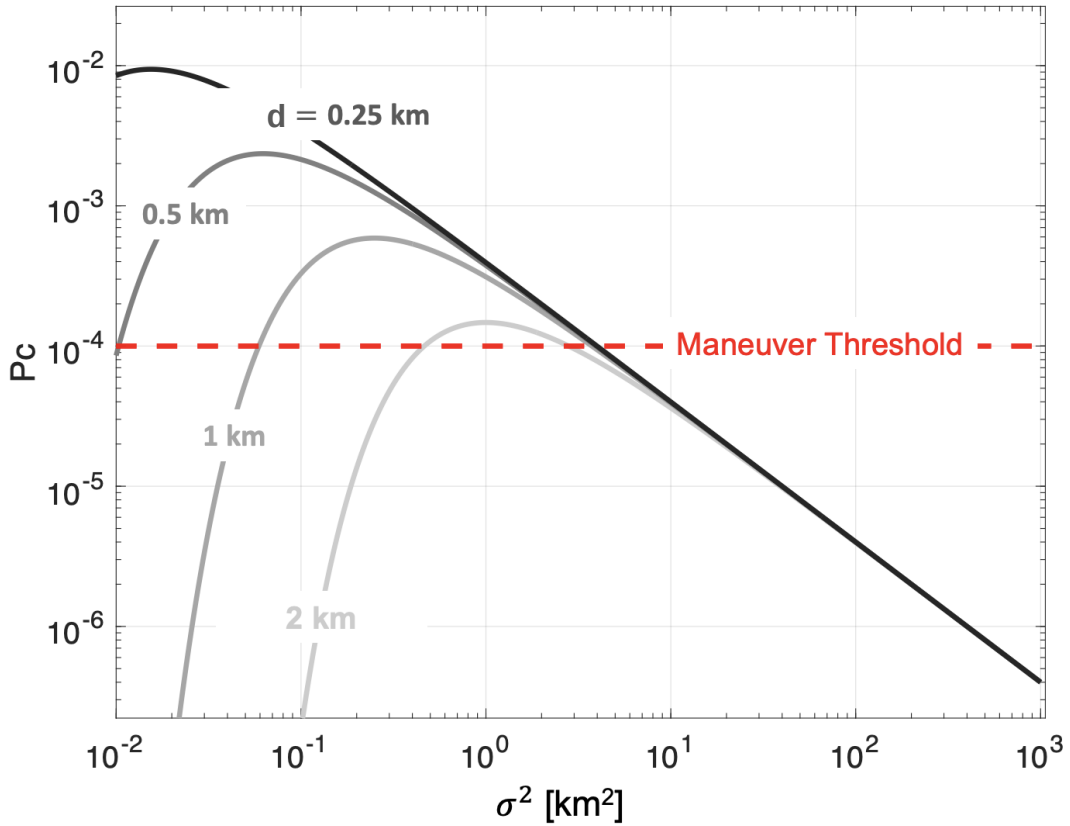
Time of Closest Approach (**TCA**)

Probability of Collision

We know a lot.

We don't know much.





Probability of collision is the same.

Forecast Comparison

