Understanding and Mitigating Data Limitations for Conjunction Assessments

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Overview

- Where We Are Today
- Clear & Present Dangers (with Orbital Data)
- Addressing These Dangers
  - Examples
- Issues with Data Formats (CDMs)
- How to be Vigilant (Conclusions)

Where We Are Today

- Many users still use GP data for CA
  - Easy availability of data and tools to use it
  - Limited access to operator ephemerides or SP data
    - Limited availability
    - Sheer data size/amounts, plus bandwidth, storage, processing requirements
    - Operator ephemerides only available for active satellites
    - Data latency
  - May not trust central CA screening
    - Military centers lack transparency and undermine international trust

Clear & Present Dangers (with Orbital Data)

- SGP4 & GP data defined in the 1970s
  - Efficient processing for limited CPU, storage, and bandwidth
  - Accuracy not limited by simple force models but by data and fit spans
- SSN sensors designed not to overload bandwidth and ops centers
  - Use EKF to fit obs and send back first/mid/last points (not as tracks)
  - Sensors primarily located in North America
  - Non-cooperative tracking for ALL RSOs
- SP data not fundamentally better than GP data
  - Better, more flexible force models, but same obs and batch processing
  - Used with eGP to fit SGP4 to SP data to produce GP catalog (linked)
- No force models for maneuvers in SGP4, SGP4-XP, or SP

Clear & Present Dangers (with Orbital Data)

- 18 SDS does NOT use operator-provided ephemerides uploaded for CA screening for use in SSA
  - That means GP, XP, and SP data lacks information on recent maneuvers that could be used to maintain track custody
- SupGP data is only available for active satellites
  - Many of these problems apply to dead satellites, rocket bodies, & debris
  - No SupGP data (yet) for most Chinese, Russian, Indian, or Japanese sats

Addressing These Dangers

- SOCRATES started using operator ephemerides in 2007
  - Positive IDs, no obs misassociation, with recent & planned maneuvers
- Simultaneously, CelesTrak saw the need for SupGP data
  - Fit independent operator data with SGP4 to produce GP-compatible data
  - Allows continued use of widely available SGP4-based tools
  - Allows use of far more compact data sources and reduces latency
  - Can and should be used to highlight issues with GP, XP, and SP data
    - Example: Continued loss of GPS satellites following pre-announced maneuvers
    - Example: Active satellites on Lost List when current SupGP data is available
    - Example: Constant maneuvering of Starlink & other pLEO satellites

Example: Lost GPS Satellite

SupGP vs. GP Comparisons

Current as of 2025 Sep 13 01:10:19 UTC (Day 256)

Element Set Age (days)							
< 0.0	0.0–0.5	0.5–1.0	1.0–1.5	1.5–2.0	2.0–2.5	2.5–3.0	> 3.0

RMS Difference (km)						
0–5	5–10	10–15	15–30	30–60	60–100	> 100

Results Summary

RMS span = 2025-09-13 01:10:02.021 UTC + 6 hours
9,734 SupGP element sets vs. 9,468 RSOs
Time step = 1 min
RMS calculation runtime = 11.794 sec

STARLINK	ONEWEB	PLANET	KUIPER	IRIDIUM	**GPS**	GLONASS
SES	INTELSAT	TELESAT	ORBCOMM	ISS	CSS	CPF	AST
UNIQUE	ALL

Show 25 entries Search:

NORAD Catalog Number	International Designator	SupGP			18 SDS GP		
		Name	Data Age (days)	RMS (km)	Name	Data Age (days)	RMS (km)
62339	2024-242A	GPS BIII-7 (PRN 01)	-1.66	0.324	NAVSTAR 83 (USA 440) &	10.88	89.269

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Example: Active Satellites on Lost List

International Designator	NORAD Catalog Number	Name	Period (minutes)	Inclination (degrees)	Apogee Height (km)	Perigee Height (km)	Eccentricity	Latest Data	GP Age (days)
2022-080C	53107	ASTROBIOCUBESAT [+]	224.26	70.17	5,866	5,833	0.0013489		987.92
2022-080D	53108	TRISAT-R [+]	224.25	70.17	5,865	5,833	0.0013109		987.46
2023-109G	57487	NULION [+]	94.97	5.01	520	514	0.0003778		645.22
2023-109F	57486	GALASSIA-2 [+]	95.19	5.00	529	527	0.0001321		636.21
2023-109E	57485	ARCADE (INSPIRESAT 4) [+]	95.07	5.00	528	515	0.0009185		629.20
2015-052G	40936	EXACTVIEW 9 [+]	97.32	6.00	638	623	0.0010627		615.98
2023-109D	57484	SCOOBII [+]	95.13	4.95	528	521	0.0005430		615.57
2023-109C	57483	ORB-12 STRIDER [+]	95.05	5.00	530	511	0.0013742		611.27
2023-109B	57482	VELOX-AM [+]	95.03	5.00	528	512	0.0011546		611.26
2024-032B	58988	VEP-4 [+]	98.16	98.12	672	670	0.0001717		569.63
2024-247P	62390	2024-247P [+]	94.90	45.00	515	513	0.0001451		250.33
2024-233C	62258	PROBA-3 OSC [+]	1,179.63	59.26	60,548	660	0.8096974		221.52
2015-052B	40931	LAPAN-A2 (IO-86) [+]	97.38	6.00	642	624	0.0012733		104.87
2024-001A	58694	XPOSAT [+]	97.42	5.99	642	628	0.0009900		88.22
2023-098C	57770	CHANDRAYAAN-3 PROPULSION MODULE [+]	17,501.16	33.93	308,388	125,438	0.4096658		77.53
2018-038A	43435	TESS [+]	18,553.03	56.25	333,626	117,919	0.4645845		49.27
2008-051A	33401	IBEX [+]	13,151.04	46.30	312,517	43,843	0.7278850		49.09
2019-067B	44625	MEV-1 [+]	1,436.01	0.34	35,786	35,783	0.0000340	*G	43.12
2020-094A	47234	GECAM-A [+]	96.07	28.99	578	563	0.0010723		42.57
2024-230A	62216	COSMOS 2580 [+]	103.10	67.15	909	901	0.0005572		42.49
2020-094B	47235	GECAM-B [+]	95.99	29.00	574	559	0.0010693		42.47
2025-153B	64867	O3B MPOWER F10 [+]	200.03	8.75	7,061	2,842	0.1862051		38.11
2025-153A	64866	O3B MPOWER F9 [+]	201.56	8.48	7,124	2,895	0.1856592		36.11
2023-109A	57481	DS-SAR [+]	95.10	4.99	540	507	0.0023376		34.18
2015-066A	41032	COSMOS 2510 [+]	718.51	63.19	39,316	1,075	0.7195458		28.44

Example: Active Satellite on Lost List Solution

NORAD Catalog Number 64867

Current as of 2025 Sep 12 23:18:24 UTC (Day 256)

Latest SupGP (TLE format) Data

Element Set Age (days)						
0–5	5–10	10–15	15–20	20–25	25–30	> 30

Show 25 entries

Search:

International Designator	NORAD Catalog Number	Name	Period (minutes)	Inclination (degrees)	Apogee Height (km)	Perigee Height (km)	Eccentricity	Latest Data	SupGP Age (days)
2025-153B	64867	O3B MPOWER F10	234.74	6.56	7,978	4,476	0.1388903		1.81

Notes:
- ⓘ Link to additional information
- Link to custom search query for related news, information, and images
- Link to raw SupGP (TLE format) data
- ⓘ and in the International Designator column are for all objects associated with that launch
- *D Link to plot of apogee, perigee, and eccentricity for potential decays (apogee < 300 km)
- *G Link to plot of longitude of the ascending node (LAN) and mean semi-major axis (SMA) for GEO altitude -200 km to +400 km
- Link to plot of orbit data: right ascension of the ascending node (RAAN), mean semi-major axis (SMA) altitude, eccentricity, inclination, and argument of perigee.
- An & in front of provides a link to the GP plot for cases where the SupGP data is more than 3 days old.

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Example: Constant maneuvering of pLEO satellites

Show 10 entries

Search:

NORAD Catalog Number	International Designator	SupGP			18 SDS GP		
		Name	Data Age (days)	RMS (km)	Name	Data Age (days)	RMS (km)
64867	2025-153B	O3B MPOWER F10	1.80	43.785	O3B MPOWER F10 &	38.10	12785.848
64866	2025-153A	O3B MPOWER F9	1.80	37.664	O3B MPOWER F9 &	36.10	8888.851
65154	2025-171Y	KUIPER-00118	0.17	0.958	KUIPER-00118 &	2.51	4111.598
63733	2025-088K	KUIPER-00018	0.16	1.800	KUIPER-00018 &	2.87	2936.140
65193	2025-175V	STARLINK-34950	0.19	0.898	STARLINK-34950 &	1.40	2583.319
65222	2025-176AA	STARLINK-34999	0.19	0.474	STARLINK-34999 &	1.61	2580.570
65191	2025-175T	STARLINK-34948	0.20	0.870	STARLINK-34948 &	1.40	2472.194
65197	2025-175Z	STARLINK-34952	0.20	0.899	STARLINK-34952 &	1.40	2306.969
65252	2025-179T	STARLINK-34961	0.20	0.548	STARLINK-34961 &	0.60	2279.272
58731	2024-005D	STARLINK-31204 *D	0.21	177.935	STARLINK-31204 D&	0.50	2278.631

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Example: Effect on Starlink Matching

Starlink Matches by Launch (GP vs. SupGP)

Current as of 2025 Sep 13 00:32:51 UTC

2025			
2025-191 2	2025-189 1	2025-184 0	2025-179 6
2025-176 11	2025-175 5	2025-167 0	2025-165 2
2025-161 17	2025-158 2	2025-157 0	2025-152 8
2025-150 7	2025-147 9	2025-144 5	2025-142 7
2025-139 1	2025-137 1	2025-133 8	2025-130 9
2025-129 0	2025-127 5	2025-126 1	2025-124 7
2025-123 8	2025-120 8	2025-119 11	2025-117 0
2025-113 8	2025-112 0	2025-111 8	2025-110 2
2025-107 7	2025-102 1	2025-101 6	2025-099 6
2025-098 0	2025-095 7	2025-094 9	2025-093 1
2025-092 4	2025-091 0	2025-089 5	2025-087 3
2025-085 9	2025-083 0	2025-076 5	2025-075 11
2025-071 4	2025-070 6	2025-069 5	2025-065 8
2025-063 4	2025-057 11	2025-053 4	2025-048 7

Issues with Data Formats (CDMs)

- Even if you are being screened with operator-provided ephemerides, there is a serious flaw in the CDM format
  - CDMs ‘convert’ the ephemeris provided to produce a state vector at TCA
  - They do NOT interpolate, they ‘fit’ the ephemeris, to match the force model, which does not not include maneuvers
  - Result is that CDMs ‘smooth’ out the maneuvers, undermining the fundamental advantage of operator-provided ephemerides
  - CDMs should use the appropriate CCSDS data format—OEM, OPM, or OMM provided—not ‘convert’ to yet another ‘format’

How to be Vigilant (Conclusions)

- Do not blindly trust the quality of the orbital data used
  - Always check your work—CelesTrak makes that easy
- Trust—supported by transparency & data sharing—is key
- We must encourage all satellite operators to share
  - Knowing where your satellites are located won't help you avoid close approaches with other's satellites if you each have different views of what's going on because you aren't sharing
- Operational status is important, too
  - Knowing which satellites can or cannot maneuver is invaluable

One More Thing…

- We run out of 5-digit catalog numbers at 70000 not 100000
- That will likely happen before summer 2026
- Documentation for how to prepare can be found at:
  - https://celestrak.org/NORAD/documentation/gp-data-formats.php
- Users need to prepare software to handle CSV or JSON formats since TLE format does not support 6-digit catalog numbers
- I am here all week if you have questions and we can set up a get-together to discuss, if there is interest (see me afterwards)