

# ASAT tests: Adverse implications to operators and the space environment

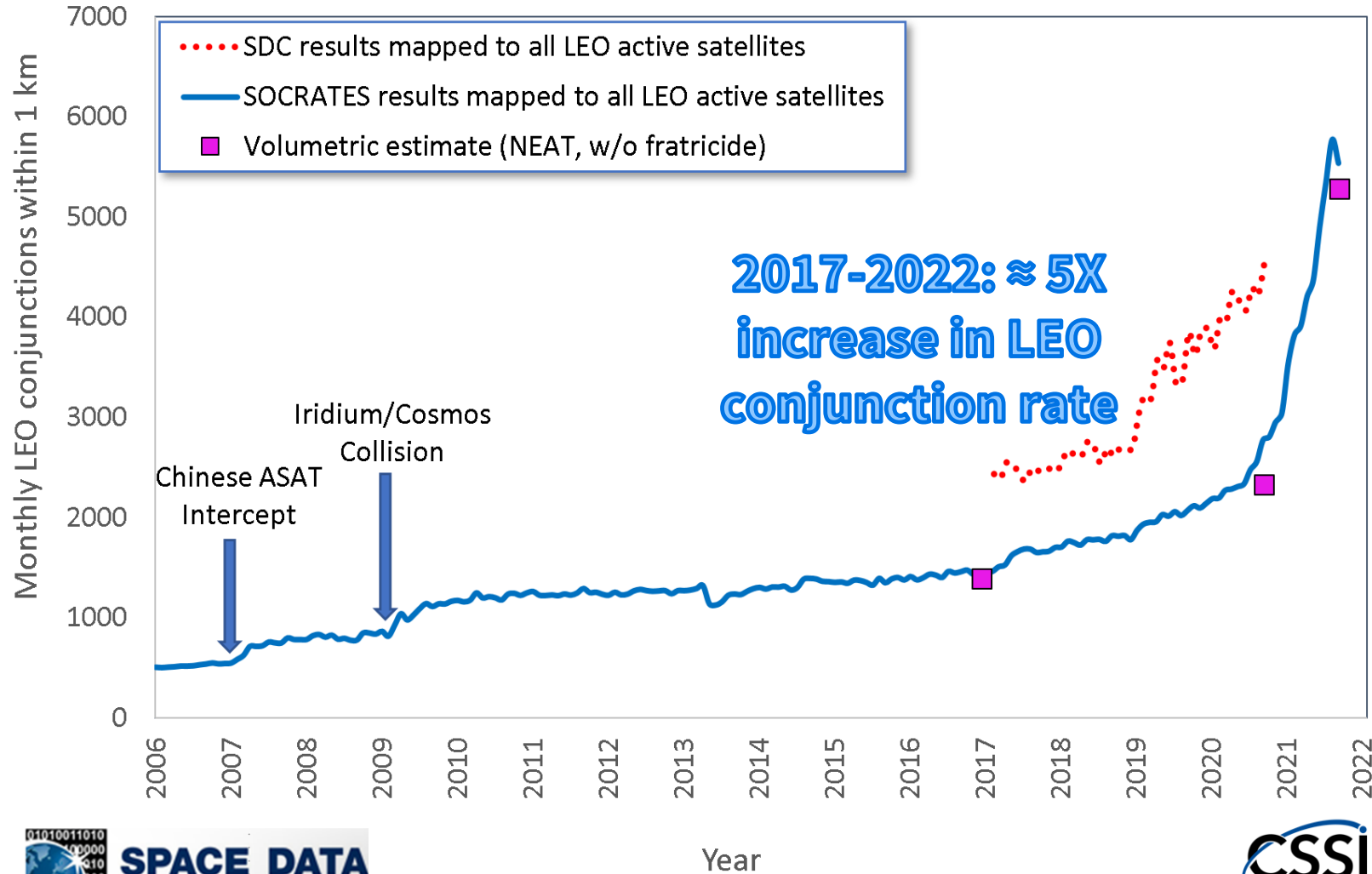
Session: Small Satellites & Space Sustainability: Why You Should Care

Dan Oltrogge, COMSPOC Corporation

8 August 2022

# Backdrop: Traffic and close conjunctions increasing

Conjunction trend for active Low Earth Orbit (LEO) satellites



## Average monthly conjunction rates surge from 2017 to 2020

Satellite operators are receiving warnings that their spacecraft are within 1 kilometer of another satellite or piece of tracked debris approximately twice as often as they did three years ago.

That was one of the key takeaways from data compiled for *SpaceNews* by Analytical Graphics Inc. (AGI), the Exton, Pennsylvania firm that hosts the Space Data Center, a platform that ingests information from Space Data Association satellite operators and compares it with commercial radar and telescope observations to assess conjunction risks and warn satellite operators. AGI also hosts Satellite Orbital Conjunction Reports Assessing Threatening Encounters in

potential collision risks since 2004.

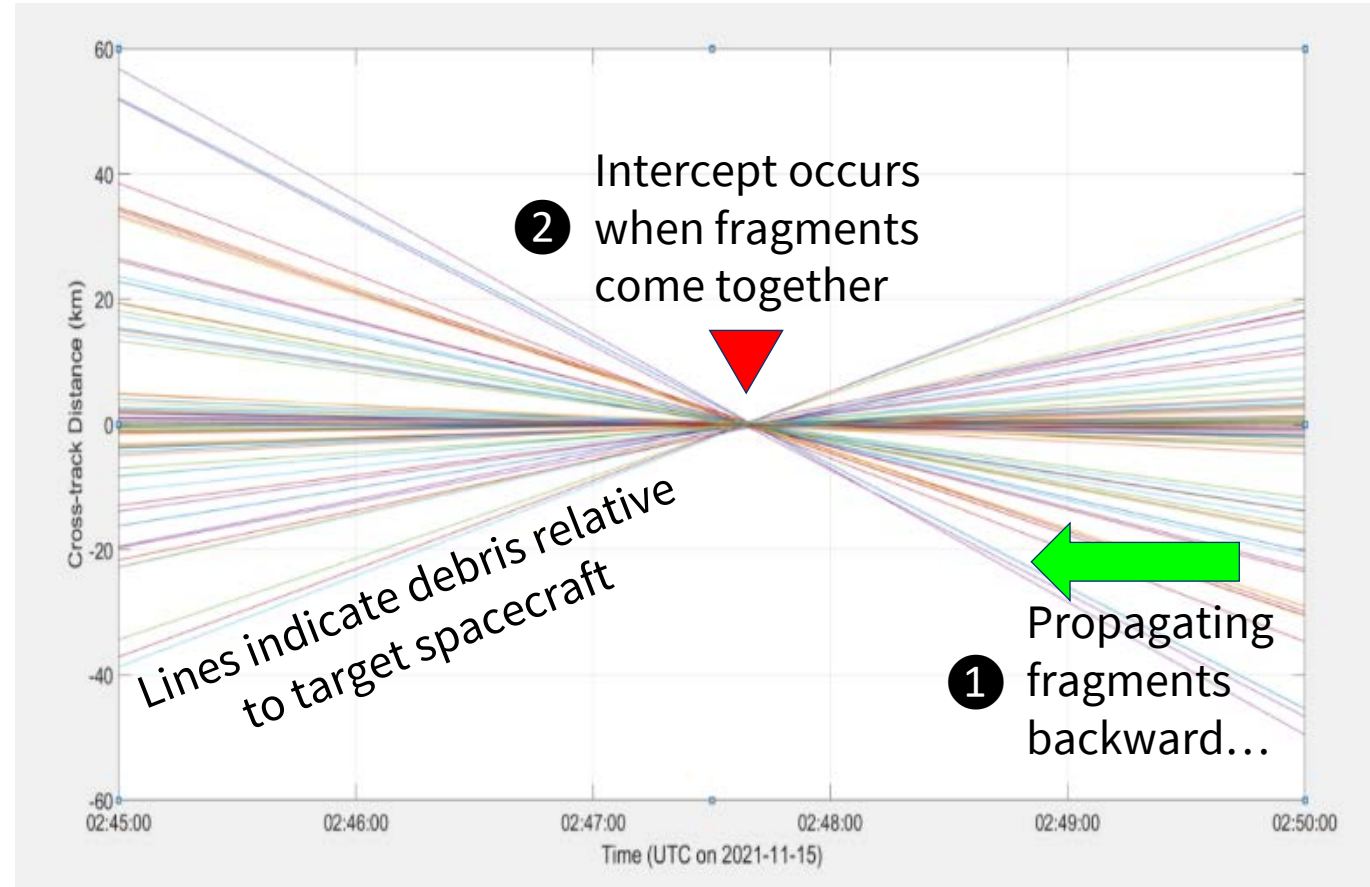
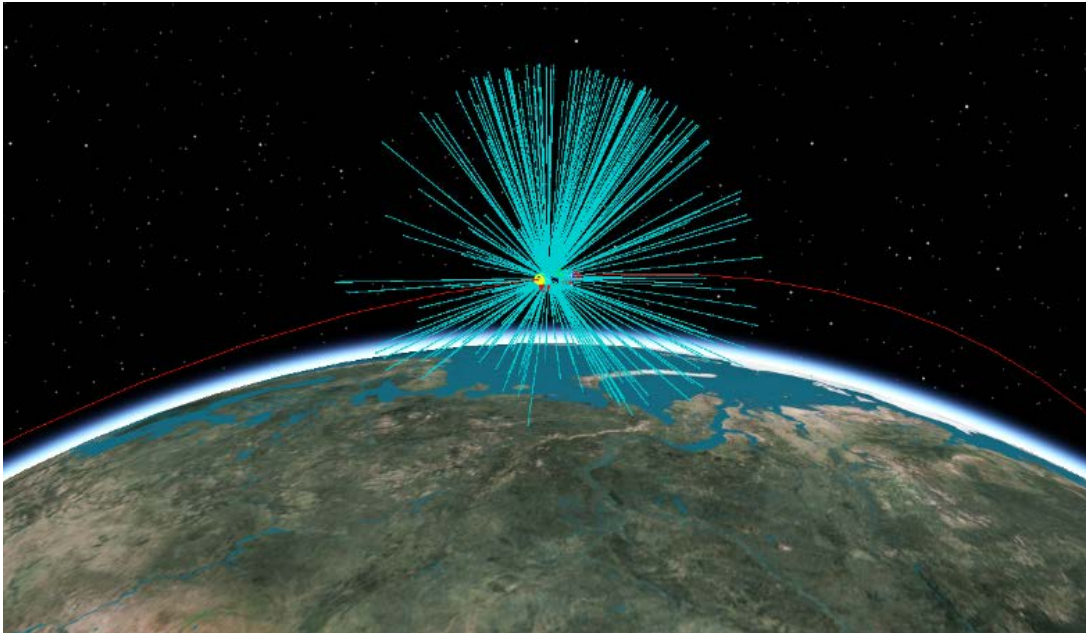
In low Earth orbit, satellite operators typically evaluate the need for a collision avoidance maneuver when one of their satellites is expected to come within 1 kilometer of another object. Space Data Center and SOCRATES data indicate that in 2017, LEO spacecraft likely came within 1 kilometer of other objects an average of 2,000 times per month. Now, it's closer to 4,000 monthly conjunctions.

Those are averages. For some satellite operators, conjunction alerts may be increasing even faster. "As steep as this curve is, there are operators that are seeing even higher conjunction rates



# When did Russian ASAT test occur, and how fast do fragments spread?

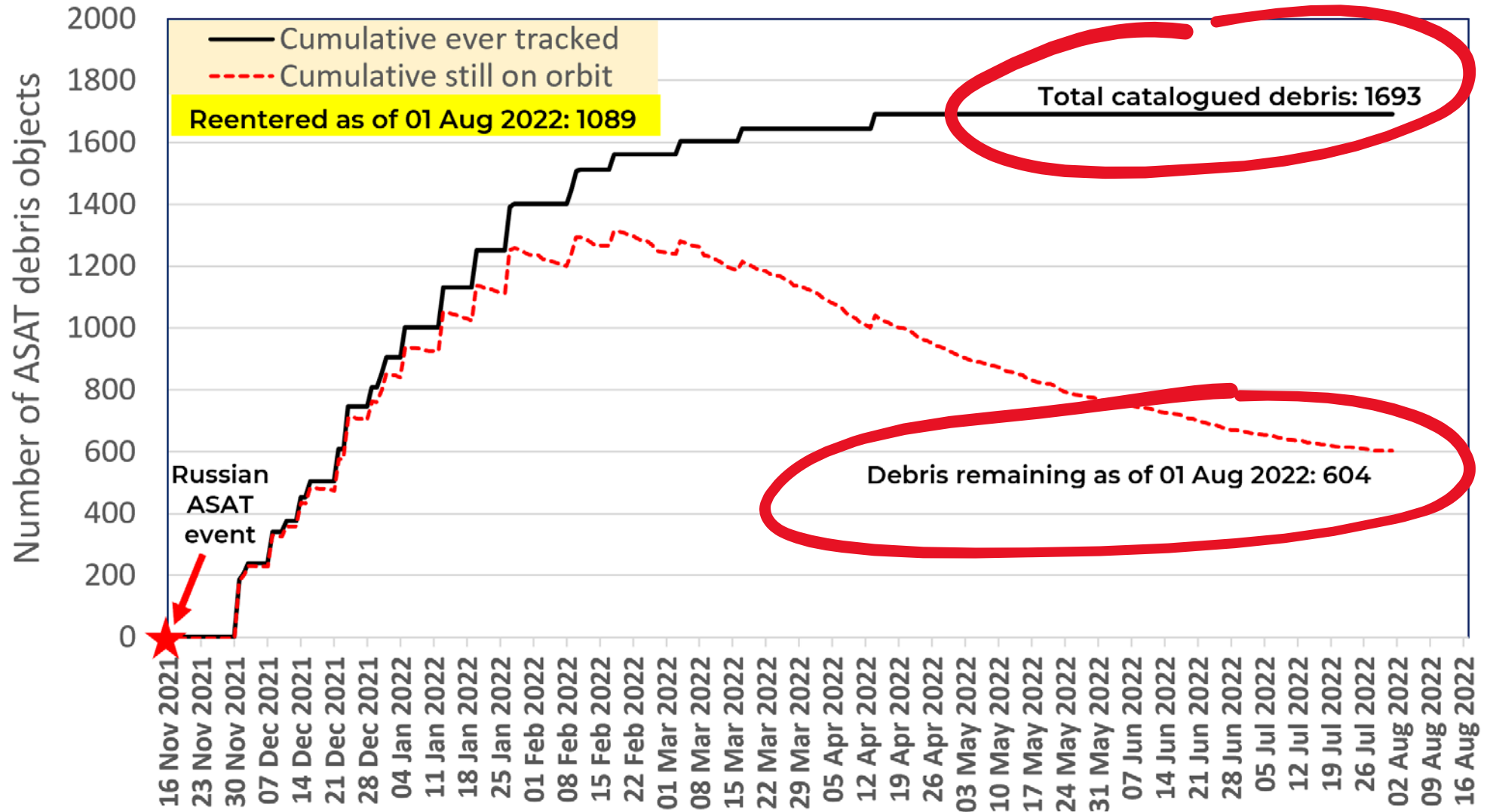
- Post-processing of Space-Track debris fragment states yielded:
  - Estimated intercept time of  
15 Nov 2021 at  $\approx 02:47:31.5$
  - Imparted velocity changes  $\approx$  omnidirectional





# ASAT debris fragment evolution on Space-Track

## COSMOS 1408 debris fragment tracking and decay evolution



Log (Probability) of Debris

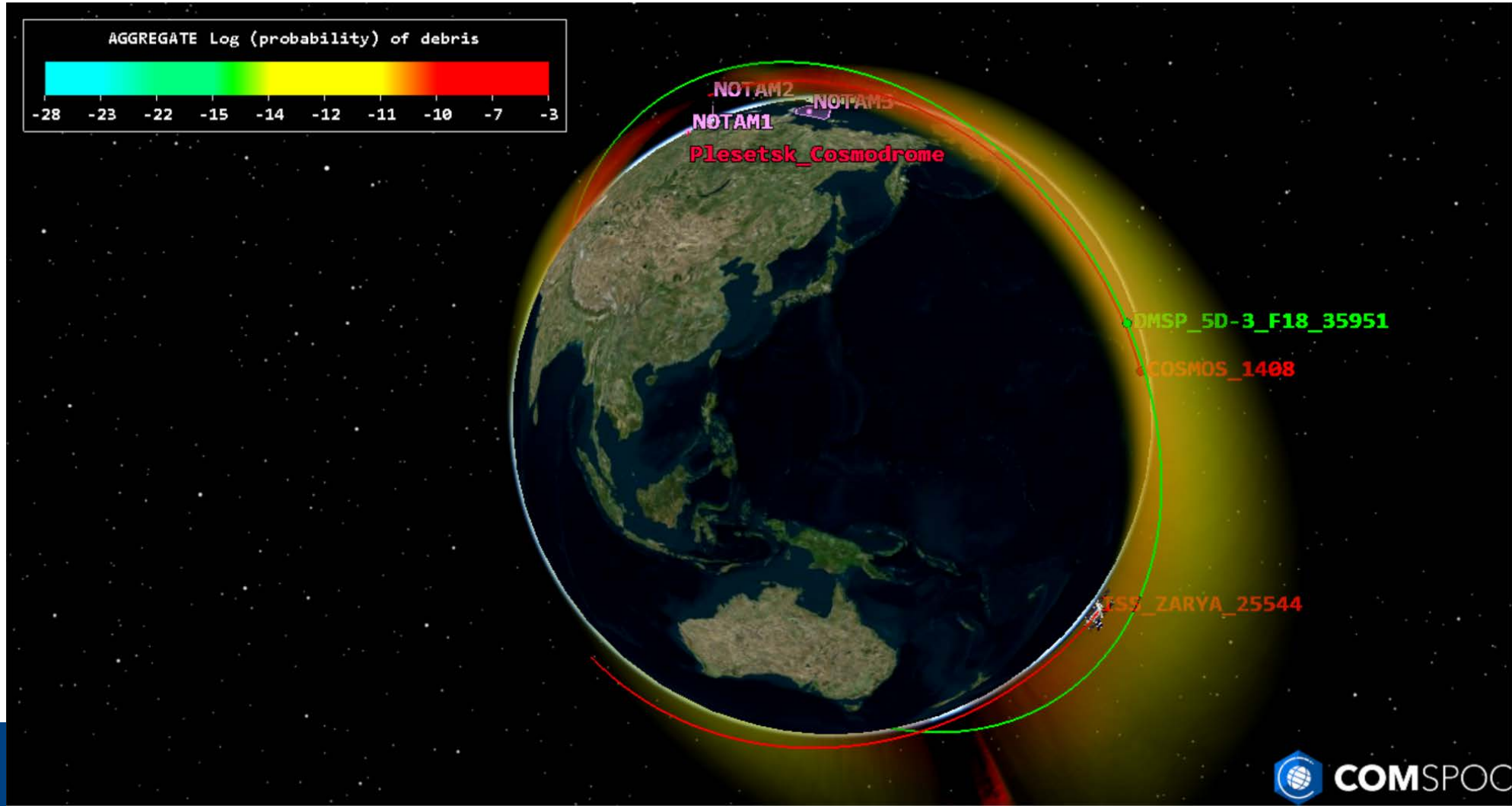


Plesetsk Cosmodrome  
NOTAM1

NOTAM2

# Where do ASAT-generated debris fragments go?

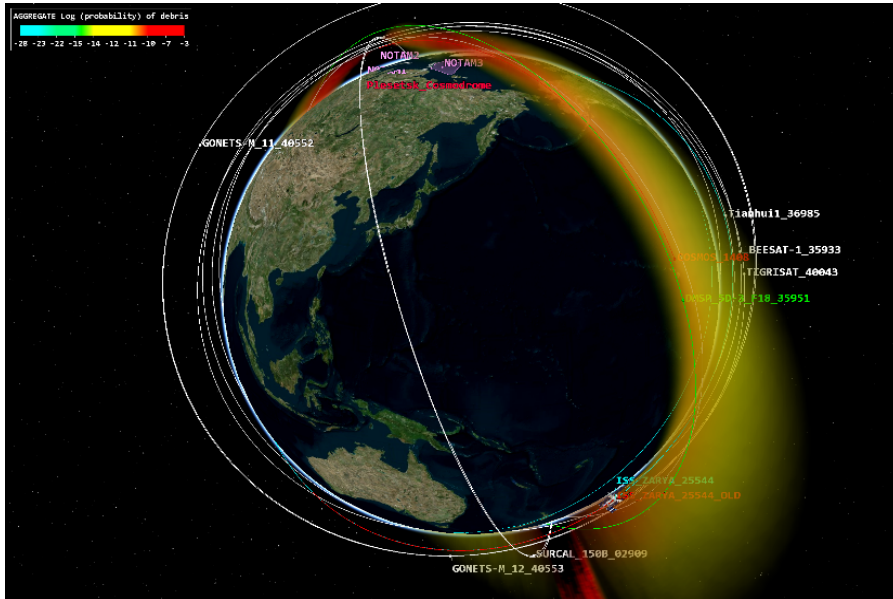
- Aggregate volume debris fragments may have occupied in first 24 hours after ASAT test.
  - Colors denote likelihood that fragments would occupy space, with red being highest risk.



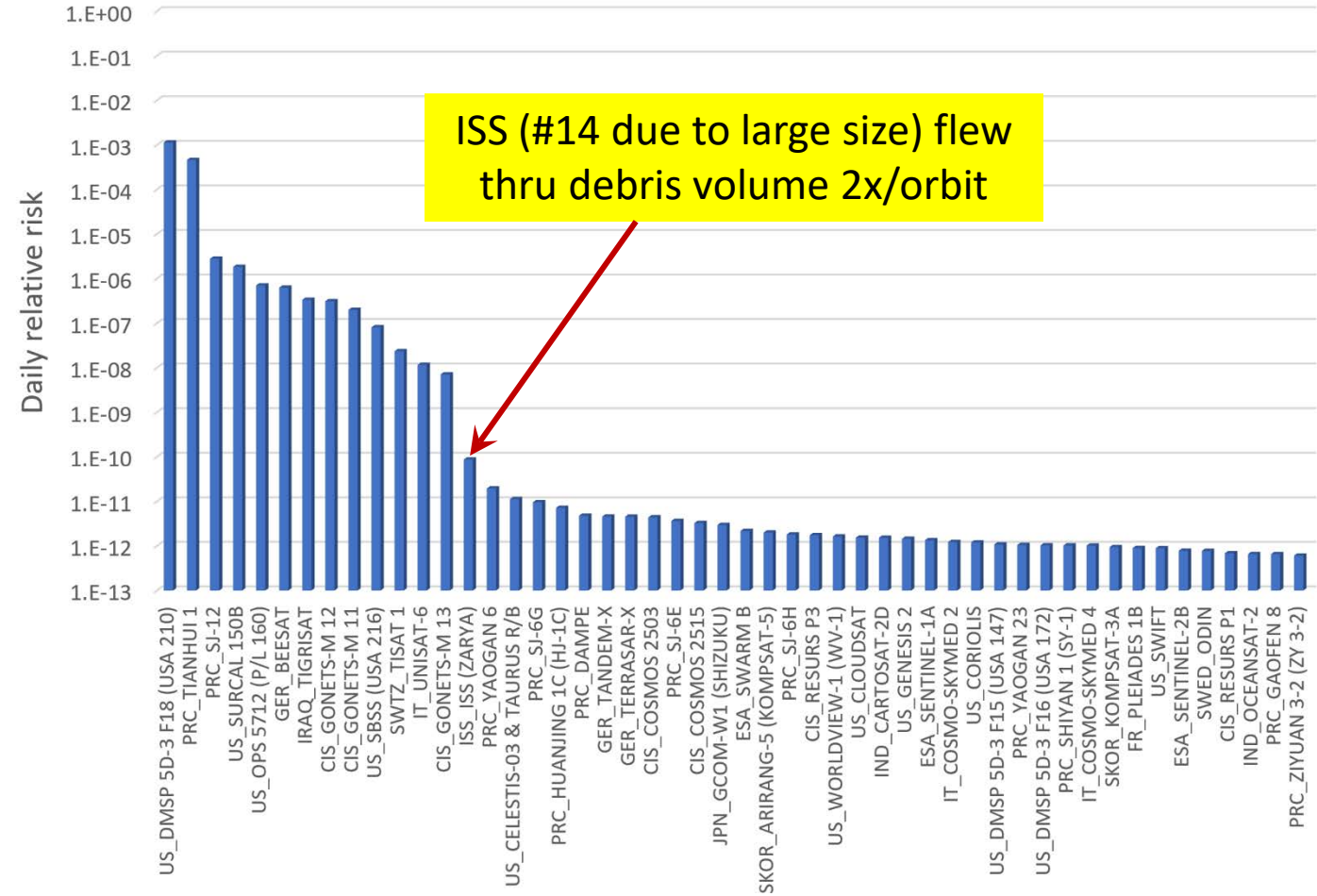


# Satellites placed at risk

- Integrating risk to active spacecraft through volumetric cloud yields relative risk in first day.
- Two conditions maximize risk
  - 1) Coplanar (e.g., DMSP on first day)
  - 2) Non-coplanar “red intersect” (Surcal)

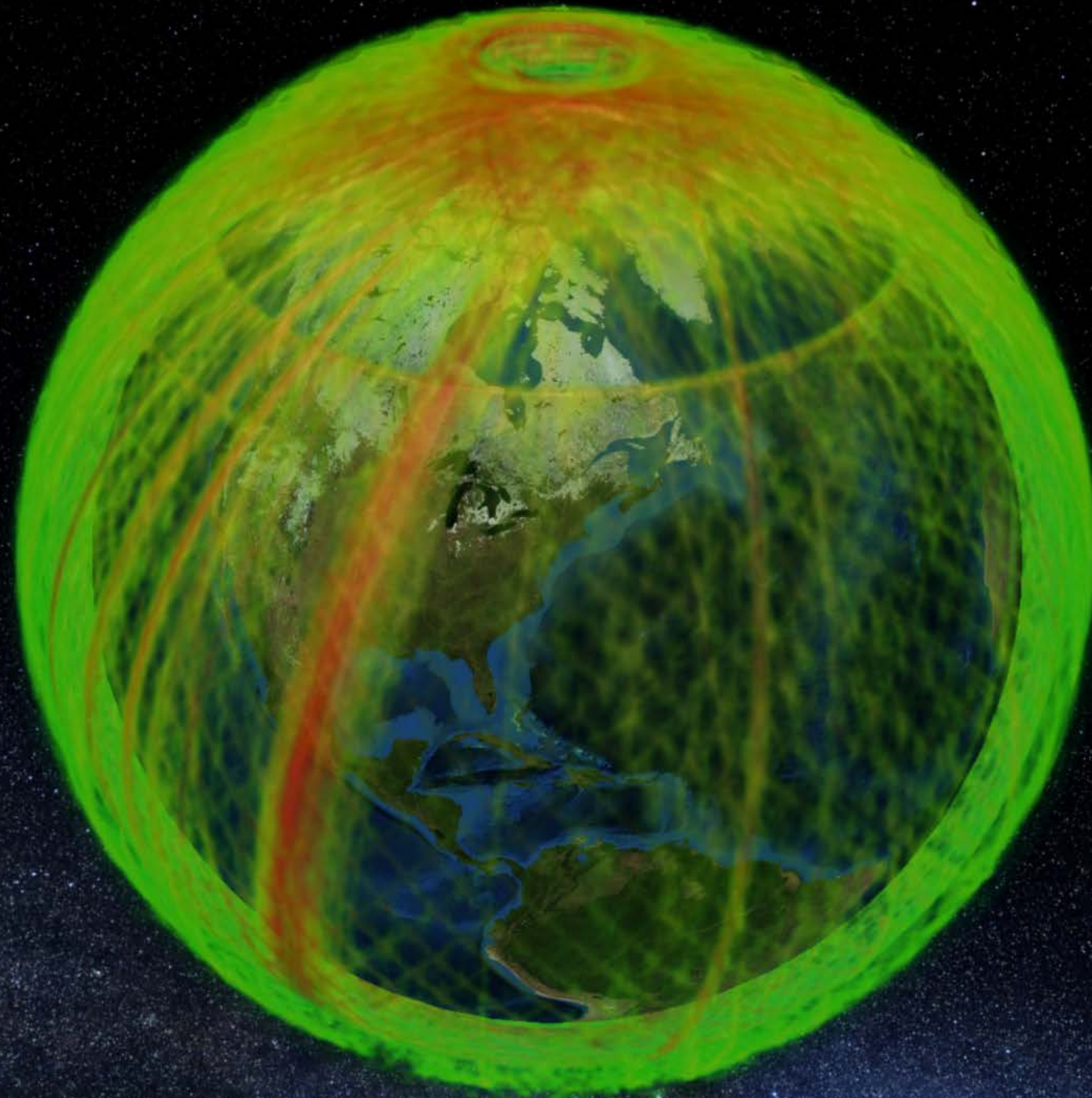


Top 50 at-risk satellites in first 24 hours





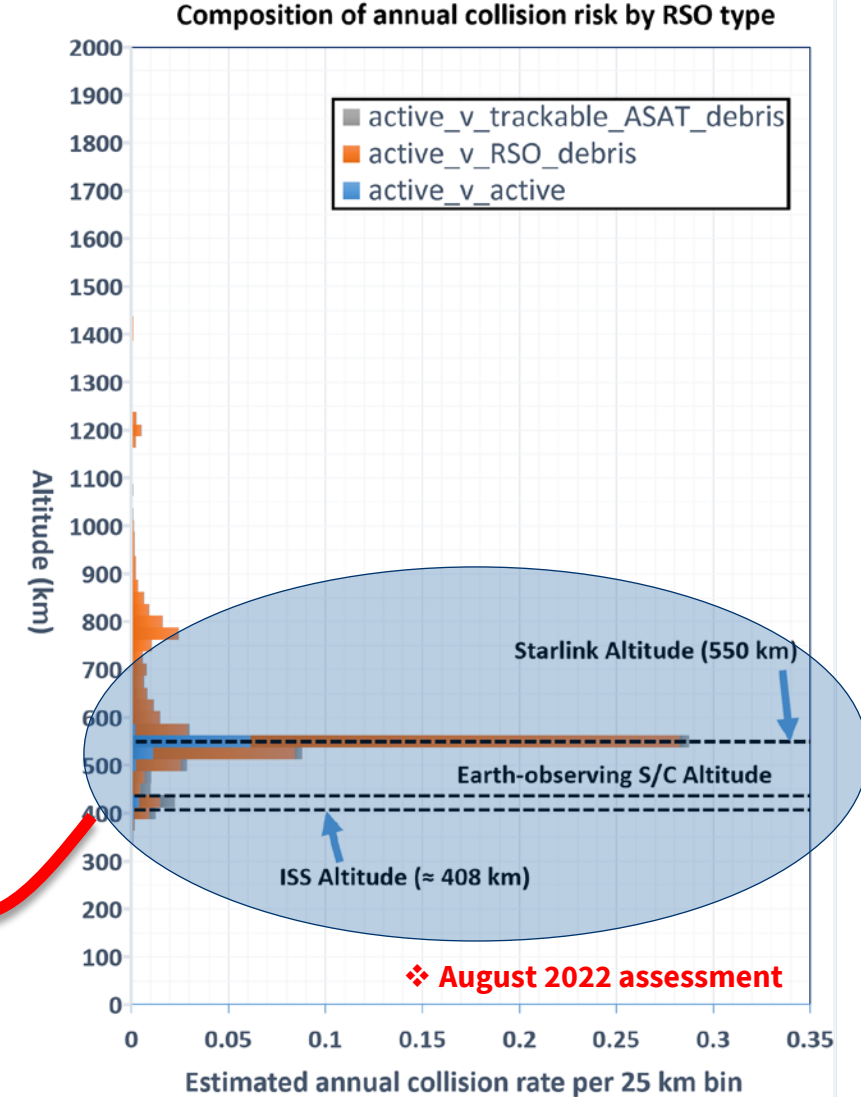
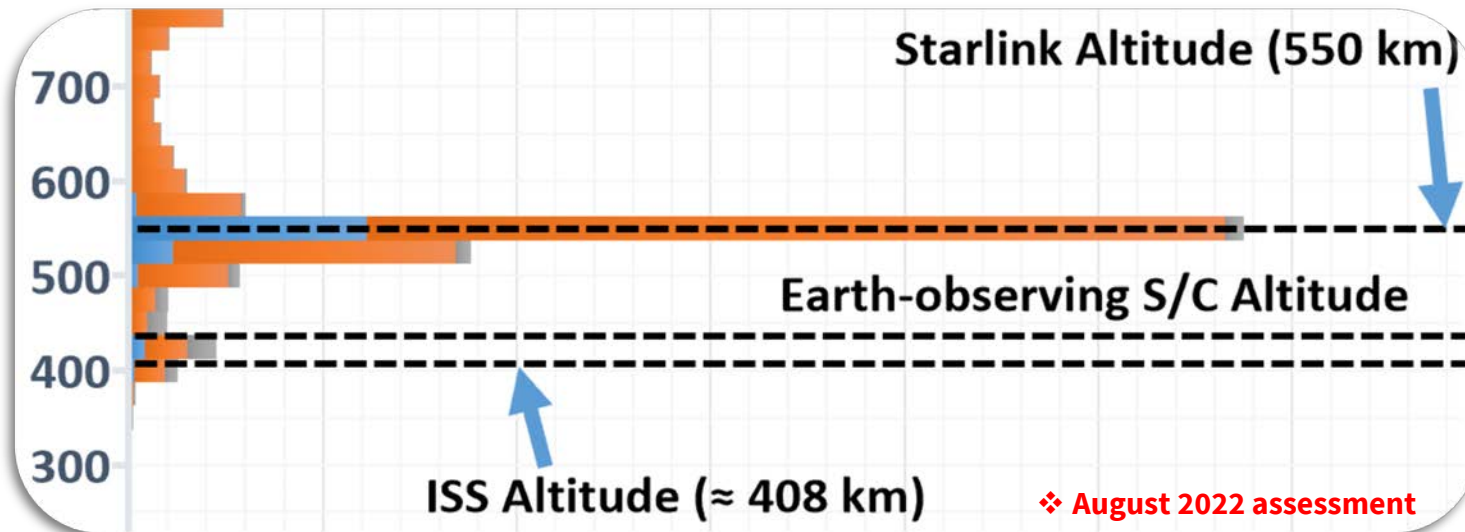
RSO\_Spatial Density (Log10)





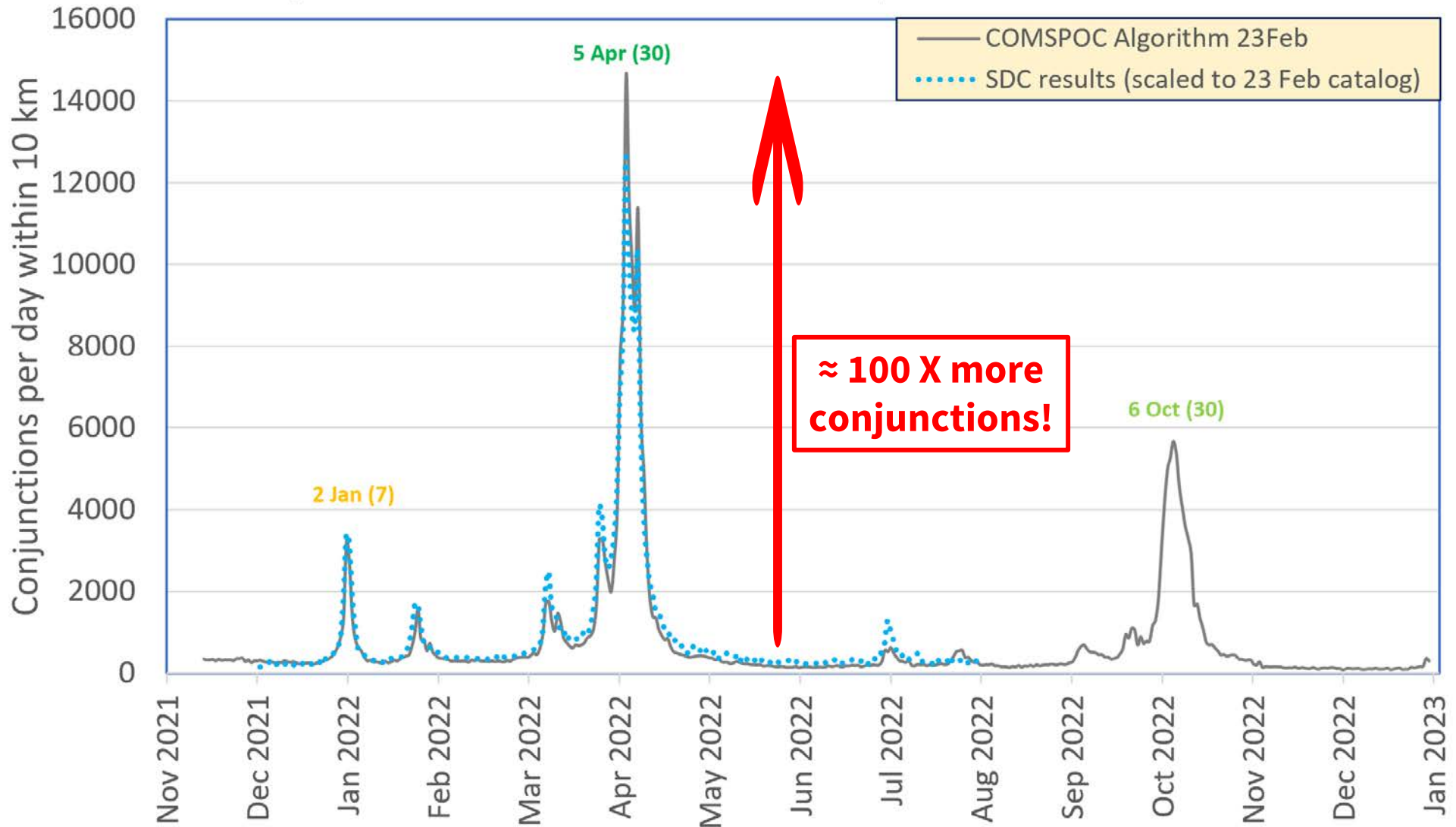
# Increased spacecraft operator workload

- Satellite operators spend much effort to avoid space debris collisions.
- How much more will be required to avoid COSMOS 1408 fragments?
- Estimated workload (and risk) increases:
  - Up to 126% at the ASAT test altitude (461 km)
  - 20% for Earth-observing spacecraft
  - Up to 10% for the ISS at present.
- **ISS safety will degrade as COSMOS 1408 fragments decay.**



# Year-long prediction: “Conjunction Squalls” ... and big ones.

Daily encounters between all Planet spacecraft and ASAT debris

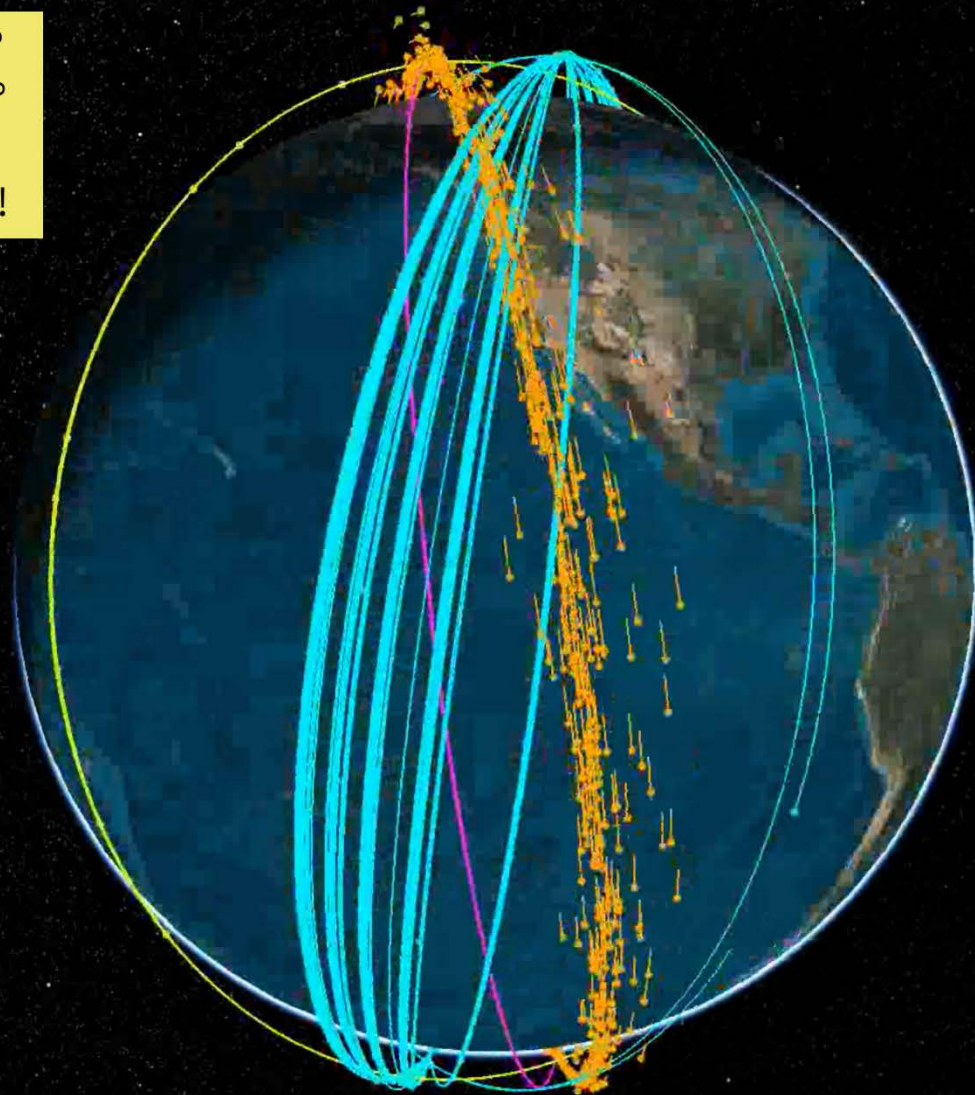




# Planet Flock conjunctions w/ASAT debris

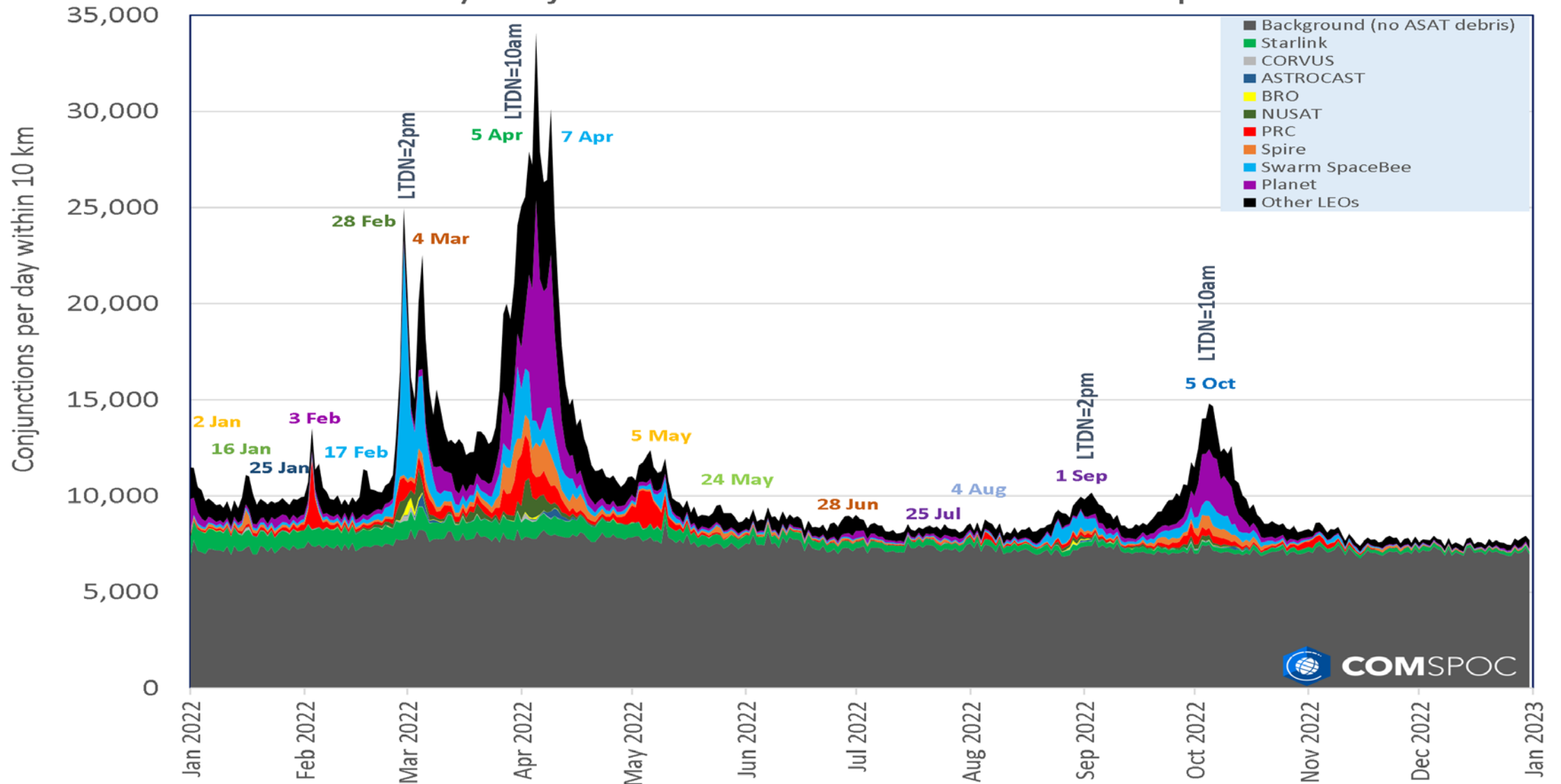
Flock (SunSync) orbit inclination  $\approx 97.7^\circ$   
Cosmos 1408 orbit inclination  $\approx 82.3^\circ$   
Sum of inclinations:  $\approx 180^\circ$   
 $\therefore$  Recurring head-on collision risk exists!

ASAT debris  
Planet Flock sats  
Flock 3K plane  
Flock 2K plane



# CubeSats had most distance-based conjunctions w/ASAT debris

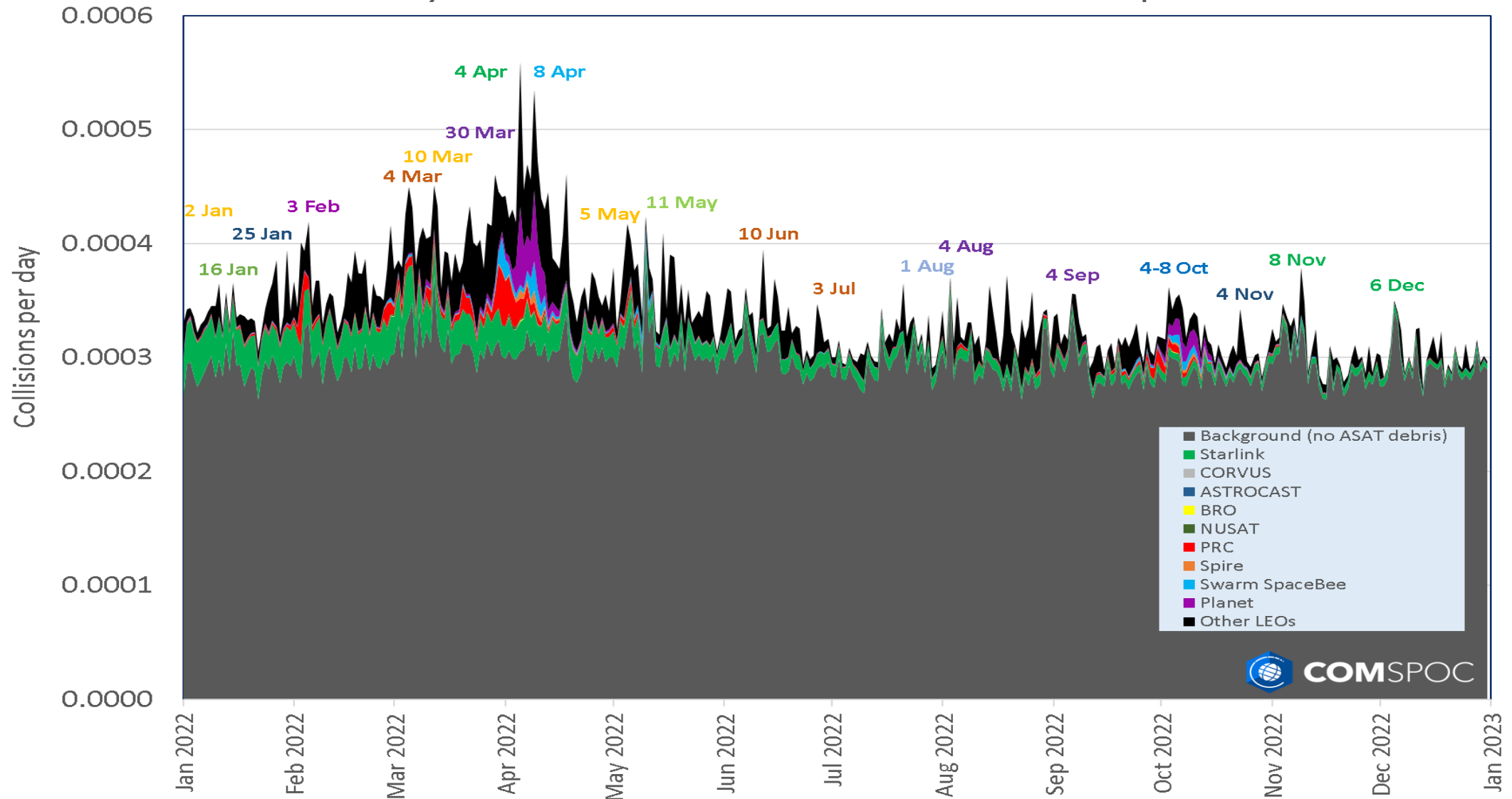
Daily conjunction breakdown for LEO active spacecraft





# Meanwhile, larger spacecraft had greatest collision risk increase

Daily collision rate breakdown for LEO active spacecraft



# Who was affected?

- All Earth Observing systems using sun-synchronous orbits adversely affected.
  - “Conjunction squalls” may overload flight safety systems and spacecraft operators.
  - CubeSat Earth observing constellations face greatest increase in warnings (e.g., < 10 km miss)
  - Larger Earth observing spacecraft will likely face greatest actual risk due to spacecraft size
- Other operators affected (ISS experiencing  $\approx 33\%$  increase in conjunctions; Starlink)

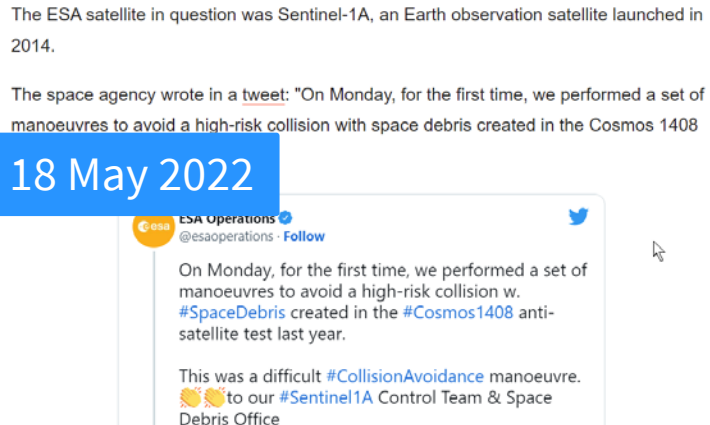
This afternoon, the International Space Station's [Progress 81](#) thrusters fired for 4 minutes, 34 seconds in a Avoidance Maneuver (PDAM) to provide the complex and extra measure of distance away from the predicted Russian Cosmos 1408 debris.

16 Jun 2022



observing systems that for their criteria, they observed a test in conjunction the Russian A

30 Apr



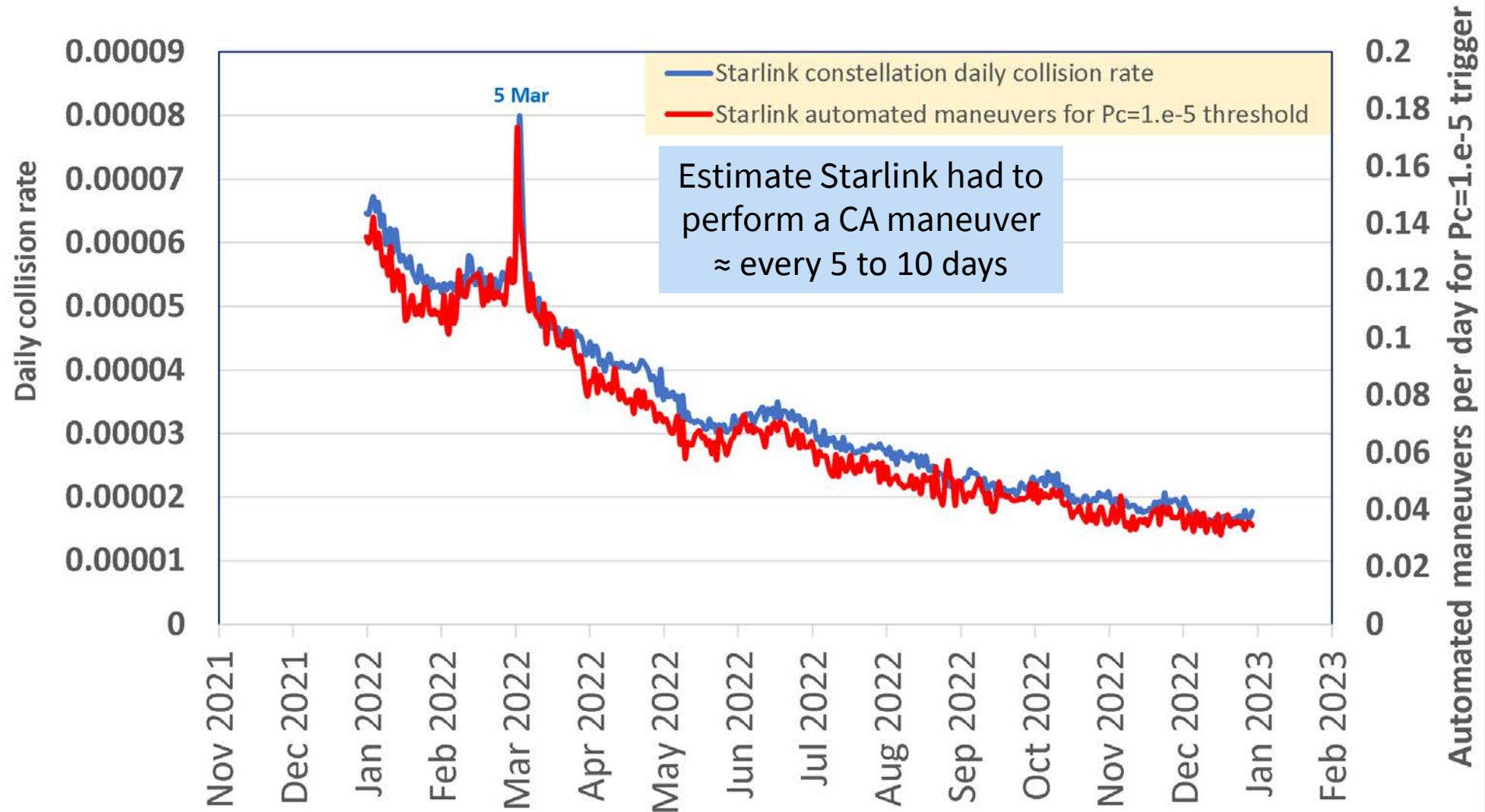
18 May 2022





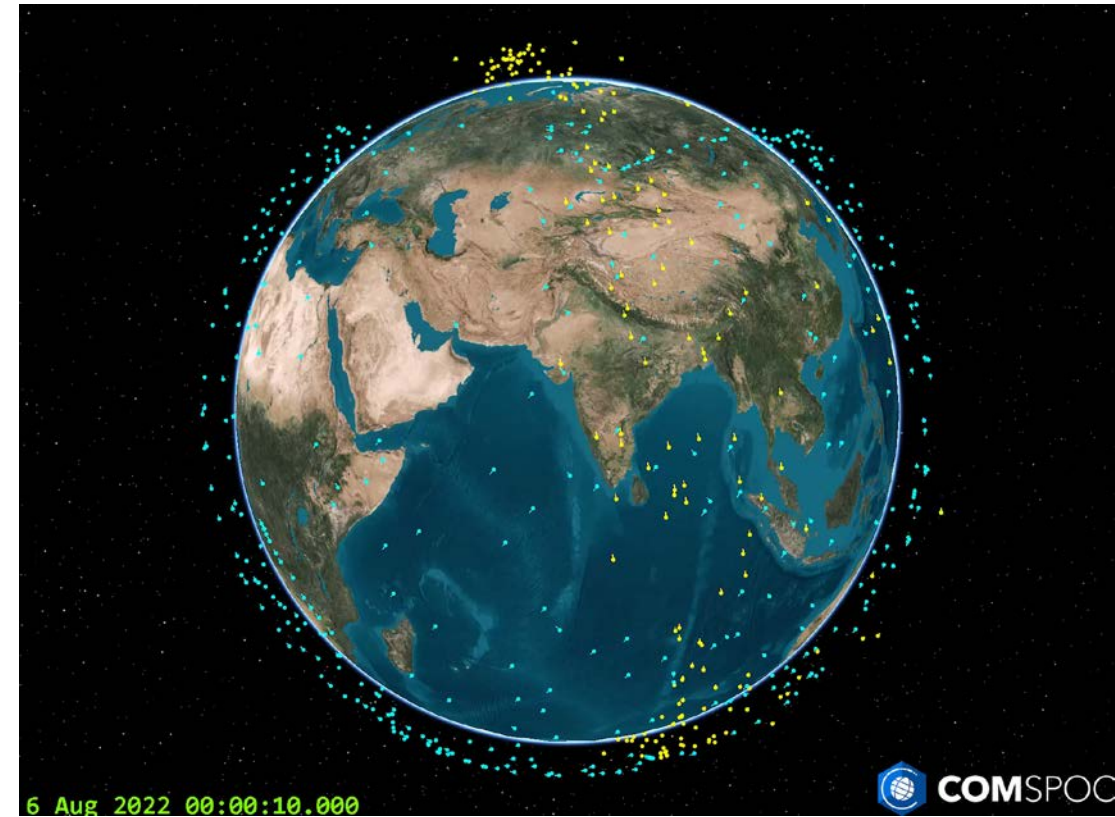
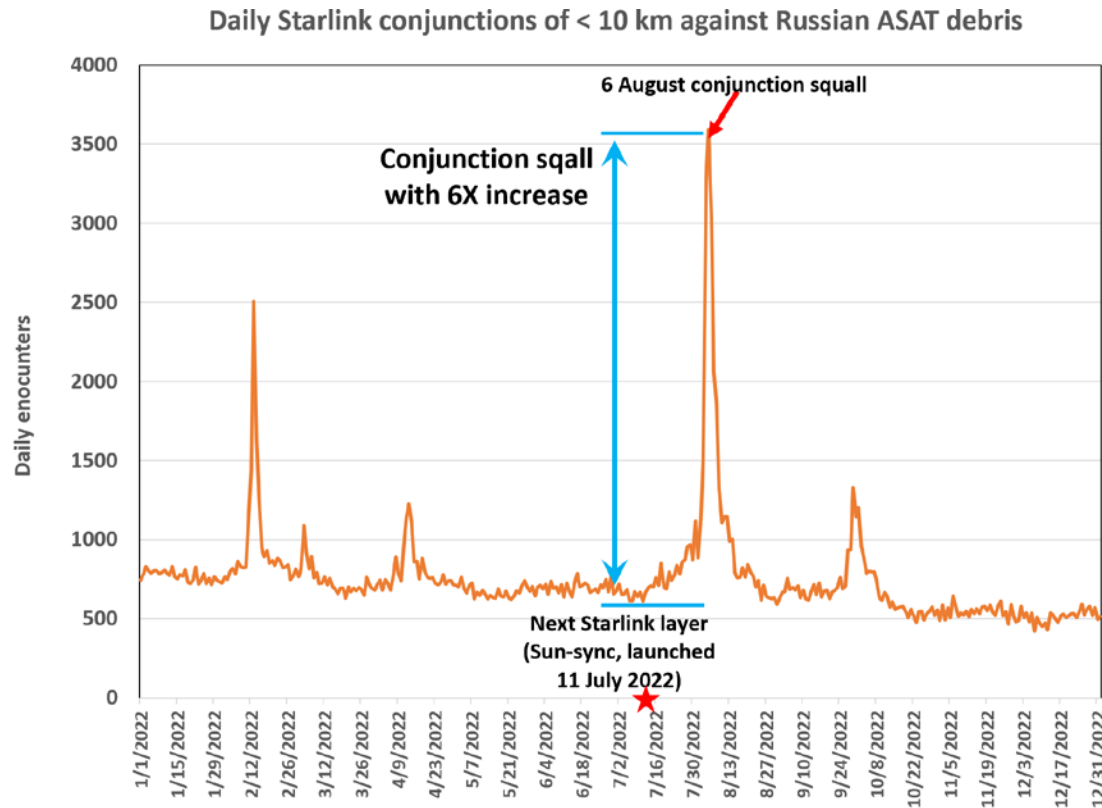
# Starlink: How have risk and avoidance maneuver fuel increased?

Daily collisions and automated maneuvers for Starlink vs COSMOS 1408 debris



# Evolving Starlink constellation: New threats from ASAT debris!

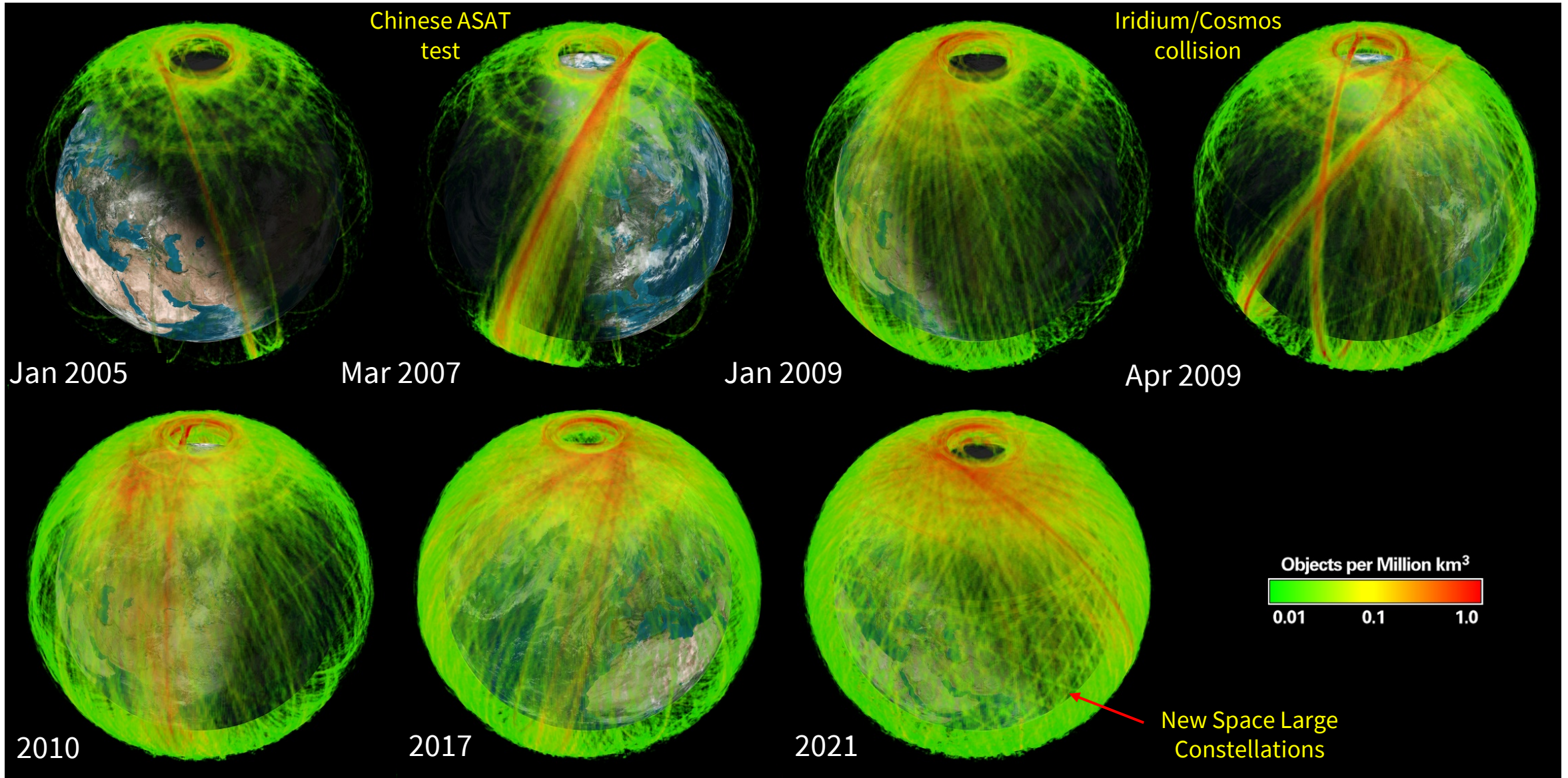
- Dec '21 – May '22: Starlink did 6,873 maneuvers, of which 1,700 were for ASAT debris\*.
- **6 Aug 2022 conjunction squall** (6153 < 10km or 6X), involving 841 of 2724 Starlink S/C.
  - Without an automated collision avoidance capability, this would challenge any operator.



\* David Goldman, "SpaceX Semi-Annual Report 1 Dec 2021 – 31 May 2022,"  
Electronic filing to Marlene H. Dortch, Secretary of FCC, filed on 1 July 2022.



# But this is not our first fragmentation event, right? Correct.

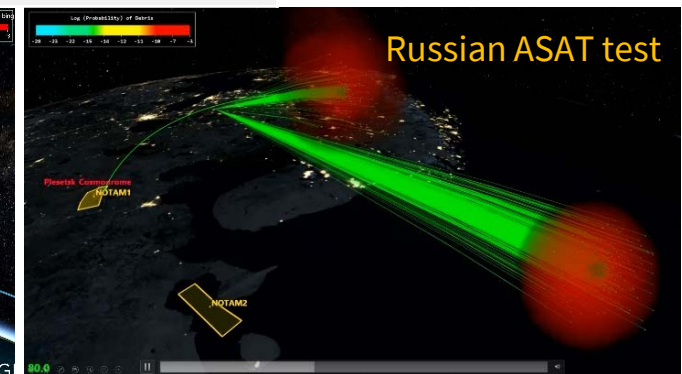
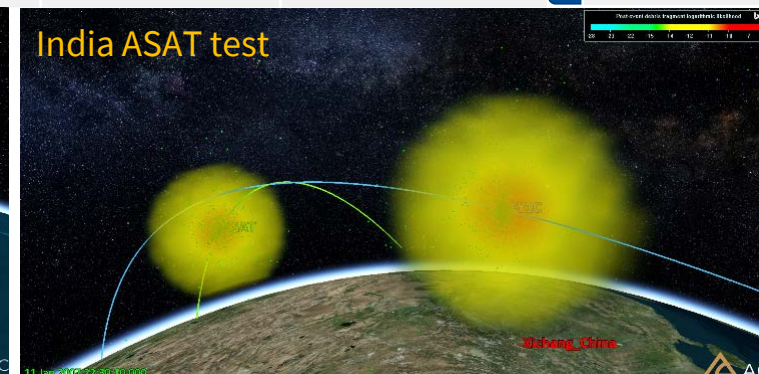
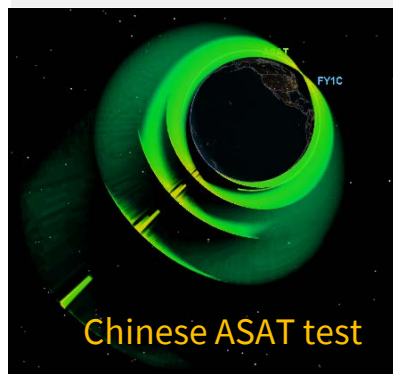
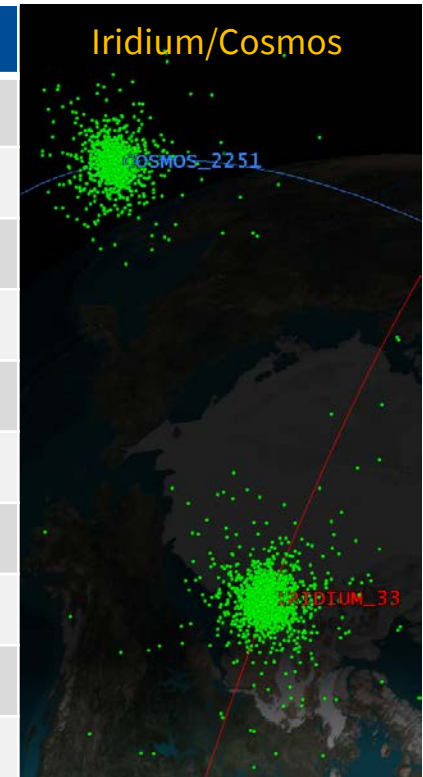




# Comparison of major fragmentation events since 2000

NOTE:  $J/kg = \frac{1}{2} \frac{m_{interceptor}}{m_{target}} \Delta V_{intercept}^2$

Category	Chinese ASAT	USA 193	Indian ASAT	Russian ASAT	Iridium/Cosmos collision
Date	11 Jan 2007	21 Feb 2008	27 Mar 2019	15 Nov 2021	10 Feb 2009
Altitude (km)	856	246	282	461	769
Velocity (hypervelocity $\sim > \approx 6$ )	14.8 km/s	8.49 km/s	9.4 km/s	4.6 km/s	11.6 km/s
$\approx$ kJ/kg (catastrophic $\approx >40$ )	15,000-35,000	1,500 – 2,500	6,000	500 – 1,000	51,500
Debris tracked by SSN	3,532	174	129	1,604 (so far)	2,369
Simulated trackable* debris	3,007	452	936	1,246	2,651
Simulated Lethal Non-Track	34,733	3728	10,439	16,386	7,883
80 <sup>th</sup> percentile lifetime (yrs)	63	0.03	0.05	1.5	56
“RSO-years” (trackable)	130,347	13	65	2,098	108,230
“RSO-years” (LNT)	1,225,972	94	784	16,464	257,442



# Conclusions

- We all need to care about and ensure space sustainability
- ASAT tests are a pressing threat to security and sustainability.
  - U.S. unilaterally committed to not conduct destructive direct ascent anti-satellite missile tests and asks other nations to commit to help establish this as an international norm.
  - Canada joined this ban on 9 May 2022, New Zealand 1 July.
  - Forums like the ongoing UN Open Ended Working Group on Space, as well as this year's UN General Assembly meeting, are opportunities to solidify this norm.
- Space operations adherence to best practices, norms of behavior, data exchange standards, transparency, and UN and ISO guidelines and treaties is also extremely important.
  - Resources: UN, IADC, ISO, CCSDS, NASA, 18SDS, SSC, SWF, CSF, AIA, SIA...



## SPACENEWS

### Canada joins U.S. in ASAT testing ban

by Jeff Foust — May 9, 2022



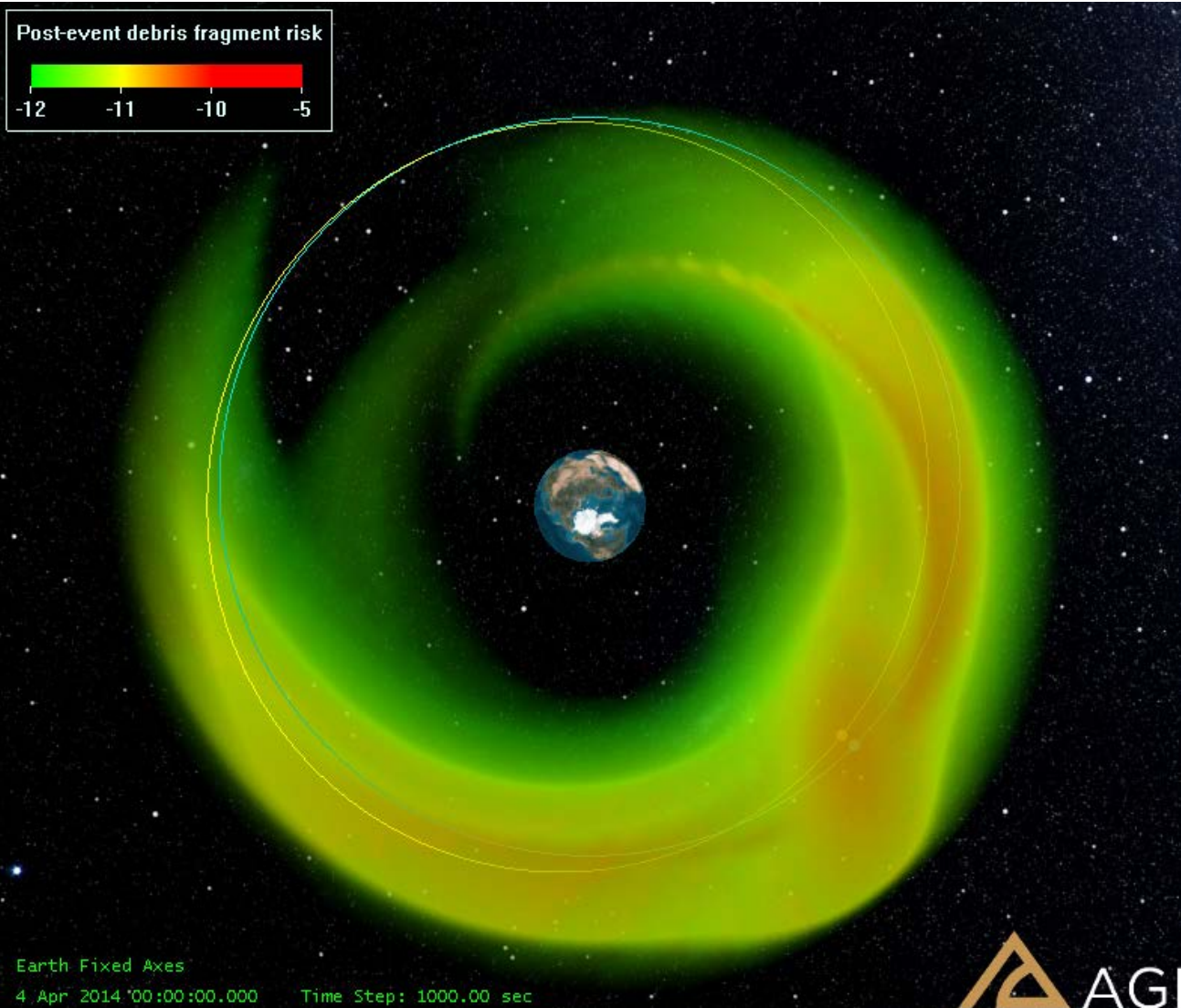
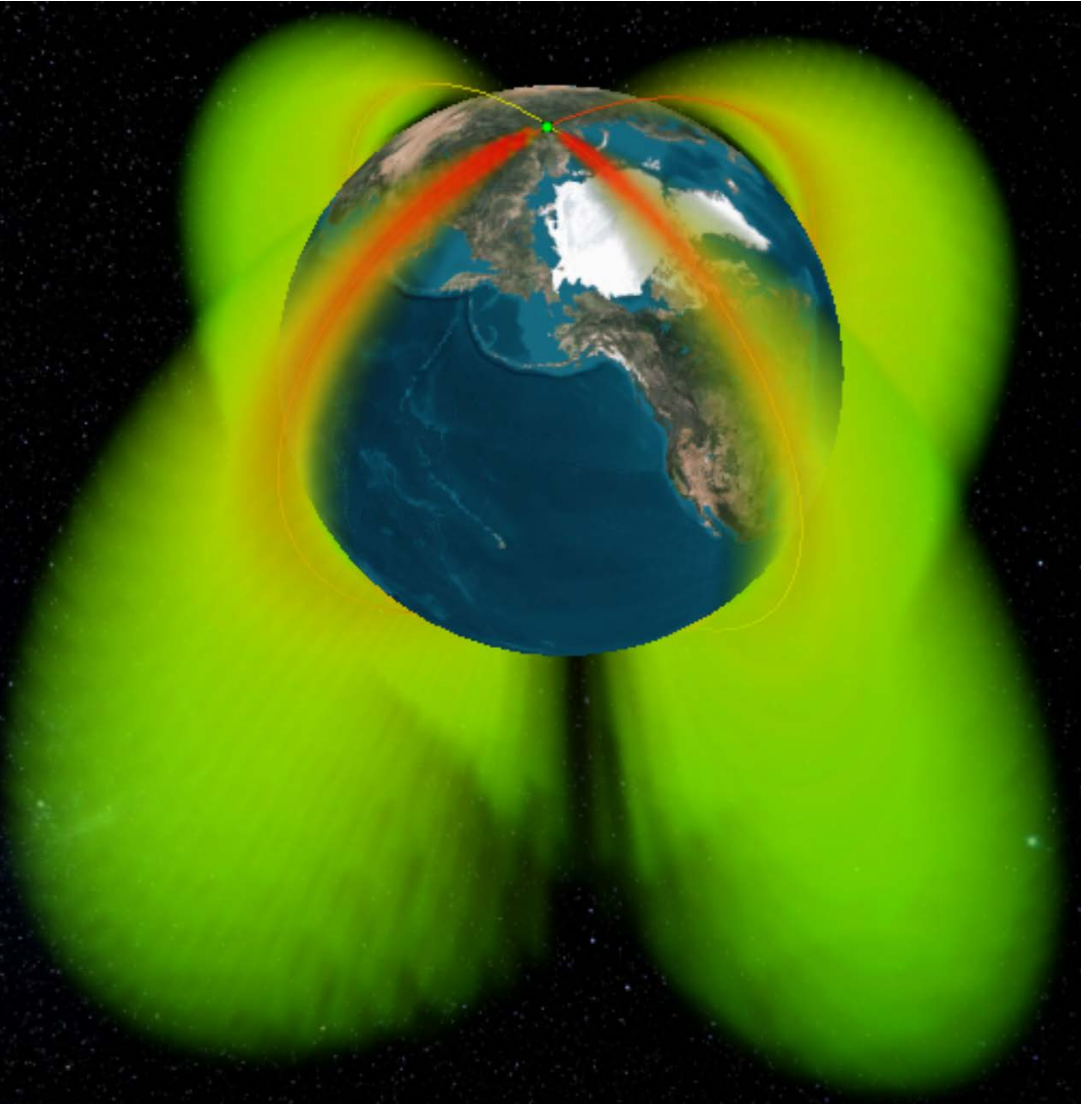
Canada's announcement of the ASAT testing ban came on the first day of meetings of a U.N. working group on reducing space threats in Geneva, Switzerland. Credit: UN

WASHINGTON — The Canadian government announced May 9 that it is joining the United States in banning tests of destructive direct-ascent antisatellite weapons as a step toward norms of responsible behavior in space.



Thanks for your attention!

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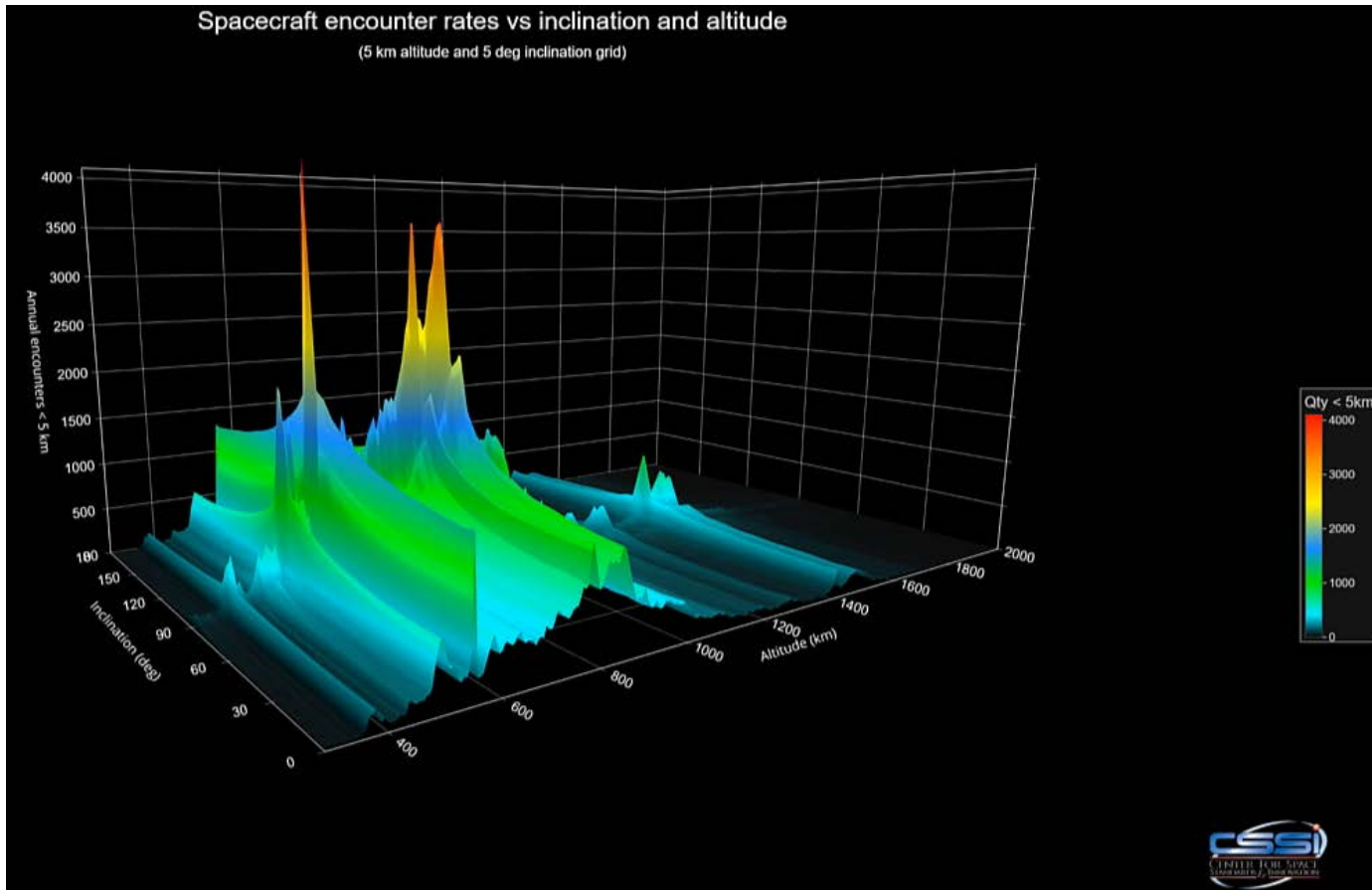


# Introduction: Number of Encounters Analysis Tool

## Number of Encounters Assessment Tool

- “NEAT” encounter rates (<http://www.comspoc.com/neat/>)
- Frequency of close approach & collision

The Number of Encounters Assessment Tool (NEAT) assesses collision risk by adjusting key parameters including constellation size, orbit altitude, and inclination. Users can also customize their threshold for warnings, maneuvers, and hard-body collisions.



### Average encounters per day:

Warnings: 1.46

Maneuvers: 0.162

Collisions: 0

Encounter Period:

Number of Satellites:

Warning Threshold (m):

Maneuver Threshold (m):

Collision Threshold (m):

Inclination (deg):

Altitude w.r.t. Earth equatorial radius (km):

Space population: