



Workshop on Long Term Sustainability

2024-02-06

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Canadian Space
Agency

Agence spatiale
canadienne



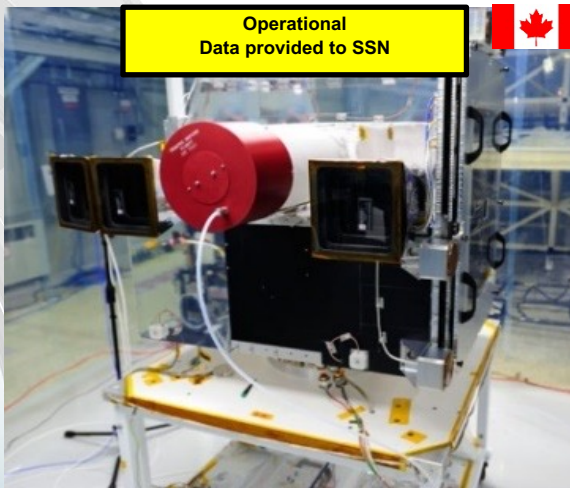
Background

- Similar to many space agencies, CSA initiated space debris developments about 12 years ago in order to better assess risks affecting its space assets and provide escape maneuvers and mitigation to protect them
- As part of international cooperation, and as per its mandate, CSA has been offering and continues to offer help and support to other groups and nations in this field
- Inline with the LTS guidelines, Canada is active multiple fronts such as the operational side, R&D side as well as the Policy side

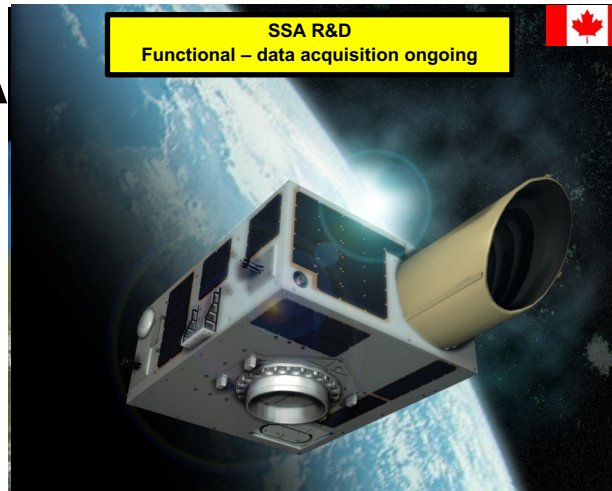
Operational Challenges

- Things are not perfect in observations and measurements especially with satellites maneuvering frequently – hence ephemeris sharing periodically
 - Covariances precision
 - Precision of shared ephemeris is key
- GPS interference/reliability detriment to space safety
 - Satellites depend on GPS, especially NEOSAT, sensitivity to ground activities related to GPS ..
- Space weather predictions, atmospheric density and solar radiation pressure are less reliable during solar max
- Solar max does affect predicted ephemeris covariance precision and therefore maneuver accuracy and frequency;
- The more maneuvers the high space safety risk....

Operational
Data provided to SSN



SSA R&D
Functional – data acquisition ongoing



SSA R&D



• Sapphire (DND)

- Owner: Dept of National Defence
- Mission: operational space surveillance
- Bus: Surrey SSTL 150
- Payload: 15cm V-band anastigmat
- Sensitivity: Mv 16
- Tracking Accuracy: < 3 arcseconds
- Orbit: 785 km dawn-dusk
- Tasking: 22 Wing North Bay/ CanSpOC
- Operator: MDA (Richmond, BC)

■ NEOSSat (DND/CSA)

- Owner: Canadian DND / CSA
- Mission: SSA R&D, Asteroid, comet & exoplanet astronomy
- Bus: MOST bus lineage
- Payload: 15cm V-band Maksutov
- Sensitivity: Mv 16
- Tracking Accuracy: 2.4 arcseconds
- Orbit: 785 km dawn-dusk
- Tasking: DRDC Ottawa, CSA Observers
- Operator: CSA, St Hubert, QC

■ Ground-Based Optical Space Surveillance Observatory (SSO) (1 of 3 shown)

- Owner: Defence R&D Canada Ottawa
- Mission: Space Surveillance, SSA R&D
- Located: Suffield, AB, Ottawa, ON, Valcartier, QC
- Instrument: 35cm V-band, EMCCD/Conventional CCD
- Sensitivity: Mv 16
- Tracking Accuracy: 1.5 arcseconds

CRAMS Overview

... for operators, by operators

Objective

Immediately following a conjunction data message notification, deliver necessary analysis to mission team to make decision on collision avoidance maneuver

Architecture

- Automation engine around Matlab & STK
- User-friendly Excel and Text files delivered via email
- Configurable for additional missions with no overhead
- Hot backup servers to ensure system up-time

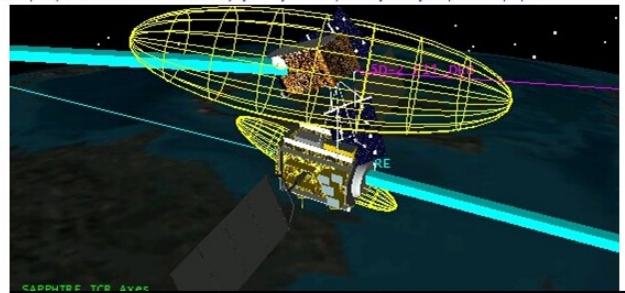
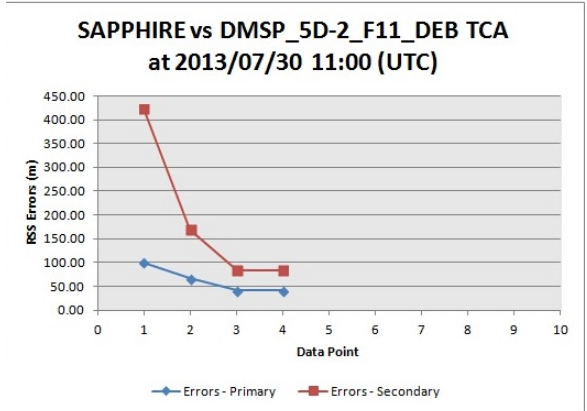
CRAMS 3.5
 Latest Datapoint (UTC) 2013-07-29 23:18:27
 TCA (UTC): 2013-07-30 11:00:00
 Run at: 2013-12-03 15:54:46
 Days to TCA 0.49 Hours to TCA 11.69

Configurable Parameters			Thresholds of Concern:	
Error scaling:	1	1	1	1
RSS Errors limit:	1700			Probability of Collision: 1.00E-04
			Depth of Intrusion:	

Date UTC	Ref #	Data Type	Miss distance (m)				Probability of Collision	Depth of Intrusion	Approach Angle (deg)	RSS Errors (m)		CRAMS Recommendation
			Radial	In-track	Cross-track	Overall				Primary	Secondary	
2013-07-27 18:08:38	1	CSM	95.2	0.1	24	98	1.17E-04	0.44	162.58	100.94	423.19	Action Required (PoC>1e-006, Miss<200m, Good data)
2013-07-28 19:51:07	2	CSM	60.5	-4.7	23.4	65	2.19E-04	0.46	162.58	66.74	169.83	Action Required (PoC>1e-006, Miss<200m, Good data)
2013-07-29 19:11:46	3	CSM	44.8	0.9	3.2	44	4.52E-04	0.36	162.58	41.81	84.57	Action Required (PoC>1e-006, Miss<200m, Good data)
2013-07-29 23:18:27	4	CSM	44.8	0.3	3.1	44	4.81E-04	0.36	162.58	41.81	84.57	Action Required (PoC>1e-006, Miss<200m, Good data)
	5											
	6											
	7											
	8											
	9											

NO WARRANTIES: The enclosed information is provided "as is" and with no warranty, either express or implied, as to the condition or suitability of the information, nor its fitness for a particular purpose

Objects	Name	SSC #	Type	Country	Launch
	SAPPHIRE	39088	PAYLOAD	CA	2013-02-25
	DMSP_5D-2_F11_DEB	28317	DEBRIS	US	1991-11-28
TCA	2013/07/30 11:00				

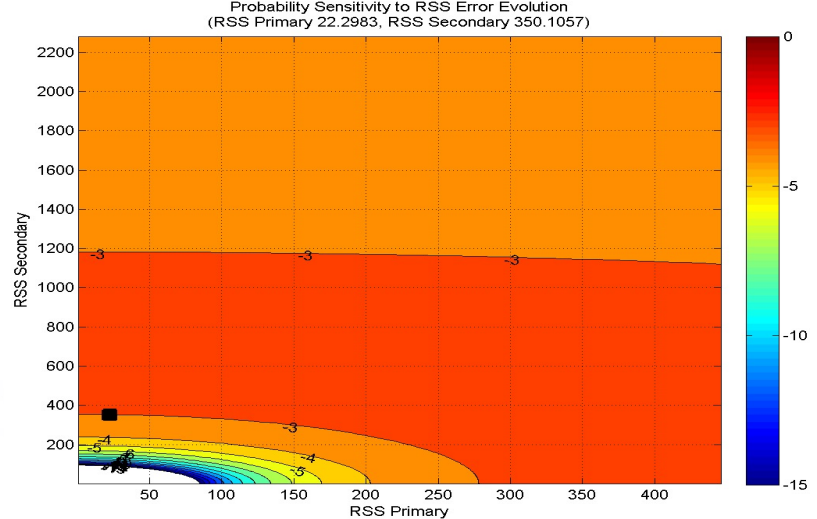
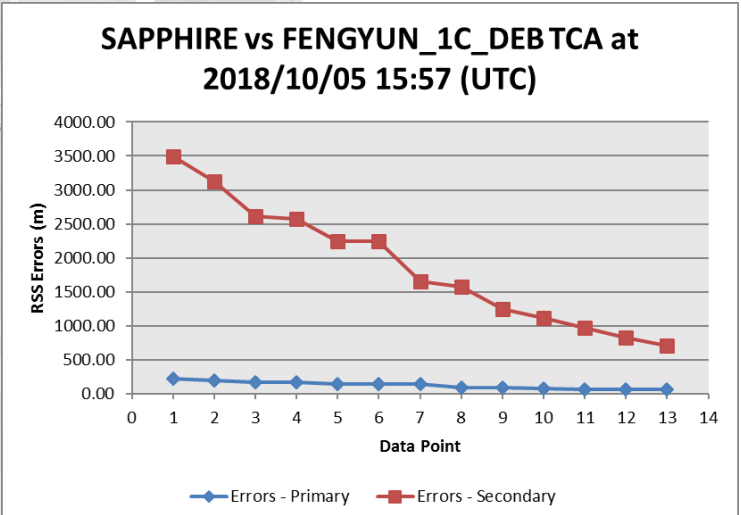


Over 100 missions now supported

CRAMS Data Quality Analysis

- Data Quality reporting “good data” and “bad data”
- Probability Sensitivity to data quality
 - Facilitates “wait” or “act-now” decision
 - ~Probability forecasting based on error reduction with expected tracking
- Linear encounter & positive semi-definite tests

Data Quality Criteria	LEO Default	GEO Default
RSS Error Limit (m)	1700	9000



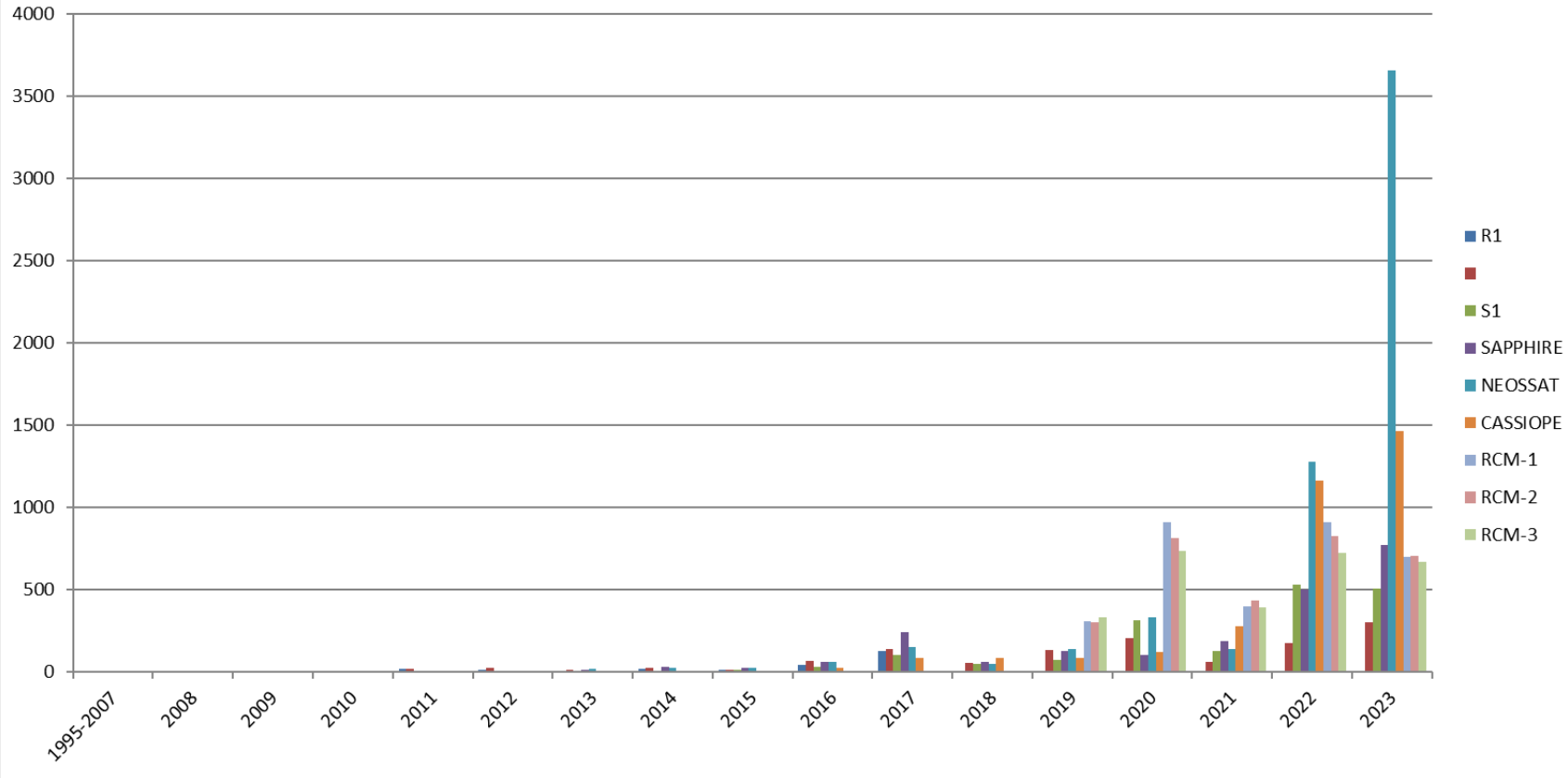
RCM Conjunction Assessment Challenges

Difficulties keeping track of maneuvering RCM in SP catalog

- Differences between SP and Ephemeris-based CDMs
- Unrealistic covariance (set to default), impacting Pc
- Maneuvering increasing as we exit solar minimum, exacerbating the issue
- Increasing CDMs against operational satellites, needing a coordinated response
- CRAMS now uploads RCM ephemeris 3x daily to increase Eph-based screening

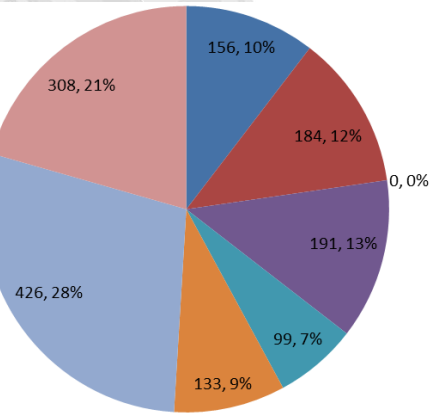
Creation Date	Ref	Data	Miss distance (m)				Probability	Depth of	Approach	RSS Errors (m)		CRAMS	TCA
UTC		Ty	Radial	In-tra	Cross-tra	Overall	of Collisi	Intrusio	Angle (de	Primary	Seconda	Recommendatio	
2022-03-31 17:43:25	2	CDM	25.1	1438.1	4207.4	4446	1.33E-14	0.00	142.33	110472561.29	17562.85	No Action Required	11:09
2022-04-01 00:17:15	7	CDM	73	-222.9	-659.6	700	1.33E-14	0.00	142.33	110472561.29	12543.16	No Action Required	11:09
2022-04-02 12:26:29	12	CDM	72.6	124.2	364.1	391	1.31E-14	0.00	142.33	110472561.29	3798.57	No Action Required	11:09
2022-04-02 17:41:59	17	CDM	65.5	304.9	897.1	949	1.31E-14	0.00	142.33	110472561.29	3797.57	No Action Required	11:09
2022-04-02 23:59:58	25	CDM	121.6	493	1435.3	1522	1.31E-14	0.00	142.33	110472561.29	2804.45	No Action Required	11:09
2022-04-03 12:21:30	40	CDM	40.9	343.8	1009.3	1067	1.31E-14	0.00	142.33	110472561.29	2057.93	No Action Required	11:09
2022-04-03 16:53:33	48	CDMe	26.7	433.3	1282.4	1353	6.20E-06	0.55	142.33	635.79	1442.89	Action Required (Po	11:09
2022-04-03 17:19:41	56	CDM	43.8	271.1	802.9	848	1.31E-14	0.00	142.33	110472561.29	1665.20	No Action Required	11:09
2022-04-03 19:59:30	65	CDMe	70.5	336.5	993.9	1051	0.00E+00	1.69	142.33	635.79	395.09	No Action Required	11:09
2022-04-03 23:53:29	73	CDM	49.5	202	595.1	630	1.40E-06	0.57	142.33	291.32	1125.18	Action Required (Po	11:09
2022-04-04 00:25:03	80	CDMe	19.1	584.2	1712.6	1809	6.28E-09	0.81	142.33	635.78	1180.27	No Action Required	11:09
2022-04-04 01:49:29	91	CDMe	72.6	324.3	943	999	0.00E+00	2.20	142.33	635.79	245.85	No Action Required	11:09
2022-04-04 08:23:06	102	CDMe	74.2	323.9	938.8	995	0.00E+00	2.64	142.33	635.79	189.40	No Action Required	11:09
2022-04-04 12:01:23	110	CDM	57	40.1	118.9	137	1.26E-06	0.59	142.33	187.57	735.00	Action Required (Po	11:09

Close Approach History By Year (CSA LEO)

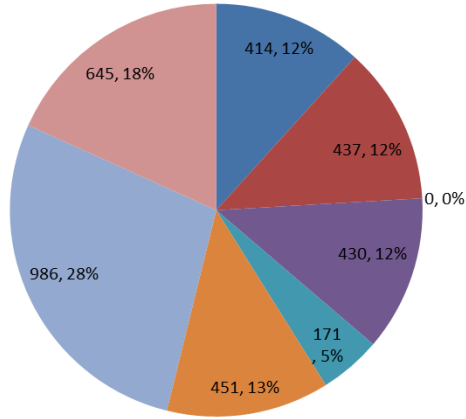


CRAMS Statistics – Evolution of LEO as seen by CSA CDMs

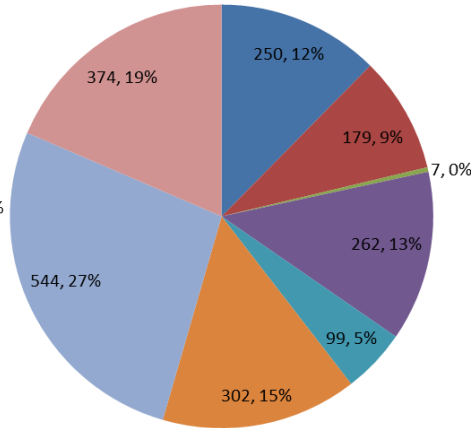
2019: 1497 events



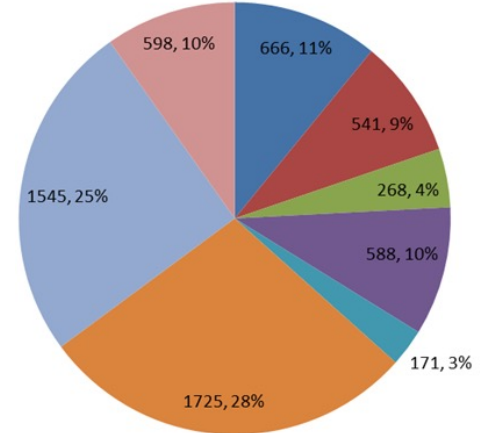
2020: 3534 events



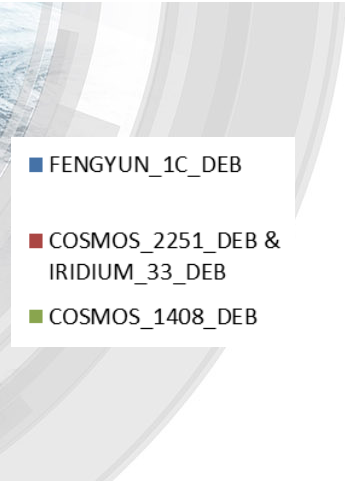
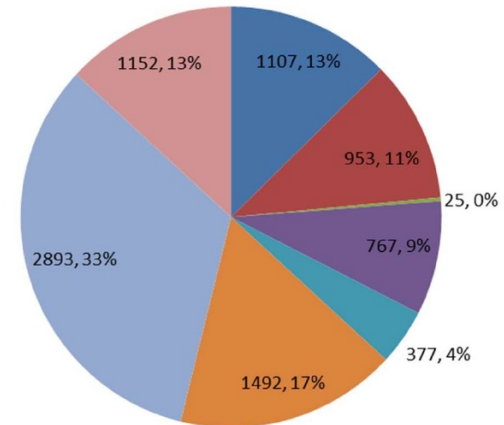
2021: 2017 events



2022: 6102 events

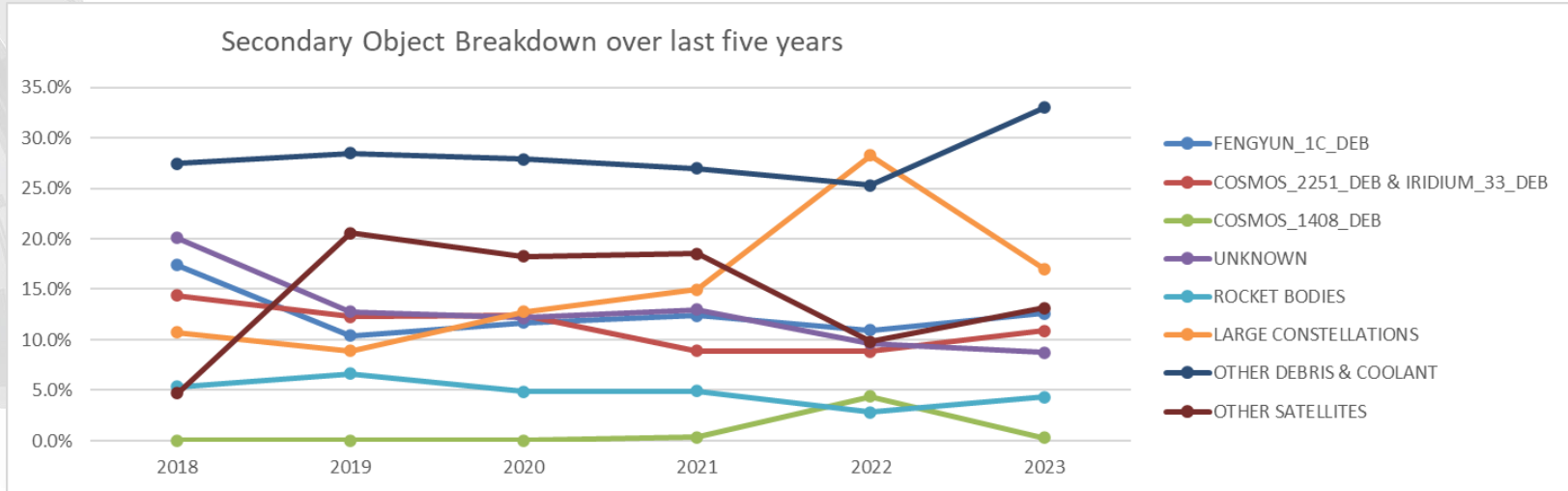


2023: 8766 events



- FENGYUN_1C_DEB
- UNKNOWN
- COSMOS_2251_DEB & IRIIDIUM_33_DEB
- ROCKET BODIES
- OTHER DEBRIS & COOLANT
- COSMOS_1408_DEB
- MEGA-CONSTELLATIONS
- OTHER SATELLITES

CRAMS Statistics – Evolution of LEO as seen by CSA CDMs

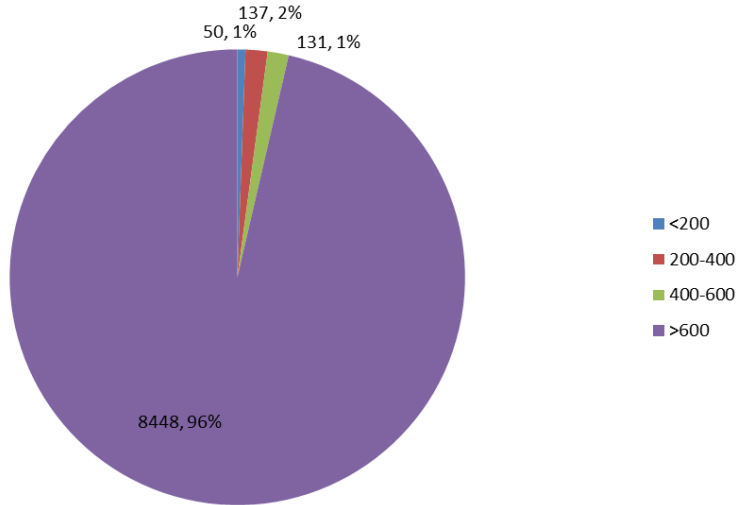


Notable points

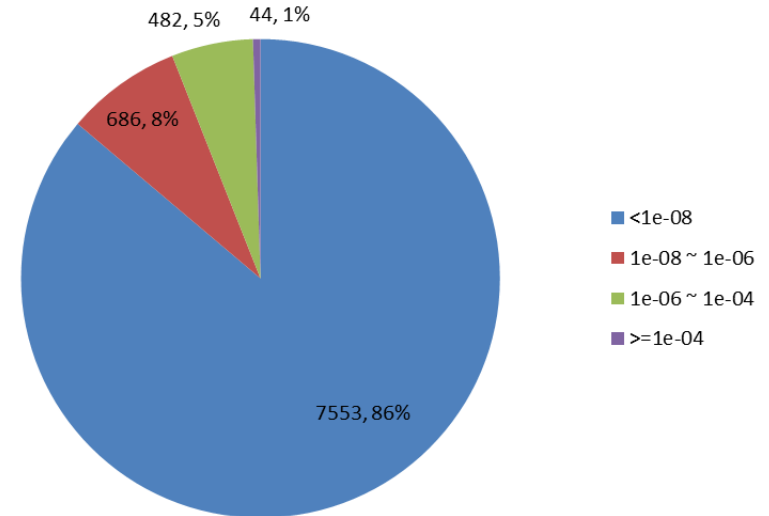
- Rocket bodies trending down... (more payloads/launch; better return practices)
- Large-constellations were trending up but slowed down
 - Preliminary analysis shows that we see less satellites of a certain constellation (2022 vs 2023); that constellation is known to be performing more autonomous maneuvers
 - ...more complex, due to new propulsion modes – operator ephemeris and interactions becoming more important than SP catalog in more and more cases
- UNKNOWN / analyst satellites continue to be an important contributor to conjunction events
- Debris and coolant increased in percentage

CRAMS statistics

Miss Distance - 2023



Probability of Collision



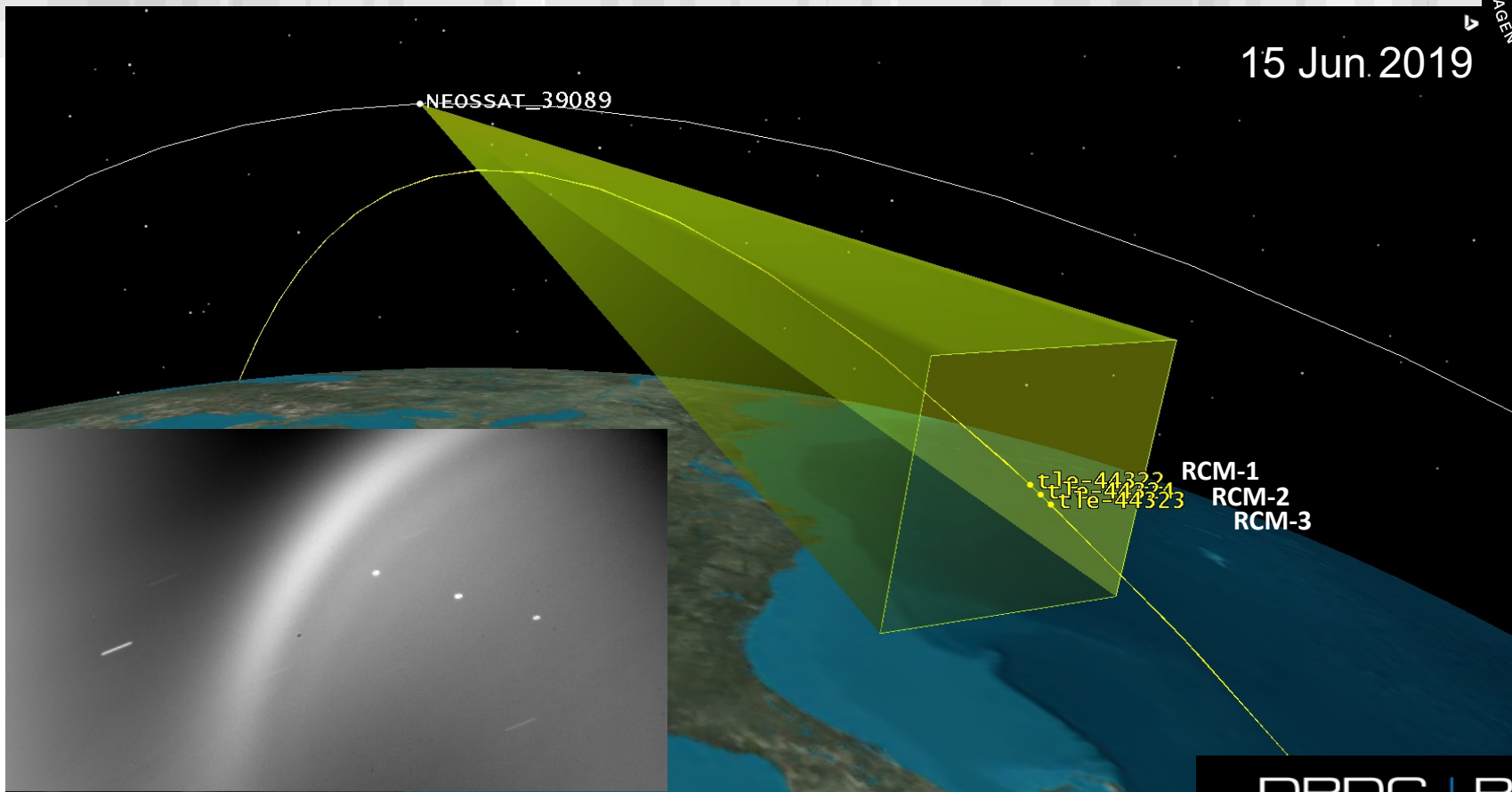
- When combined, 100% → 10% deserving attention
→ 1% action or further analysis

NEOSSat imaging RCM satellites post-launch

NON CLASSIFIÉ / U



15 Jun. 2019



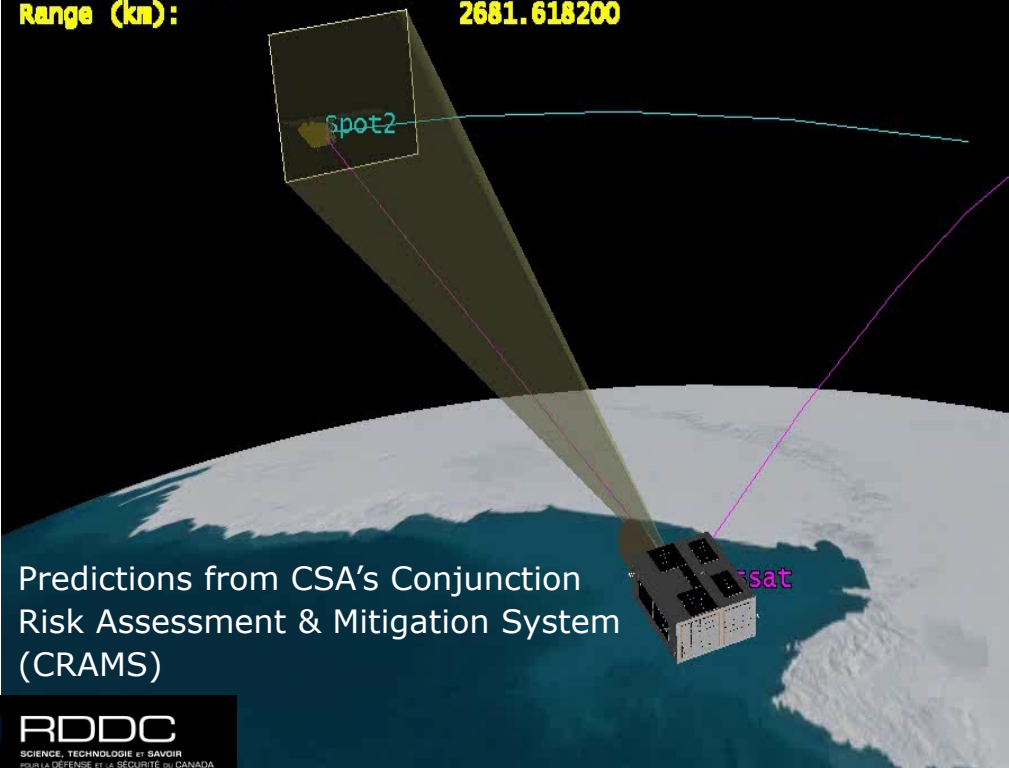
NEOSSAT_39089 ICR Axes
15 Jun 2019 11:37:10.000 Time Step: 10.00 sec

NEOSSat observations of conjuncting objects

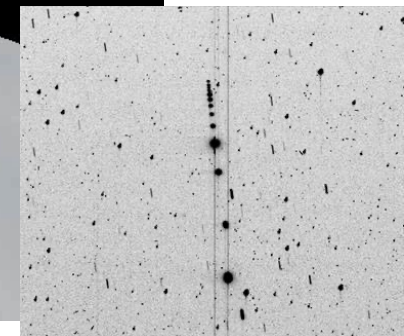
- Spot2 – miss distance 2.2 km

NeosSat-To-Spot2 AER
Time (UTCG): 16 Jul 2018 06:21:01.000
Azimuth (deg): 313.658
Elevation (deg): -10.937
Range (km): 2681.618200

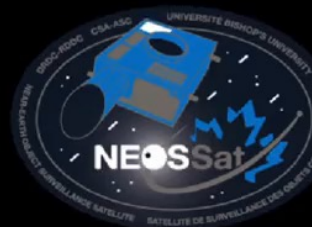
DateTime: '2018-07-16T06:20:40.142'
SPOT-2
RA (hours): '23 45 27.10'
DEC (deg): '-12 21 19.8'
ExpTime (sec): 1.0
Solar Phase (deg): 58.54
Earth Limb (deg): 15.549



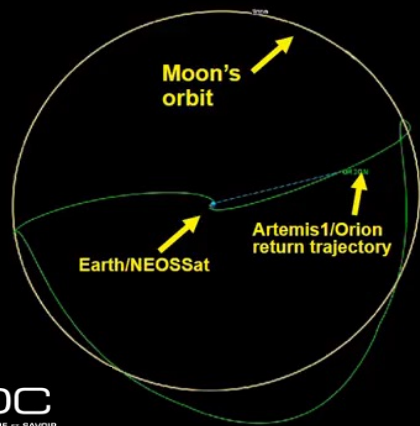
Predictions from CSA's Conjunction Risk Assessment & Mitigation System (CRAMS)



Date: 2022-12-10T05:25:20.128
Object: Artemis-1/Orion
Visual Magnitude: 12.0
Range: 252111 km



← ORION

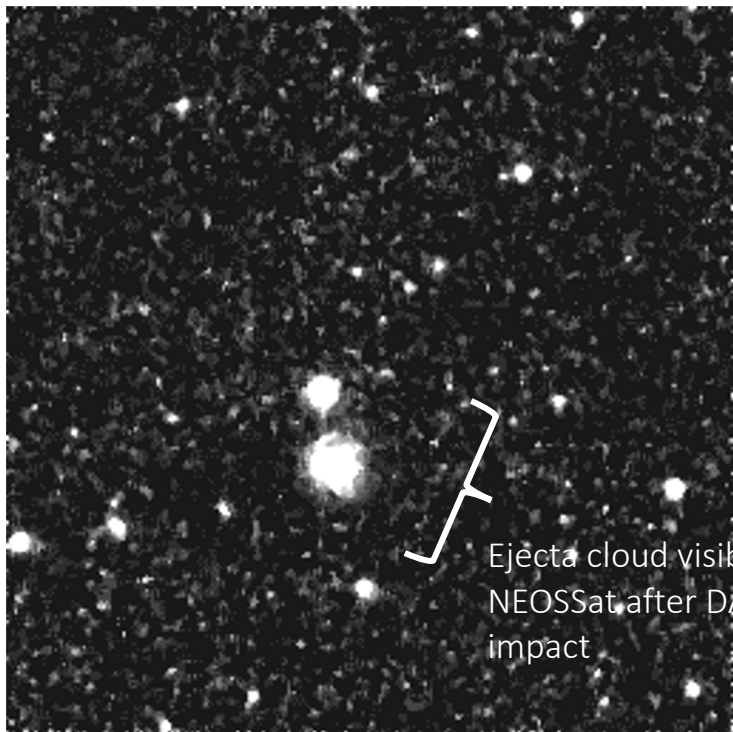


Observing impact of NASA's DART on near-Earth asteroid Didymos

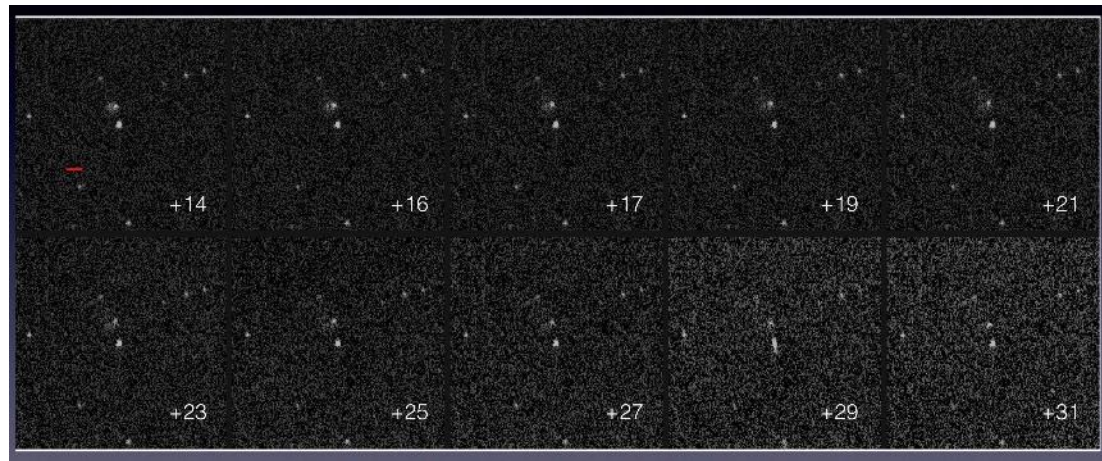
NOI



*DART - Didymos asteroid impact event by NEOSat
2022-Sep-26 23:28, 14 minutes after impact*



Ejecta cloud visible
NEOSat after DART
impact





**Vers la durabilité des
activités spatiales**

26 au 30 mai 2025

**Towards Space
Sustainability**

May 26-30, 2025

MONTRÉAL, QUÉBEC, CANADA – Palais des congrès



Agence spatiale
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