Satellites Tracking Data Analysis and Comparison from Laser Ranging and Other Detection Methods

by

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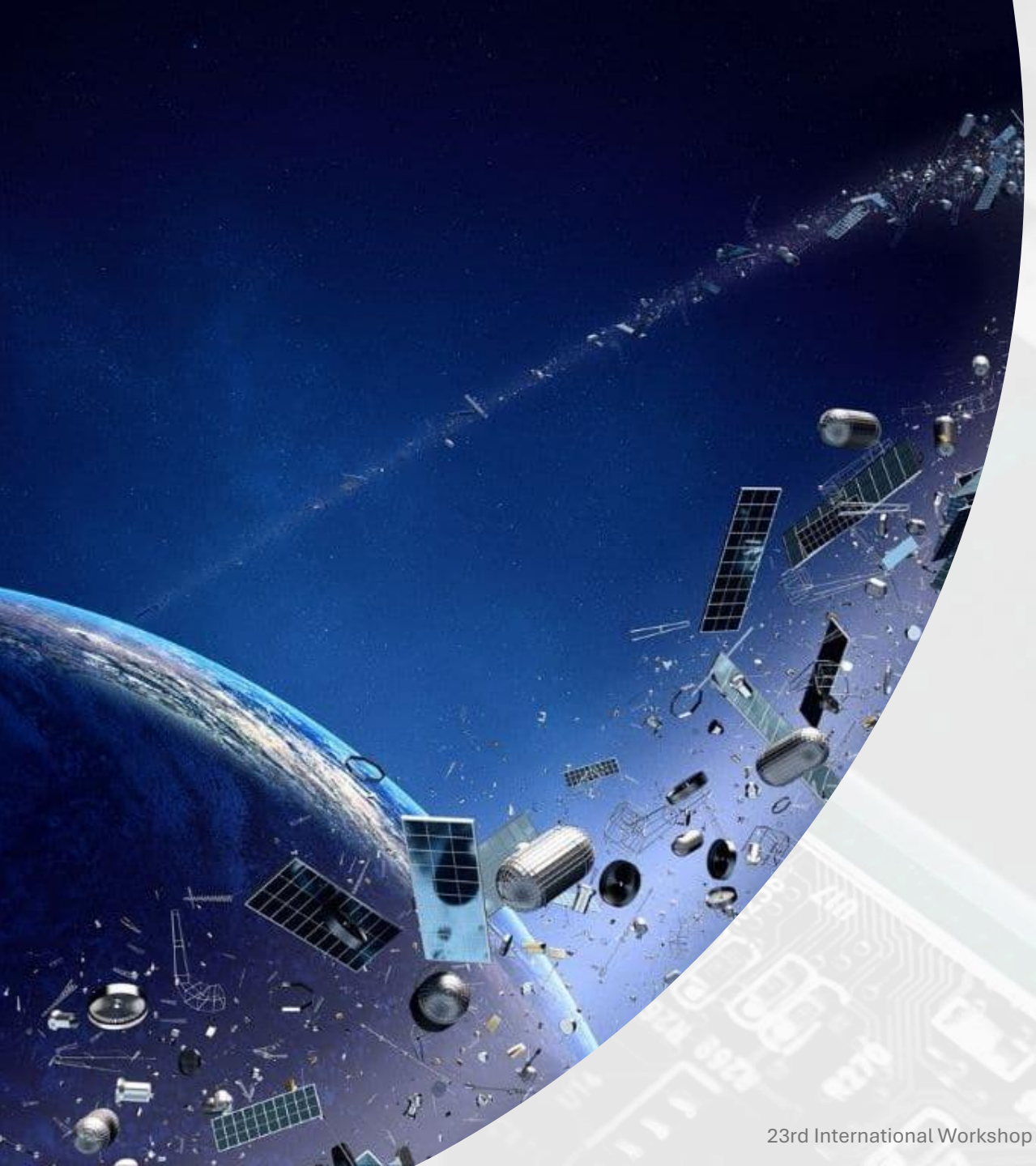
Agendas

1. Introduction to Space objects Tracking Data
2. Satellites Tracking Data Performance & Comparison
3. Space Debris Tracking
4. Conclusion

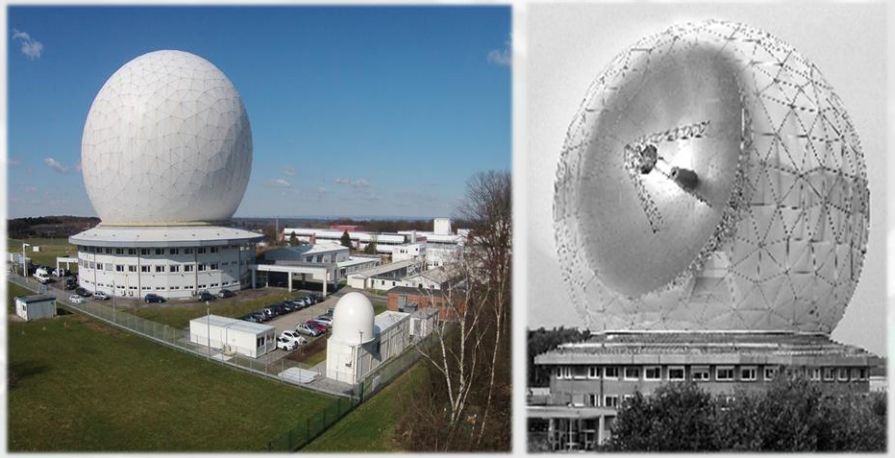


1. Introduction to Space objects Tracking Data

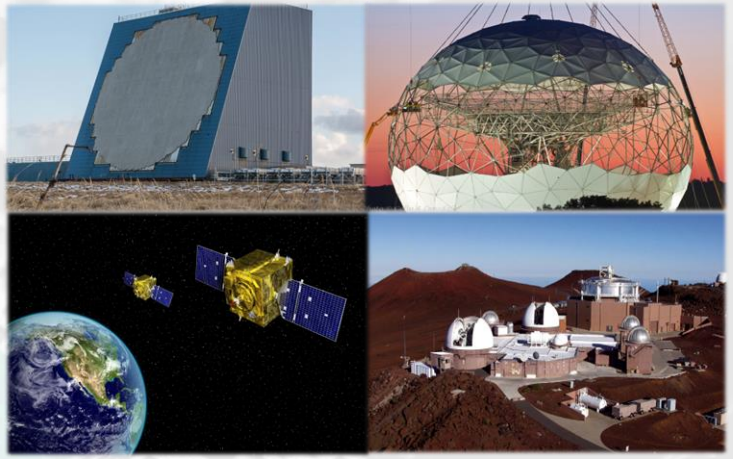
Space Objects Tracking Data format & sources

The Space Objects Tracking & Monitoring could be employed by various sensors operating methods, for example

Laser Ranging



Radars



Combination Sensors
(e.g. optical, radar, etc.)

Results

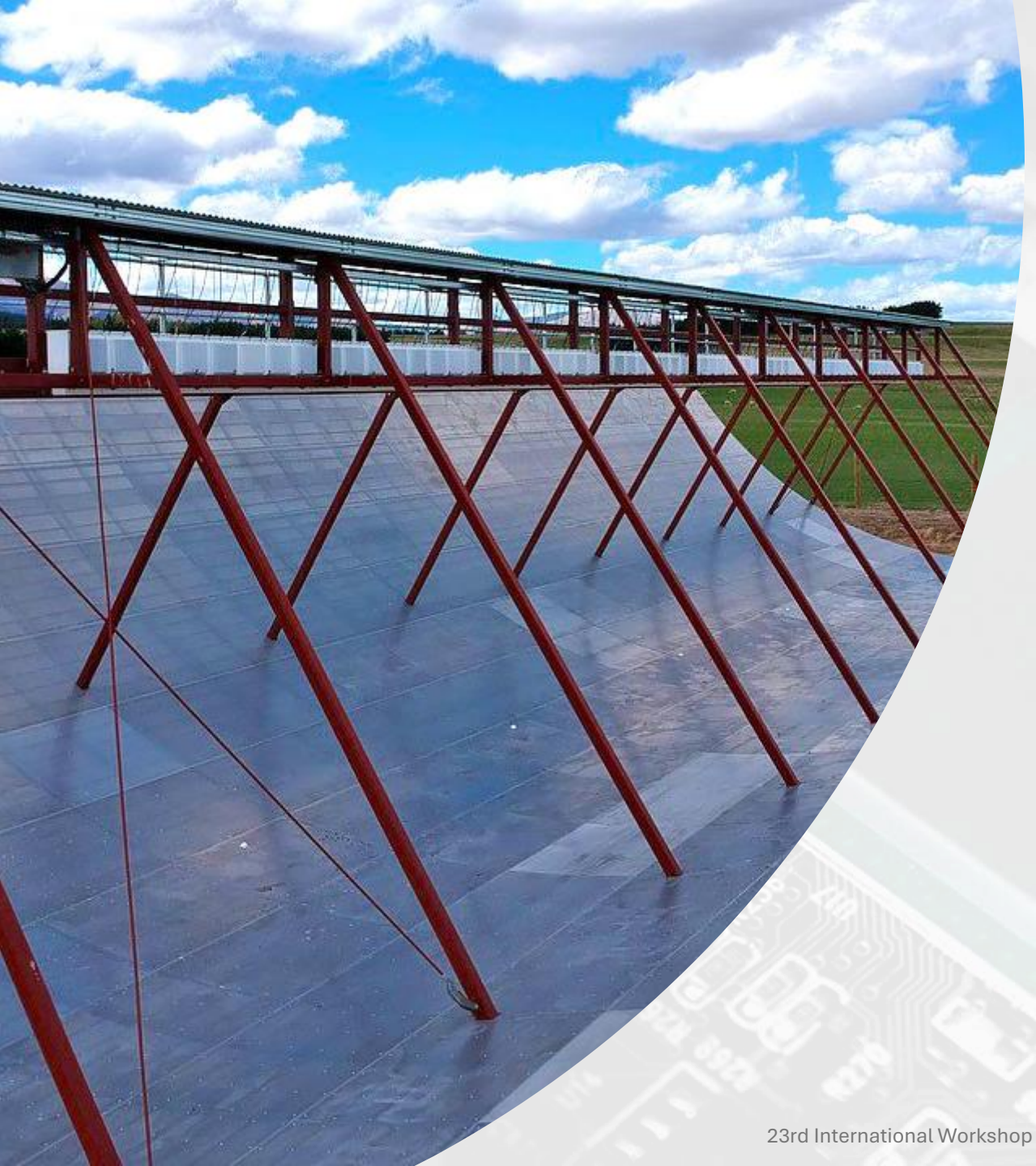
Laser ranging data
(e.g. ILRS ephemerides)

Results

Radar state vectors data
(e.g. LeoLabs' radar network)

Results

TLE files
(US SSN)



2. Satellites Tracking Data Performance & Comparison

A Radars' Satellites Tracking

LeoLabs' Radar Network

Tracking & mapping data service applications for "***Space Traffic Management***" in LEO

PFISR

Poker Flat Incoherent Scatter Radar

MSR

Midland Space Radar

Azores Space Radar

Costa Rica Space Radar

CRSR

AZSR

WASR

KSR

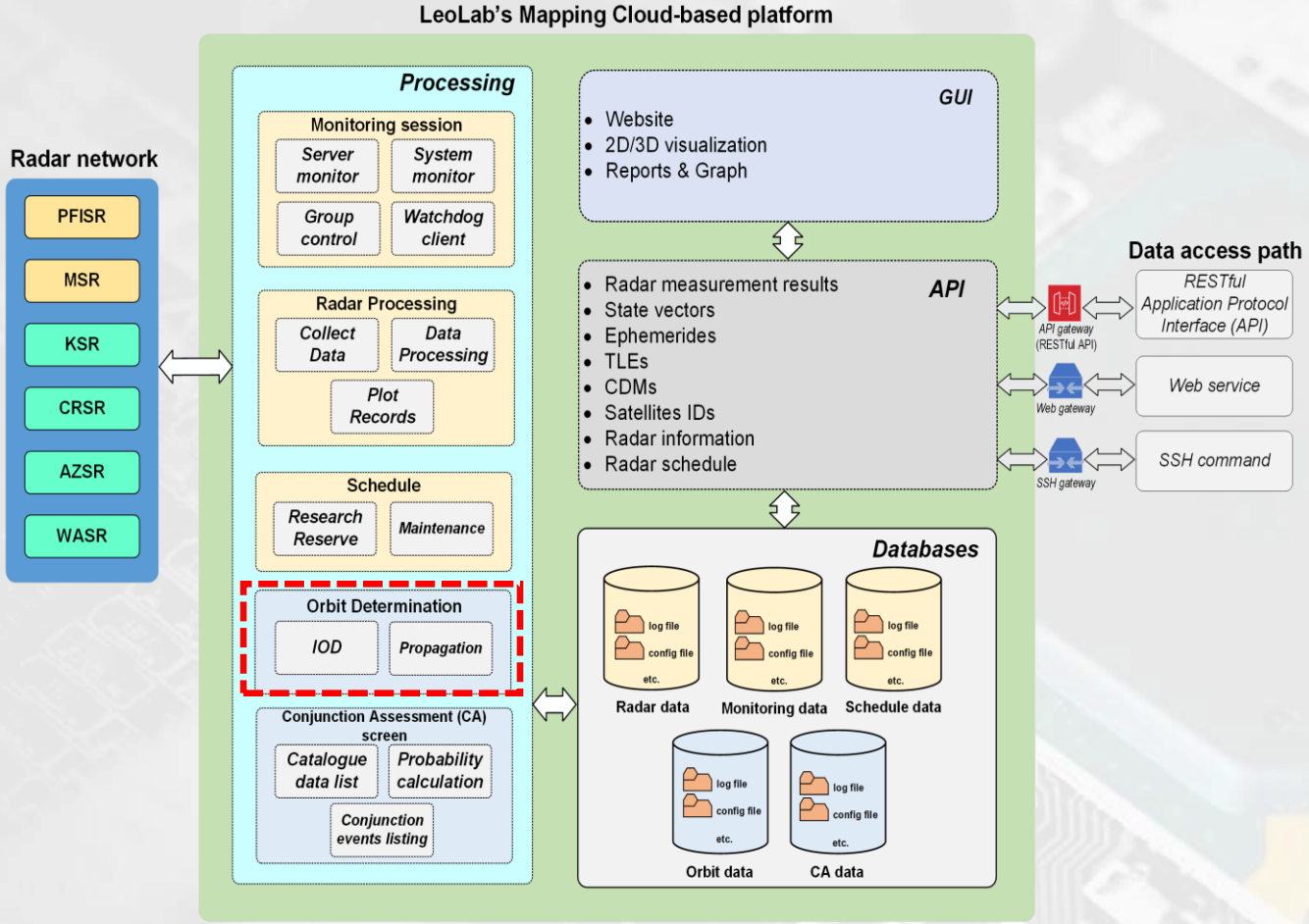
West Australian Space Radar

Kiwi Space Radar (KSR)

Radar Network composes with *6 locations* of *UHF-band* and *S-band* ***Phased array radars.***

A Radars' Satellites Tracking

LeoLabs' Radar Network



- *Data processing platform* ***on cloud web-based platform*** *via RESTful application program-interface*
- ***Orbit Determination (OD)*** *system utilizes:* ***Unscented Kalman Filter (UKF)*** *for nominal-state estimation/ tracking*
- ***OD propagation modeled forces*** consists of:
  - ✓ ***42 x 42 gravitational field model, JGM3***
  - ✓ ***Solar & Lunar 3rd body gravity***
  - ✓ *Atmospheric drag (****NRLMSISE-00*** *model)*
  - ✓ ***Solar Radiation pressure***

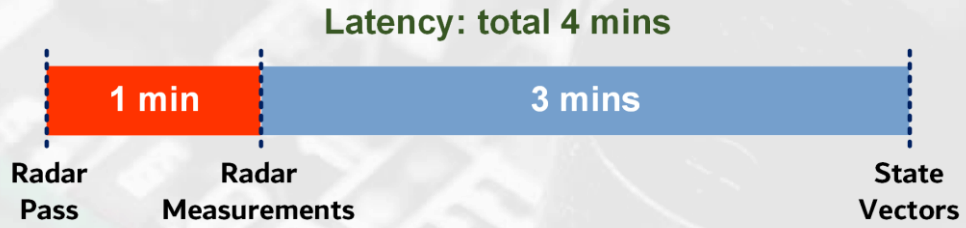
A Radars' Satellites Tracking

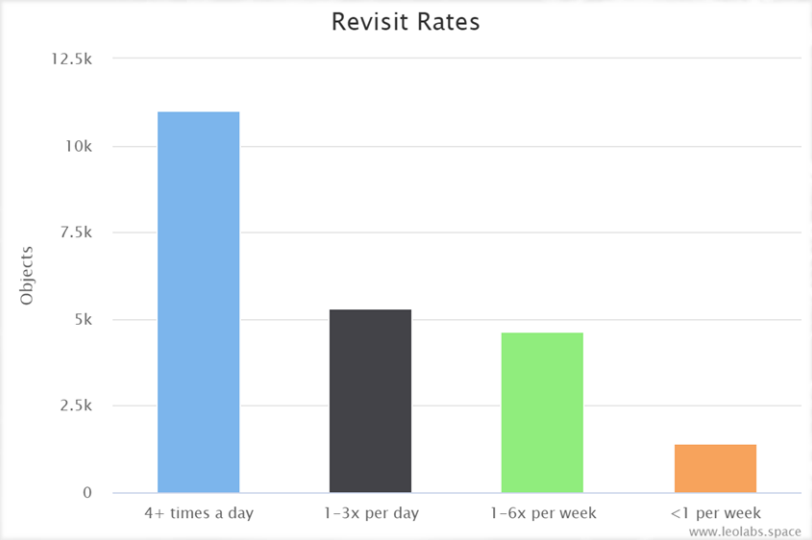
LeoLabs' Radar Network

Overall Tracking Results

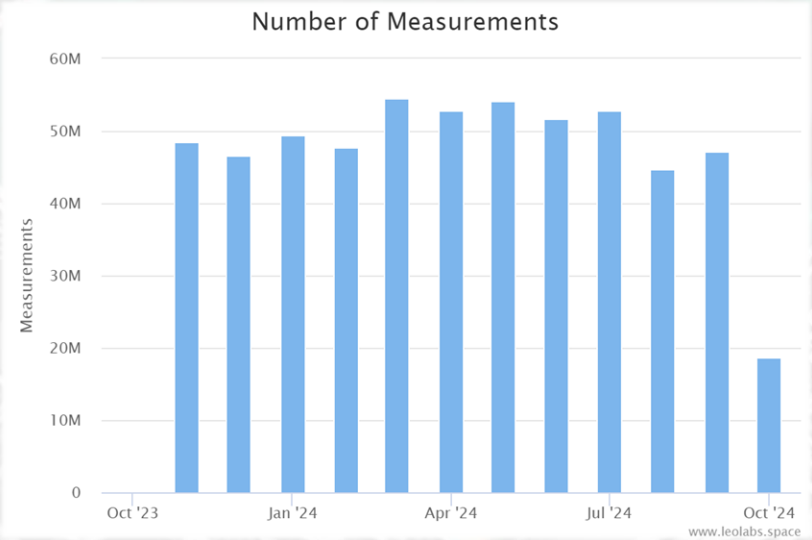
Updated: 2024-10-13

Result Type	*Last 30 days*
Radar Measurements	45,963,983
Observed Passes	2,676,370
State Vectors	2,610,648

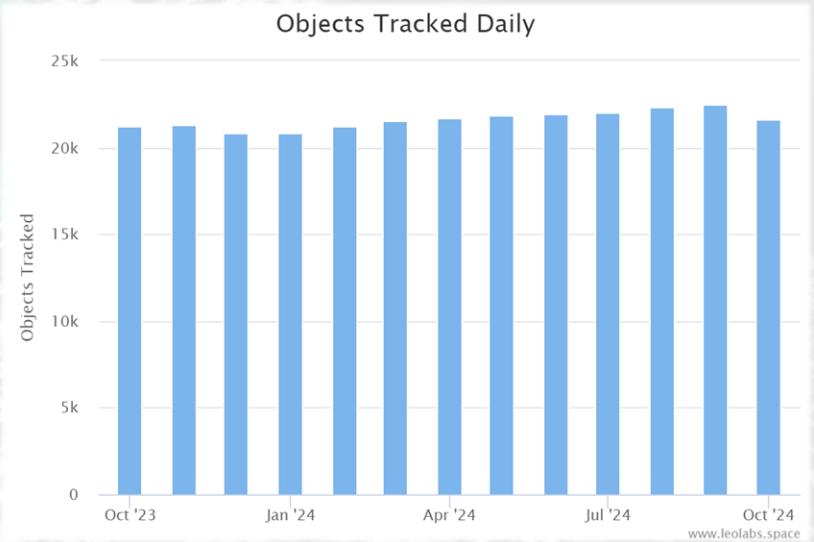




Revisit Rates in last *30-day* average



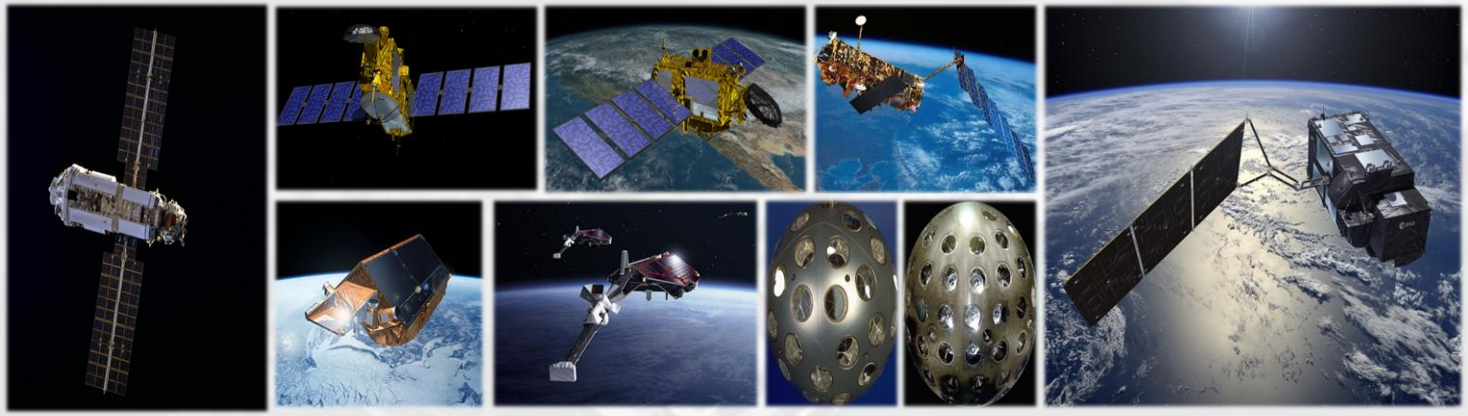
Monthly Number of Measurements in a year



Monthly Objects Tracked daily in a year

A Radars' Satellites Tracking

LeoLabs' Radar Network Tracking Results



Radar measurement data from ***11 ILRS objects***:

1. *ISS ZARYA*
2. *JASON-2*
3. ***JASON-3***
4. ***CRYOSAT-2***
5. *ENVISAT*
6. *SENTINEL-3A*
7. ***SWARM A***
8. *SWARM B*
9. *SWARM C*
10. *LARES*
11. *STELLA*

Updated: 2024-10-13

Result Type	All time	Last 30 days	Last 7 days
Radar Measurements	4506912	100041	23703
Observed Passes	168834	4122	980
State Vectors	139412	4083	926

A Radars' Satellites Tracking

LeoLabs' Radar Network Tracking Results

3 out of 11 Tracked ILRS objects characteristics

Characteristics	ILRS Objects		
	JASON-3	***CRYOSAT-2***	***SWARM A***
NORAD ID	41240	36508	39452
Altitude	1340 km	720 km	460 km
Inclination	66º	92º	87º
RCS	39 m^2	17.27 m^2	28 m^2

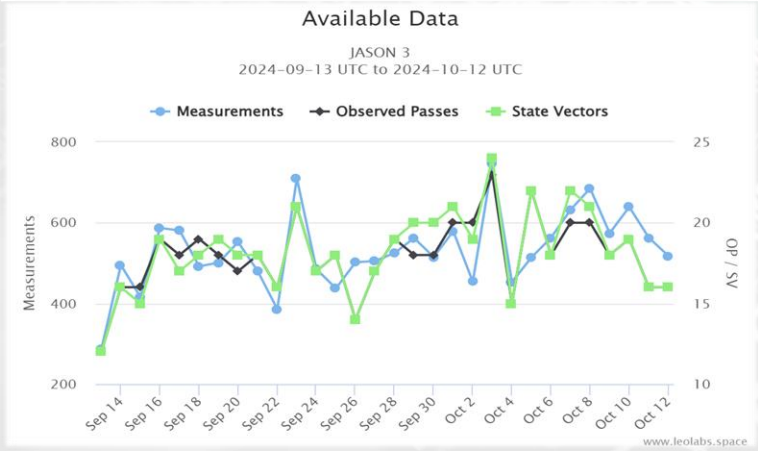
A Radars' Satellites Tracking

LeoLabs' Radar Network Tracking Results

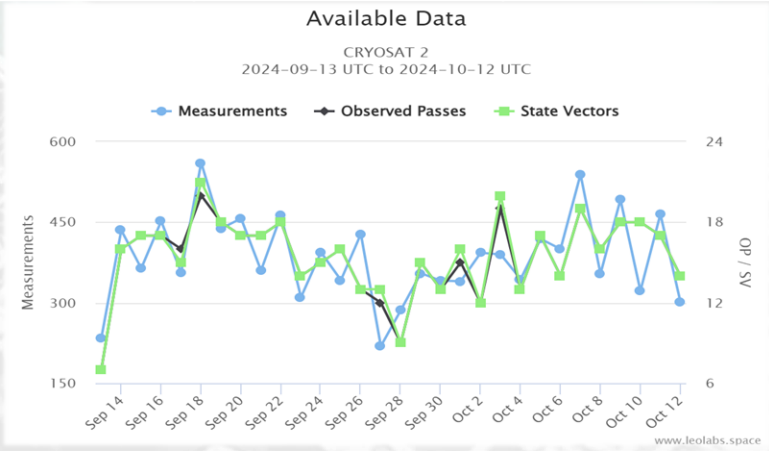
3 out of 11 Tracked ILRS objects Tracking results

Updated: 2024-10-13

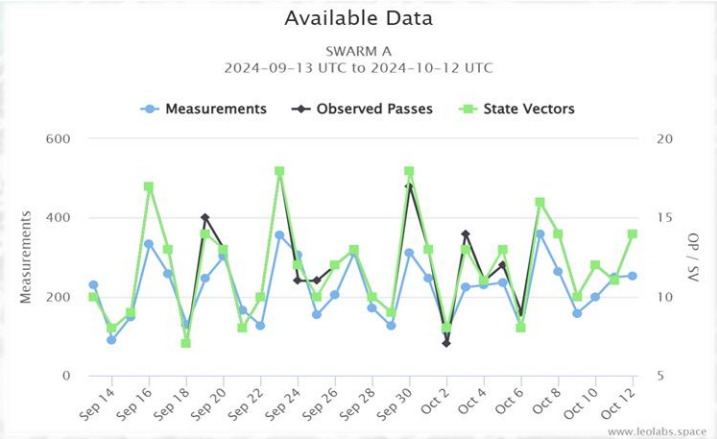
Result Type	JASON-3		CRYOSAT-2		SWARM A	
	All times	Last 30 days	All times	Last 30 days	All times	Last 30 days
Radar Measurements	661459	15939	530478	11555	269348	6618
Observed Passes	19315	538	19060	462	14951	354
State Vectors	17137	545	16193	465	11988	354



JASON-3



CRYOSAT-2



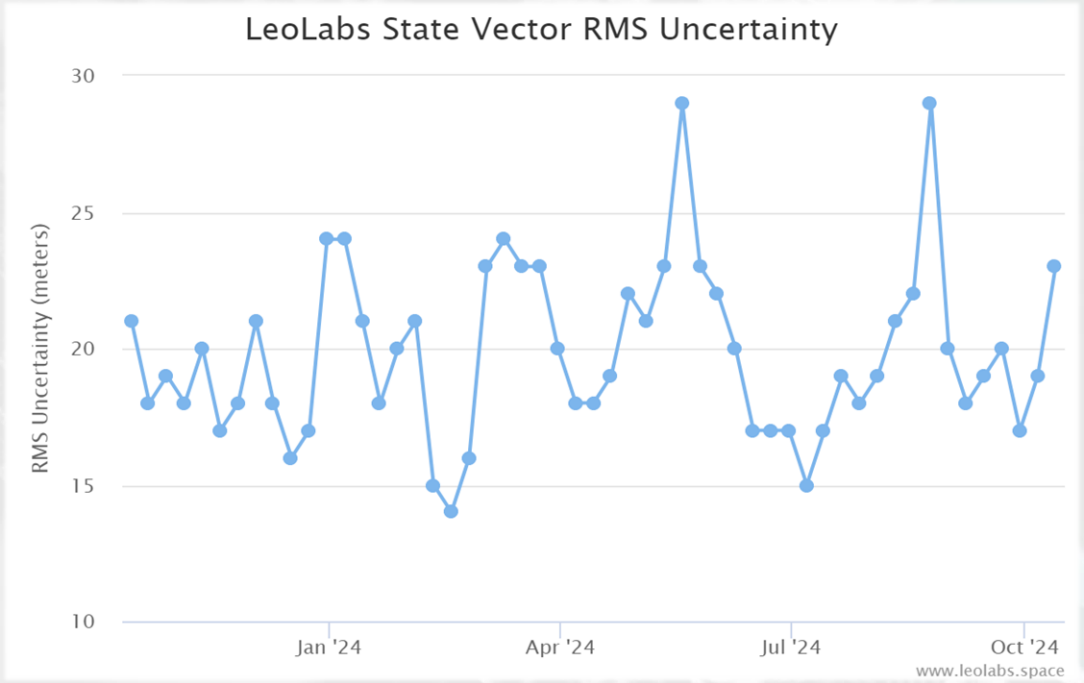
SWARM A

A Radars' Satellites Tracking

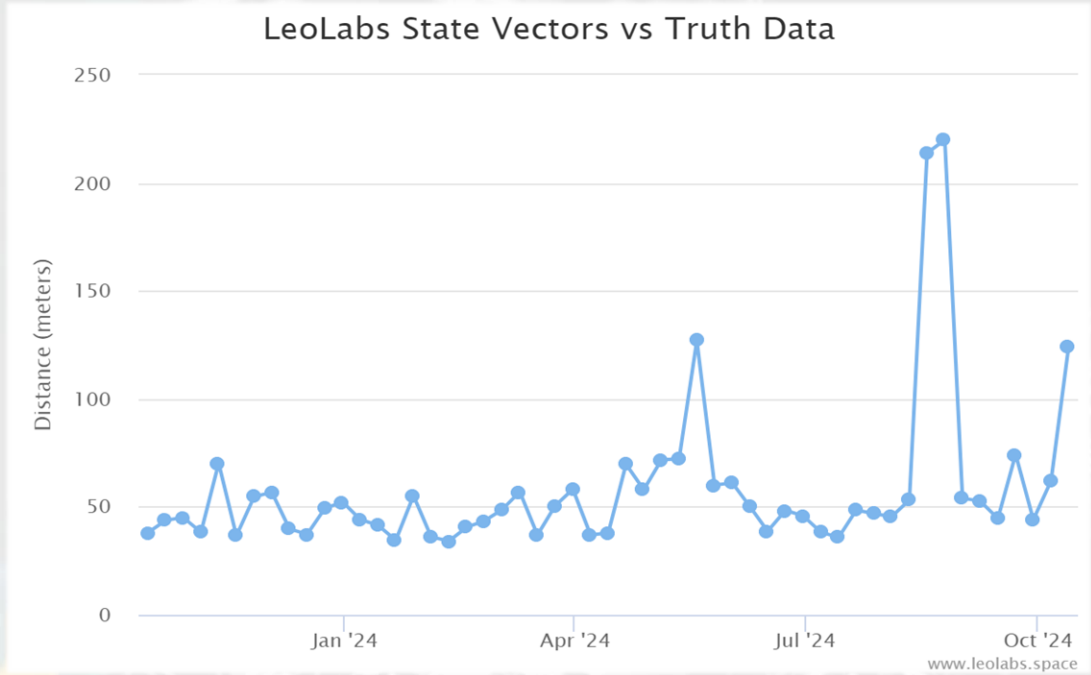
The LeoLabs' radar network tracking results as "*State vectors*" performance would be referred with *Fitted normal distributions data*, and *International Laser Ranging Service (ILRS) ephemerides* called *"Truth data*."

Overall Tracking Performance

Updated: 2024-10-13



RMS Uncertainty (weekly average ~ 20 m)



Different between LeoLabs' state vectors and ILRS "Truth data" (weekly average ~ 55 m)

A Radars' Satellites Tracking

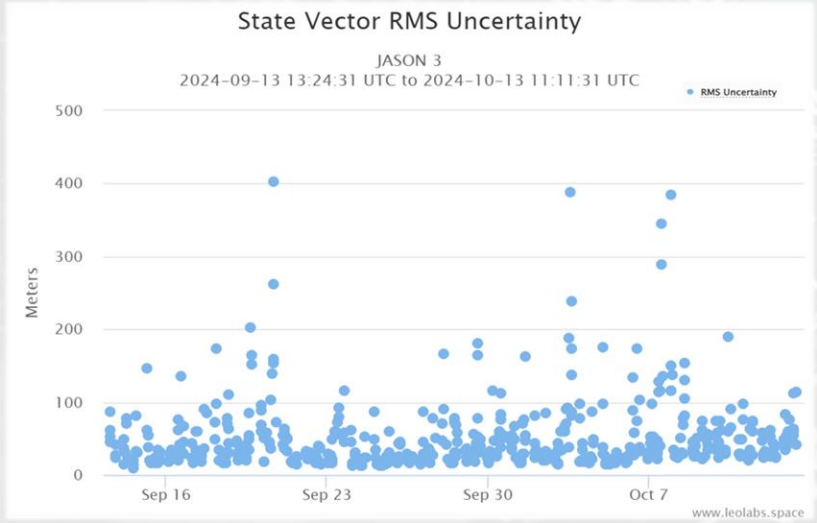
LeoLabs' Radar Network Tracking Performance

3 out of 11 Tracked ILRS objects Tracking performance

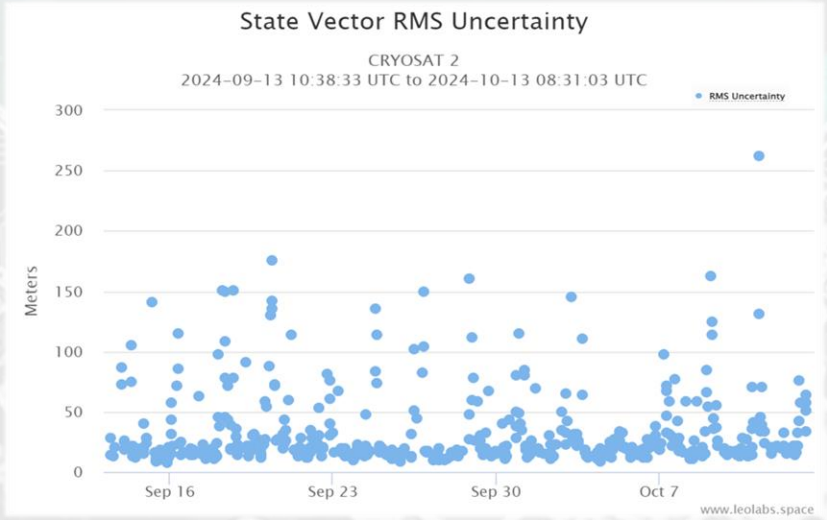
Update on 2024-10-13

State vector RMS uncertainty

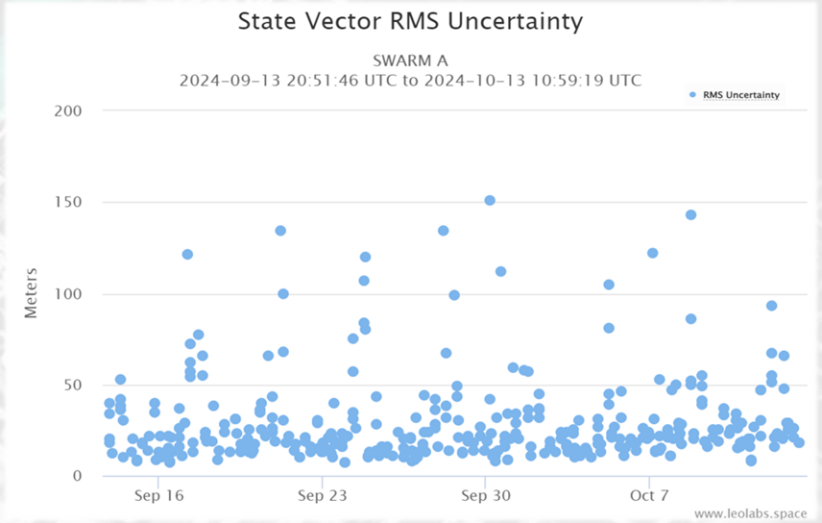
ILRS Objects	Average State vector RMS Uncertainty (m)
JASON-3	42
CRYOSAT-2	33
SWARM A	27



JASON-3



CRYOSAT-2



SWARM A

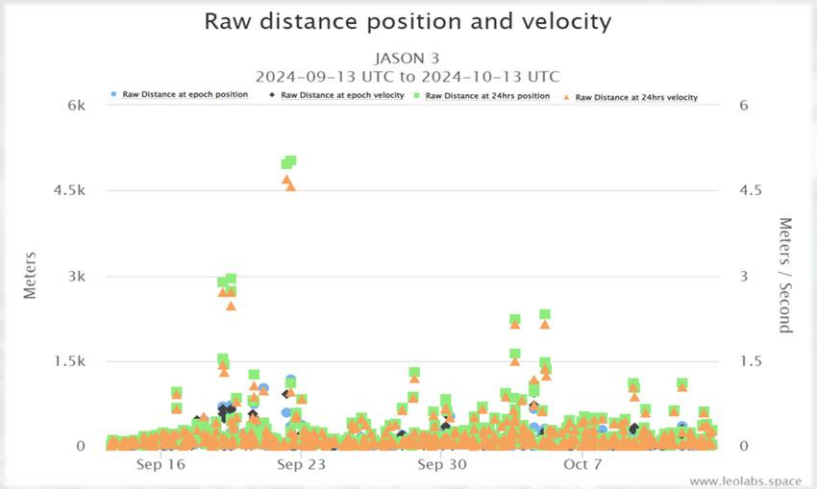
A Radars' Satellites Tracking

LeoLabs' Radar Network Tracking Performance

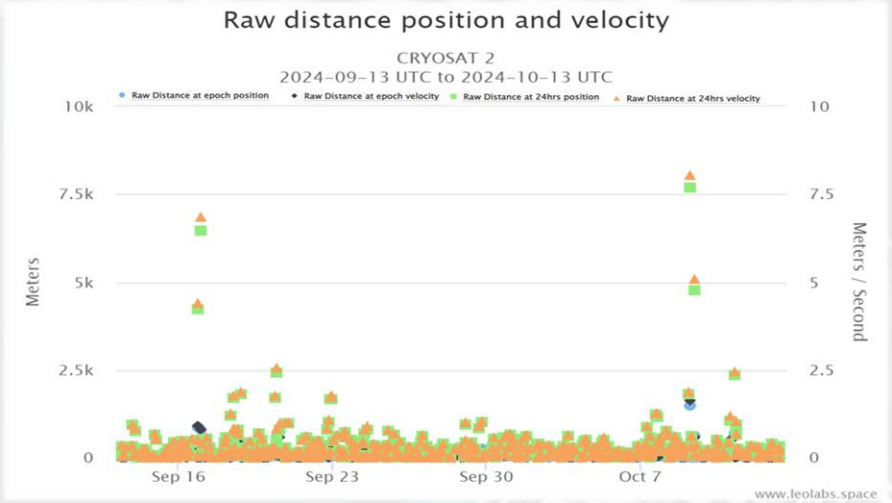
3 out of 11 Tracked ILRS objects Tracking performance

Update on 2024-10-13

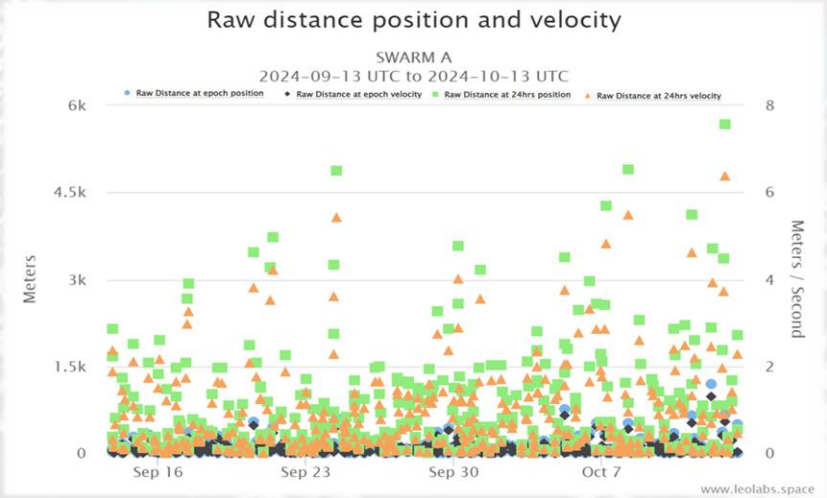
Raw distance position and velocity



JASON-3



CRYOSAT-2



SWARM A

B. Satellites Tracking Data Comparison

Comparison of Satellite Ranging data performance

The accuracy of laser ranging data from *International Laser Ranging Service (ILRS*) could be initially summarize and compare with LeoLabs' radar and TLE for *3 out of 11 ILRS Objects example.*

Space Objects	NORAD ID	Average accuracy		
		SLR (m)	LeoLabs' Radar (m)	TLE (m)
JASON 3	41240	< 0.0030	42	~1000
CRYOSAT 2	36508	0.0150	34	~1000
SWARM A	39452	0.040 - 0.050	27	~1000

3. Space Debris Tracking

A Laser Ranging

Result from laser ranging station

1. Shanghai station

2020 – The development of 1KHZ repetition rate multi-pulse picosecond laser for 60cm telescope with 10W output power by *Long Mingliang et al*. The laser wavelength is 532 nm but divided into multi-pulse with 100 ps of each sub-pulse duration. Finally, the best accuracy results for LEO debris detection is 16.44 cm.

Table 1 Results of laser space debris ranging with multi-pulse picosecond laser

Number	Date	Name	RCS /m^2	Root mean square /cm	Measured distance /km
1	2020-03-15	SL-14R_B	4.6	31.06	727.5–749.0
2	2020-03-15	Cz-2c-r-b1_Gz	10.7	16.44	1083.4–1150.7
3	2020-03-18	Delta2R_B	9.8	118.17	1006.4–1049.3
4	2020-03-18	SL_DEB(814)	7.5	28.65	836.7–899.4
5	2020-03-18	DELTA2R_B_O	5.5	64.27	1100.3–1162.9
6	2020-03-18	SL-3R_B	6.6	150.51	643.8–646.5

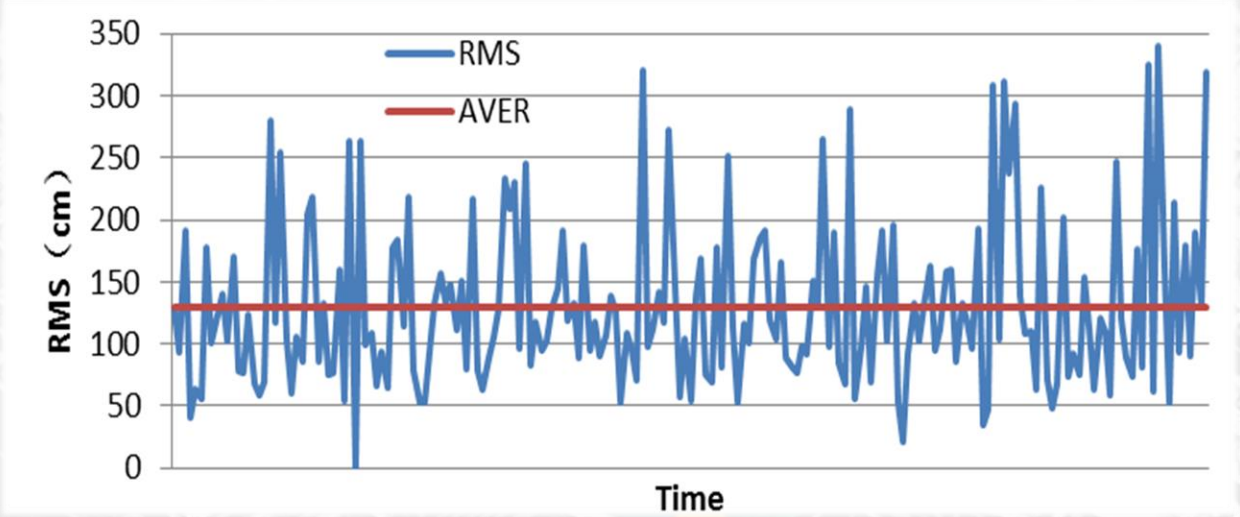
2020- Experiment Results

A Laser Ranging

Result from laser ranging station

2. Changchun station

2014- The experiment on 532 nm laser pulse wavelength with 500 Hz of repetition frequency. The minimum radar cross section of the experimental system observation target is 1.2 m^2, the diameter is about 1m, the maximum slant range is measured to be 1732 km, and the average RMS is 129.4 cm.



2014- Experiment Results

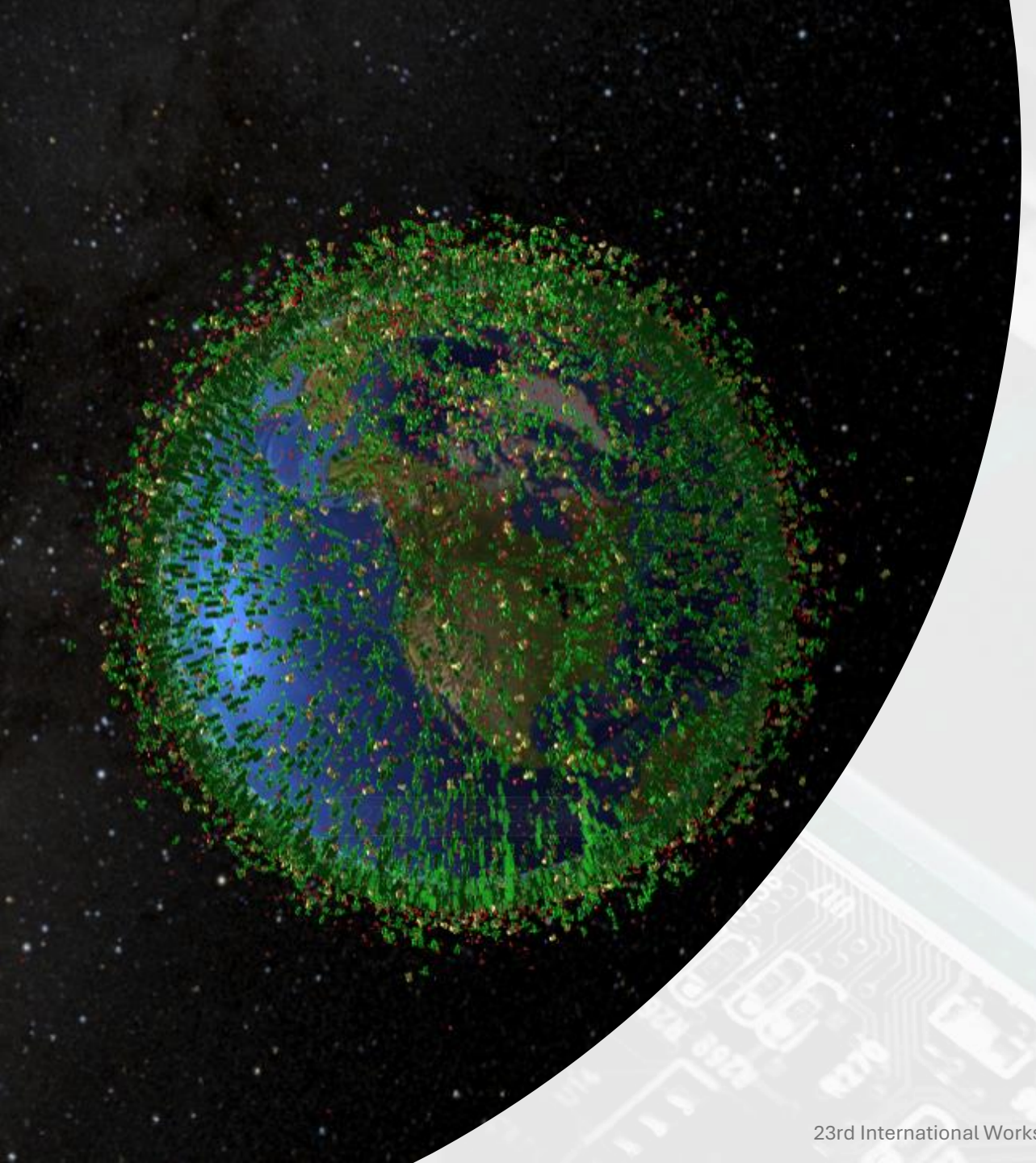
B. Radars

Result from LeoLabs' global radar network

According to the information from LeoLabs' radar network, we have chosen the tracking results from 4 space debris targets for the analysis due to the altitude as follow:

Space Debris	Characteristics			Performance
	NORAD ID	***Altitude (km)***	***RCS (m^2)***	***Accuracy (m)***
YZ-1S	43644	665	4.84	19
IRIDIUM 33	33886	765	1.23	22
CZ-4C	40114	842	9.43	26
SL-12	27476	1187	2.42	28

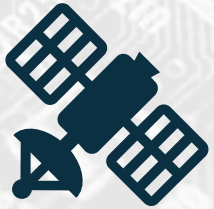
Updated: 2024-10-13



4. Conclusion

Conclusion

- According to results, the different types of tracking data (e.g. *laser ranging data*, *radar state vectors*, and *TLE*) declares different accuracy of data, which could be utilized for space objects detection and monitoring with different advantages.

THANK YOU