# COMSPOC Corp

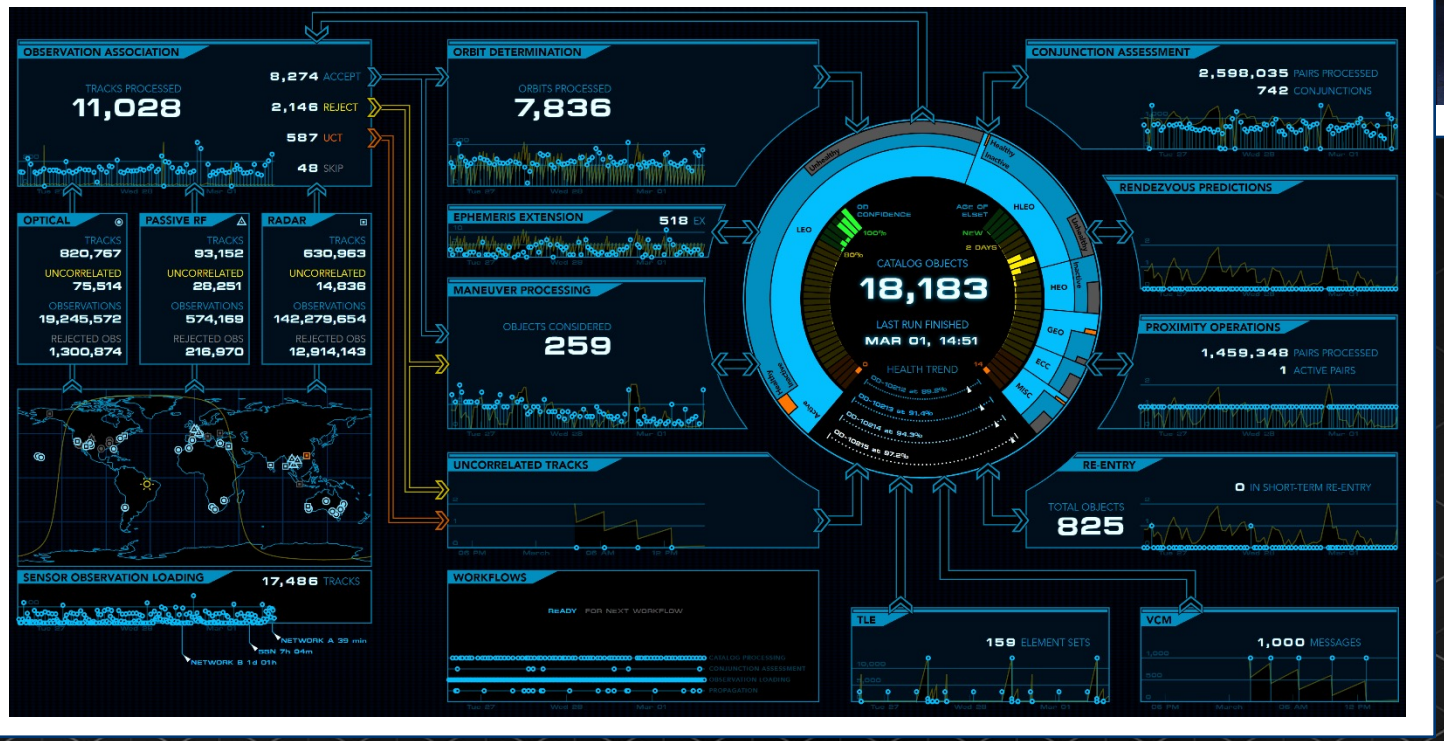
Preserve and protect space operations and the benefits of space

Jim Cooper
Lead, SSA Solutions
7 Jun 23

# COMSPOC

*Established 2014*

www.comspoc.com




Unmatched Space Situational Awareness, Space Domain Awareness, and Space Traffic Management software and services to meet the current and emerging challenges of the space domain

# COMSPOC

*Protecting and characterizing the space domain*

www.comspoc.com

## Operations

- Space Domain Awareness
- Space Situational Awareness
- Space Traffic Coordination & Mgmt.

## Research and Standards Development

CSSI

IMPORTANT AFFILIATIONS

SPACE DATA ASSOCIATION

Consultative Committee for Space Data Systems (CCSDS)

SSC Space Safety Coalition

ISO

## Featured Product Line

### SSASUITE

Integrates all phases of space situational awareness, from initial observation collection and processing to actionable predictive analysis.

### SOTA

Assesses space object's vulnerability to another's actions or events, decreasing satellite mission risk and increasing survivability against threats

### SEG

Rapidly and accurately simulates space events for Test, Training, and Exercise (TTX).

### ODSSA

Automatically characterizes non-cooperative maneuvers and allows analysts to examine and fix observation association problems.

### AVOID

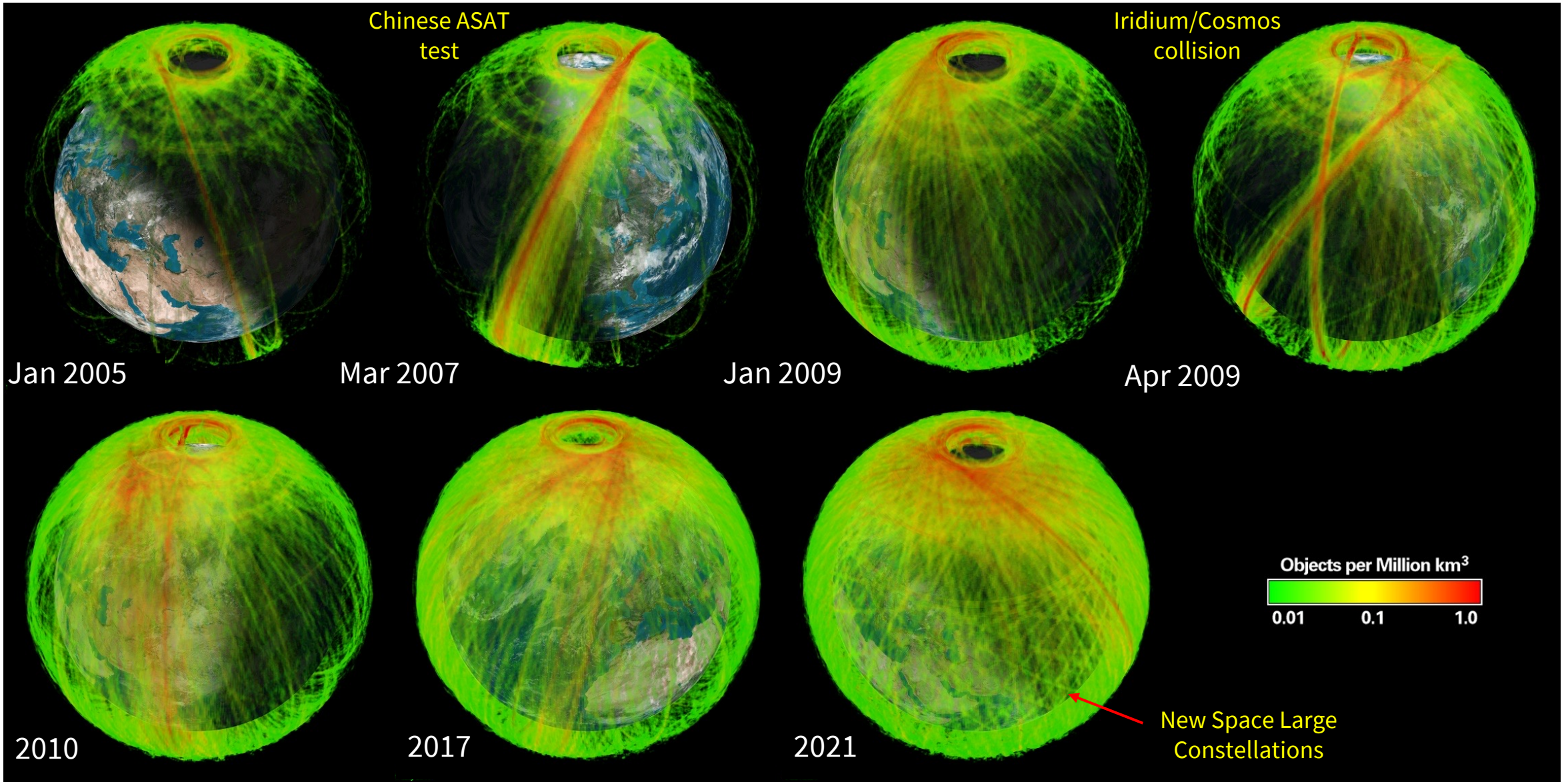
Analysis and Visualization for Orbit Insertion Deconfliction, providing Launch Collision Avoidance (LCOLA) support.

# Congested, Contested Domain

New space and large constellations

Kinetic energy ASATs

# There's a lot of "stuff" in space now!  How did we get here?



# The "New Space" Era – With access comes complexity

**100,000+**
New spacecraft applications filed for 2019-2029

**42%**
Of all payloads since 1957 have been launched within the past 5 years

**6X**
Objects/year over past 5 years compared to previous 50 years

**15,000**
Daily conjunctions within 10 km for all active LEO satellites

SPD-3 released Jun 2018

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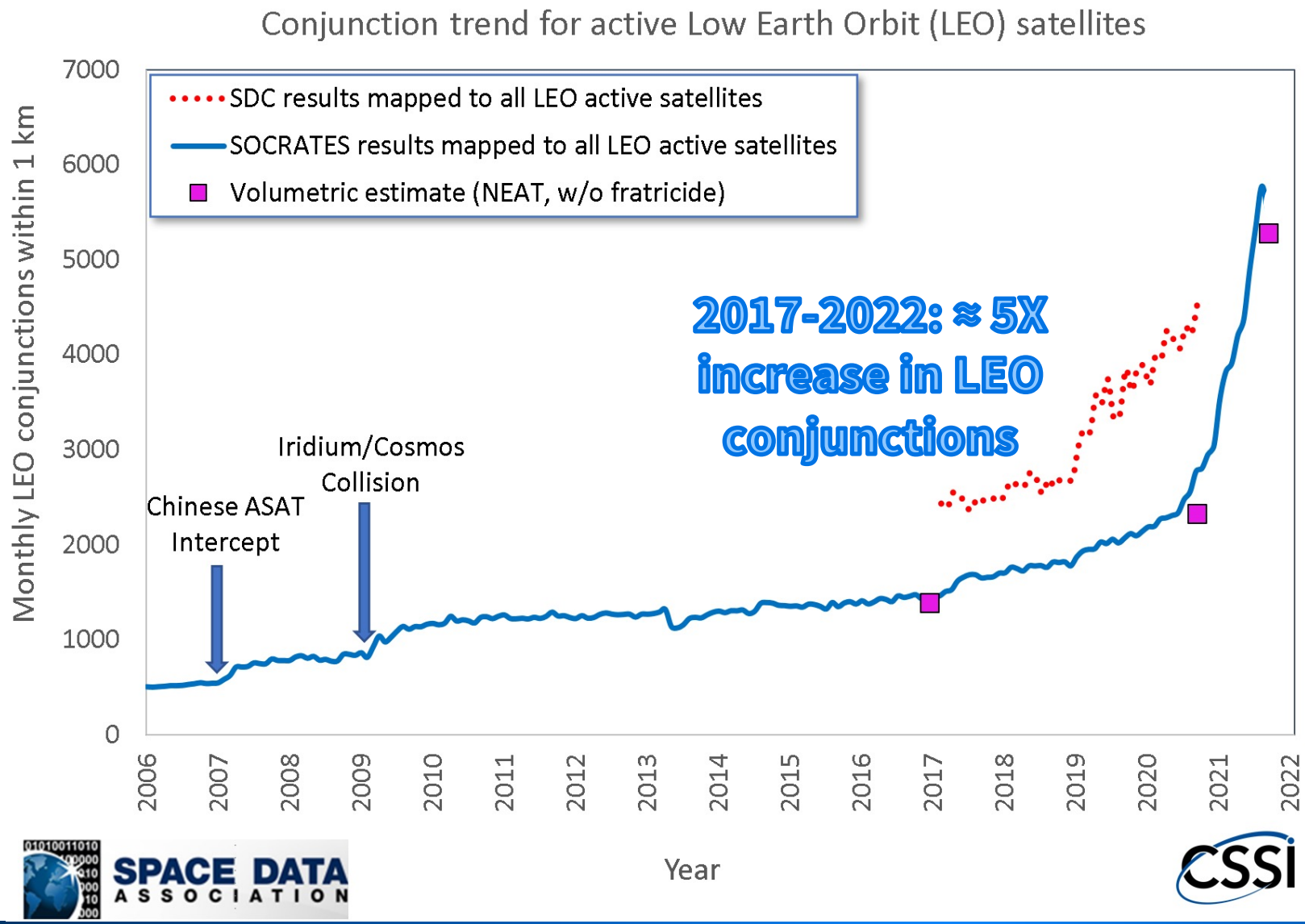
# Traffic and close conjunctions already increasing




SPACE DATA ASSOCIATION

CSSI

SPACENEWS
BUSINESS | POLITICS | PERSPECTIVE
OCTOBER 19, 2020

**CONGESTED**

Space traffic management transition stuck in first gear

## 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.

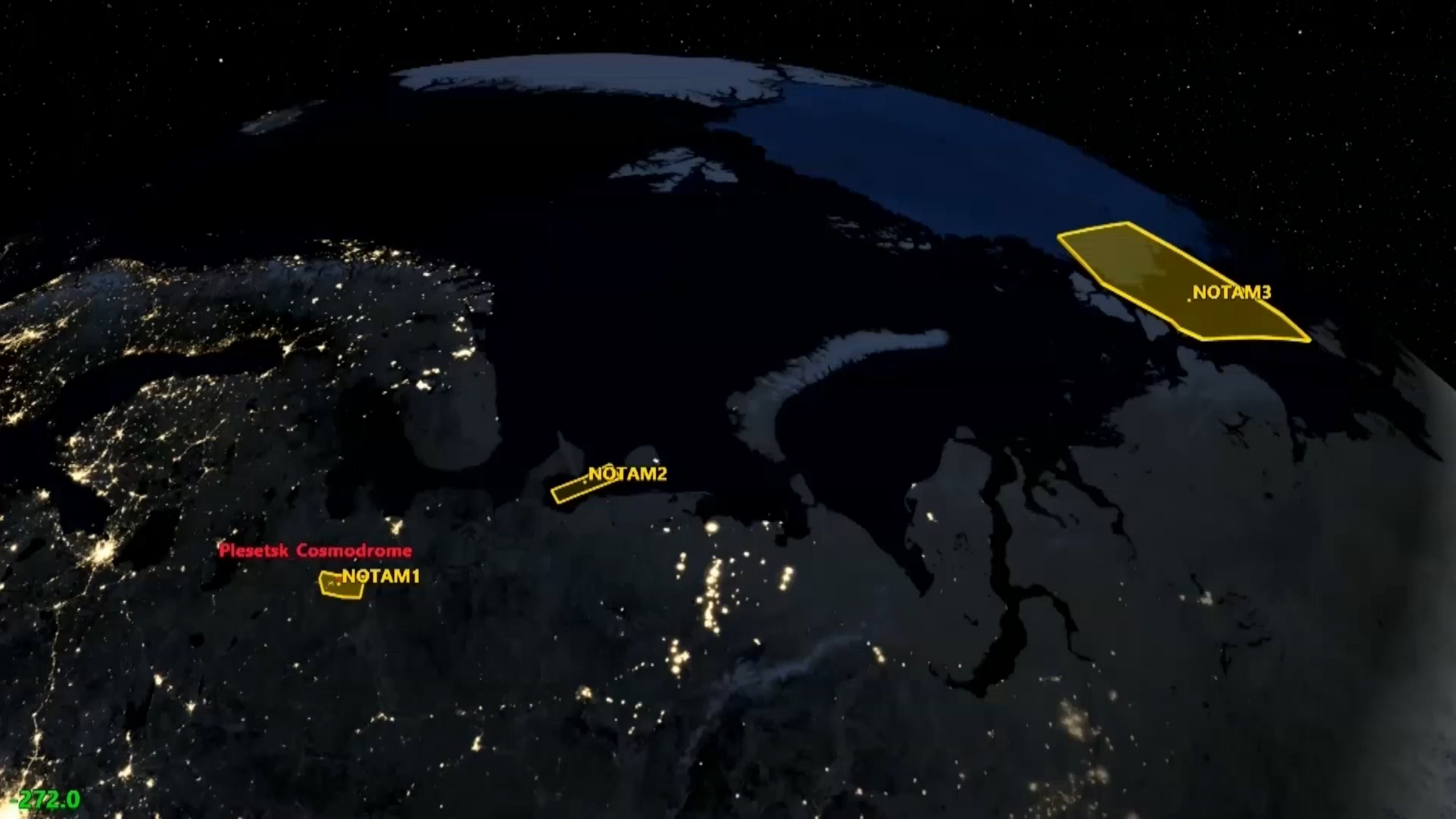
That was one of the key takeaways from data compiled for *SpaceNews* by Analytical Graphics Inc. (AGI), the Exton, Pennsylvania firm that hosts the Space Data Center, a platform that ingests information from Space Data Association satellite operators and compares it with commercial radar and telescope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

AGI also hosts Satellite Orbital Conjunction Reports Assessing Threatening Encounters in

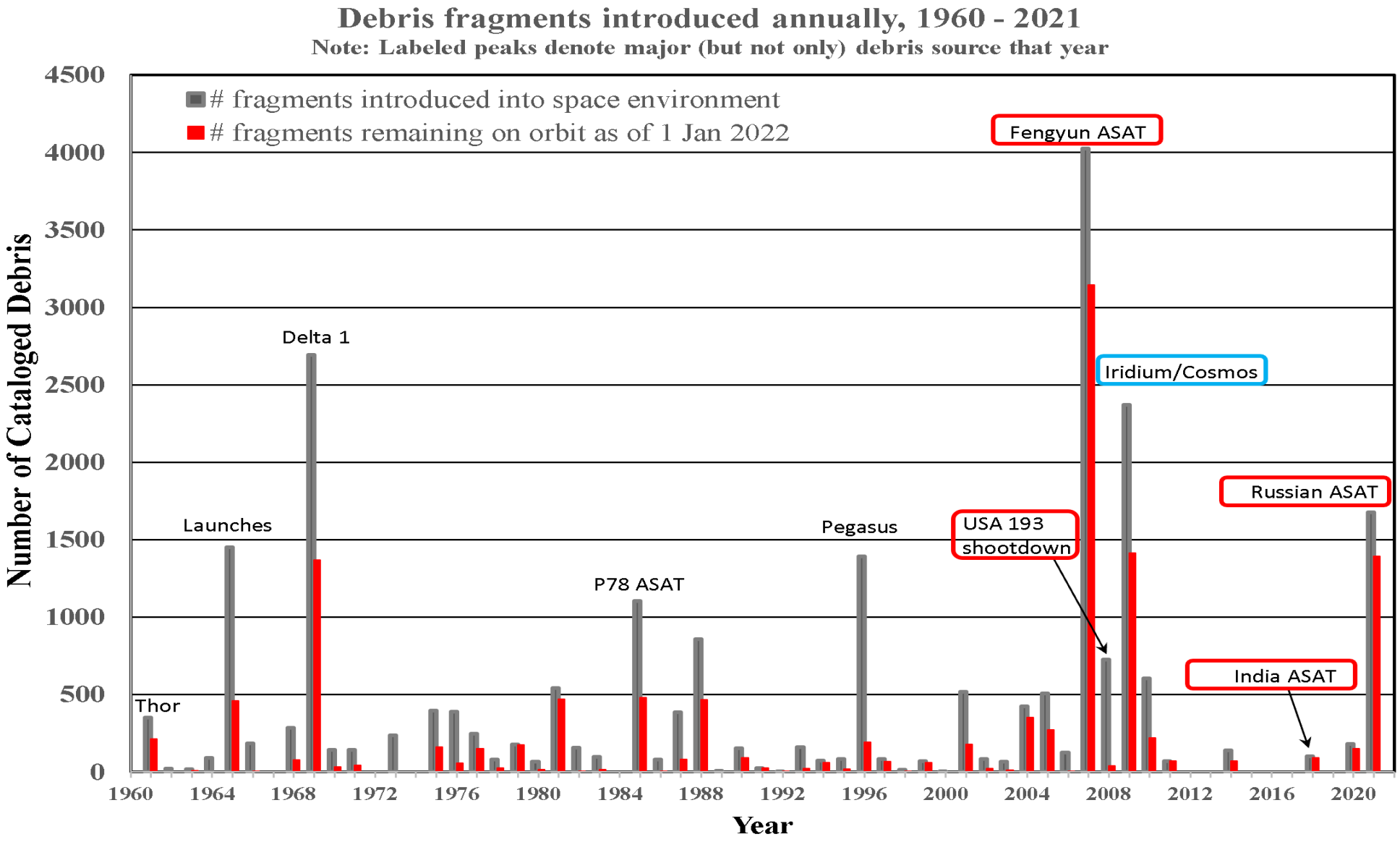
potential collision risks since 2004.

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


NOTAM3
NOTAM2
Plesetsk Cosmodrome
NOTAM1
-272.0

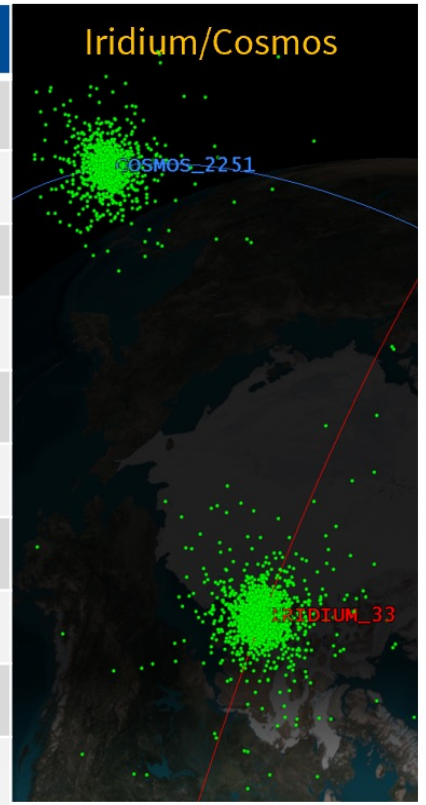
# Major debris-generating events in space era

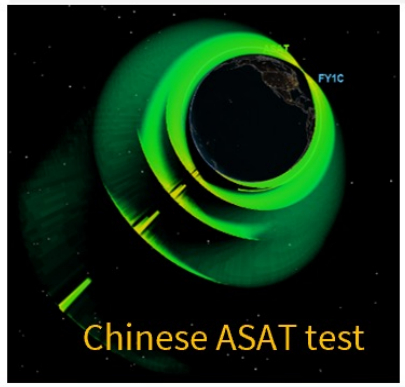


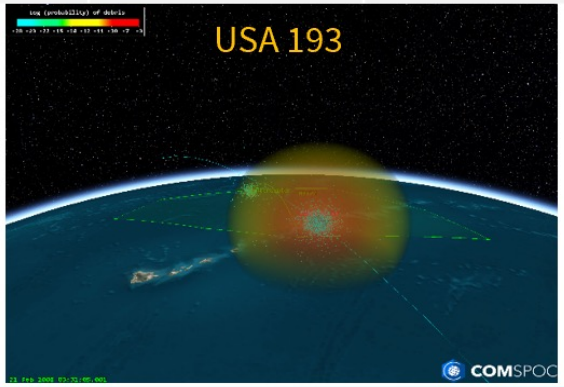
# Comparison of major fragmentation events since 2000

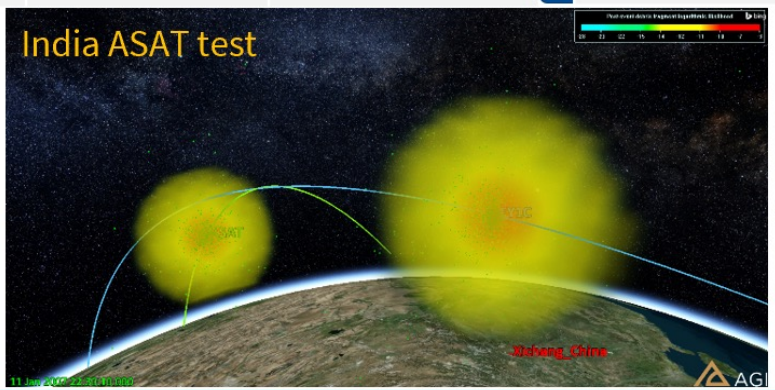
$$NOTE: {}^{J}/_{kg} = \frac{1}{2}\frac{m_{interceptor}}{m_{target}}\Delta V^2_{intercept}$$

| 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~ > ≈ 6) | 14.8 km/s | 8.49 km/s | 9.4 km/s | 4.6 km/s | 11.6 km/s |
| ≈ kJ/kg (catastrophic ≈ >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 |
| 80th 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 |



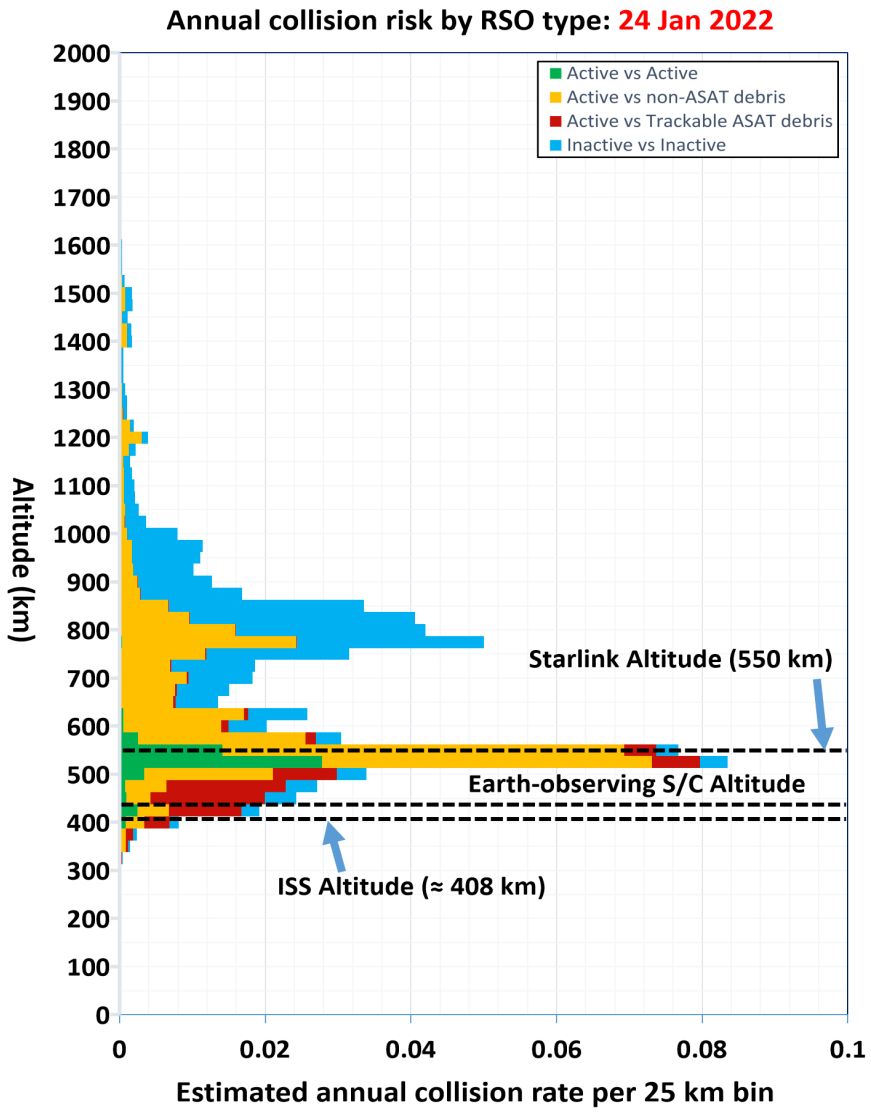



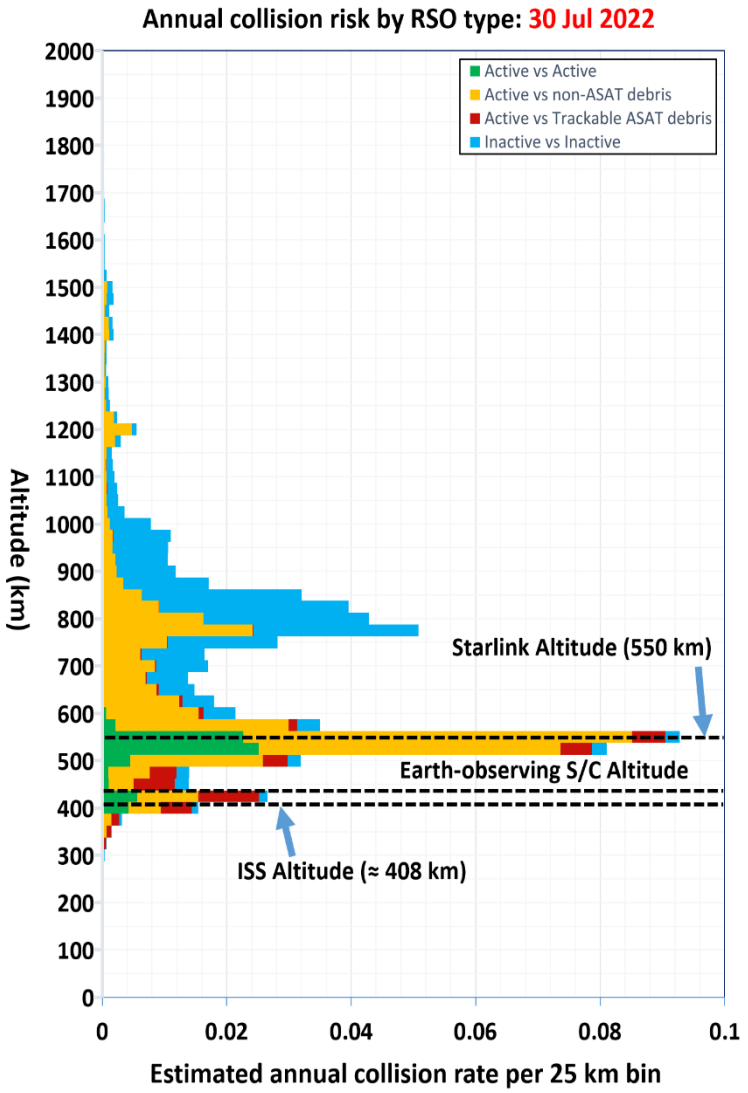


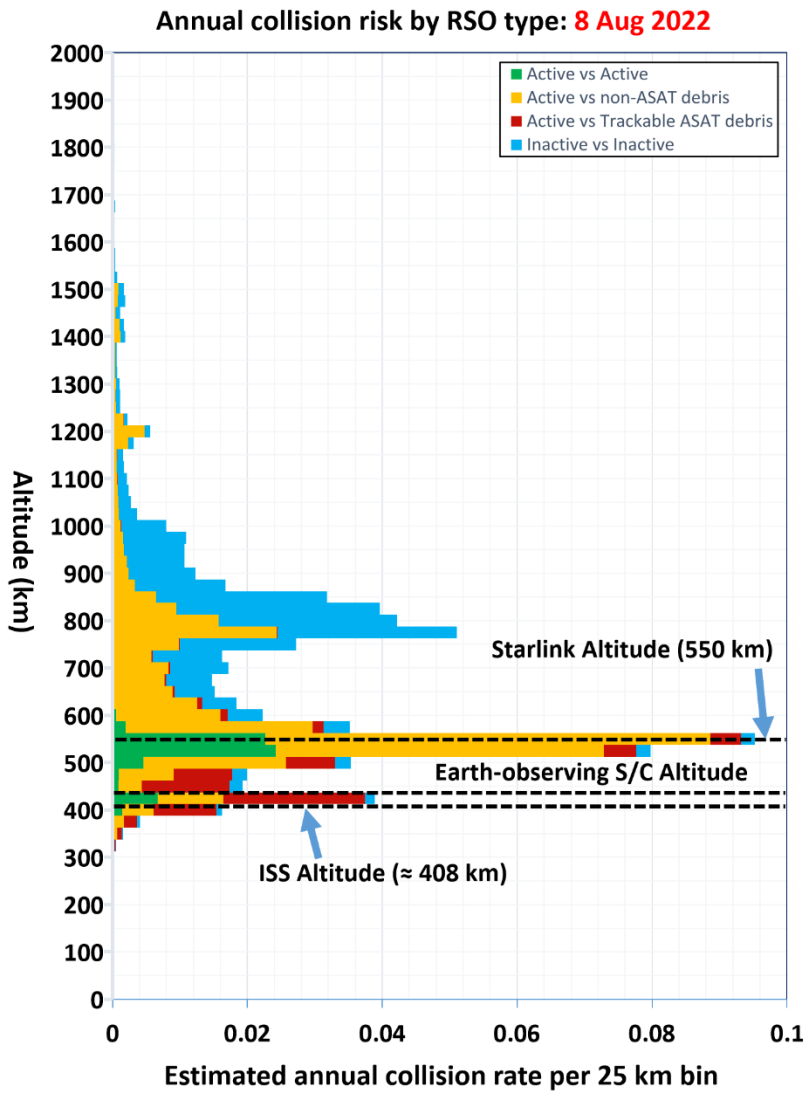
~Speed of sound in AL, TI, Steel, etc. = 3 – 6.5 km/s *Trackable means characteristic length >5 cm with orbit lifetime exceeding 1 day

https://www.engineeringtoolbox.com/sound-speed-solids-d_713.html

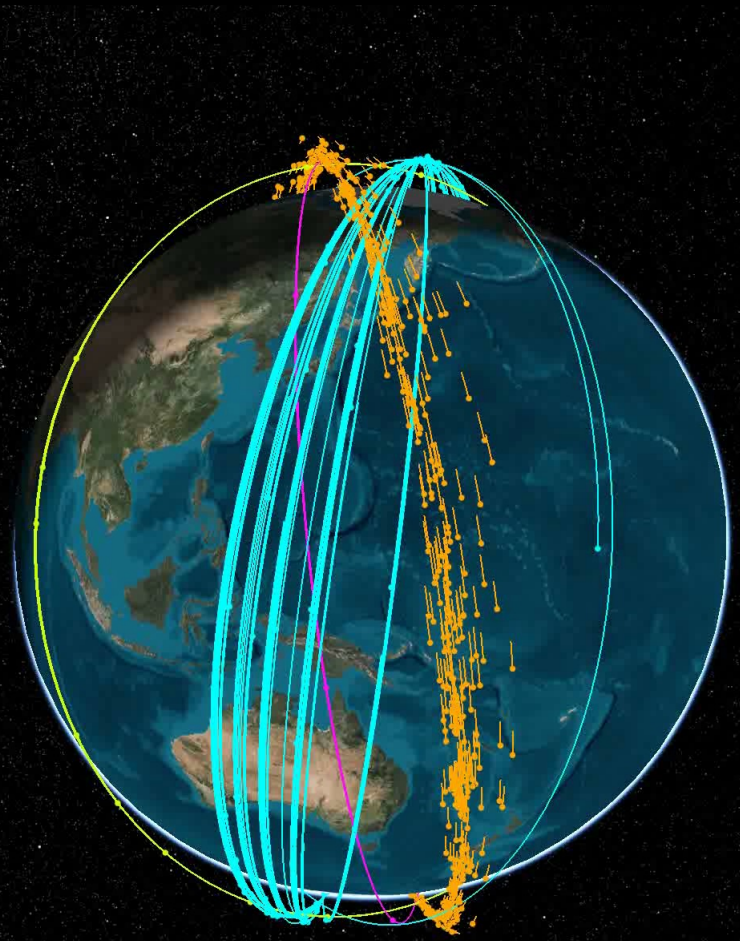
# Annual collision risk during “tenure” of Russian ASAT Debris



# Planet Flock conjunctions w/ASAT debris




| | |
|---|---|
| Flock (SunSync) orbit inclination | ≈ 97.7° |
| Cosmos 1408 orbit inclination | ≈ 82.3° |
| Sum of inclinations: | ≈ 180° |

∴ Recurring head-on collision risk exists!

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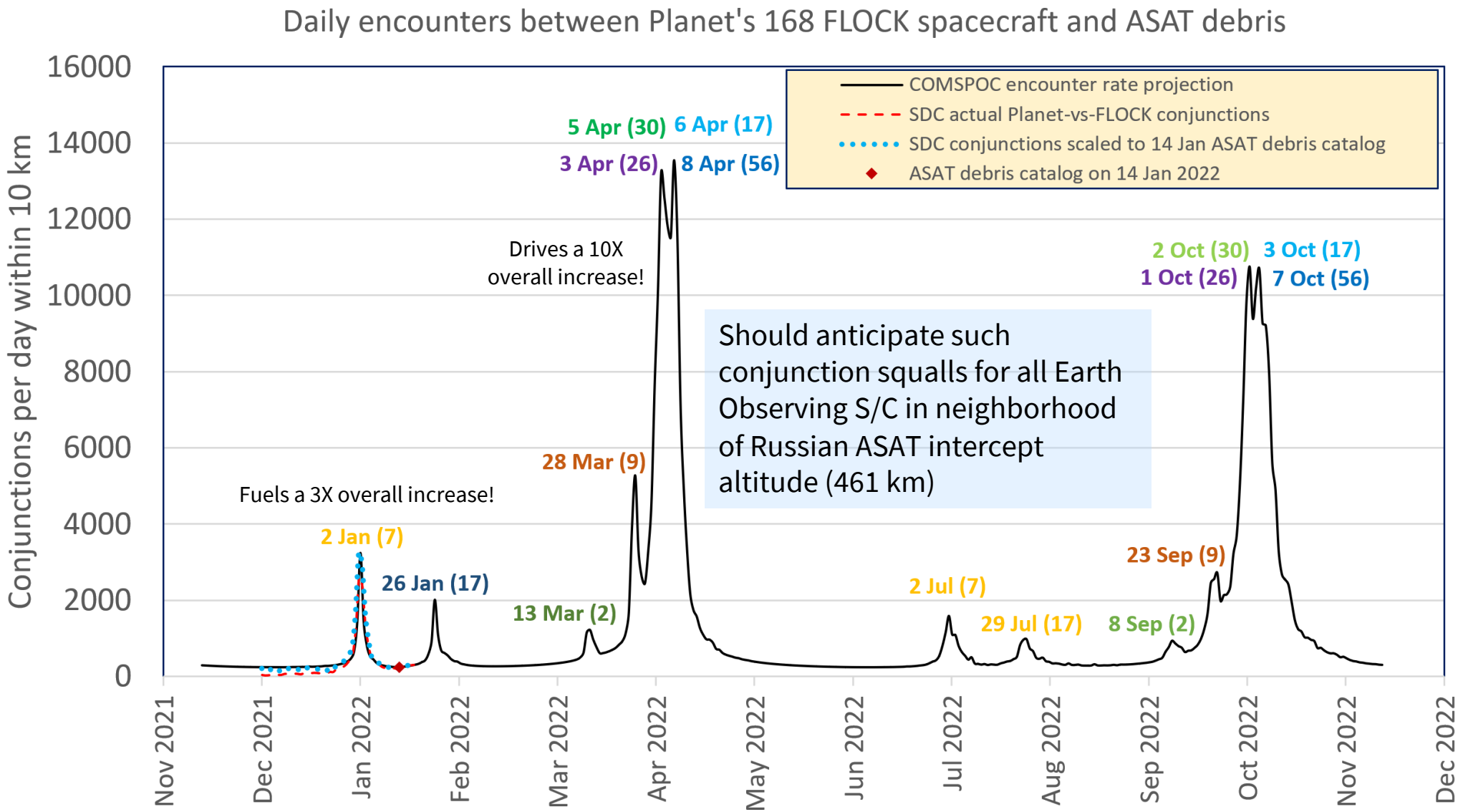
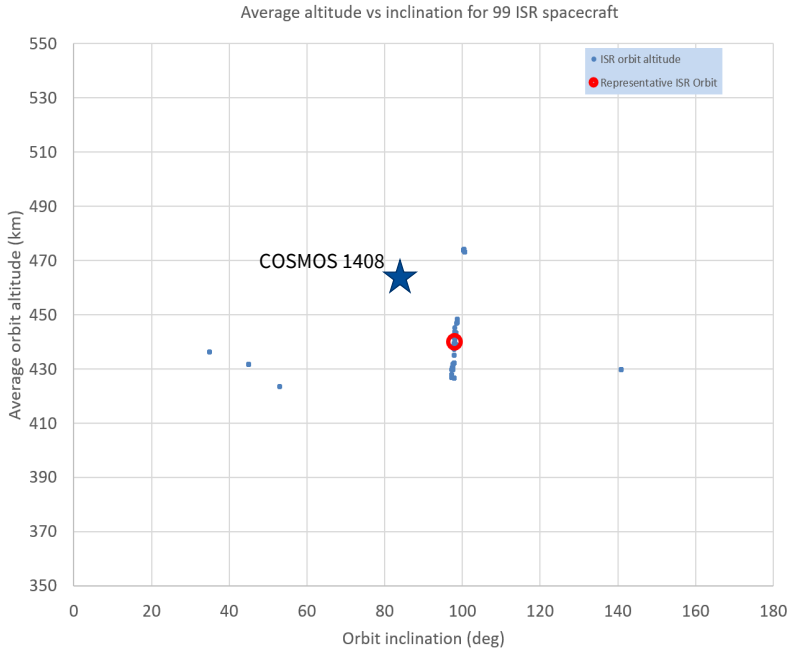
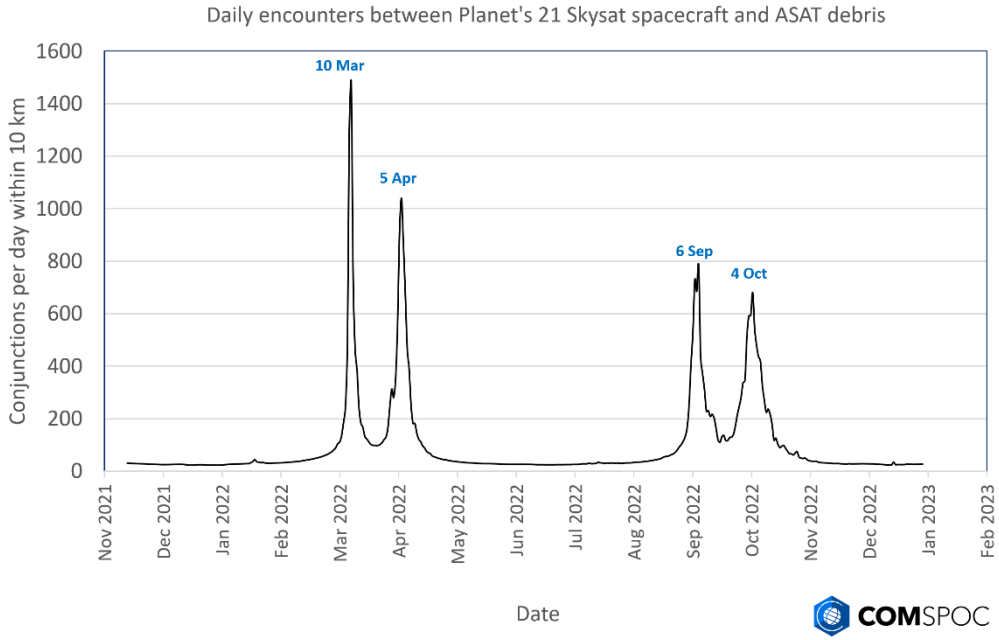
# ASAT debris causing “Conjunction Squalls”

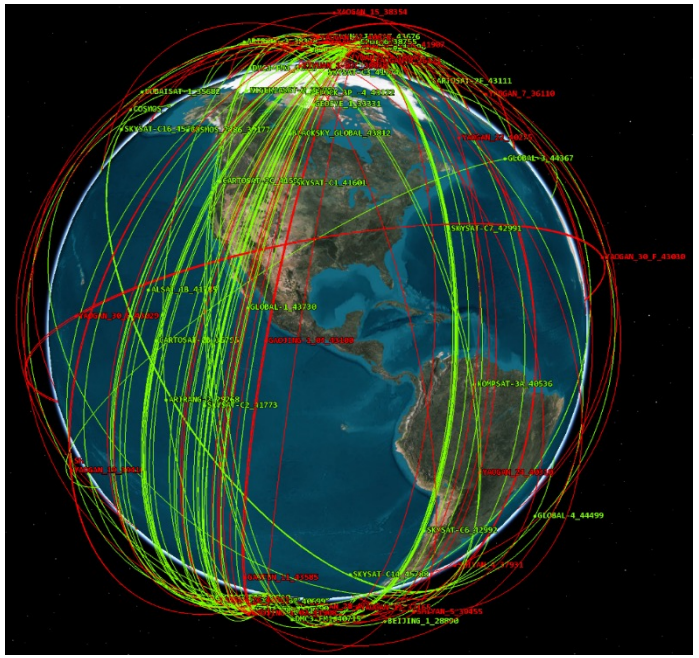


# Other Earth observing spacecraft similarly at risk

- Earth Observing S/C tend to be Sun synch (i≈98°) at ≈440 km
  - All will experience Russian ASAT conjunction squalls
  - Planet's SkySat constellation experienced four of them in 2022
  - Are Earth observing satellite operators and SSA centers aware and prepared?
- Fragmentation-based conjunction squall peaks disperse after several years

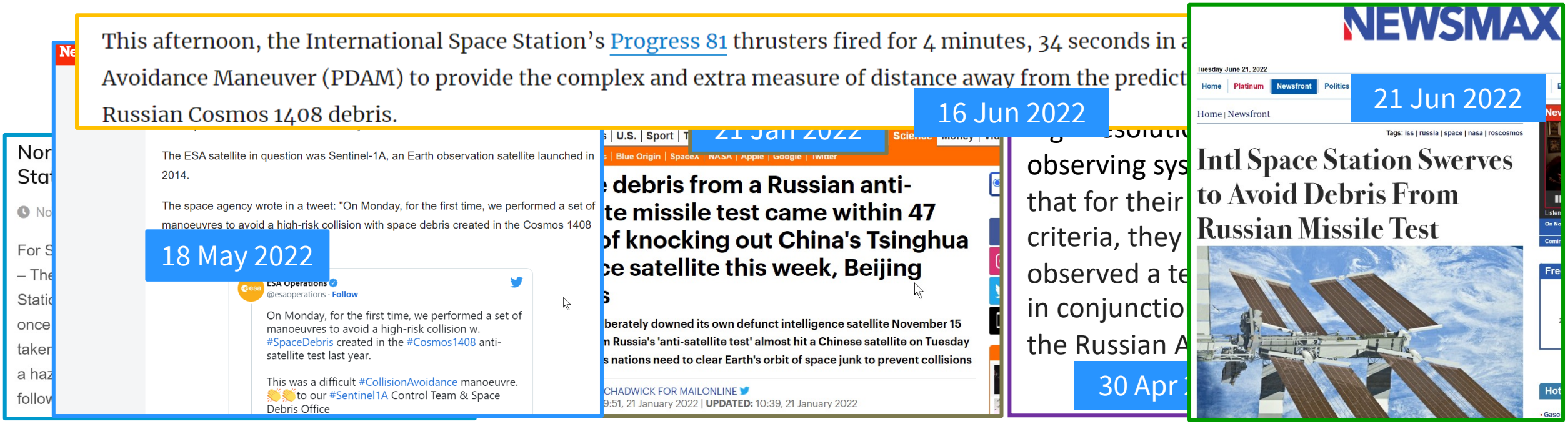


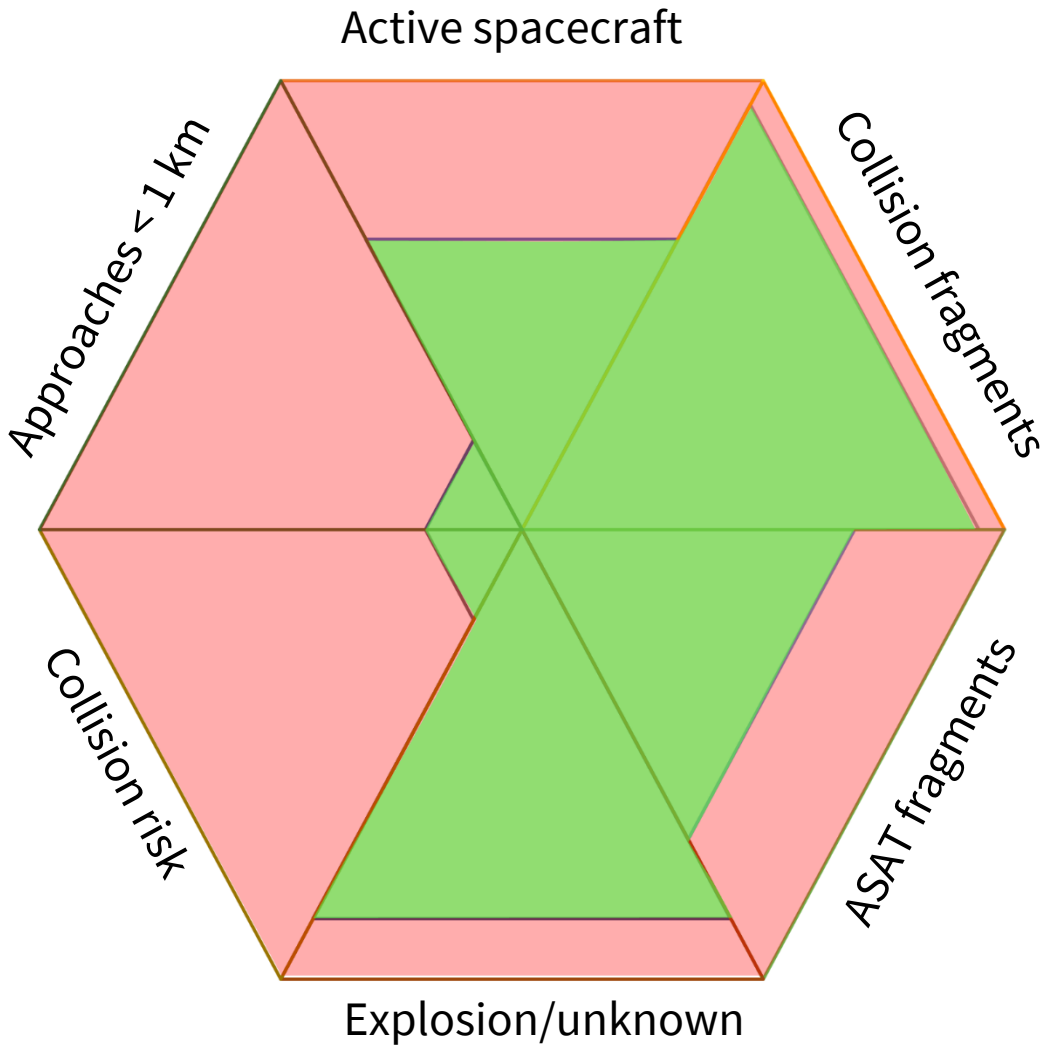



# Who was affected?

- 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 ≈ 33% increase in conjunctions; Starlink)



# Increases in space population and operational risk



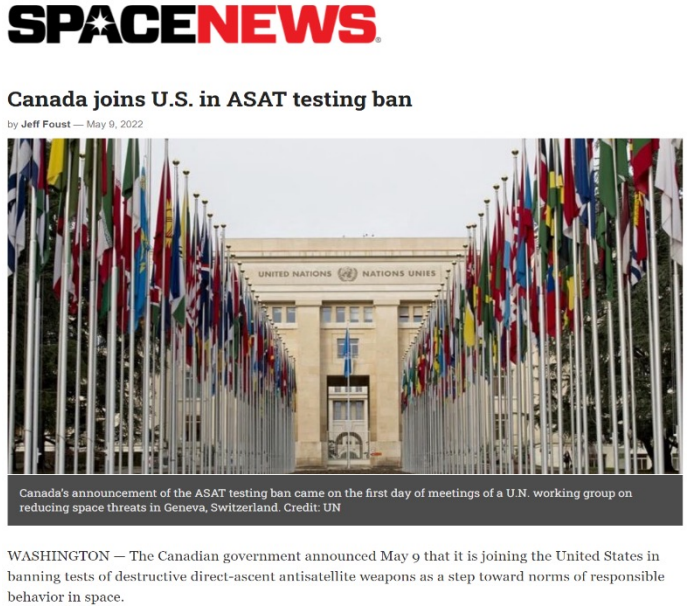

Situation in 2017

Situation in 2022

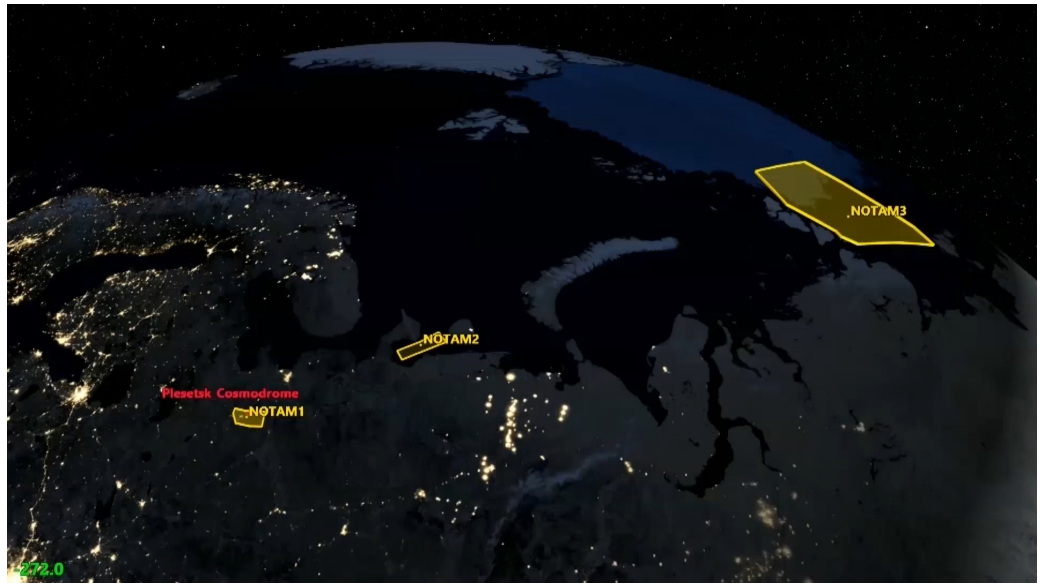
Incorporates data from "*HISTORY OF ON-ORBIT SATELLITE FRAGMENTATIONS 15th Edition", NASA/TM–2018–220037, NASA Orbital Debris Program Office, 4 July 2018* and COMSPOC research

# 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 a moratorium on destructive direct ascent anti-satellite missile tests
    - Asks other nations to commit to help establish this as an international norm
  - Subsequently joined by Canada, New Zealand, Japan, Germany, United Kingdom, South Korea, Australis, Switzerland and France
  - 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…

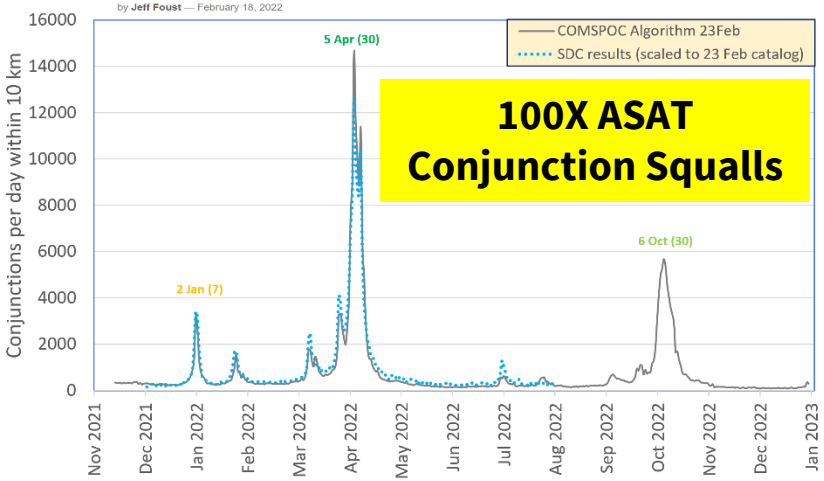
# ASATS and Conjunction Squalls and New Space - - Oh My!




SPACENEWS

**Russian ASAT debris creating "squalls" of close approaches with satellites**

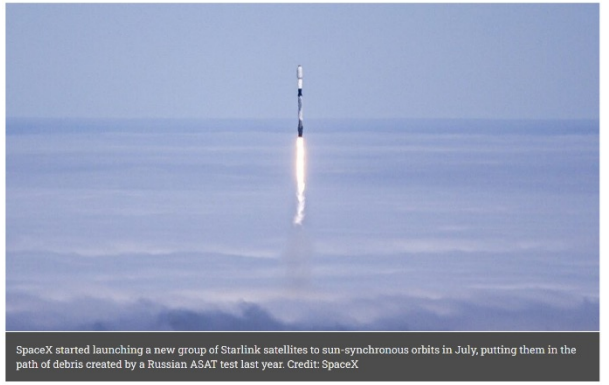
by Jeff Foust — February 18, 2022




SPACENEWS

**Starlink satellites encounter Russian ASAT debris squalls**

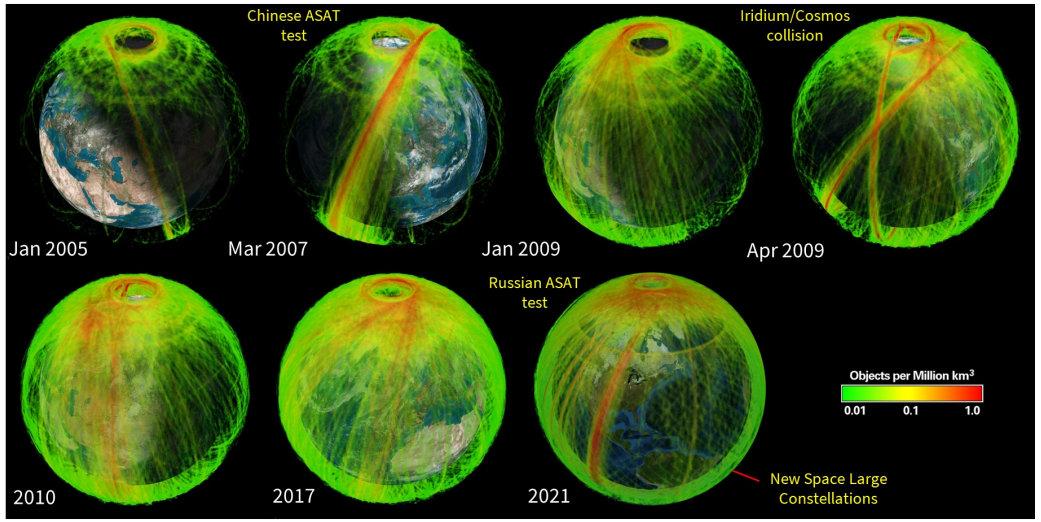
by Jeff Foust — August 9, 2022

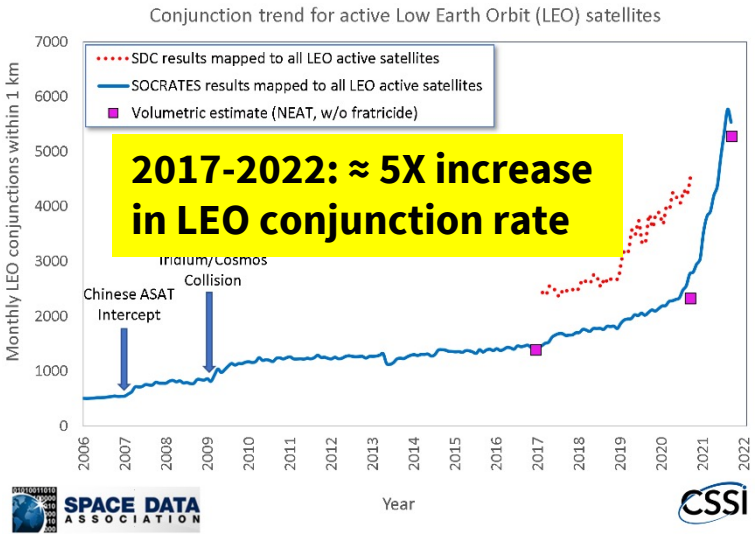


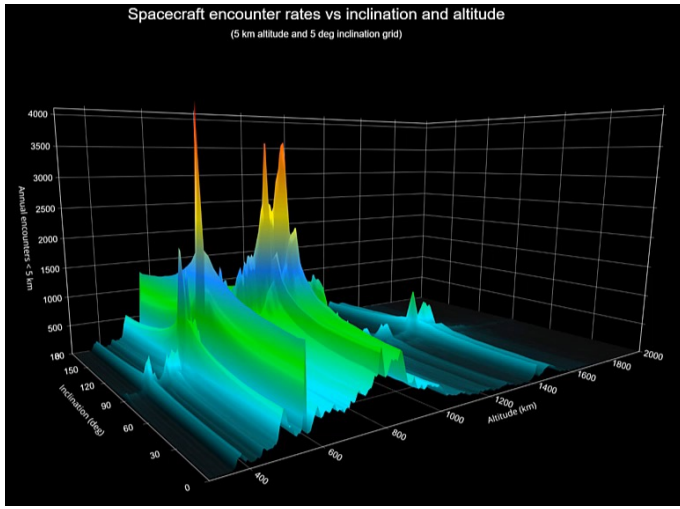
SpaceX started launching a new group of Starlink satellites to sun-synchronous orbits in July, putting them in the path of debris created by a Russian ASAT test last year. Credit: SpaceX

LOGAN, Utah — Debris from a Russian antisatellite weapon demonstration that caused "squalls" of close approaches to satellites earlier this year is now affecting a new series of Starlink satellites.

During a presentation at a Secure World Foundation event during the Small Satellite Conference here Aug. 8, Dan Oltrogge, chief scientist at COMSPOC, said his company found a "conjunction squall" affecting Starlink satellites Aug. 6, with a spike in the number of close approaches of debris from the



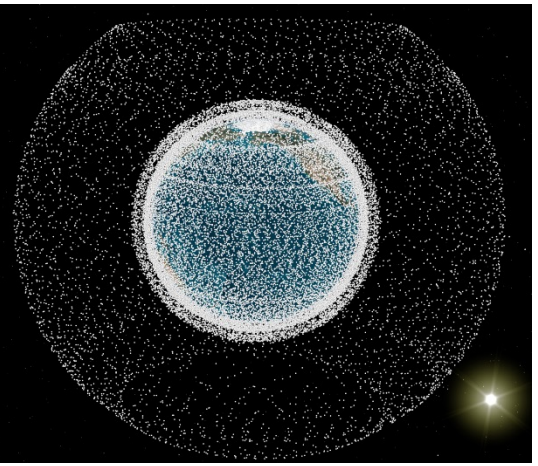



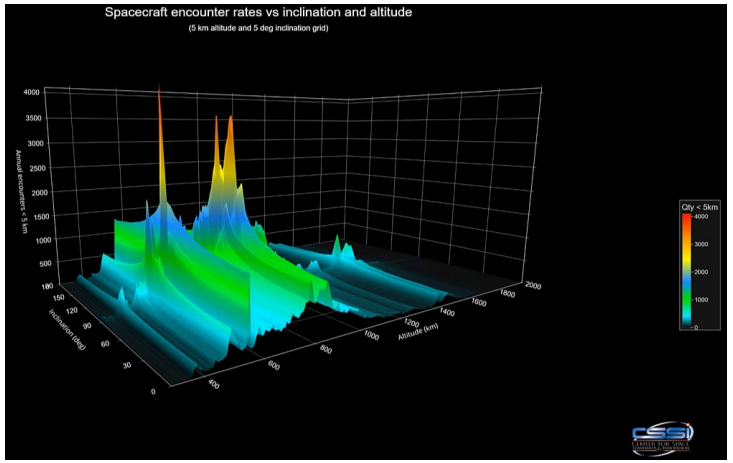



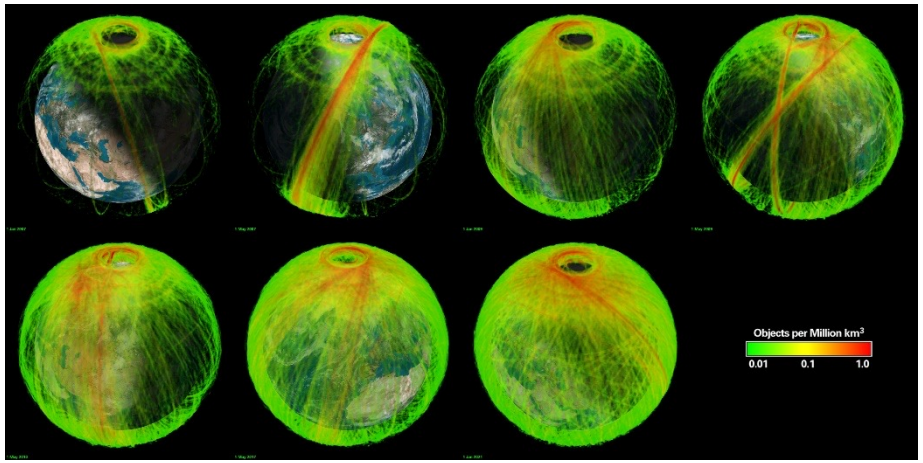
# Carrying capacity research emphasizes “impact to operator”

Top 20 Large Constellations by size

| Country_Operator | Spacecraft |
|---|---|
| USA_SpaceX | 44019 |
| USA_Astra | 13620 |
| China_SatNet | 12992 |
| UK_WorldVu | 7606 |
| USA_Boeing | 5921 |
| USA_STEAM | 4408 |
| USA_Amazon | 3236 |
| Canada_Telesat | 1671 |
| USA_Hughes | 1440 |
| USA_Space_Devel_Agency | 1024 |
| USA_CommSat | 800 |
| USA_Mangata | 791 |
| USA_Kepler | 360 |
| Spain_AISTech_Danu | 300 |
| Germany_EightyLEO | 300 |
| China_Hongyan | 300 |
| Luxembourg_KSM | 300 |
| Argentina_Satellogic | 300 |
| USA_Swarm | 300 |
| Russia_Efir | 288 |



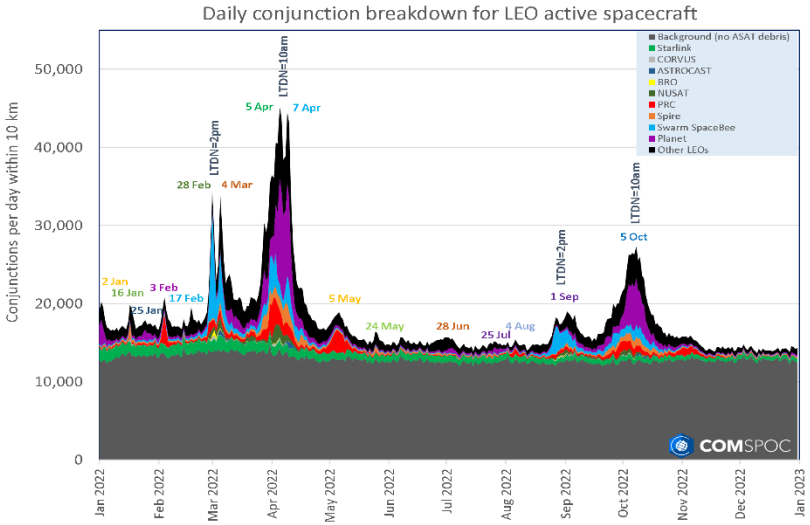


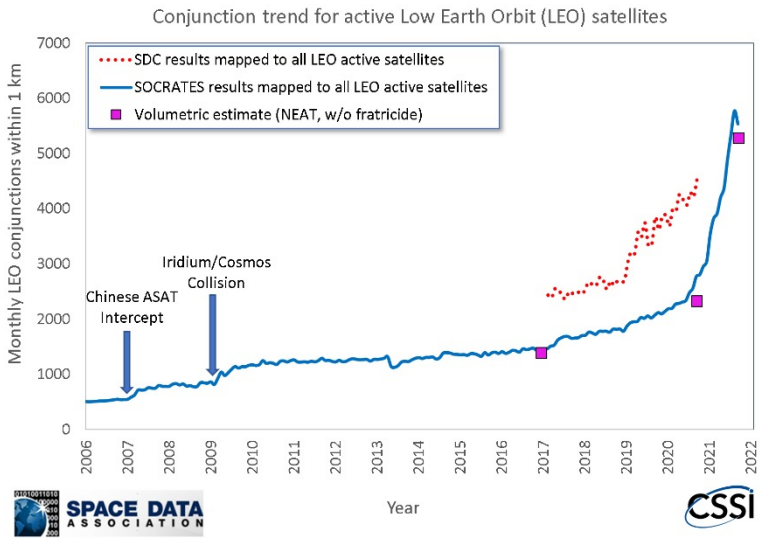



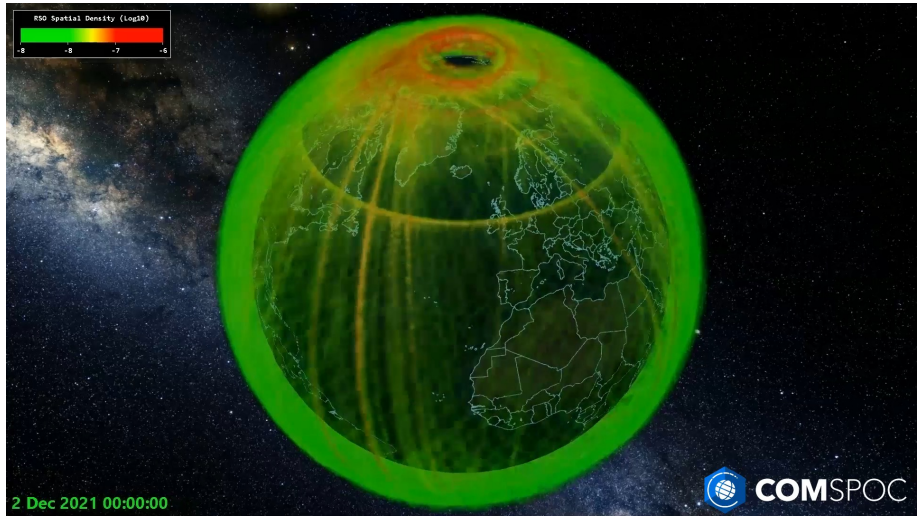

- Large constellations + STM stds
- Conjunction squalls

“NEAT” encounter rates ([http://www.comspoc.com/neat/](http://www.comspoc.com/neat/))

- Spatial density over time
- Implications of ASAT tests

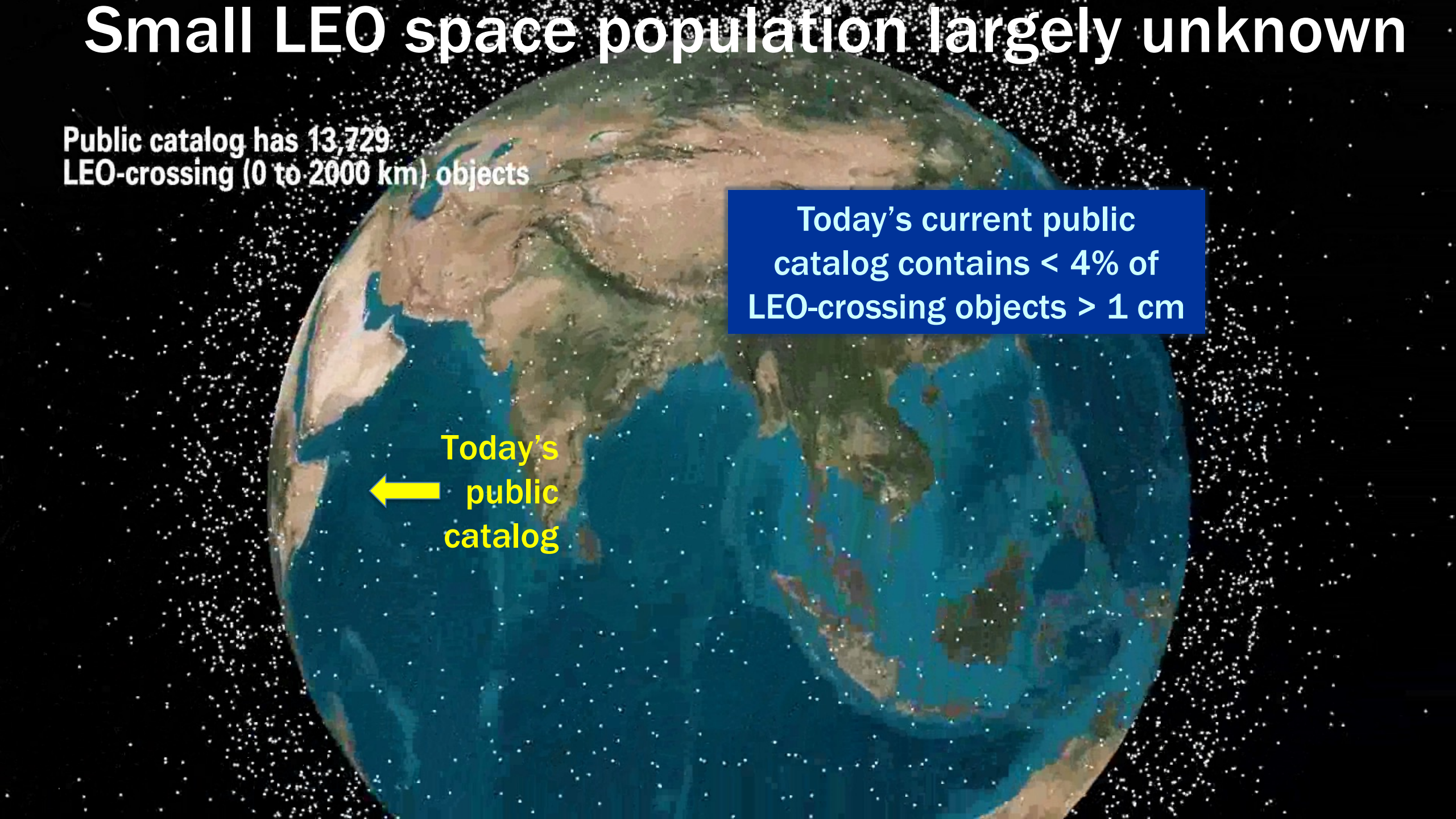


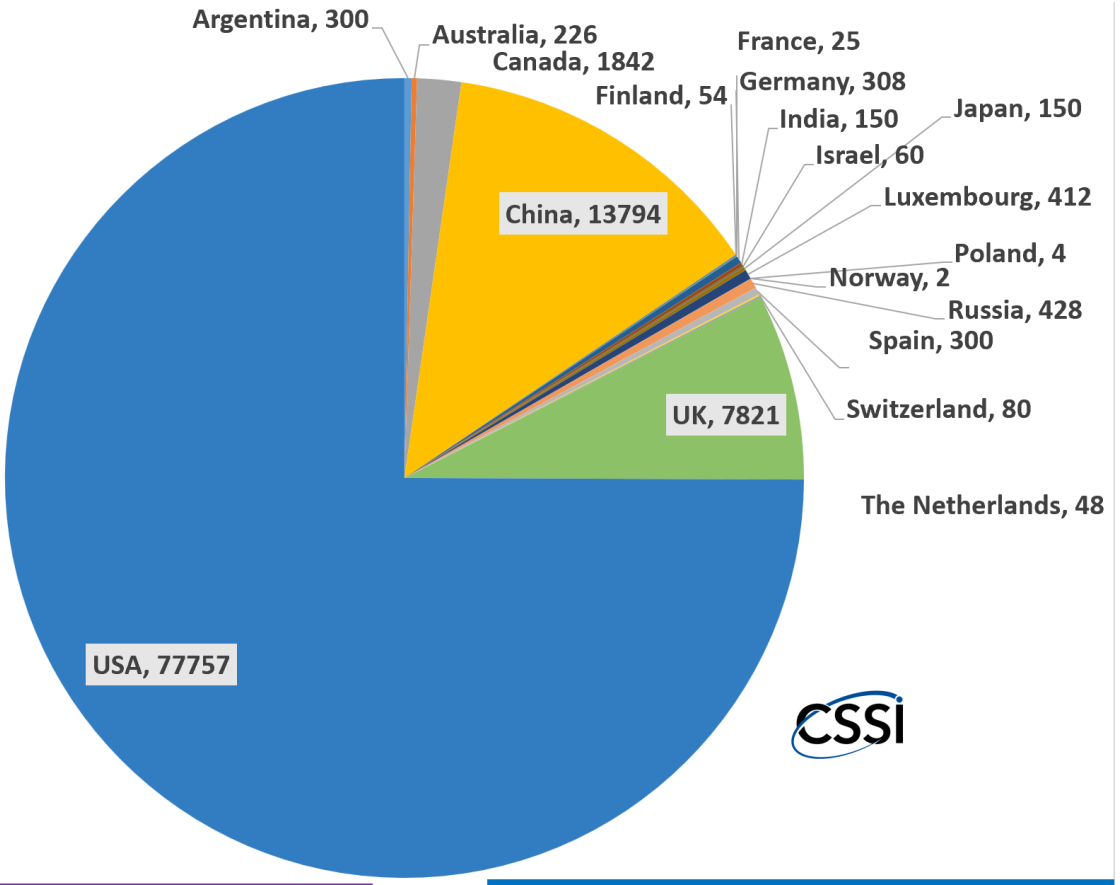




agi

# Small LEO space population largely unknown



# 103,761 large constellation spacecraft proposed through 2029

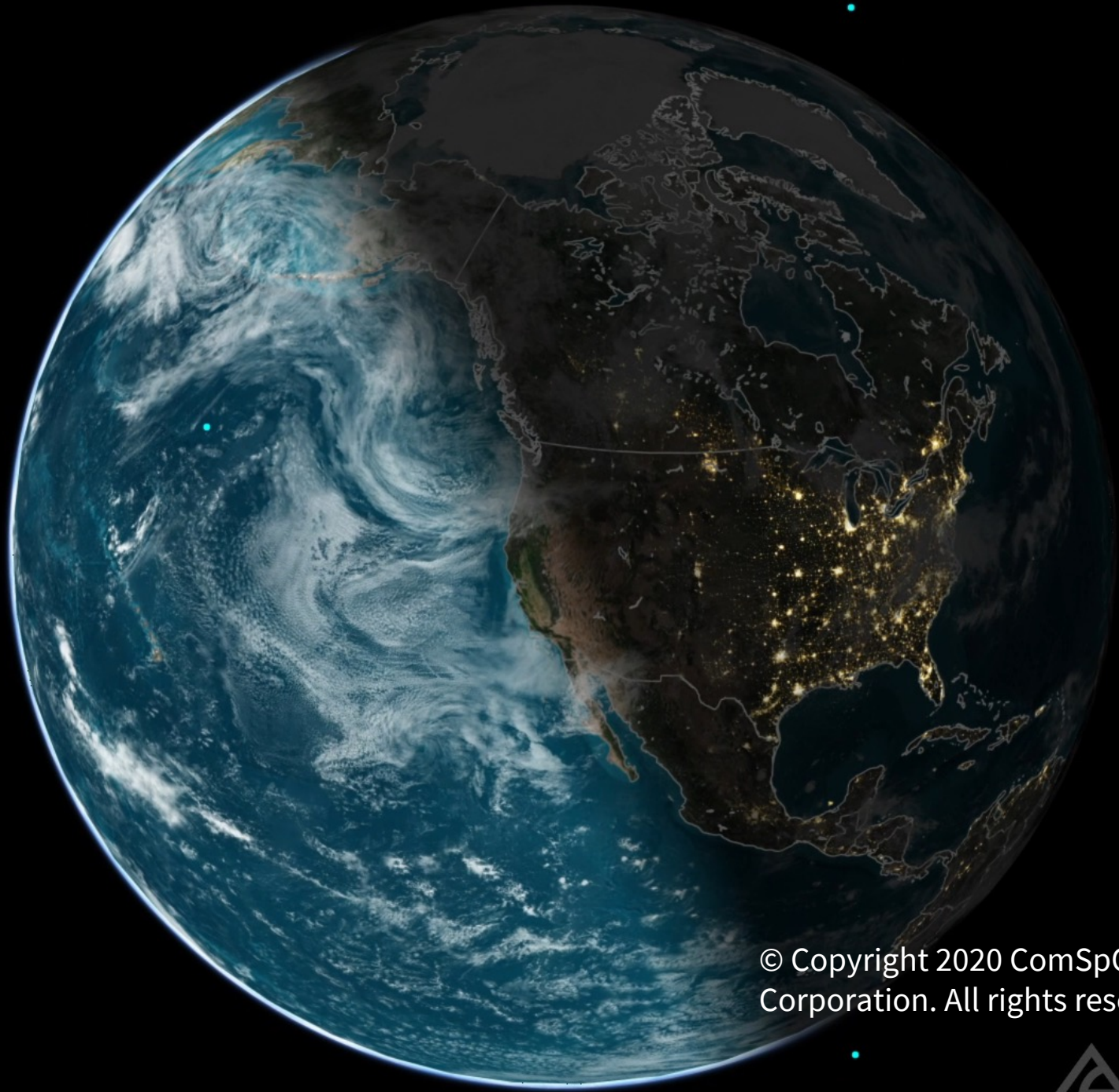



U.S. and UK account for 82% of 103,761 spacecraft applied for through 2029, 5X more than all other countries combined.

U.S. accounts for 75% of 103,761 spacecraft applied for through 2029, 3X more than all other countries combined.

2017

GlobalStar: 7



# Top 20 large constellations at risk of collision

| Operator | # S/C | Alt (km) | Current (>10 cm) RSO catalog average number | | | ~200,000 (≈2 cm) RSO catalog average number | | |
|---|---|---|---|---|---|---|---|---|
| | | | *Estimated collisions in 10 years* | *3km warnings in 10 years* | *1km maneuvers in 10 years* | *Estimated collisions in 10 years* | *3km warnings in 10 years* | *1km maneuvers in 10 years* |
| AISTech_Danu | 300 | 591 | 0.07 | 479,649 | 53,294 | 0.19 | 4,635,985 | 515,109 |
| Amazon | 3,236 | 590 | **0.18** | **3,768,872** | **418,764** | **0.09** | **36,120,810** | **4,013,423** |
| Boeing_1 | 1,120 | 1,200 | 0.14 | 331,965 | 36,885 | 1.09 | 4,739,224 | 526,580 |
| Boeing_2 | 1,210 | 550 | 0.10 | 234,358 | 26,040 | 0.84 | 3,646,359 | 405,151 |
| Boeing_3 | 1,000 | 585 | 0.23 | 1,812,814 | 201,424 | 0.59 | 16,903,756 | 1,878,195 |
| CommSat | 800 | 600 | 0.07 | 1,362,606 | 151,401 | 0.03 | 12,835,938 | 1,426,215 |
| ExactView | 72 | 820 | 0.21 | 326,914 | 36,324 | 1.10 | 2,768,355 | 307,595 |
| Hongyan | 300 | 1,100 | 0.04 | 241,520 | 26,836 | 0.16 | 3,434,841 | 381,649 |
| Iridium | 85 | 781 | 0.06 | 399,037 | 44,337 | 0.12 | 2,514,772 | 279,419 |
| LuckyStar | 156 | 1,000 | 0.02 | 318,736 | 35,415 | 0.01 | 2,616,385 | 290,710 |
| OneWeb | 2,560 | 1,200 | 0.32 | 754,868 | 83,874 | 2.49 | 10,832,864 | 1,203,652 |
| OneWeb_next | 720 | 1,200 | 0.17 | 286,598 | 31,844 | 1.69 | 4,726,261 | 525,140 |
| Satellogic | 300 | 477 | 0.02 | 236,040 | 26,227 | 0.02 | 2,254,977 | 250,553 |
| SpaceX | 4,425 | 1,200 | **6.43** | **2,050,452** | **227,828** | **77.73** | **30,310,084** | **3,367,787** |
| SpaceX_VLEO | 1584 | 550 | 3.45 | 1,101,453 | 122,384 | 35.63 | 13,894,159 | 1,543,795 |
| Space_X_M-T | 20,940 | 500 | **43.13** | **13,753,896** | **1,528,211** | **404.53** | **157,747,388** | **17,527,488** |
| Space_X_U-W | 9,000 | 330 | 0.93 | 347,030 | 38,559 | 21.86 | 10,053,221 | 1,117,025 |
| Theia | 211 | 775 | 1.08 | 783,728 | 87,081 | 7.57 | 7,520,310 | 835,590 |
| Xingyun | 156 | 1,000 | 0.04 | 360,898 | 40,100 | 0.06 | 2,831,654 | 314,628 |
| Yaliny | 140 | 1,000 | 0.03 | 321,780 | 35,753 | 0.05 | 2,599,648 | 288,850 |

# Does collision risk alter space business case?

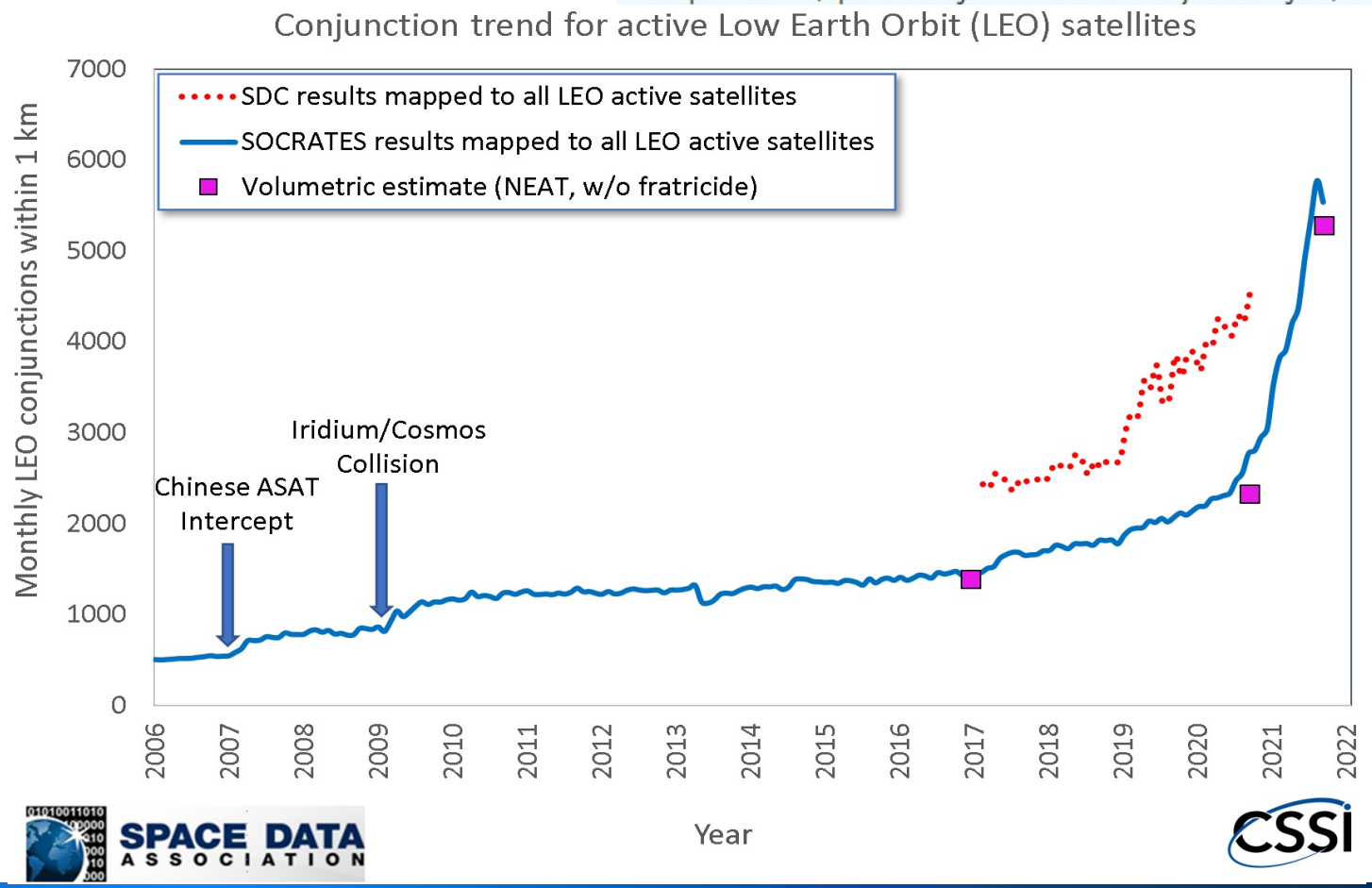
- **Traffic (and close conjunctions) ever increasing**
  - **Affects Flight Dynamics staff; what about consumer confidence?**
- **Challenges continue to grow**
  - **5-day conjunction rate from legacy capabilities/processes = 3300 (1/3 from one satellite operator)**
  - **One operator receiving 407,000 Conjunction Data Messages (CDMs) per month for their 200 spacecraft**

## Average monthly conjunction rates surge from 2017 to 2020

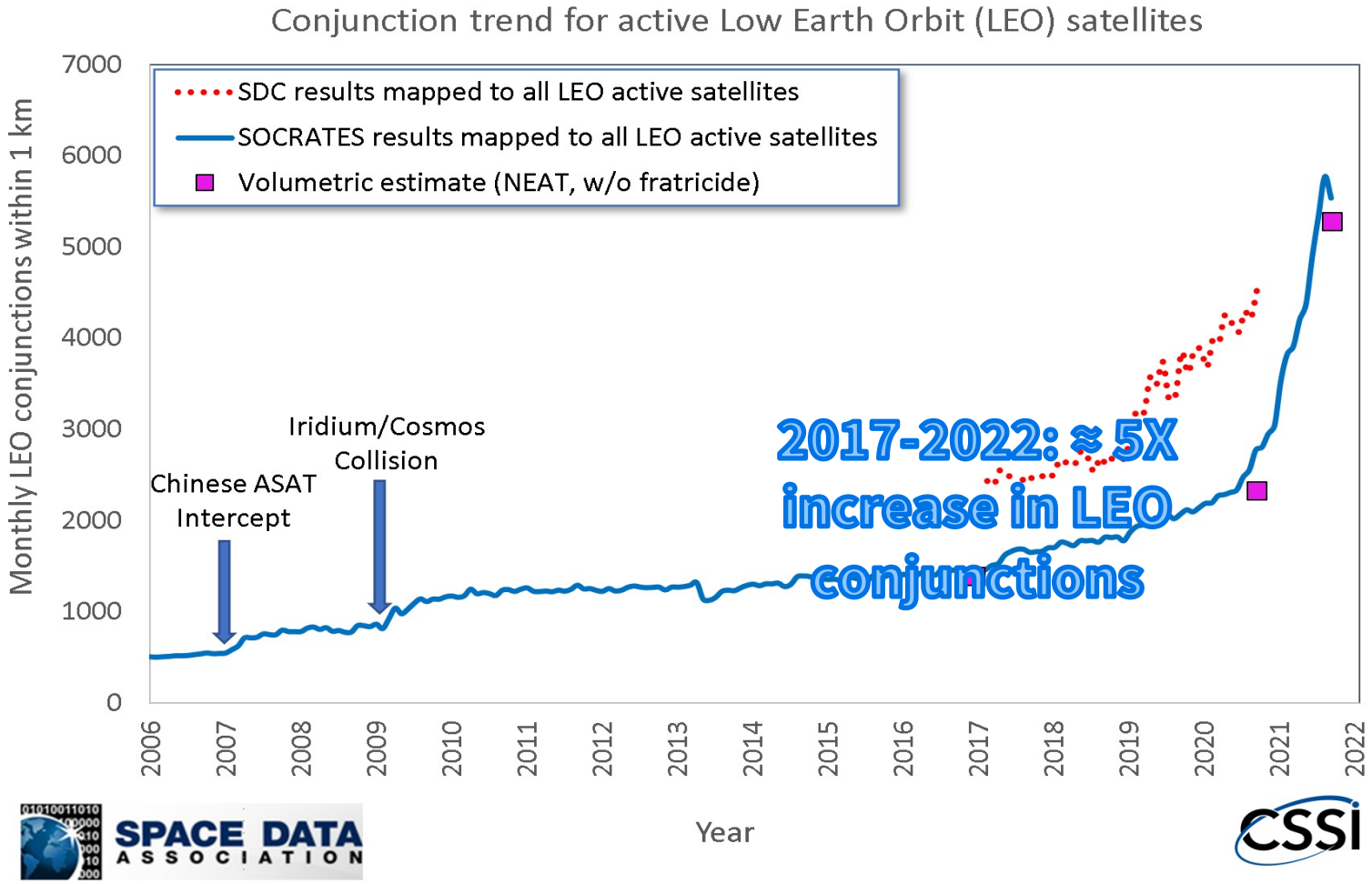
Satellite operators are receiving warnings that their spacecraft are within 1 kilometer of another satellite or piece of tracked debris approximately twice as often as they did three years ago.

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 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

# Traffic and close conjunctions already increasing





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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

- **Traffic (and close conjunctions) ever increasing**
  - **Affects Flight Dynamics staff; what about consumer confidence?**
- **Challenges continue to grow**
  - **5-day conjunction rate from legacy capabilities/processes = 3300 (1/3 from one satellite operator)**
  - **One operator receiving 407,000 Conjunction Data Messages (CDMs) per month for their 200 spacecraft**

# How is New Space changing the picture of the active space population?

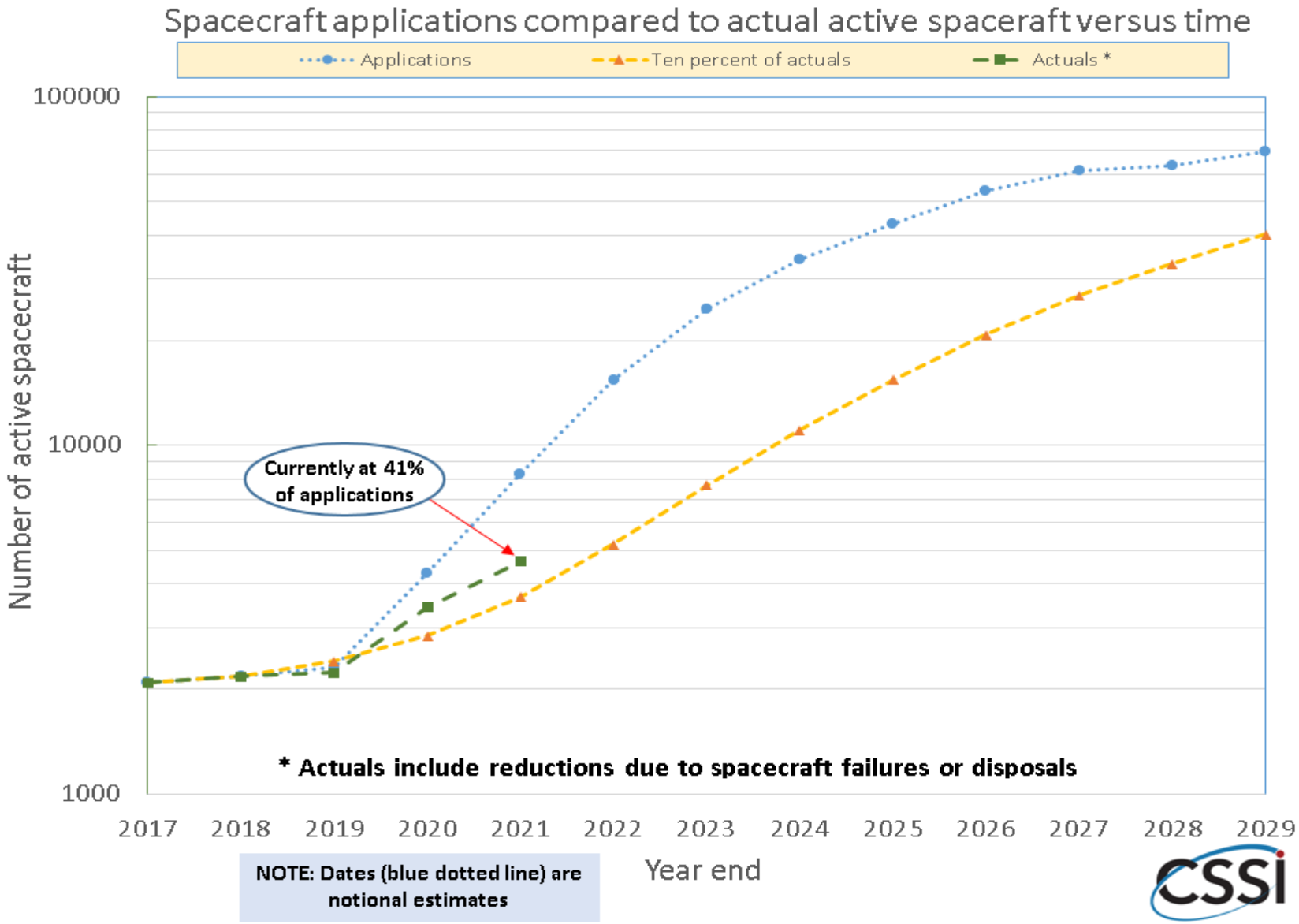
2019 - Present
Starlink payloads – 1789
OneWeb payloads – 358

2018 – Present
Total payloads – 3683

1957 – Present
Total payloads – 11513

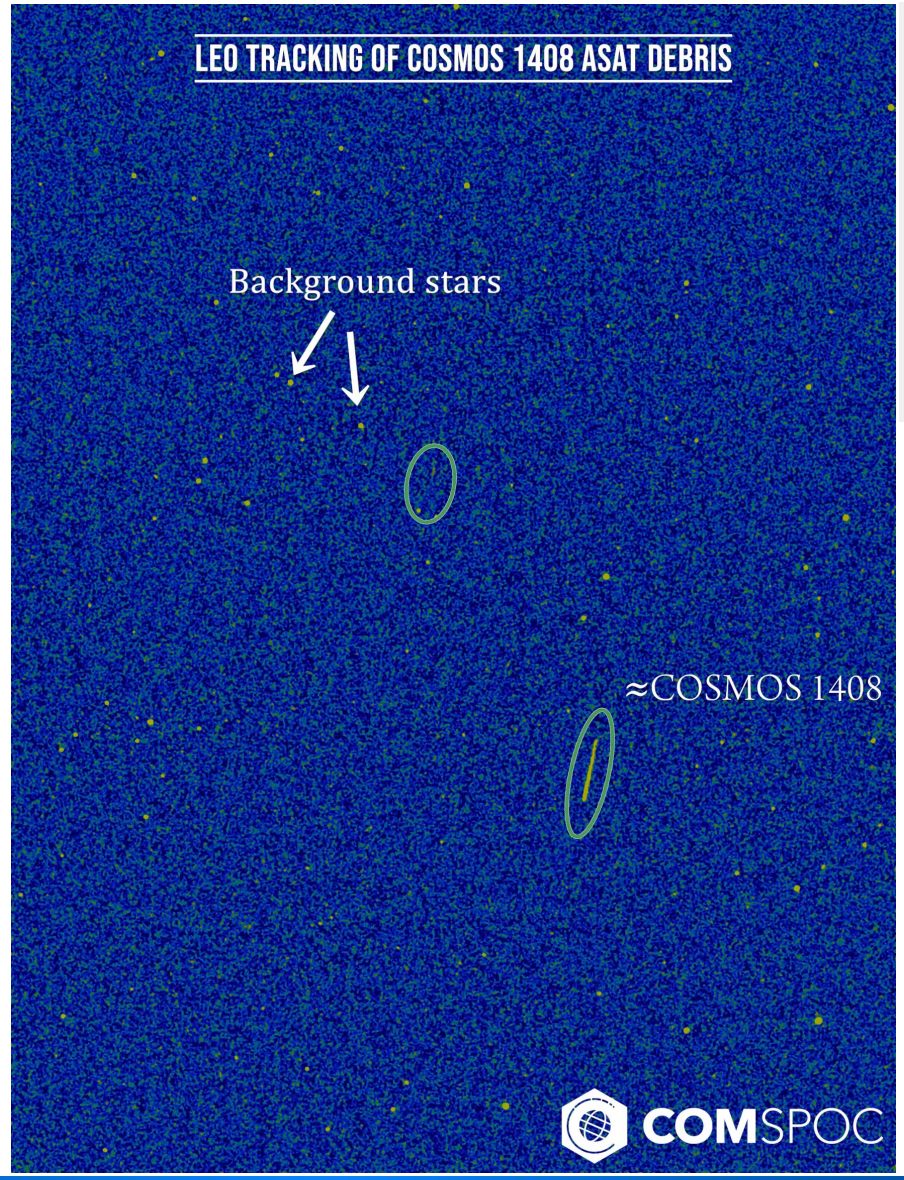
32% of all payloads launched into space since 1957 (64 years) have been launched in the last 4 years (since 2018)*

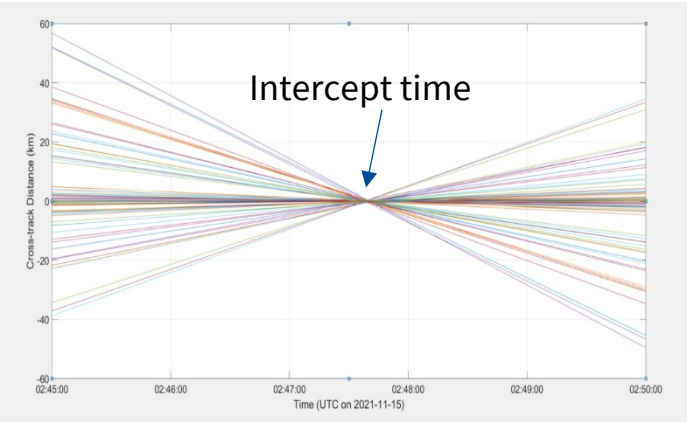
*SPD-3 released in 2018

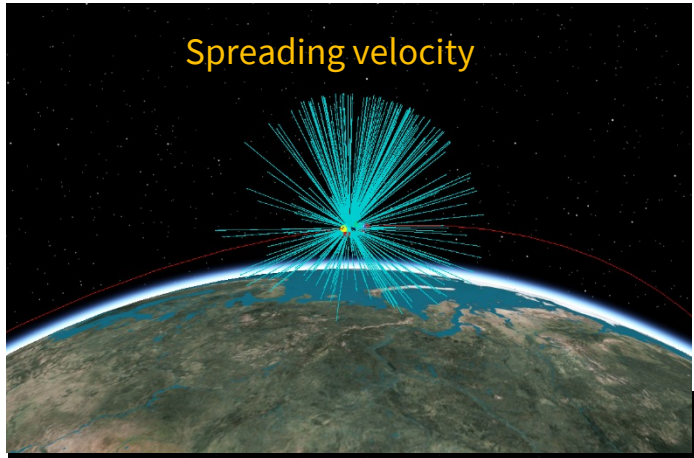


# Russian ASAT Intercept fragment tracking, conditions, calibration

- COMSPOC optical trackers detected several fragments
- Post-processing of Space-Track TLEs yielded estimated intercept time of 15 Nov 2021 02:47:31.5
- Back-propagation to intercept yielded 3D spread velocity
- NOTAM interpretation yielded representative interceptor
- Sub-hypervelocity impact required model calibration



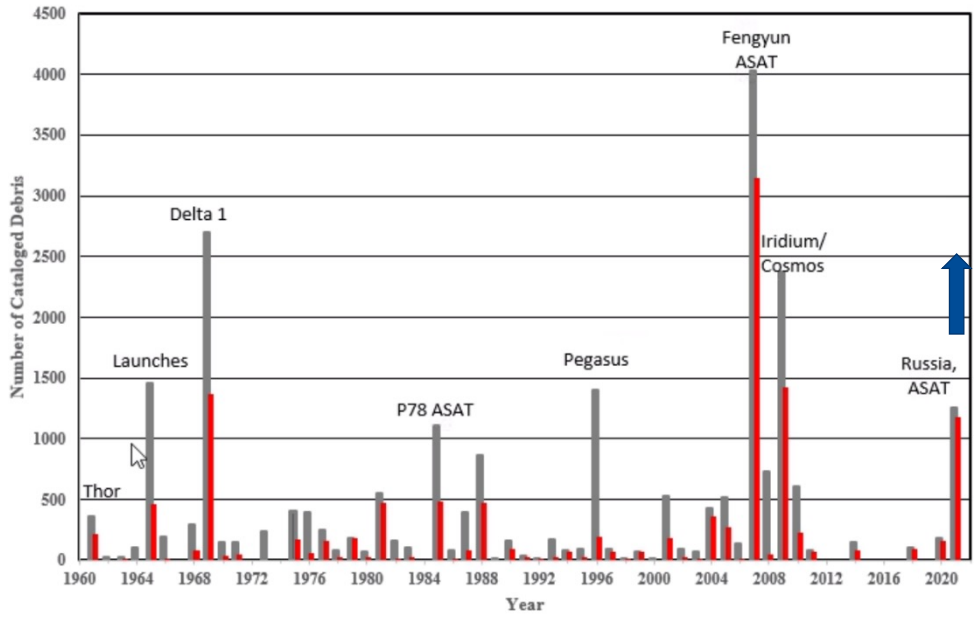



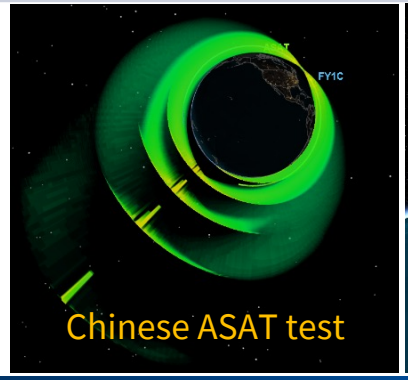




# Comparison with previous ASAT events

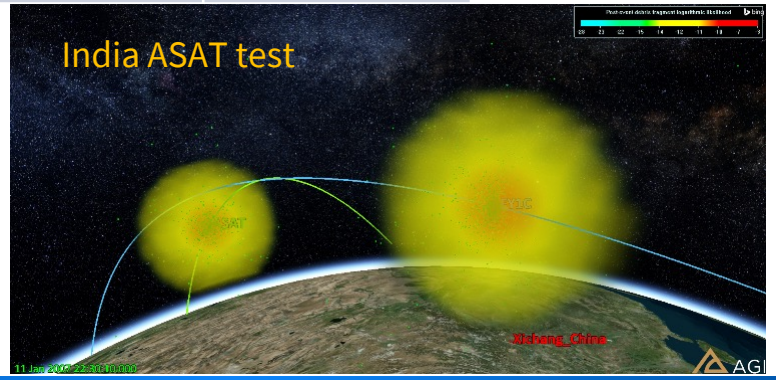
*Trackable means large enough to track, with > 2 wk orbital lifetime

| Category | Chinese ASAT | USA 193 | Indian ASAT | Russian ASAT |
|---|---|---|---|---|
| Date | 11 Jan 2007 | 21 Feb 2008 | 27 Mar 2019 | 15 Nov 2021 |
| Altitude (km) | 769 | 246 | 282 | 461 |
| Relative velocity (km/s) | 14.8 | 8.49 | 9.4 | 4.6 |
| Debris tracked by SSN | 3,532 | 173 | 129 | 1,252 (so far) |
| Simulated trackable debris* | 4,049 | 344 | 207 | 1,196 |
| Simulated Lethal Non-Track | 23,007 | 441 | 4,909 | 3,047 |
| 80th percentile lifetime (yrs) | 46 | 0.015 | 0.016 | 1.83 |
| “RSO-years” (trackable) | 105,904 | 36.6 | 43 | 1,363 |
| “RSO-years” (LNT) | 597,241 | 52 | 118 | 400 |



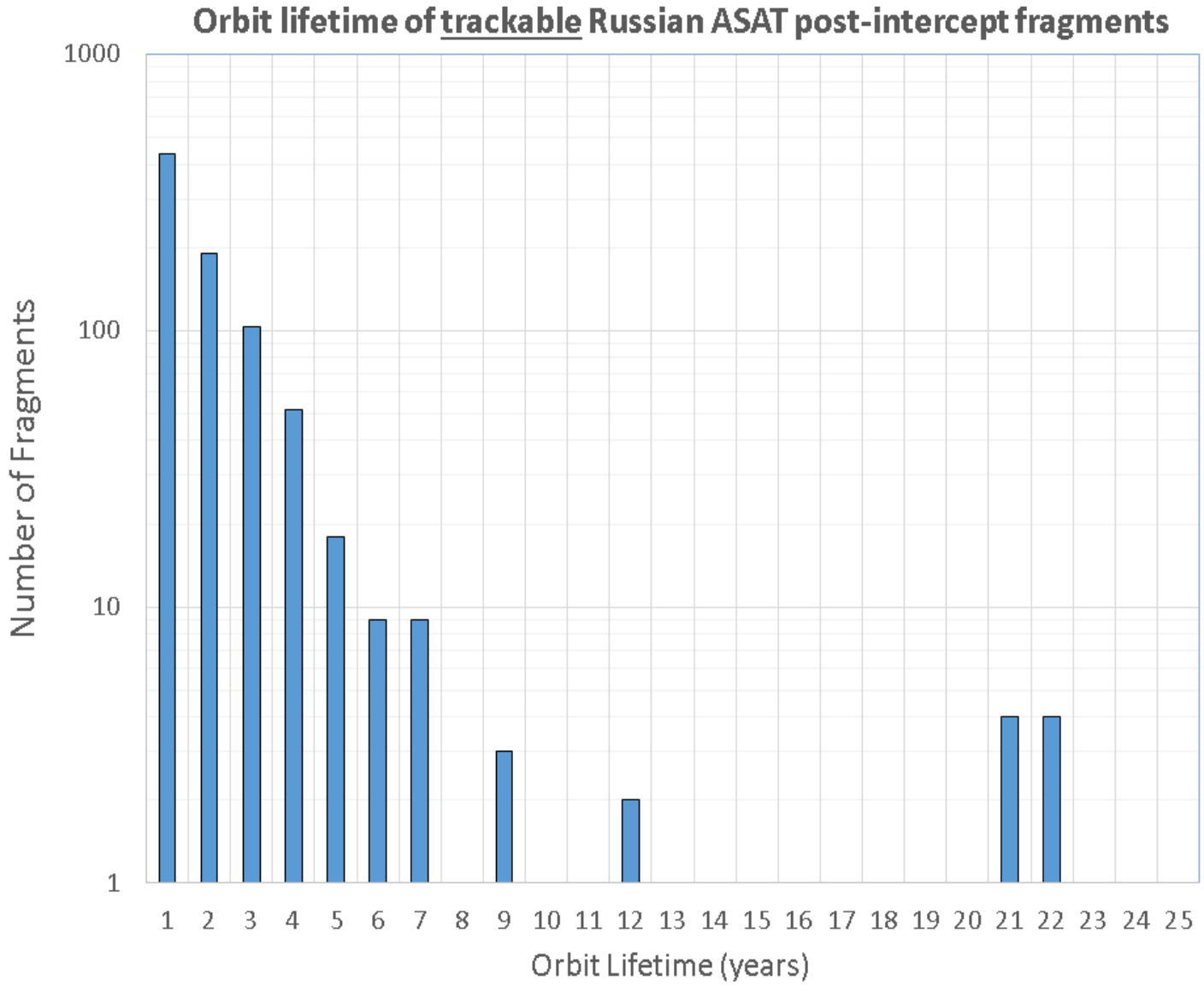







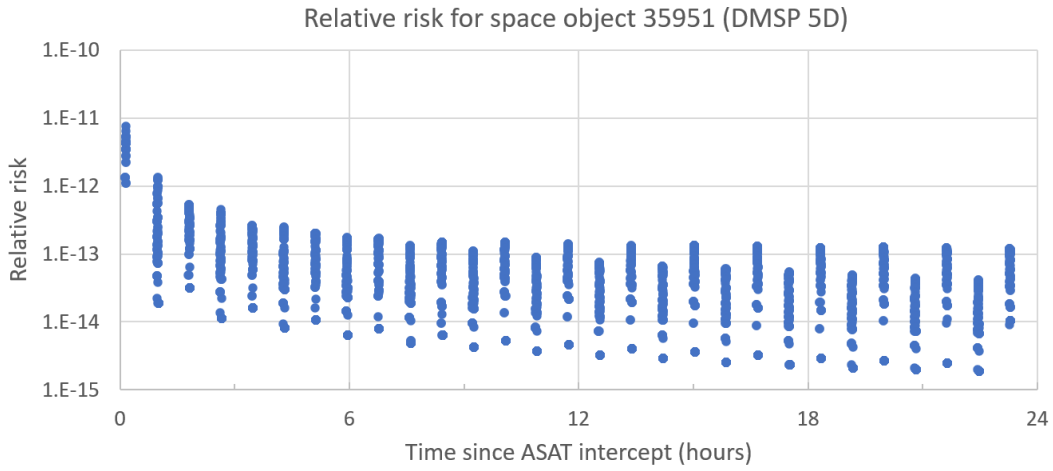

# Russian ASAT debris fragment lifetime distribution

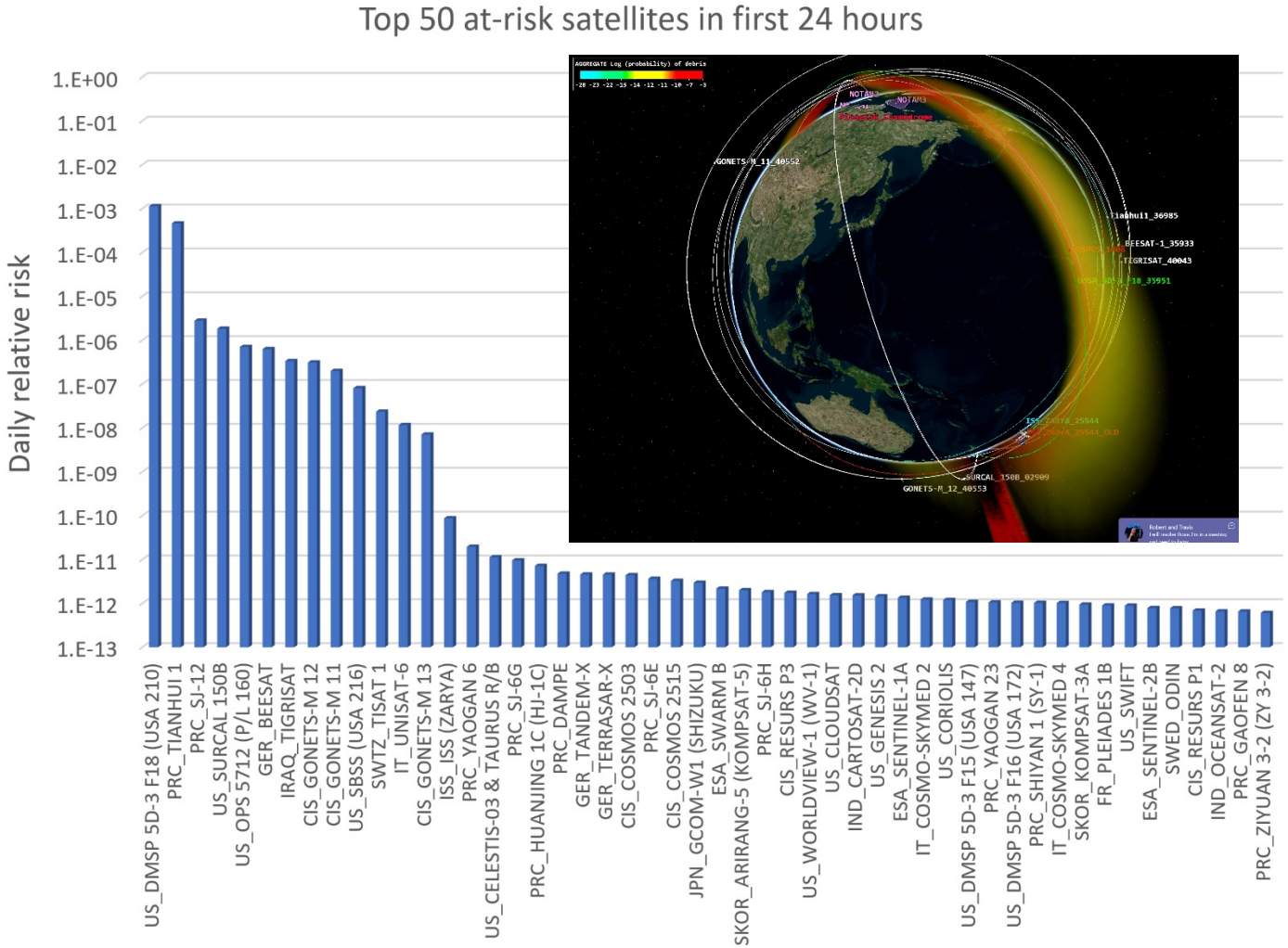
- Used representative COMSPOC breakup scenario to estimate orbit lifetime
  - Half of ASAT debris should reenter within first year.
  - 75% within two years.
  - Remaining debris orbital for ten or more years.
    - Until then, collision risk will remain elevated.
- Likely thousand(s) more fragments are too small to track, yet large enough to kill a satellite ("**Lethal Non-Trackables**", or LNTs).



# Satellites placed at risk

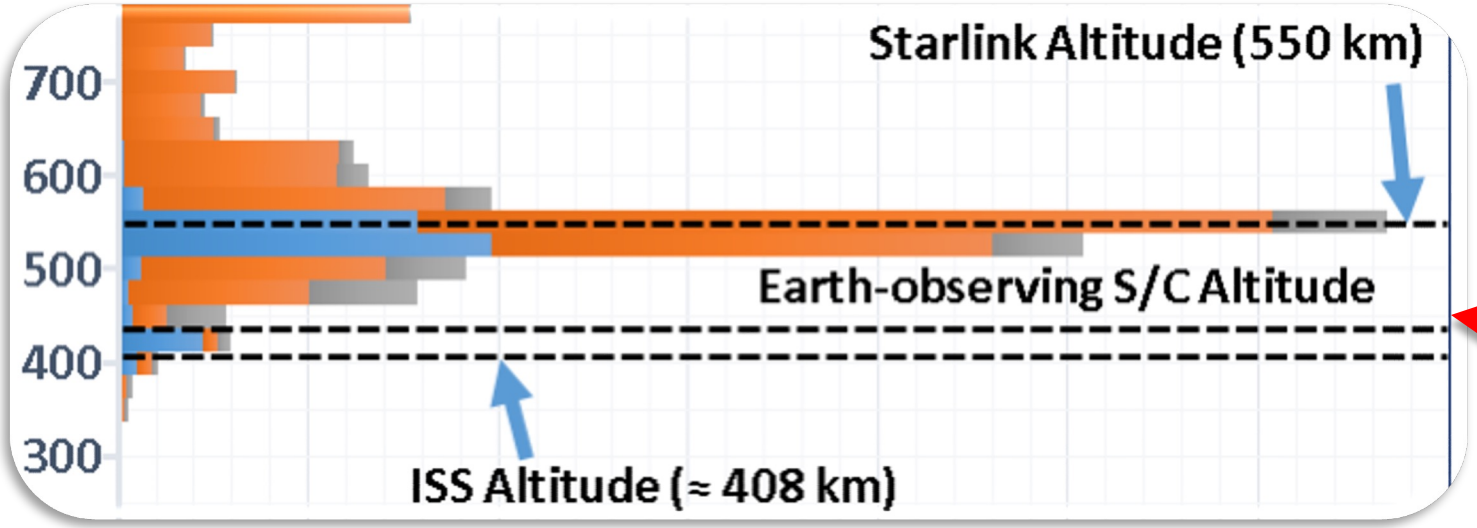
- Integrating risk to active spacecraft through volumetric cloud yields relative risk in first day.
- Two conditions maximize risk
  1) Coplanar (e.g., DMSP on first day)
  2) non-coplanar “red intersect” (Surcal)
- ISS flew thru debris volume 2x/orbit

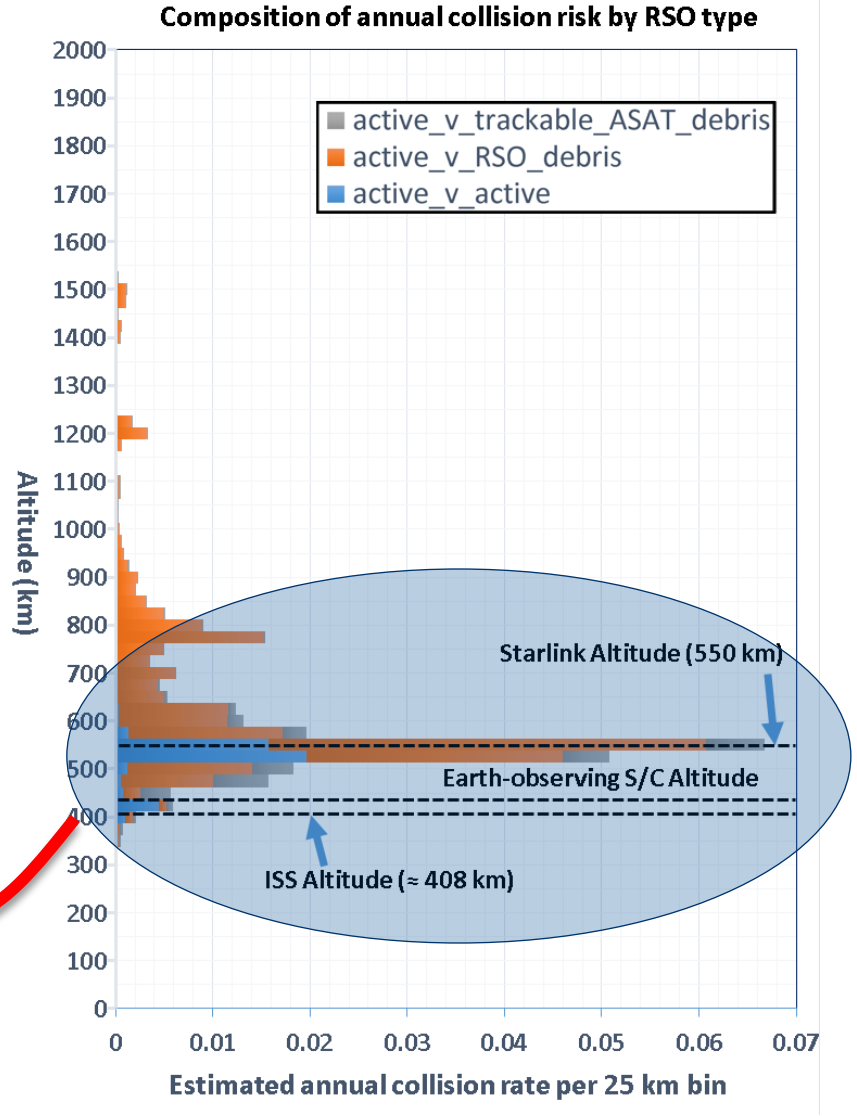


# Increased spacecraft operator workload

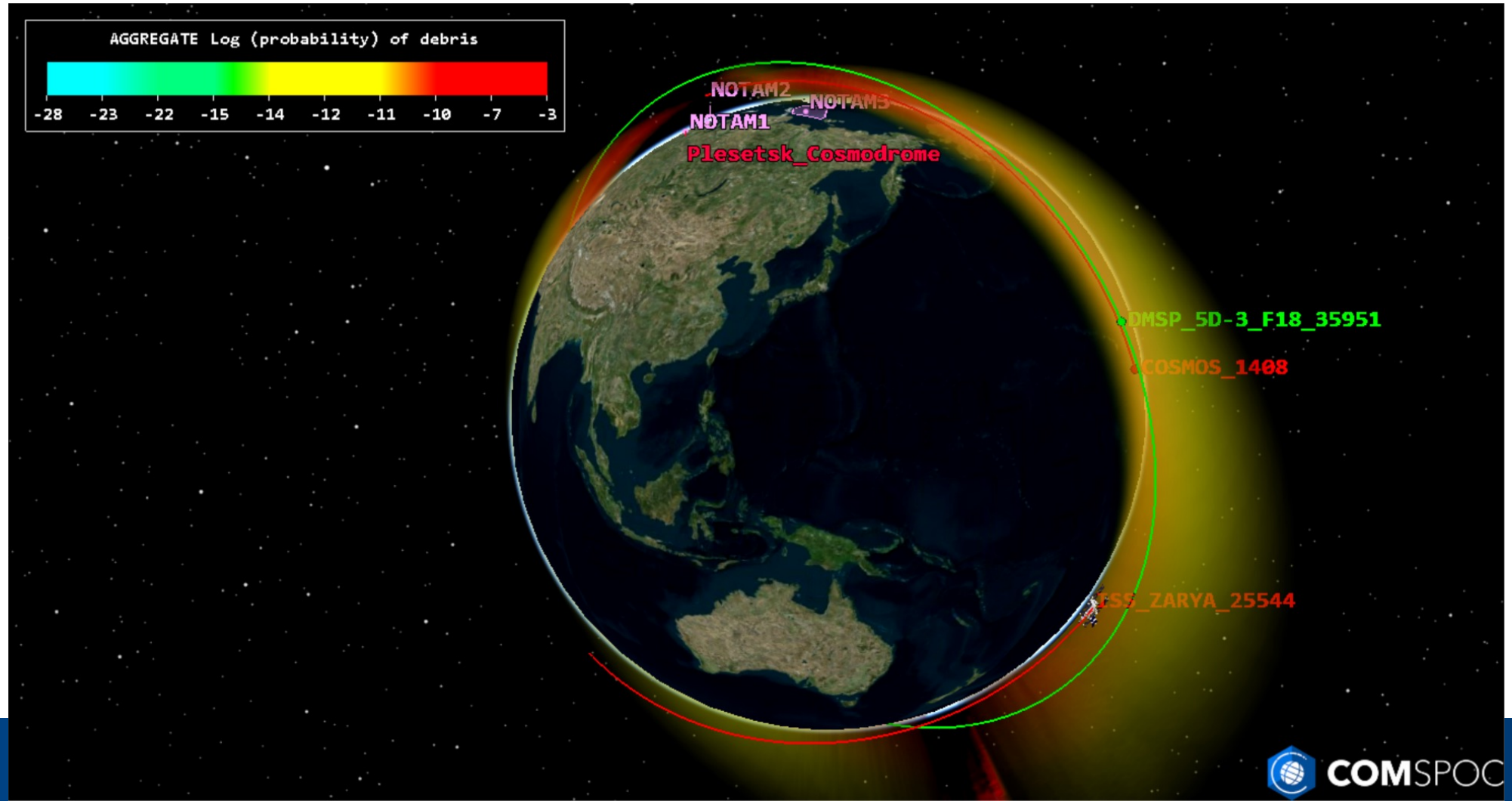
- Satellite operators spend much effort to avoid space debris collisions.
- How much more will be required to avoid COSMOS 1408 fragments?
- Estimated workload (and risk) increases:
  - Up to 126% at the ASAT test altitude (461 km)
  - 20% for Earth-observing spacecraft
  - Up to 10% for the ISS at present.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



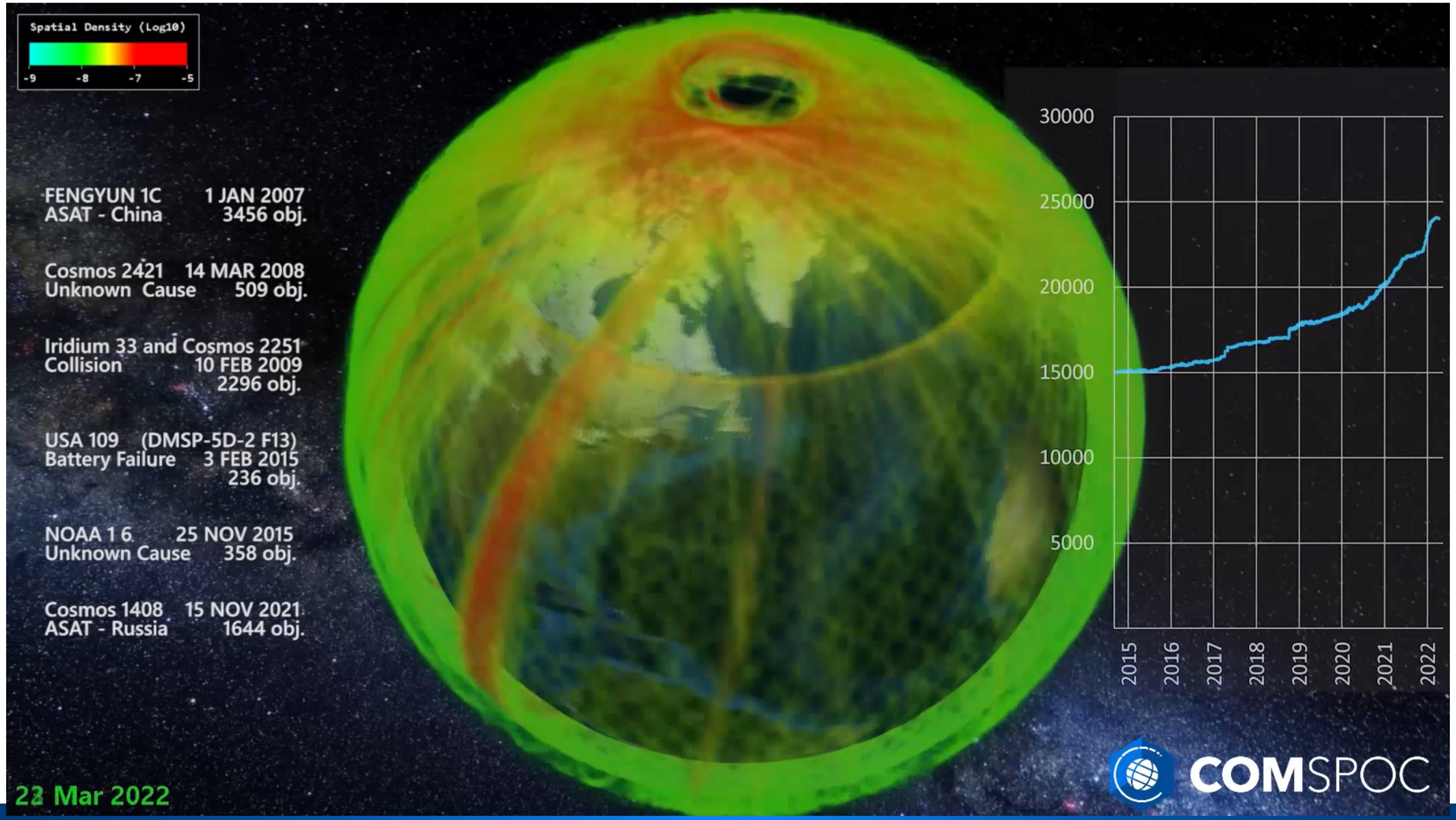



# Where do ASAT-generated debris fragments go?

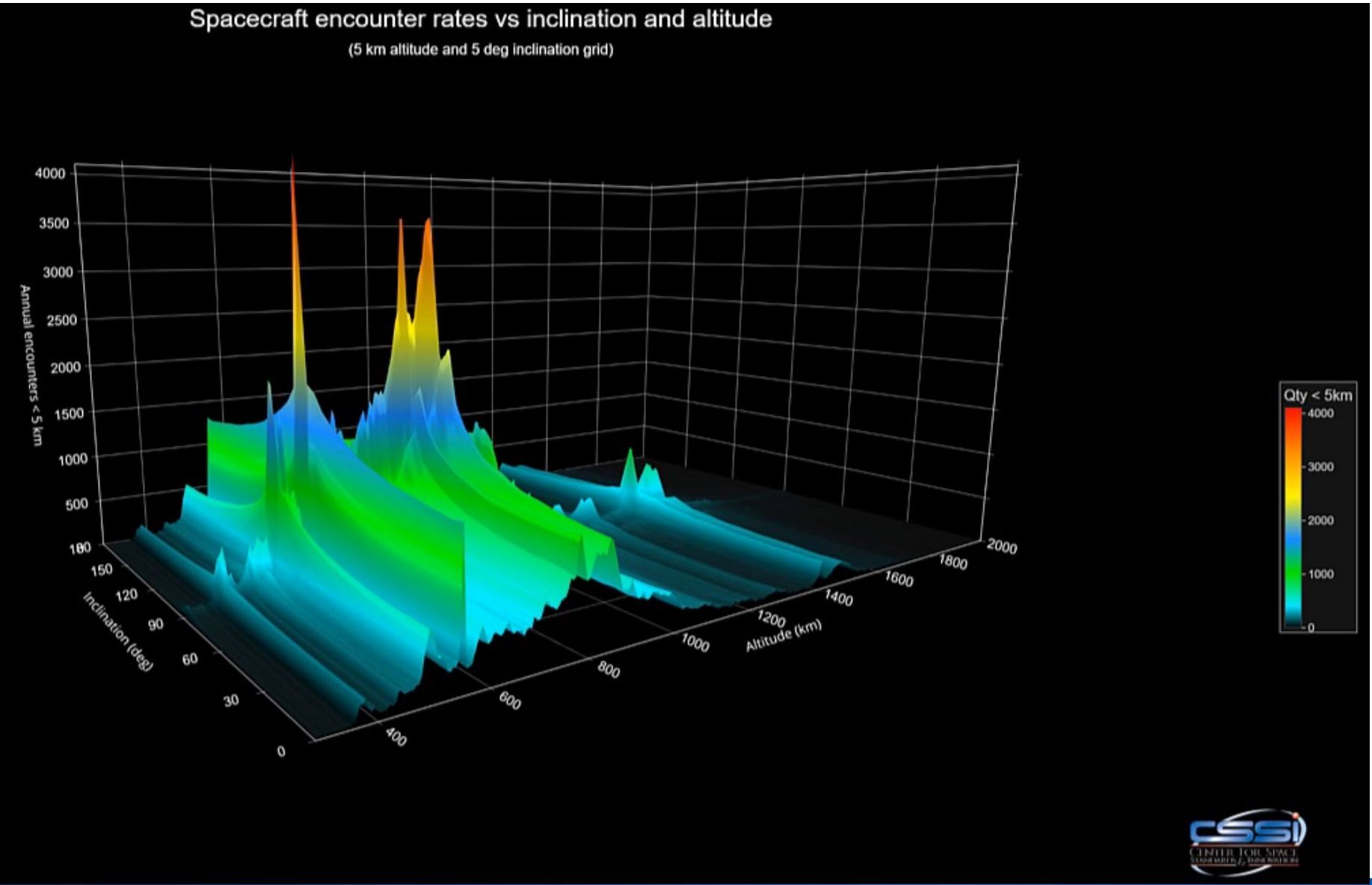
- Aggregate volume debris fragments may have occupied in first 24 hours after ASAT test.
  - Colors denote likelihood that fragments would occupy space, with red being highest risk.



# Resident space objects 1957-2022



# Free Number of Encounters Analysis Tool




## Number of Encounters Assessment Tool

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**

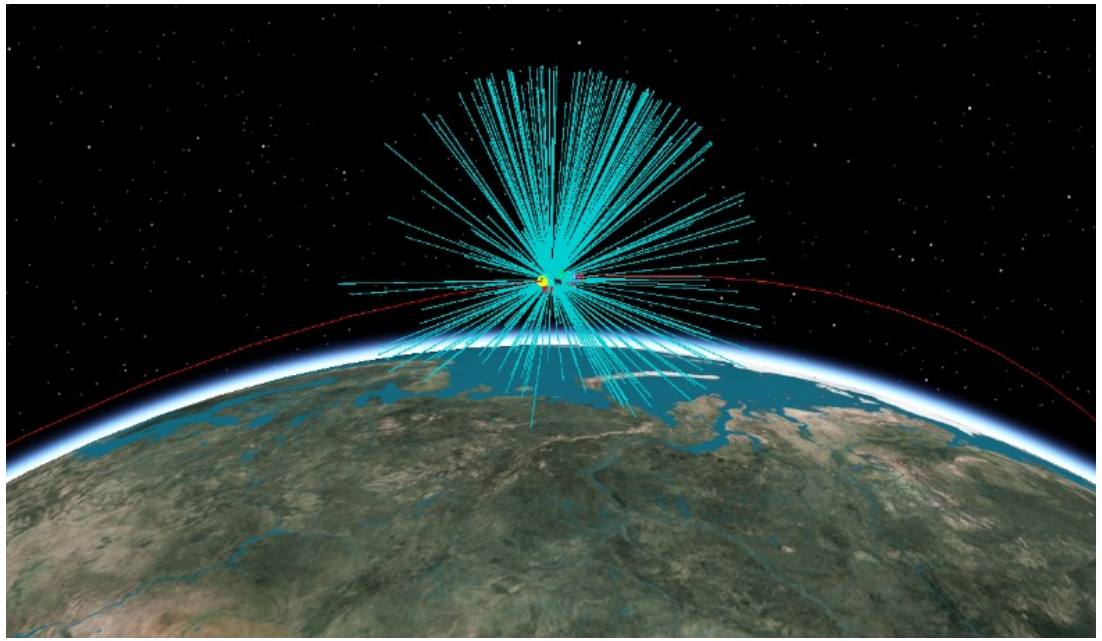
| | |
|---|---|
| Encounter Period: | Days |
| | 1 |
| Number of Satellites: | 64 |
| Warning Threshold (m): | 3000 |
| Maneuver Threshold (m): | 1000 |
| Collision Threshold (m): | 5 |
| Inclination (deg): | 3 |
| Altitude w.r.t. Earth equatorial radius (km): | 330 |
| Space population | 19697 |

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

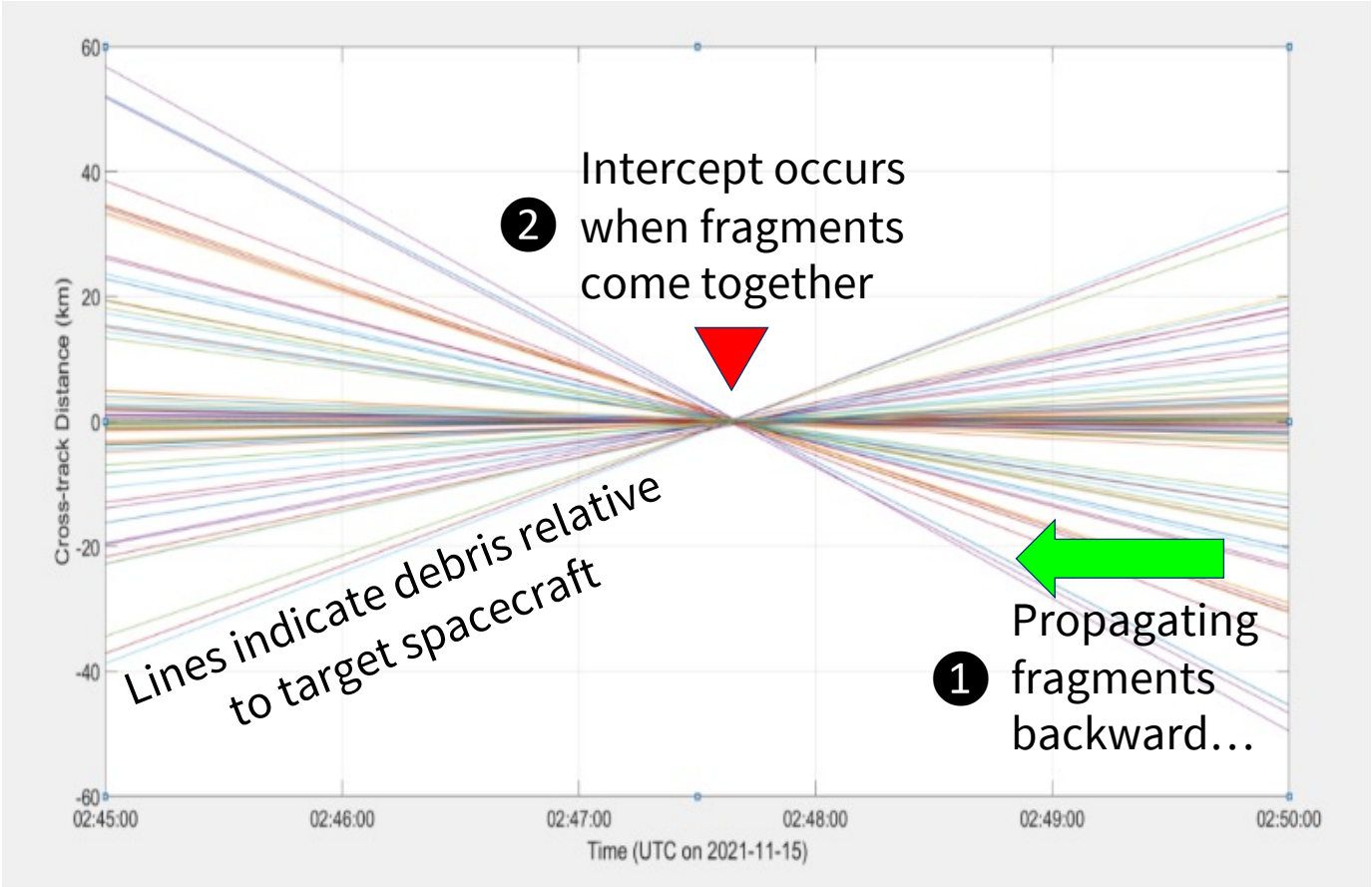
- Estimated intercept time of

  15 Nov 2021 at ≈ 02:47:31.5

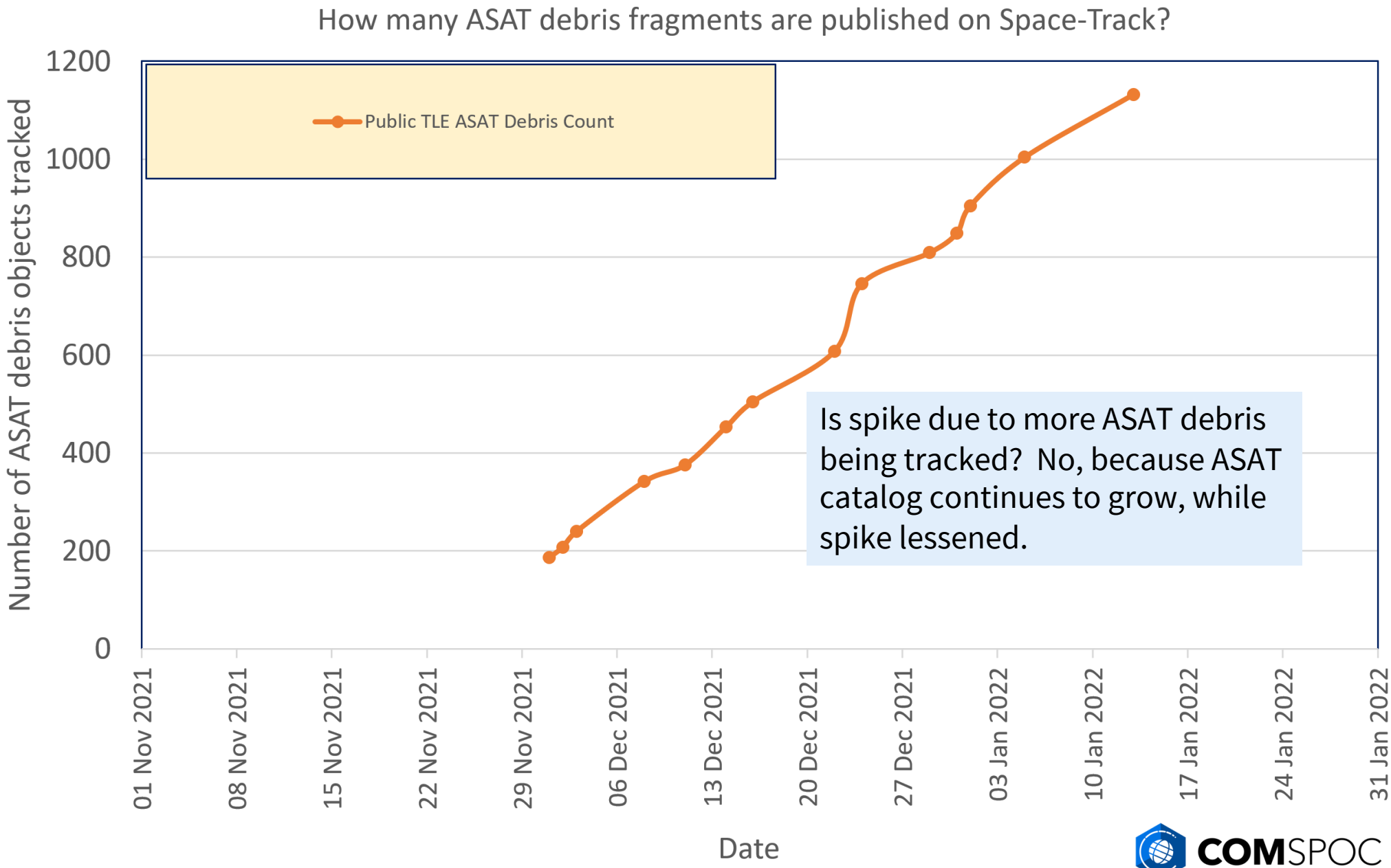
- Imparted velocity changes ≈omnidirectional



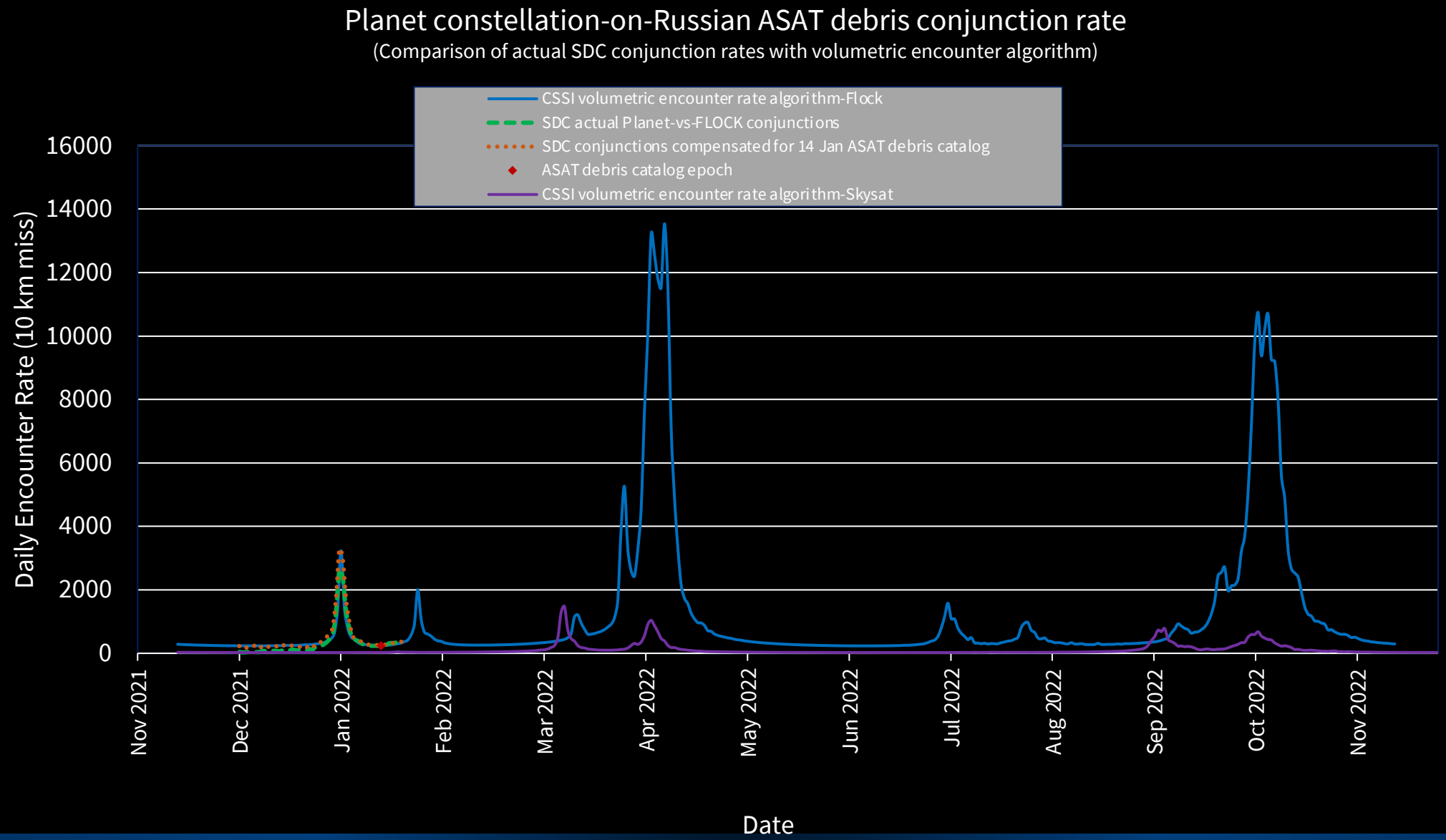
Post-processing of Space-Track debris fragment states



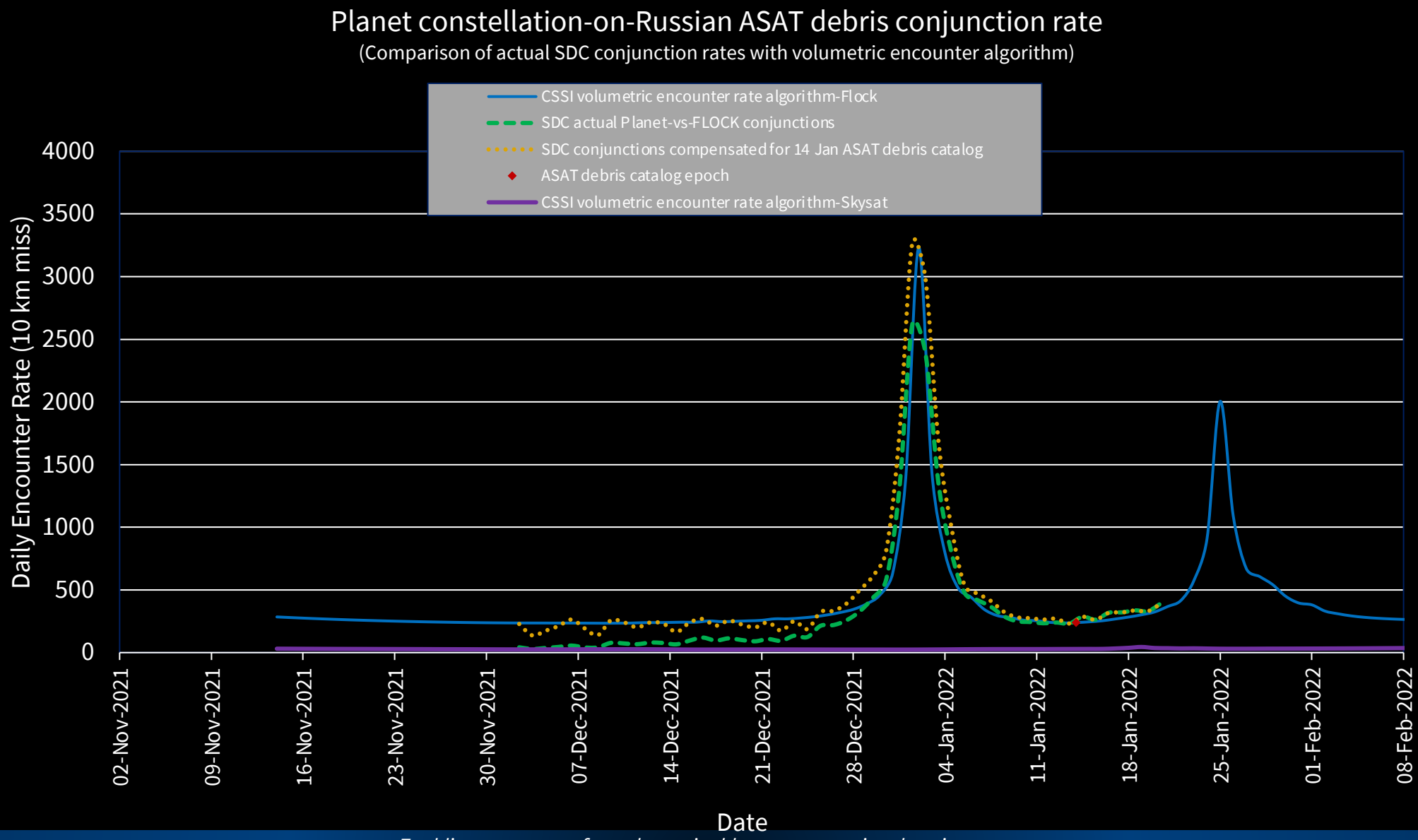
# ASAT debris Space-Track TLE growth



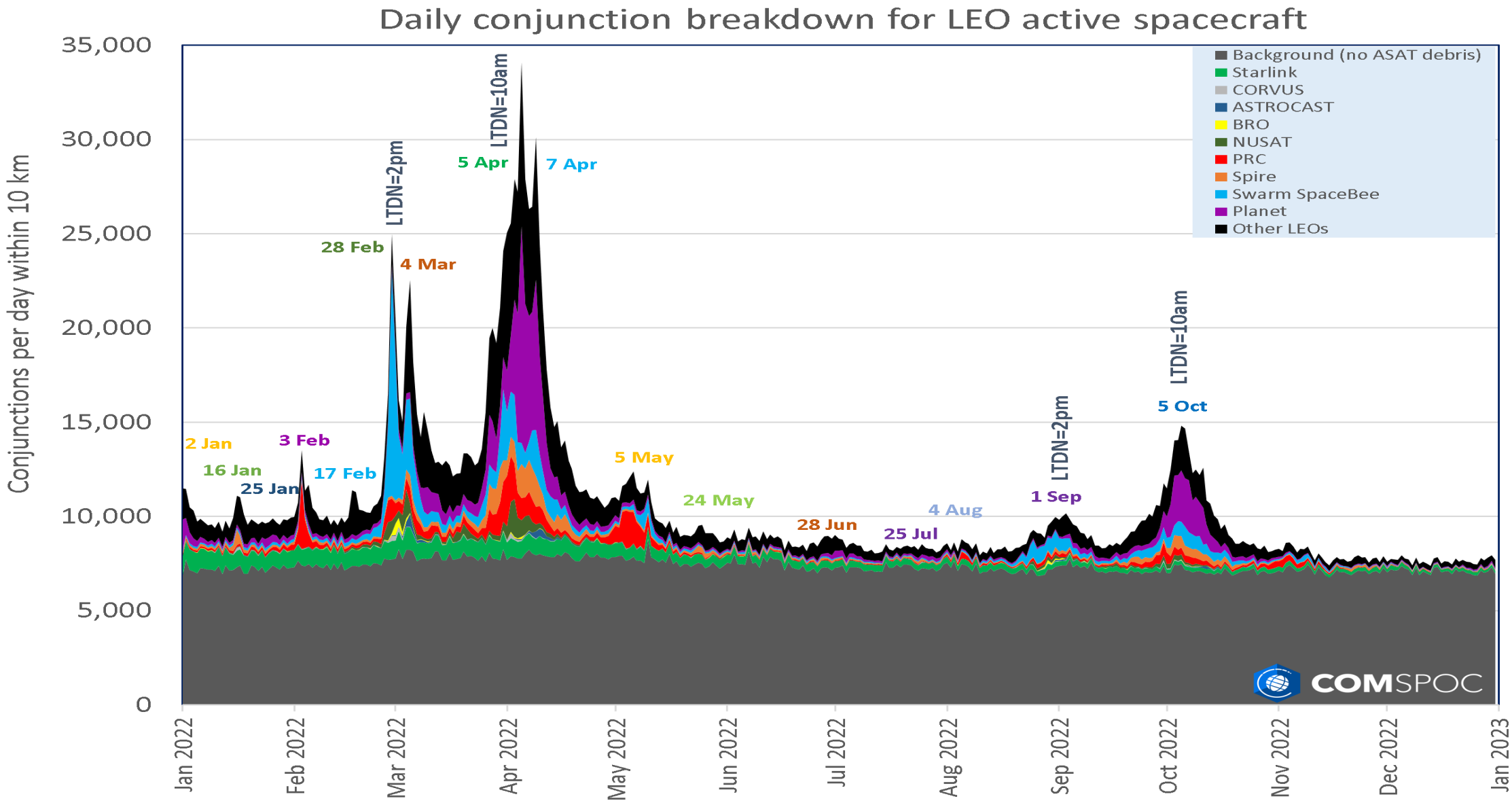
# Analytical Assessment of 2022



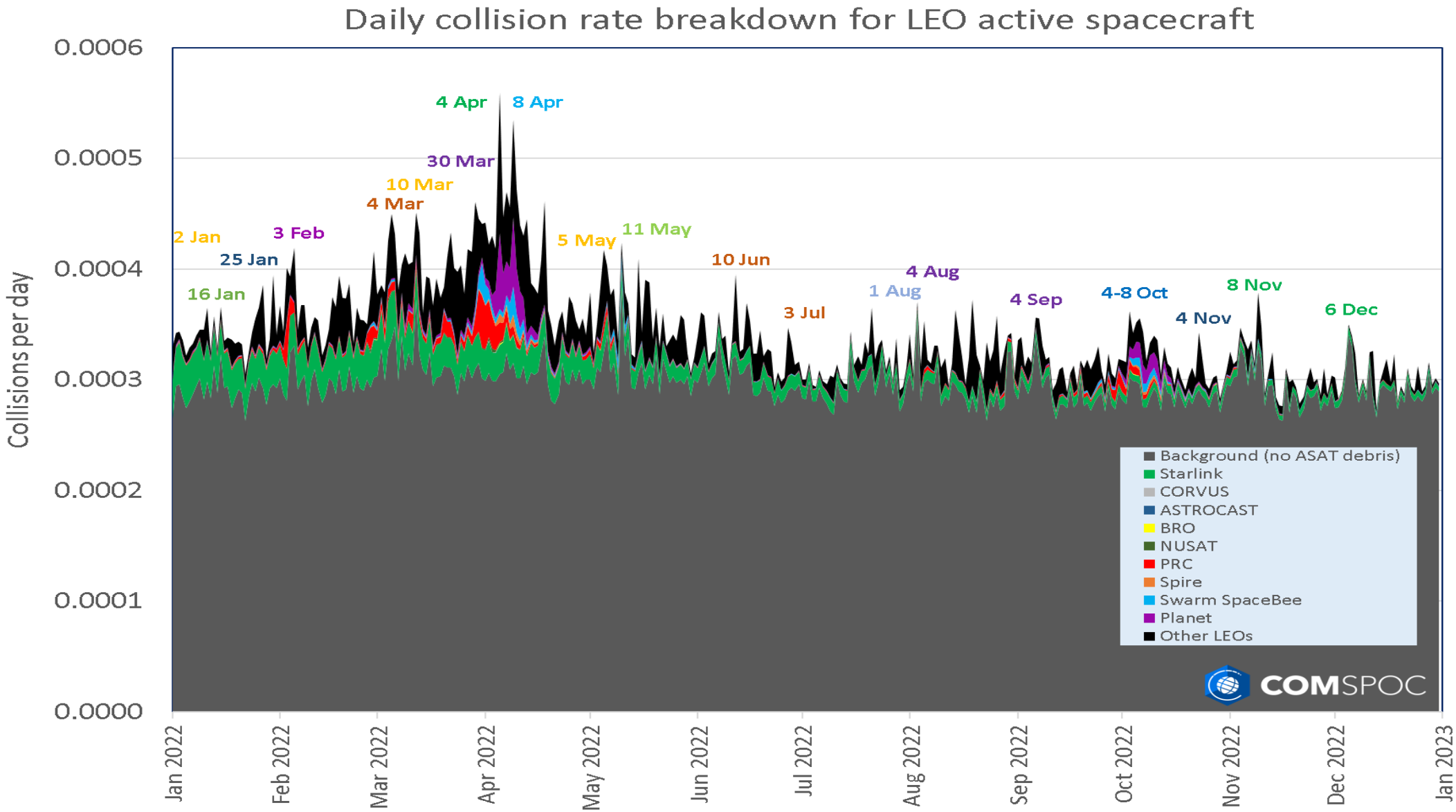
# Actuals v. Model



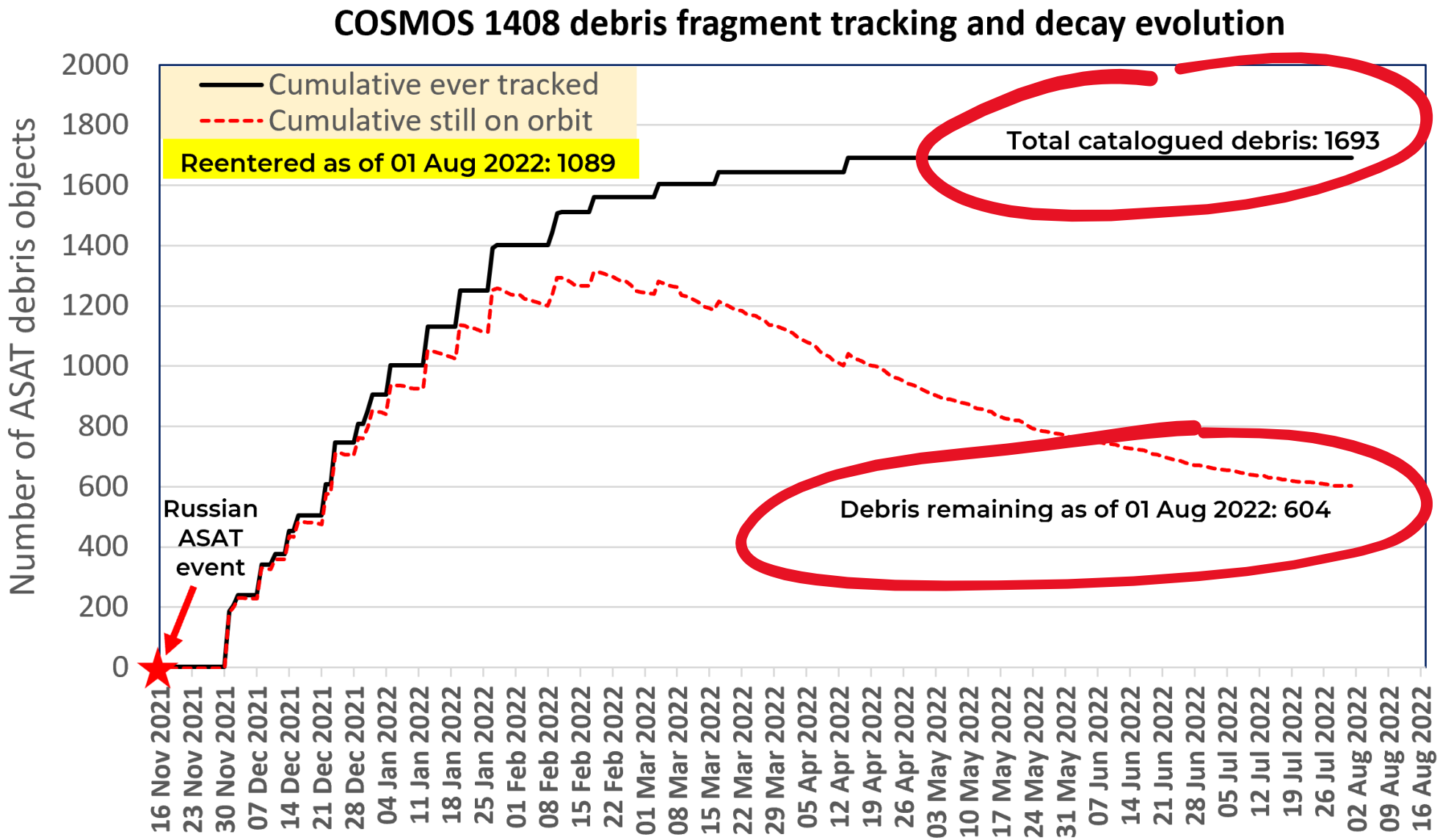
# CubeSats had most distance-based conjunctions w/ASAT debris



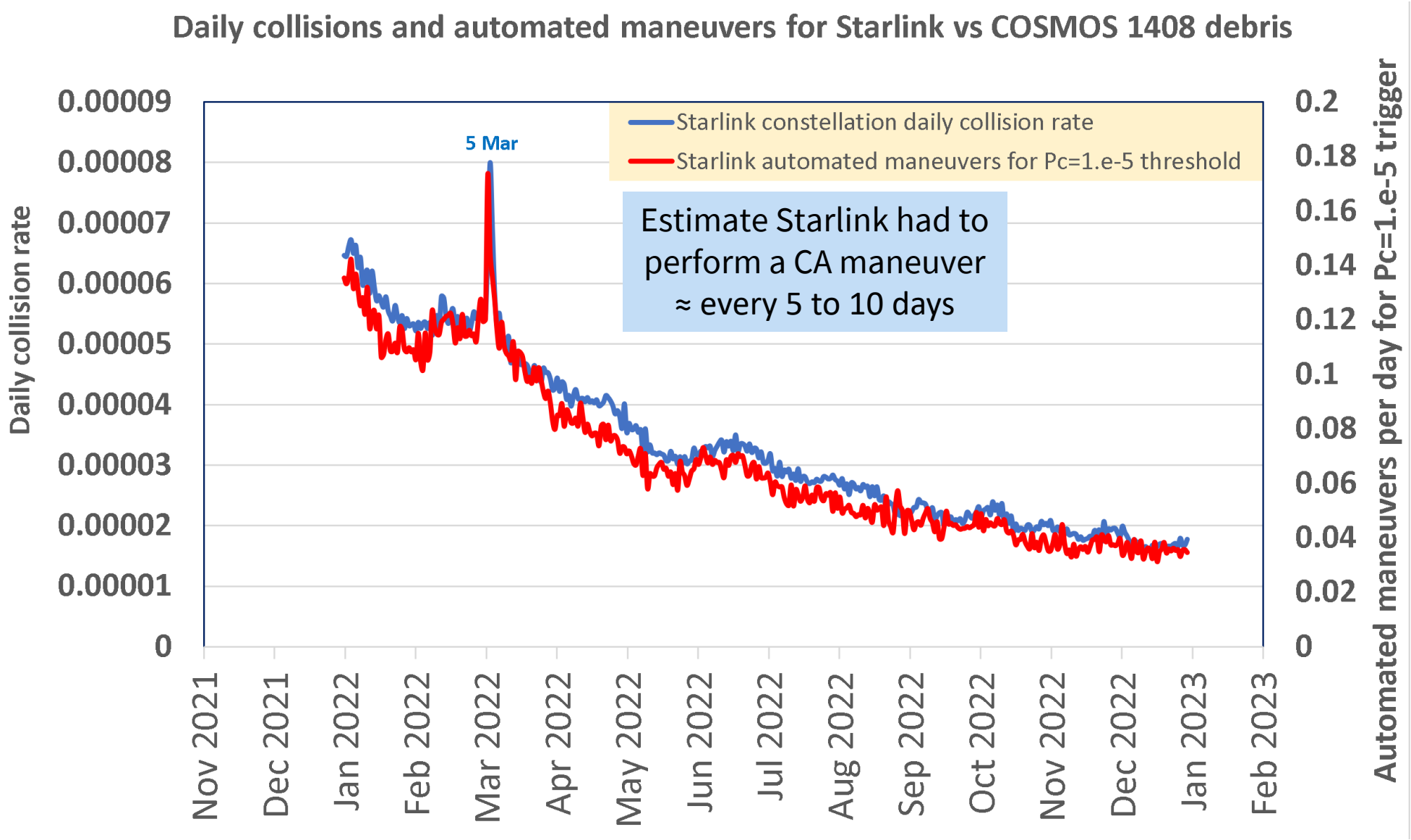
# Meanwhile, larger spacecraft had greatest collision risk increase



# ASAT debris fragment evolution on Space-Track

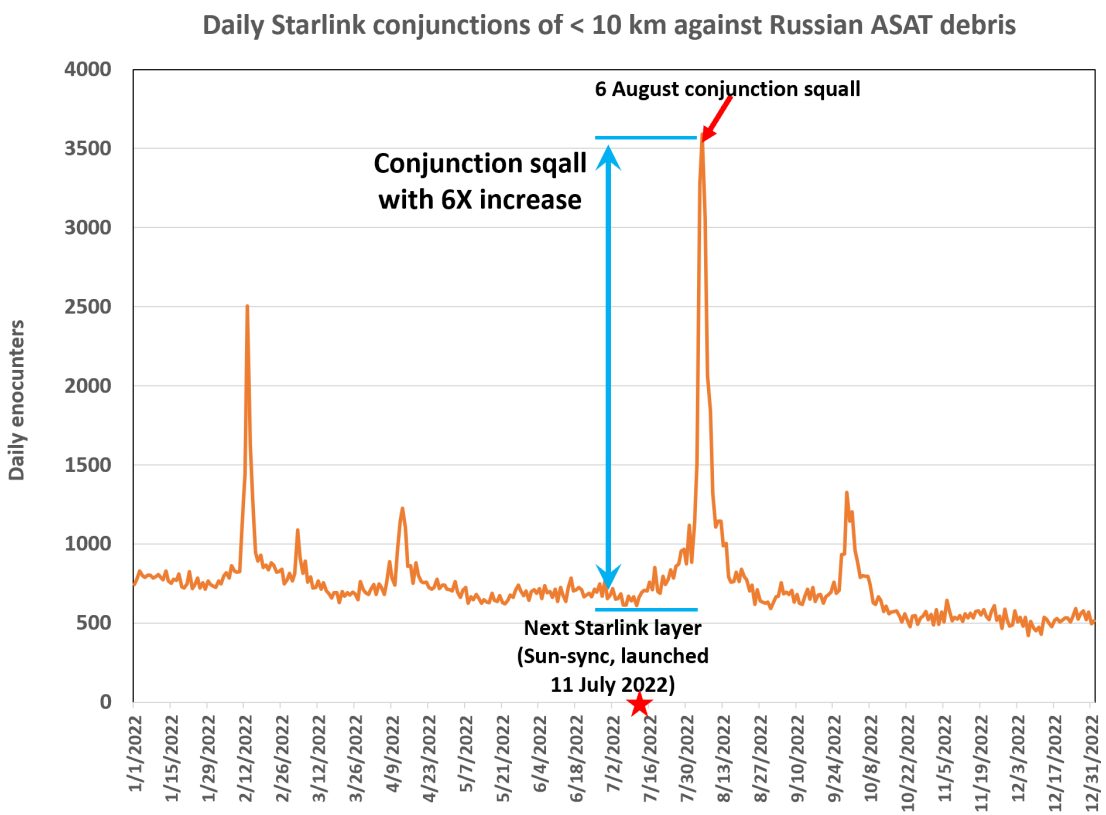


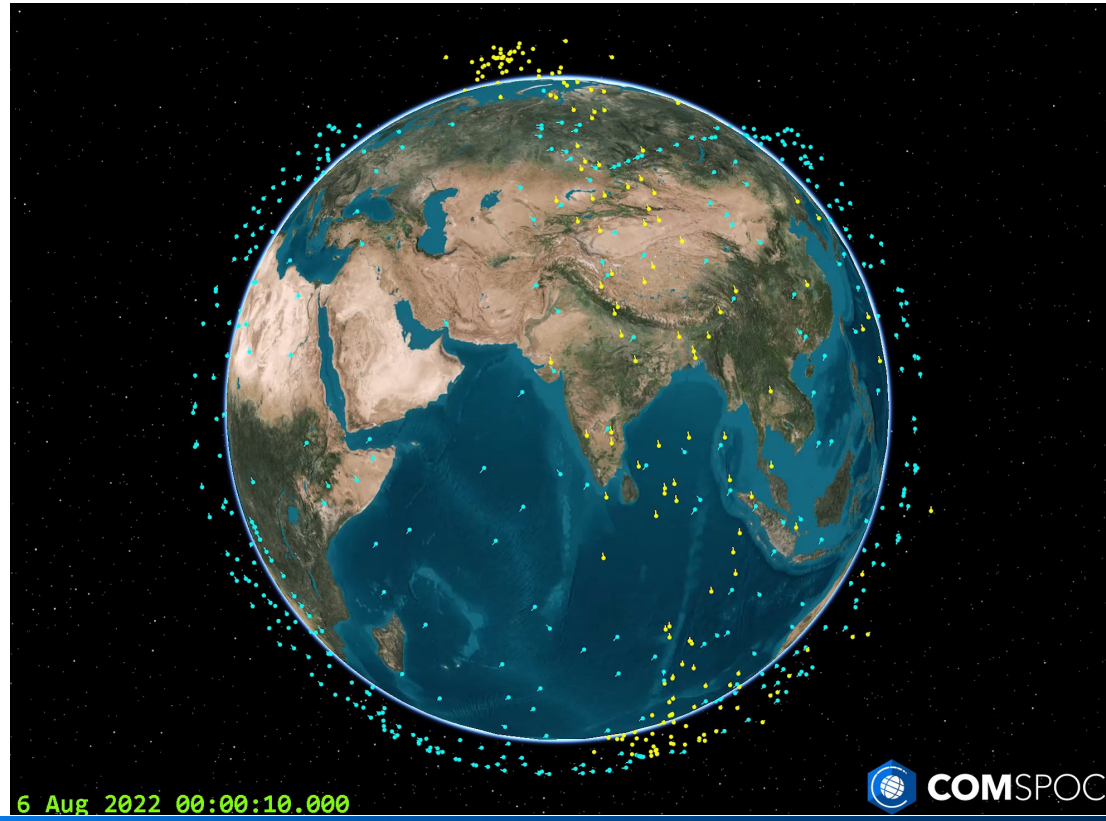
# Starlink: How have risk and avoidance maneuver fuel increased?



# 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.

# Ideal mix of international, inter-agency, and industry contributions

- International
  - UN COPUOS:
    - Treaties
    - Principles
    - Guidelines (incl. Long-Term Sustainability LTS)

- Inter-agency
  - IADC: Debris research and guidelines
  - CCSDS: Data message standards
- National
  - Regulatory
  - Applications
  - Monitoring

- Industry (companies, associations, coalitions):
  - Research for operations, environment
  - Higher-TRL innovations
  - Commercial best practices
  - Conducting operations
  - Manufacturing
- Academia:
  - Research for operations, environment
  - New, typically lower-TRL, innovative techniques, algorithms

# Which triggers prompt high interest in a close approach in LEO?

- All LEO operators monitor probability of collision as a trigger for collision avoidance.
- Some use geometrical metrics together with statistical ones.
- Operators who need to interrupt service to perform collision avoidance accept comparatively high Pc.


**Data courtesy:** SPACE DATA ASSOCIATION

# Summary and next steps

- Significant increase in LEO collision risk, conjunction warnings and avoidance maneuvers
  - Especially for **Earth observing spacecraft**.
  - "**Conjunction squalls**" may overload flight safety systems and spacecraft operators.
  - Forward looking, predictive risk assessment is a gap for satellite operators
- Orbital lifetime of ASAT debris:
  - Half of ASAT debris should reenter within first year.
  - 75% within two years.
  - Remaining debris orbital for ten or more years.
- Next steps: informational briefings
  - Commercial satellite operators; collaboration with other SSA/STM service providers
  - National Security Space: USSF, 18 SPCS, National Space Council, …
  - Civil space: NASA, Dept of Commerce
  - International community