

# NGSLR Performance in High and Low Energy Operation

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The Next Generation Satellite Laser Ranging System (NGSLR) has been designed to track targets at lunar distance as well as Earth-orbiting retroreflector-equipped satellites. NGSLR's eye-safe, single photon, high frequency observations of the closer targets exhibit characteristics of system and satellite signature which must be considered in an effective orbit determination in combination with data collected by other observatories in the global SLR network. To help isolate these features, observations taken by the instrument as the receiver in a two-station configuration with MOBILAS-7 at Goddard Geophysical and Astronomical Observatory (GGAO) have been used to calibrate the NGSLR event timer and processor. High energy returns from available Earth orbiting satellites have now been used to calibrate the longer-pulse transmit system built into NGSLR to support the up-coming Lunar Reconnaissance Orbiter (LRO) Mission. Special efforts by stations in the tracking network will provide the timing required to construct the lunar observations from signals received at LRO. We will show the results of a continuing analysis of the accuracy and precision of each of the two NGSLR systems observing returns from geodetic satellites ranging in altitude from Larets to Etalon.

# Passes from NGSLR/S2k and NGSLR/LR taken this year

Satellite	DOY	Accepted Obs	RMS(mm)	NPTs	Obs/NPT	Skew	Kurtosis	NPT RMS (mm)	Mean Pass Bias (mm)	Overlap ping NPTs	Peak to Peak (mm)
Ajaisai	24	269552	53.3	28	9626	0.46	2.91				
Jason	31	3966	39.7	39	1011	0.31	2.92				
BEC	31	1064	57.8	18	59	0.49	3.14				
Starlette	31	105661	42.4	24	4402	0.31	2.81				
Glomass-95	31	601	42.5	6	100	0.07	2.39				
Envisat	31	93909	36.3	13	7223	0.36	2.86				
Envisat	60	26993	31.6	17	1587	0.32	2.93				
Jason	60	1013	35.2	12	84	-0.3	3.22				
ERS-2	60	82731	31.3	10	8273	0.27	3.01				
Jason	66	1113	43.1	20	95	0.28	3.22				
Larets	66	1195	43.4	7	170	0.28	2.9				
ERS-2	66	35227	34.1	20	1761	0.4	2.94				
Ajaisai	66	7800	54.2	22	354	0.53	3.04				
BEC	66	157123	37.7	35	4489	0.39	2.9				
Ajaisai	67	4607	44.5	11	418	0.42	2.86				
Lageos-2	67	694	81.3	13	53	0.23	2.72				
ERS-2	108	154721	38.8	28	5525	0.25	2.99	0.6			
ERS-2	114	31270	41.4	23	1359	0.23	3	4.5			
Larets	114	7968	39.9	14	569	0.29	3.38	3.3			
BEC	150	2392	43.1	17	140	0.38	3.08	5			
BEC	150	23587	36.7	11	2144	0.47	3	1.5			
Larets	150	25062	37.7	29	895	0.44	2.98	4.3			
BEC	151	11767	48.2	22	534	0.3	2.9	4.3			
BEC	151	170364	46	29	5874	0.36	2.9	1.2			
Lageos-2	151	3756	47.7	21	178	0.08	2.37	0.8			
Starlette	151	6195	37.9	16	387	0.36	2.93	3.2			
BEC	151	118216	56	7	16888	0.41	2.91	0.4			
Ajaisai	162	117852	44.4	31	3801	0.39	2.84	3.4			
Starlette	162	2177	40.1	15	145	0.188	2.95	4.3			
Lageos-2	164	4846	32.1	15	323	0.1	2.2	2.3	9.6	3	11.7
Envisat	164	54192	34.6	31	1748	0.35	2.92	2.1			
Ajaisai	164	110559	44.8	30	3685	0.46	2.9	1.6			
ERS-2	164	22894	33.1	33	693	0.35	2.87	2			
Starlette	164	7716	32	20	385	0.33	2.9	1.8	4.3	19	15.8
BEC	165	4946	33.1	8	618	0.35	3.03	1.6	-56.1	6	28
ERS-2	165	152440	32.6	34	4477	0.39	3	1			
Ajaisai	165	601211	43.7	28	21471	0.57	2.02	0.5	-16.2	4	14.4
Lageos-2	165	15590	34	18	865	0.1	2.24	1.9	22.4	9	20.1
GFO	177	189751	34.3	31	6121	0.38	2.99	0.6			
Lageos-2	177	2061	49.6	15	137	0.1	2.72	3.8	-9.9	14	18.5
Starlette	177	70201	31	24	2825	0.42	2.92	1	-25.4	4	18.1
ERS-2	177	71341	32.7	24	2972	0.42	2.95	1.9	-28.4	1	0
Jason	177	24033	30.4	42	572	0.38	2.88	2.6	-12.9	21	29.7
Starlette	178	93276	32	19	4909	0.42	2.92	0.6	-33.1	18	42.7
Lageos-2	178	1666	47.2	17	98	0.09	2.74	5.3	23.5	12	23.8
Ajaisai	178	32431	44.4	24	1351	0.5	2.95	2.7	1.4	17	32.8
Ajaisai	184	104957	48.9	26	4036	0.49	3.01	2.7			
Jason	184	49014	37.9	32	1531	0.39	2.97	2.9			
Larets	184	16393	33.9	13	1261	0.34	2.98	3.2	-48.6	7	51.6
ERS-2	184	29398	43.5	17	1729	0.37	2.92	2.6	-38.9	5	20.8
Ajaisai	193	413332	46.7	28	14761	0.59	3.03	0.8	4	3	11.3
Lageos-2	193	5648	36.8	17	332	0.11	2.24	2.5	5.4	12	15
Lageos	198	1253	30	7	179	0.09	2.02	2.5			
Lageos-2	198	463	42.7	7	66	0.21	2.66	6.5			
Envisat	212	8202	30.5	14	585	0.29	2.89	2.1	-21.4	5	45.6
BEC	220	63161	35.9	30	2105	0.3	2.83	1.1	-20.2	7	17
BEC	221	13582	37.6	25	543	0.29	2.82	2			
Envisat	225	3306	27.6	17	194	0.23	2.9	2.1			
ERS-2	225	9175	32.8	19	482	0.22	2.92	2.3			
BEC	225	11811	33.9	33	357	0.35	2.85	2.6			
Starlette	225	37254	31.4	11	3395	0.29	2.9	2.5			
Envisat	226	983	31.5	10	98	0.23	2.83	3.8	-31.4	7	15.1
BEC	226	158274	36.8	47	3367	0.36	2.91	1.7			
Larets	226	3044	27.5	12	753	0.27	2.92	2.7			
Starlette	234	133693	28.8	17	7864	0.32	2.93	1	-4.2	10	26.5
Lageos-1	234	134	40.1	4	33	0.6	3.34	5.9	23.2	3	2.3
Larets	234	33972	25.3	10	3397	0.33	2.93	1.1	-24.2	2	20.2
Envisat	234	1458	29.2	14	104	0.18	2.85	3.9	8	6	10.3
Lageos	247	3959	43.9	23	172	0.19	3.04	4.7	45.1	5	15.5
Larets	247	63275	35.7	11	5752	0.08	3.16	0.7			
Envisat	247	2537	33	12	211	0.215	3.19	3.9	1.4	3	2.5
Starlette	247	176600	35	22	8027	0.06	3.21	0.7			
Lageos	263	1245	44.8	13	95	0.35	3.18	4.7			
Larets	263	15628	31.9	13	1202	0.36	2.92	2.4			
Ajaisai	267	37583	47.3	21	1769	0.44	2.88	1.8	-9320.8	19	64.8
Larets	268	89335	36.3	16	6565	0.23	3.04	1.6	-15.4	9	32.3
Ajaisai	268	202346	47.5	30	6744	0.38	2.9	1.1	-18.9	30	53.8

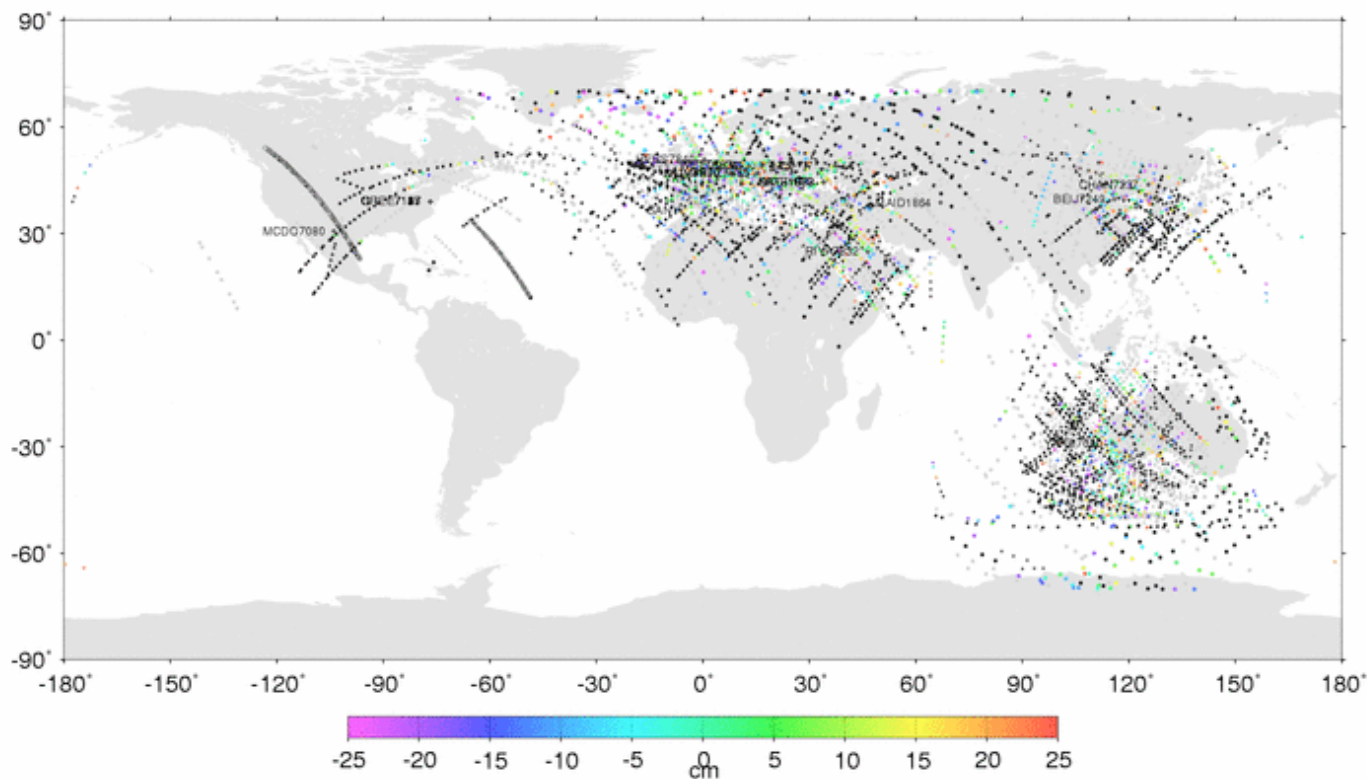
Satellite	SIC	DOY	Start Time	Accepted Obs.	RMS(mm)	NPTs	Obs/NPT	Skew	Kurtosis	NPT RMS (mm)	Mean Pass Bias (mm)	Overlap ping NPTs	Peak to Peak (mm)
Larets	5557	5	2:31	2214	279.5	10	221	0.3	2.62				
Ajaisai	1500	5	3:17	5542	266.8	15	369	0.34	2.76				
Etalon-1	525	5	3:30	276	322.3	6	46	0.12	3.07				
Starlette	1134	5	4:26	4141	240.6	7	591	0.29	2.82				
BEC	317	21	1:30	5170	282.3	27	191	0.38	2.9				
Etalon-1	525	21	1:44	18	316.2	7	2	0.08	4.4				
Ajaisai	1500	21	2:59	5388	247.2	21	256	0.25	2.9				
Jason	4378	73	2:02	2109	310.5	17	124	0.43	2.84	37.5			
ERS-2	6178	73	2:54	8701	274.3	27	322	0.31	2.8	18.1			
Jason	4378	74	0:26	27011	296.1	46	587	0.43	2.91	16.4			
Lageos-2	5986	81	3:14	200	357.1	9	22	0.22	2.76	71.8			
Starlette	1134	107	1:38	10459	310.6	10	1045	0.24	2.89	10.5			
Lageos-2	5986	107	1:45	25601	284.1	8	3200	0.42	2.83	14.8			
ERS-2	6178	116	2:06	2093	287.6	17	123	0.31	2.97	30			
Larets	5557	116	3:02	4334	297.6	9	481	0.29	2.8	23.6			
Etalon-2	4146	170	0:39	299	477.4	10	29	0.12	2.5	77.5			
Envisat	6179	170	1:36	2019	341.4	22	91	0.51	2.89	38.8			
Ajaisai	1500	170	1:57	23941	266.30	30	798	0.51	3.01	10.1			
Lageos-2	5986	170	3:00	12739	306.6	29	439	0.37	2.84	19.5			
Larets	5557	207	2:29	1217	288.1	9	135	0.27	2.88	26.4	-65.5	5	245.4
BEC	317	207	3:15	34684	241.9	44	788	0.17	2.87	8.5	-165.1	34	385.6
Etalon-2	525	207	3:22	3179	237.9	1	3179	0.11	2.71	3.6			
ERS-2	6178	207	2:42	9738	259.3	24	405	0.31	2.82	16.5	-97.4	19	385.1
Lageos-1	1155	207	3:48	1688	303.3	17	99	0.41	2.76	33.8			
Lageos	1155	248	0:53	294	256.1	8	36	0.39	2.82	44.8			
Envisat	6179	248	2:24	3184	240.6	11	289	0.28	2.83	21.2			

# NGSLR 2khz Current Configuration

- Laser per pulse energy: 120 microJoules (eyesafe).
- Pulsewidth: ~ 300 picosec
- Pulse repetition rate: variable from 2.0 khz to 1.96 khz. Modified periodically to prevent collision between fires and returns.
- Laser divergence: nominally 4 x 6 arcseconds. Can modify this as needed. On LAGEOS we can run as low as 3 x 5 arcseconds.
- Telescope pointed behind, Risleys used to point laser beam ahead.
- Quadrant MCP: High Quantum Efficiency (~32%) Hamamatsu model R4110U-74-M004C.
- Discriminators with threshold setting nominally  $< 1/2$  single PE voltage
- Receiver FOV nominally set at 11, 16 or 25 arcseconds.
- Mount pointing: ~ 1 arcsec. Starcal RMS:  $< 2.5$  arcsec.

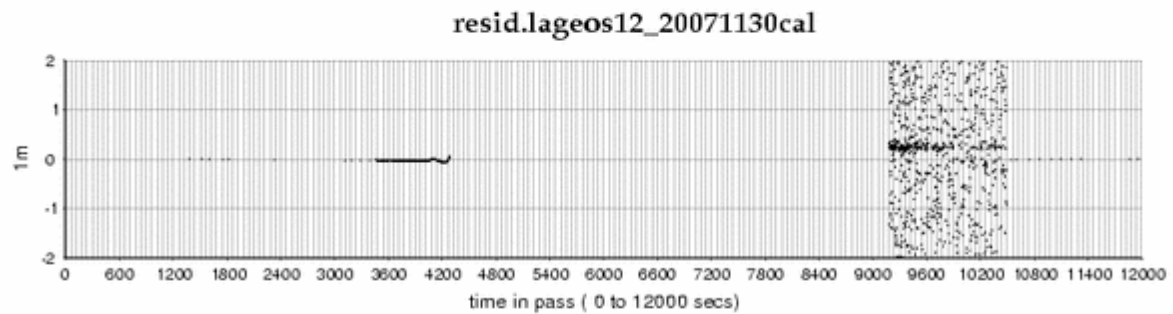
### orbit fit residuals for 20071123 through 20071130 12 hr UTC

•	ETALON-1	19120 km	64.9 deg	info (mm)	ave	-59 +/- 3282	max 3401	min -30208	for 98 obs of 102 input
★	ETALON-2	19120 km	65.5 deg	info (mm)	ave	583 +/- 8153	max 80748	min -5012	for 102 obs of 111 input
●	LAGEOS-1	5895 km	109 deg	info (mm)	ave	-9 +/- 20385	max 69213	min -86470	for 23635 obs of 23708 input
◆	LAGEOS-2	5785 km	52 deg	info (mm)	ave	57 +/- 26086	max 73304	min -89692	for 475165 obs of 475254 input
■	AJISAI	1492 km	50 deg	info (mm)	ave	81 +/- 1224	max 4439	min -4617	for 1789 obs of 2092 input
▼	STARLETTE	953 km	50 deg	info (mm)	ave	3 +/- 597	max 2197	min -1557	for 994 obs of 1160 input
▲	STELLA	795 km	99 deg	info (mm)	ave	48 +/- 692	max 2687	min -2778	for 506 obs of 637 input

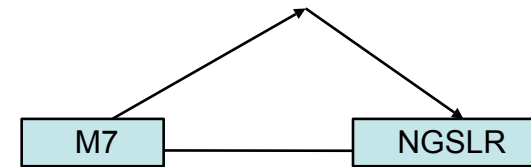


Range residuals to Day 334 Lageos 2 normal points  
and Lageos 1 full rate observations

The orbit was determined with SLR data  
from the Global Laser Tracking Network



## NGSLR/2K Calibration with MOBLAS7



In 3-way configuration:

MOBLAS-7 fires – NGSLR receiving only

Cables run from MOB-7 to NGSLR Event Timer for Start and Stop

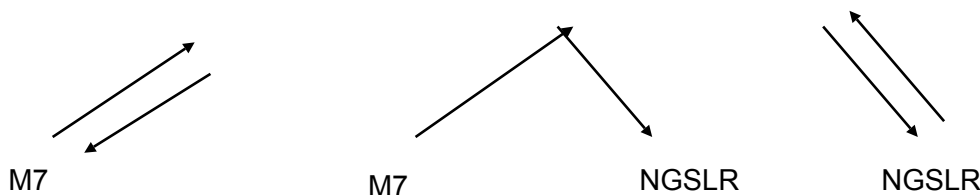
NGSLR quadrant detector also receiving

NGSLR uses threshold discriminator: higher detection noise level

MOBLAS transmits short pulses but multi-photon

In 2-way configuration:

NGSLR transmits longer, single photon pulses



## NOISE LEVELS OF 2 WAY DATA



MOB7-MOB7

MOB7(NGSLR)

8 mm

10

10

15

8 mm

10

10

15

ERS-2

STARLETTE

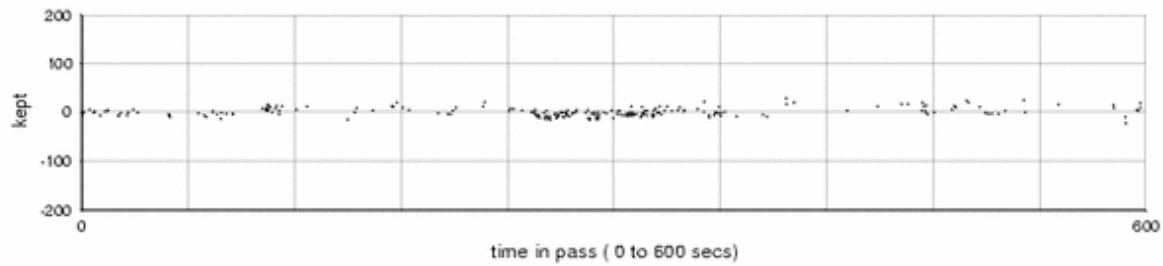
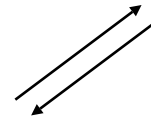
LAGEOS2

AJISAI

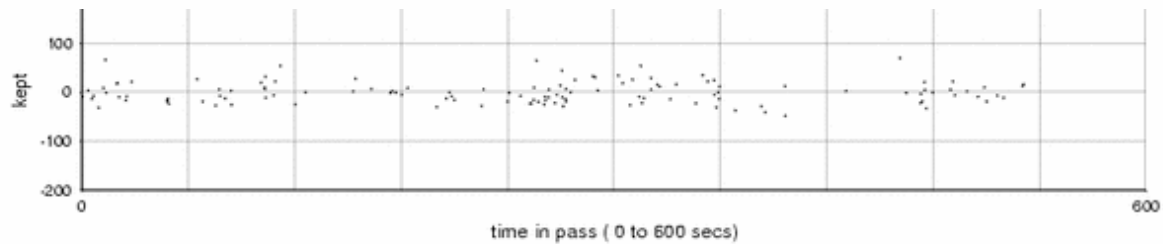
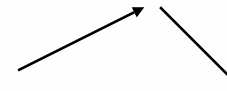
NGSLR Timing and Software checked

# NGSLR RECEIVING FROM LAGEOS2 Aug 22

MOB7/MOB7 10mm



MOB7/NGSLR 28mm





## NOISE LEVELS OF 2 WAY AND 3-WAY DATA

MOB7  
(NGSLR)

MOB7-  
NGSLR

NGSLR-  
NGSLR

8 mm

21 mm

30 mm

ERS-2

10

26

30 STARLETTE

10

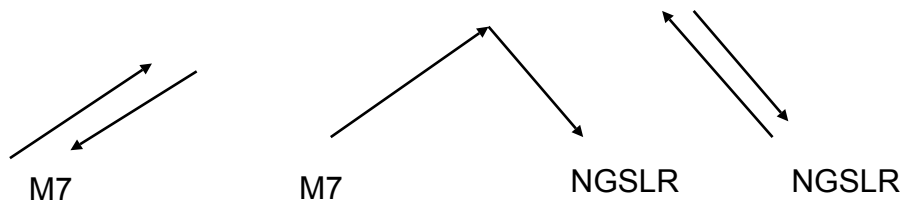
21

35 LAGEOS2

15

35

42 AJISAI



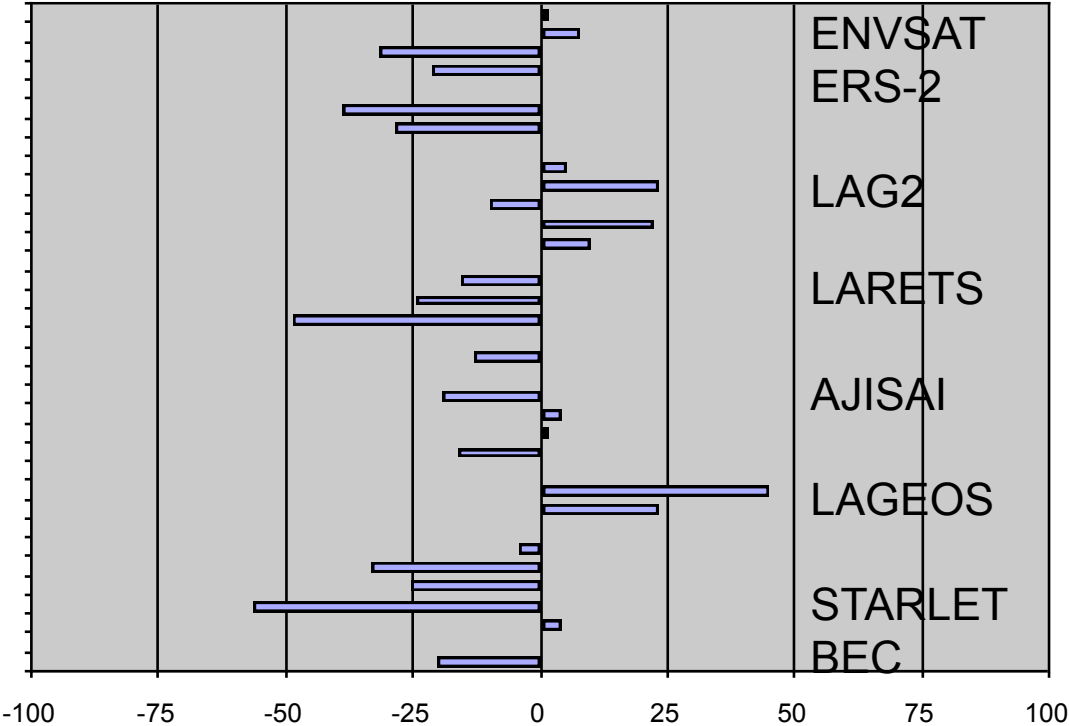
# NGSLR/2K Passes in 2008

Satellite	DOY	Accepted Obs.	RMS(mm)	NPTs	Obs/NPT	Skew	Kurtosis	NPT RMS (mm)	Mean Pass Bias (mm)	Overlap ping NPTs	Peak to Peak (mm)
Ajsai	24	269552	53.3	28	9626	0.46	2.91				
Jason	31	3966	38.7	39	101	0.31	2.92				
BEC	31	1064	57.8	18	59	0.49	3.14				
Starlette	31	105661	42.4	24	4402	0.31	2.81				
Glonass-95	31	601	42.5	6	100	0.07	2.39				
Envisat	31	93909	36.3	13	7223	0.36	2.86				
Envisat	60	26993	31.6	17	1587	0.32	2.93				
Jason	60	1013	35.2	12	84	-0.3	3.22				
ERS-2	60	82731	31.3	10	8273	0.27	3.01				
Jason	66	1113	43.1	20	55	0.28	3.22				
Larets	66	1195	43.4	7	170	0.28	2.9				
ERS-2	66	35227	34.1	20	1761	0.4	2.94				
Ajsai	66	7800	54.2	22	354	0.53	3.04				
BEC	66	157123	37.7	35	4489	0.39	2.9				
Ajsai	67	4607	44.5	11	418	0.42	2.86				
Lageos-2	67	694	81.3	13	53	0.23	2.72				
ERS-2	108	154721	38.8	28	5525	0.25	2.99	0.6			
ERS-2	114	31270	41.4	23	1359	0.23	3	4.1			
Larets	114	7968	39.9	14	569	0.29	3.38	3.3			
BEC	150	2392	43.1	17	140	0.38	3.08	5			
BEC	150	23587	36.7	11	2144	0.47	3	1.5			
Larets	150	25962	37.7	29	895	0.44	2.98	4.3			
BEC	151	11767	48.8	22	534	0.3	2.9	4.3			
BEC	151	170364	46	29	5874	0.36	2.9	1.2			
Lageos-2	151	3756	47.7	21	178	0.08	2.37	3.8			
Starlette	151	6195	37.9	16	387	0.36	2.93	3.2			
BEC	151	118216	56	7	16888	0.41	2.91	0.4			
Ajsai	162	117852	44.4	31	3801	0.39	2.84	3.4			
Starlette	162	2177	40.1	15	145	0.188	2.95	4.3			
Lageos-2	164	4846	32.1	15	323	0.1	2.2	2.3	9.6	3	11.7
Envisat	164	54192	34.6	31	1748	0.35	2.92	2.1			
Ajsai	164	110559	44.8	30	3685	0.48	2.9	1.6			
ERS-2	164	22894	33.1	33	693	0.35	2.87	2			
Starlette	164	7716	32	20	385	0.33	2.9	1.8	4.3	19	15.8
	165	4946	33.1	8	618	0.35	3.03	1.6	-56.1	6	28
ERS-2	165	152240	32.6	34	4477	0.39	3	1			
Ajsai	165	601211	43.7	28	21471	0.57	2.02	0.5	-16.2	4	14.4
Lageos-2	165	15580	34	18	865	0.1	2.24	1.9	22.4	9	20.1
GFO	177	189751	34.3	31	6121	0.38	2.99	0.6			
Lageos-2	177	2061	49.6	15	137	0.1	2.72	3.8	-9.9	14	18.5
Starlette	177	70201	31	24	2925	0.42	2.92	1	-25.4	4	18.1
ERS-2	177	71341	32.7	24	2972	0.42	2.95	1.9	-28.4	1	0
Jason	177	24033	30.4	42	572	0.38	2.88	2.6	-12.9	21	29.7
Starlette	178	93276	32	19	4909	0.42	2.92	0.6	-33.1	18	42.7
Lageos-2	178	1666	47.2	17	98	0.09	2.74	5.3	23.5	12	23.8
Ajsai	178	32431	44.4	24	1351	0.5	2.95	2.7	1.4	17	32.8
Ajsai	184	104957	48.9	26	4036	0.49	3.01	2.7			
Jason	184	49014	37.9	32	1531	0.39	2.97	2.9			
Larets	184	16393	33.9	13	1261	0.34	2.98	3.2	-48.6	7	51.6
ERS-2	184	29398	43.5	17	1729	0.37	2.92	2.6	-38.9	5	20.8
Ajsai	193	413332	46.7	28	14761	0.59	3.03	0.8	4	3	11.3
Lageos-2	193	5648	36.8	17	332	0.11	2.24	2.5	5.4	12	15
Lageos	198	1253	30	7	179	0.09	2.02	2.5			
Lageos-2	198	463	42.7	7	66	0.21	2.66	6.5			
Envisat	212	8202	30.5	14	585	0.29	2.89	2.1	-21.4	5	45.6
BEC	220	63161	35.9	30	2105	0.3	2.83	1.1	-20.2	7	17
BEC	221	13582	37.6	25	543	0.29	2.82	2			
Envisat	225	3306	27.6	17	194	0.23	2.9	2.1			
ERS-2	225	9175	32.8	19	482	0.22	2.92	2.3			
BEC	225	11811	33.9	33	357	0.35	2.85	2.6			
Starlette	225	37354	31.4	11	3395	0.29	2.9	2.5			
Envisat	226	983	31.5	10	98	0.23	2.83	3.8	-31.4	7	15.1
BEC	226	158274	36.8	47	3367	0.36	2.91	1.7			
Larets	226	9044	27.5	12	753	0.27	2.92	2.7			
Starlette	234	133693	28.8	17	7864	0.32	2.93	1	-4.2	10	26.5
Lageos-1	234	134	40.1	4	33	0.6	3.34	5.9	23.2	3	2.3
Larets	234	33972	25.3	10	3397	0.33	2.93	1.1	-24.2	2	20.2
Envisat	234	1458	29.2	14	104	0.18	2.85	3.9	8	6	10.3
Lageos	247	3959	43.9	23	172	0.19	3.04	4.7	45.1	5	15.5
Larets	247	63275	35.7	11	5752	0.08	3.16	0.7			
Envisat	247	2537	33	12	211	0.215	3.19	3.9	1.4	3	2.5
Starlette	247	176600	35	22	8027	0.006	3.21	0.7			
Lageos	263	1245	44.8	13	95	0.35	3.18	4.7			
Larets	263	15628	31.9	13	1202	0.36	2.92	2.4			
Ajsai	267	37583	47.3	21	1789	0.44	2.88	1.8	-9320.8	19	64.8
Larets	268	89535	36.3	16	5595	0.23	3.04	1.5	-15.4	9	32.3
Ajsai	268	202346	47.5	30	6744	0.38	2.9	1.1	-18.9	30	53.8

# Co-located Passes

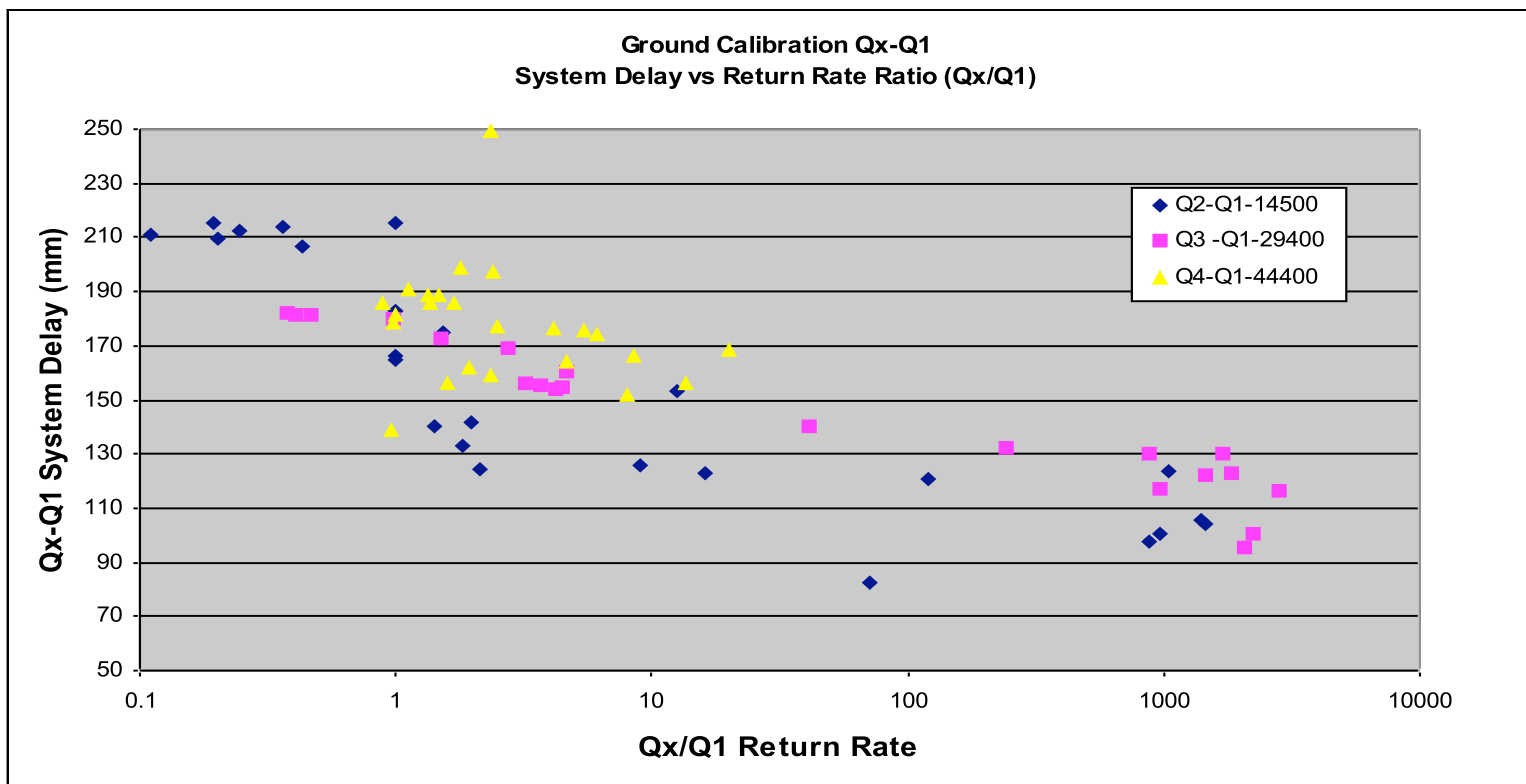
Satellite	DOY	Accepted Obs.	RMS(mm)	NPTs	NPT RMS (mm)	Mean Pass Bias (mm)	NPT over lap	Peak to Peak (mm)	Mean Pass Bias (mm)
BEC	220	63161	35.9	30	1.1	-20.2	7	17	-20.2
Starlette	164	7716	32	20	1.8	4.3	19	15.8	4.3
Starlette	165	4946	33.1	8	1.6	-56.1	6	28	-56.1
Starlette	177	70201	31	24	1	-25.4	4	18.1	-25.4
Starlette	178	93276	32	19	0.6	-33.1	18	42.7	-33.1
Starlette	234	133693	28.8	17	1	-4.2	10	26.5	-4.2
Lageos-1	234	134	40.1	4	5.9	23.2	3	2.3	23.2
Lageos	247	3959	43.9	23	4.7	45.1	5	15.5	45.1
Ajisai	165	601211	43.7	28	0.5	-16.2	4	14.4	-16.2
Ajisai	178	32431	44.4	24	2.7	1.4	17	32.8	1.4
Ajisai	193	413332	46.7	28	0.8	4	3	11.3	4
Ajisai	268	202346	47.5	30	1.1	-18.9	30	53.8	-18.9
Jason	177	24033	30.4	42	2.6	-12.9	21	29.7	-12.9
Larets	184	16393	33.9	13	3.2	-48.6	7	51.6	-48.6
Larets	234	33972	25.3	10	1.1	-24.2	2	20.2	-24.2
Larets	268	89535	36.3	16	1.5	-15.4	9	32.3	-15.4
Lageos-2	164	4846	32.1	15	2.3	9.6	3	11.7	9.6
Lageos-2	165	15580	34	18	1.9	22.4	9	20.1	22.4
Lageos-2	177	2061	49.6	15	3.8	-9.9	14	18.5	-9.9
Lageos-2	178	1666	47.2	17	5.3	23.5	12	23.8	23.5
Lageos-2	193	5648	36.8	17	2.5	5.4	12	15	5.4
ERS-2	177	71341	32.7	24	1.9	-28.4	1	0	-28.4
ERS-2	184	29398	43.5	17	2.6	-38.9	5	20.8	-38.9
Envisat	212	8202	30.5	14	2.1	-21.4	5	45.6	-21.4
Envisat	226	983	31.5	10	3.8	-31.4	7	15.1	-31.4
Envisat	234	1458	29.2	14	3.9	8	6	10.3	8
Envisat	247	2537	33	12	3.9	1.4	3	2.5	1.4
								Mean	-9.5
								Std Err.	4.5
								Std Dev	23.6
								Count	27

NGSLR-MOB7 Pass Bias: Mean  $-9.5 \pm 4.5$  mm





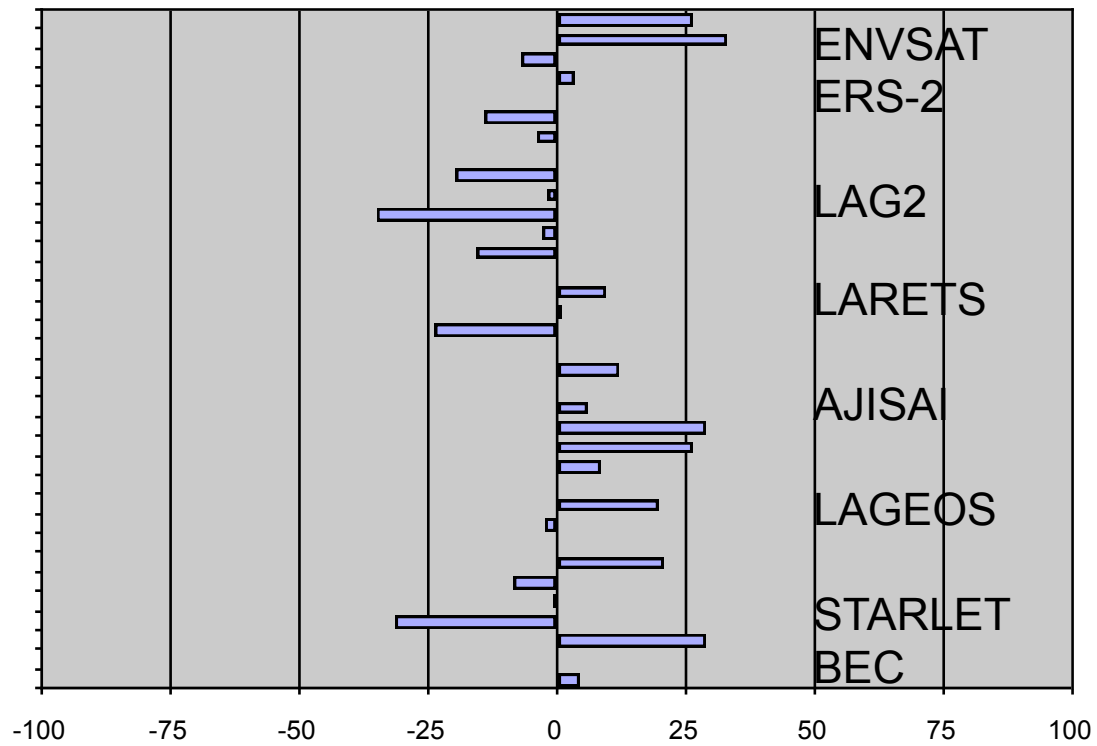
# NGSLR System Signature



# Co-located Passes

Satellite	DOY	Accepted Obs.	RMS(mm)	NPTs	NPT RMS (mm)	Mean Pass Bias (mm)	NPT over lap	Peak to Peak (mm)	Mean Pass Bias (mm)	Bias with system function (mm)
BEC	220	63161	35.9	30	1.1	-20.2	7	17	-20.2	4.8
Starlette	164	7716	32	20	1.8	4.3	19	15.8	4.3	29.3
Starlette	165	4946	33.1	8	1.6	-56.1	6	28	-56.1	-31.1
Starlette	177	70201	31	24	1	-25.4	4	18.1	-25.4	-0.4
Starlette	178	93276	32	19	0.6	-33.1	18	42.7	-33.1	-8.1
Starlette	234	133693	28.8	17	1	-4.2	10	26.5	-4.2	20.8
Lageos-1	234	134	40.1	4	5.9	23.2	3	2.3	23.2	-1.8
Lageos	247	3959	43.9	23	4.7	45.1	5	15.5	45.1	20.1
Ajisai	165	601211	43.7	28	0.5	-16.2	4	14.4	-16.2	8.8
Ajisai	178	32431	44.4	24	2.7	1.4	17	32.8	1.4	26.4
Ajisai	193	413332	46.7	28	0.8	4	3	11.3	4	29
Ajisai	268	202346	47.5	30	1.1	-18.9	30	53.8	-18.9	6.1
Jason	177	24033	30.4	42	2.6	-12.9	21	29.7	-12.9	12.1
Larets	184	16393	33.9	13	3.2	-48.6	7	51.6	-48.6	-23.6
Larets	234	33972	25.3	10	1.1	-24.2	2	20.2	-24.2	0.8
Larets	268	89535	36.3	16	1.5	-15.4	9	32.3	-15.4	9.6
Lageos-2	164	4846	32.1	15	2.3	9.6	3	11.7	9.6	-15.4
Lageos-2	165	15580	34	18	1.9	22.4	9	20.1	22.4	-2.6
Lageos-2	177	2061	49.6	15	3.8	-9.9	14	18.5	-9.9	-34.9
Lageos-2	178	1666	47.2	17	5.3	23.5	12	23.8	23.5	-1.5
Lageos-2	193	5648	36.8	17	2.5	5.4	12	15	5.4	-19.6
ERS-2	177	71341	32.7	24	1.9	-28.4	1	0	-28.4	-3.4
ERS-2	184	29398	43.5	17	2.6	-38.9	5	20.8	-38.9	-13.9
Envisat	212	8202	30.5	14	2.1	-21.4	5	45.6	-21.4	3.6
Envisat	226	983	31.5	10	3.8	-31.4	7	15.1	-31.4	-6.4
Envisat	234	1458	29.2	14	3.9	8	6	10.3	8	33
Envisat	247	2537	33	12	3.9	1.4	3	2.5	1.4	26.4
								Mean	-9.5	2.5
								Std Err.	4.5	3.5
								Std Dev	23.6	18.5
								Count	27	27

NGSLR-MOB7 Pass Bias with system function: Mean 2.5 +/- 3.5 mm

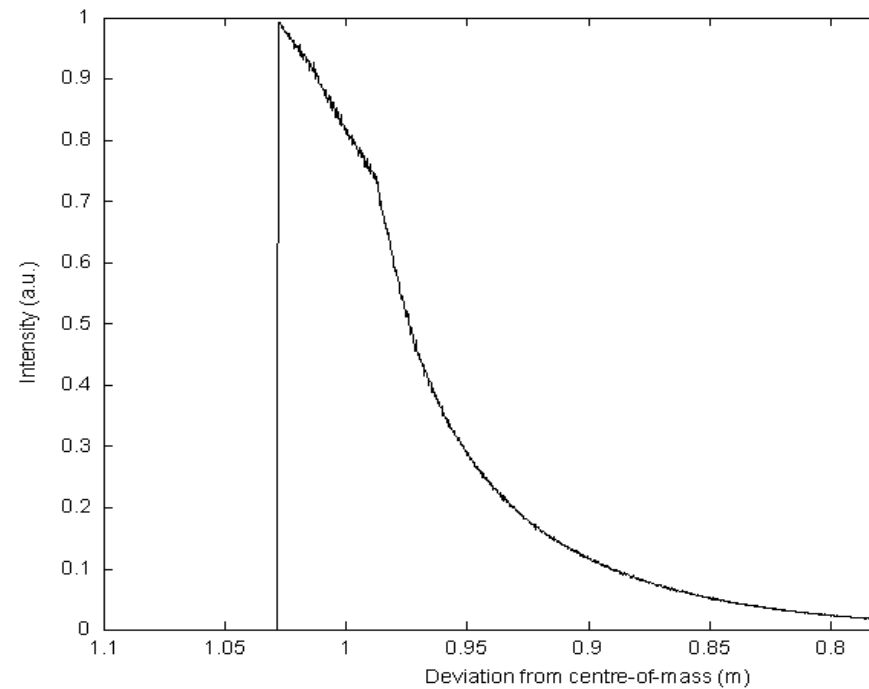




# Satellite Response Function

## Centre-of-mass correction of Ajisai

- response function



before tail-clipping: centroid = 0.9711 m; rms = 0.0568 m  
after 3xrms tail clipping: centroid = 0.9824 m; rms = 0.0363 m

click [here](#) for the ASCII table of this function (80kB).

updated: 8 June 1999; [t.otsubo@ite.ac.uk](mailto:t.otsubo@ite.ac.uk)

# Satellite Signature NGSLR/2K longer than MOB LAS7 by 25 mm

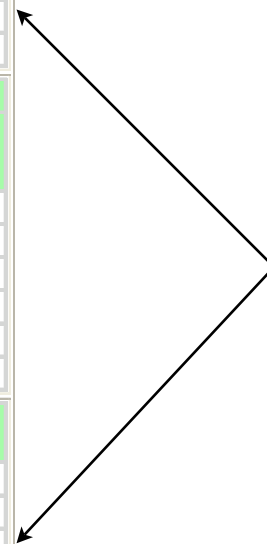
## Ajisai

### Center of Mass Information:

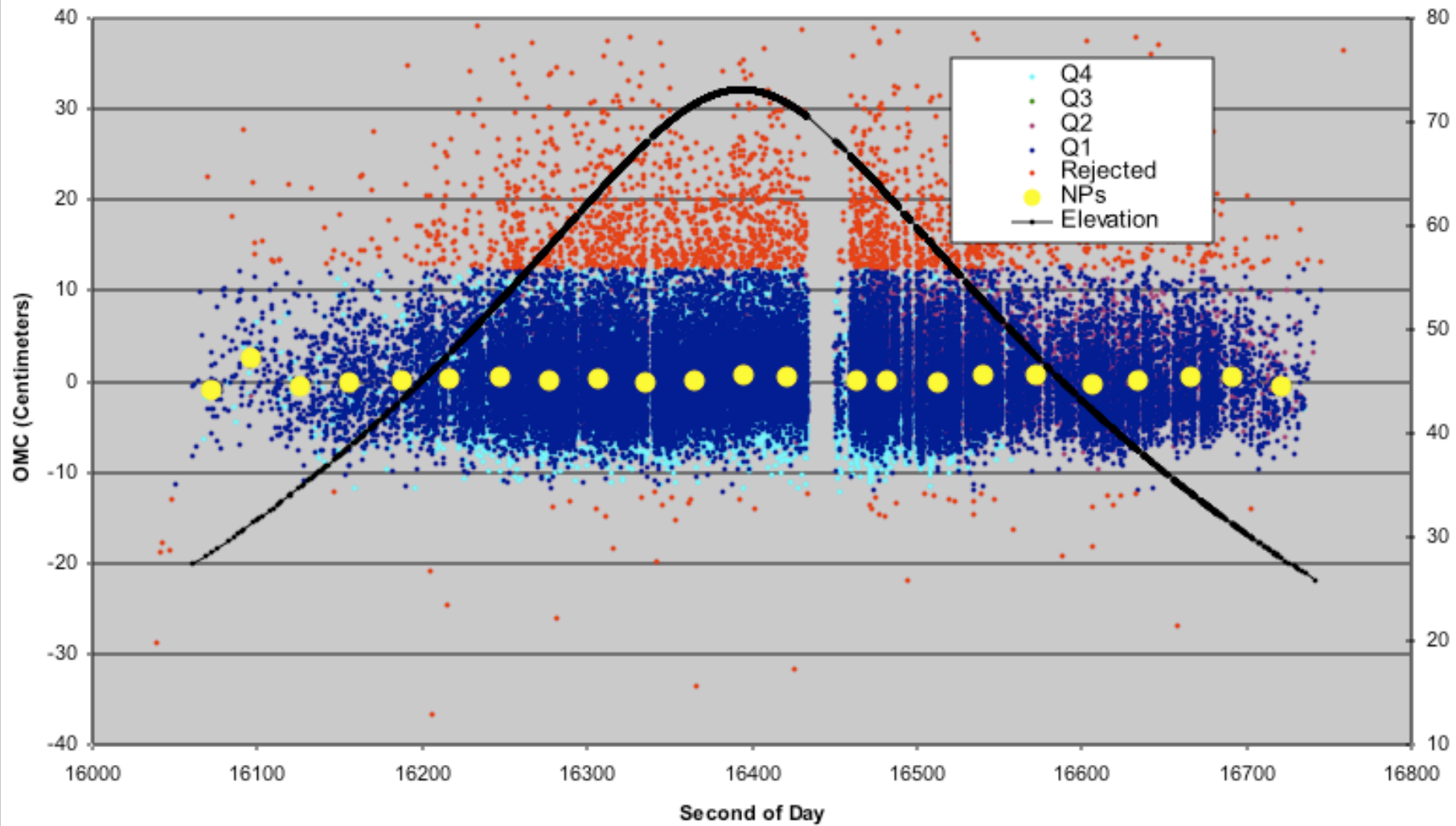
ref: [Otsubo and Appleby, "System-dependent centre-of-mass correction for spherical geodetic satellites" Journal of Geophysical Research, 108, B4, 2201, doi:10.1029/2002JB002209, 2003.](#)

The *standard* Ajisai center-of-mass correction is 1010 mm.

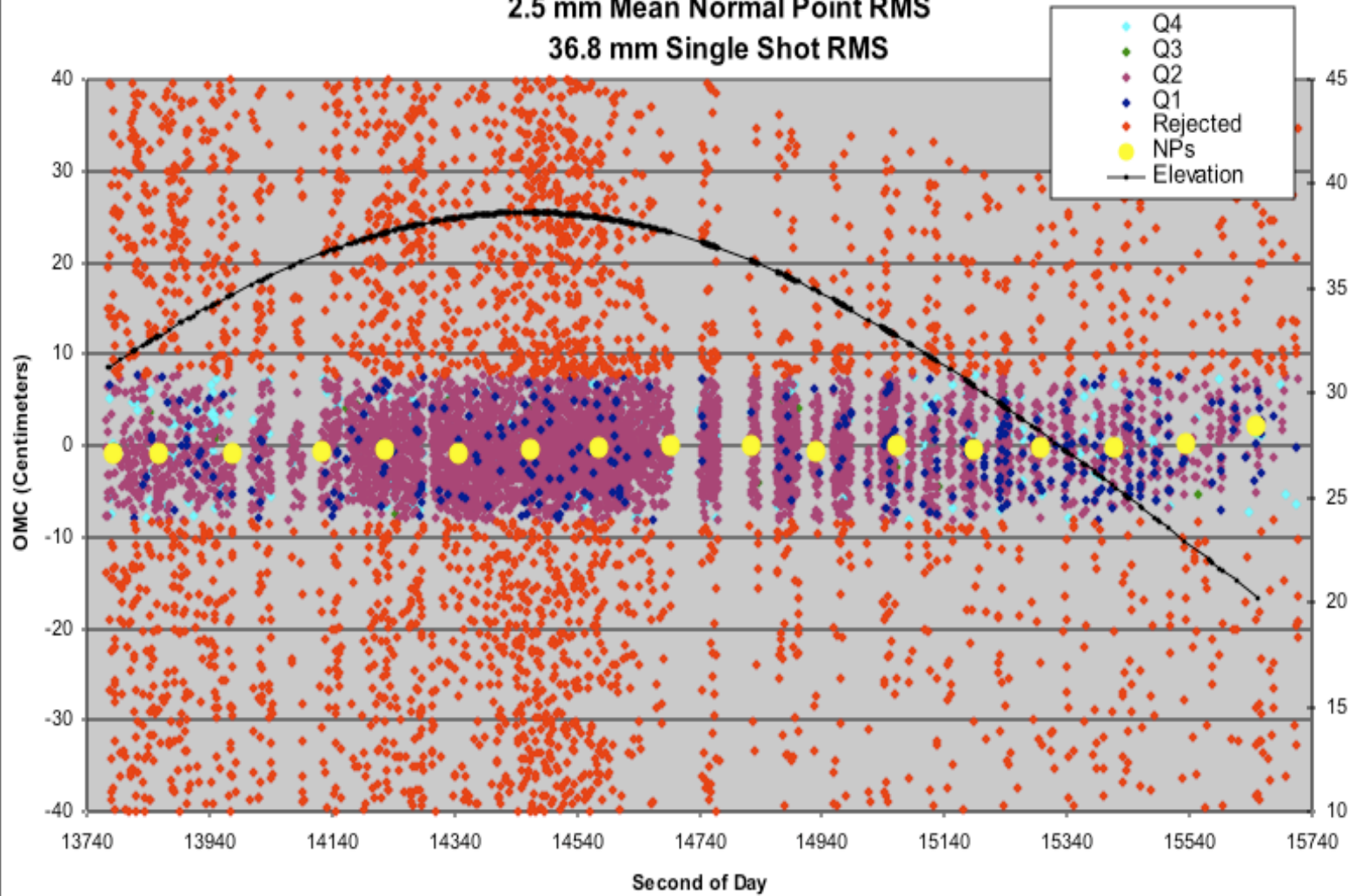
correction for single photon systems	<b>edit level</b>		<b>com (mm)</b>			
	none		962			
	3.0		976			
	2.5		985			
	2.0		997			
correction for C-SPAD (mm)	<b>FWHM pulse width (ps)</b>	<b>edit level</b>	<b>ave. num detected photons</b>			
			<b>0.1</b>	<b>1</b>	<b>10</b>	<b>100</b>
			1	3.0	977	990
		2.5	985	996	1020	1023
		2.0	997	1004	1021	1023
	100	3.0	976	989	1012	1016
		2.5	985	995	1013	1016
		2.0	997	1002	1013	1016
	correction for leading-edge-half maximum systems (mm)	<b>FWHM pulse width (ps)</b>		<b>com (mm)</b>		
1		1022				
100		1017				
300		1009				
1000		993				
3000		976				



Ajisai y07 d178 t0425 400000 obs. 4.2 cm rms  
(1 / 7 observations plotted)



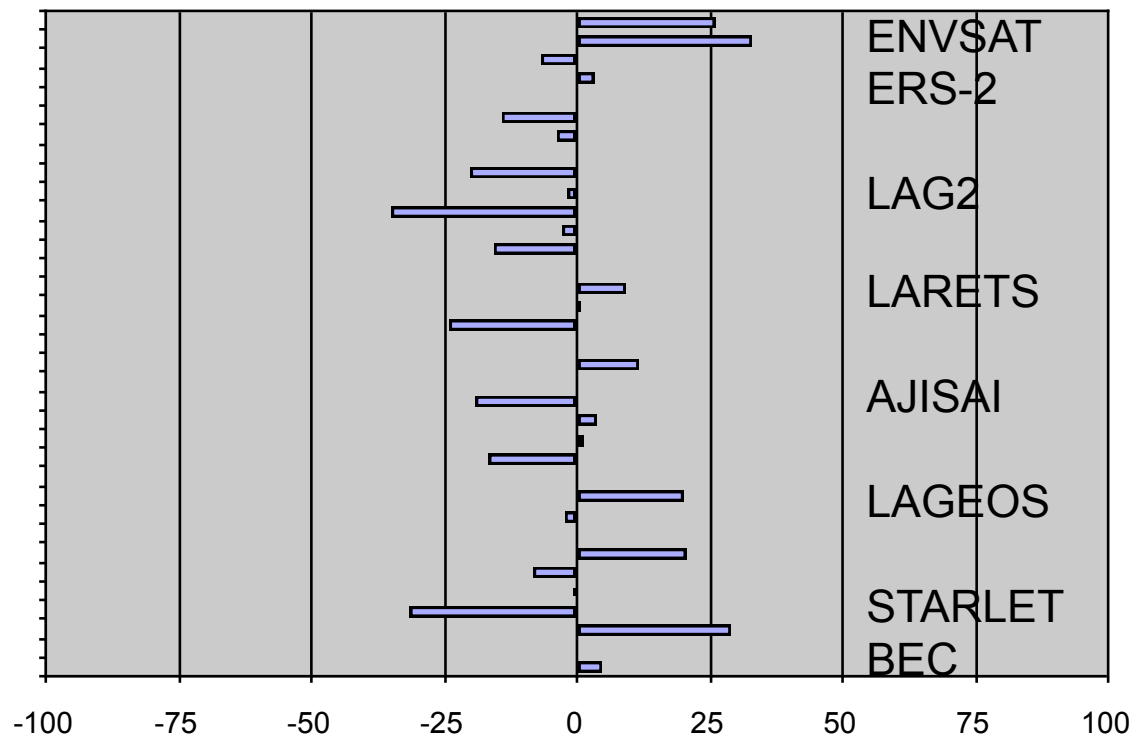
Lageos-2 y08 d193 t0349 5645 obs.  
2.5 mm Mean Normal Point RMS  
36.8 mm Single Shot RMS



# Co-located Passes

Satellite	DOY	Accepted Obs.	RMS(mm)	NPTs	NPT RMS (mm)	Mean Pass Bias (mm)	NPT over lap	Peak to Peak (mm)	Mean Pass Bias (mm)	Bias with system function (mm)	Bias with system/satellite function
BEC	220	63161	35.9	30	1.1	-20.2	7	17	-20.2	4.8	4.8
Starlette	164	7716	32	20	1.8	4.3	19	15.8	4.3	29.3	29.3
Starlette	165	4946	33.1	8	1.6	-56.1	6	28	-56.1	-31.1	-31.1
Starlette	177	70201	31	24	1	-25.4	4	18.1	-25.4	-0.4	-0.4
Starlette	178	93276	32	19	0.6	-33.1	18	42.7	-33.1	-8.1	-8.1
Starlette	234	133693	28.8	17	1	-4.2	10	26.5	-4.2	20.8	20.8
Lageos-1	234	134	40.1	4	5.9	23.2	3	2.3	23.2	-1.8	-1.8
Lageos	247	3959	43.9	23	4.7	45.1	5	15.5	45.1	20.1	20.1
Ajisai	165	601211	43.7	28	0.5	-16.2	4	14.4	-16.2	8.8	-16.2
Ajisai	178	32431	44.4	24	2.7	1.4	17	32.8	1.4	26.4	1.4
Ajisai	193	413332	46.7	28	0.8	4	3	11.3	4	29	4
Ajisai	268	202346	47.5	30	1.1	-18.9	30	53.8	-18.9	6.1	-18.9
Jason	177	24033	30.4	42	2.6	-12.9	21	29.7	-12.9	12.1	12.1
Larets	184	16393	33.9	13	3.2	-48.6	7	51.6	-48.6	-23.6	-23.6
Larets	234	33972	25.3	10	1.1	-24.2	2	20.2	-24.2	0.8	0.8
Larets	268	89535	36.3	16	1.5	-15.4	9	32.3	-15.4	9.6	9.6
Lageos-2	164	4846	32.1	15	2.3	9.6	3	11.7	9.6	-15.4	-15.4
Lageos-2	165	15580	34	18	1.9	22.4	9	20.1	22.4	-2.6	-2.6
Lageos-2	177	2061	49.6	15	3.8	-9.9	14	18.5	-9.9	-34.9	-34.9
Lageos-2	178	1666	47.2	17	5.3	23.5	12	23.8	23.5	-1.5	-1.5
Lageos-2	193	5648	36.8	17	2.5	5.4	12	15	5.4	-19.6	-19.6
ERS-2	177	71341	32.7	24	1.9	-28.4	1	0	-28.4	-3.4	-3.4
ERS-2	184	29398	43.5	17	2.6	-38.9	5	20.8	-38.9	-13.9	-13.9
Envisat	212	8202	30.5	14	2.1	-21.4	5	45.6	-21.4	3.6	3.6
Envisat	226	983	31.5	10	3.8	-31.4	7	15.1	-31.4	-6.4	-6.4
Envisat	234	1458	29.2	14	3.9	8	6	10.3	8	33	33
Envisat	247	2537	33	12	3.9	1.4	3	2.5	1.4	26.4	26.4
								Mean	-9.5	2.5	-1.1
								Std Err.	4.5	3.5	3.3
								Std Dev	23.6	18.5	17.5
								Count	27	27	27

Bias with system/satellite function: Mean  $-1.1 \pm 3.3$  mm



# NGSLR/2K Intercomparison with MOBLAS7

- Uncompensated Mean Range Bias -9.5 +/- 4.5 mm
- System Signature Applied 2.5 +/- 3.5 mm
- System and Satellite Signature -1.1 +/- 3.3 mm

# NGSLR/LR

- 50 milliJoule, 28 hz Northrup-Grumman laser added to system (532.2 nm wavelength, 6 nanosec pulsewidth).
- Removable kinematic mirror mount added to launch LRO transmit beam, and ensure easy transition between SLR and LRO lasers.
- Aircraft avoidance radar added to system (LRO laser not eyesafe).
- I/O chassis added to provide single toggle switch between SLR and LRO in the electronics.
- Cesium added to system to provide 10 Mhz ext. trigger to Event Timer
- Same start diode, Event Timer and RGG used for both SLR & LRO
- Modifications added to software to support LRO: more precision in fire-time recording, control of laser to hit Earth Window, automated processes removed, recorded all fires, and CRD added as output.



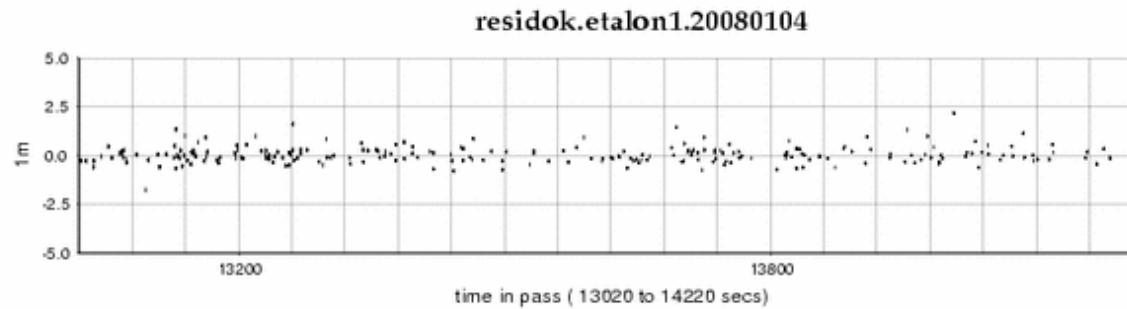
# NGSLR/R Passes in 2008

Satellite	SIC	DOY	Start Time	Accepted Obs.	RMS(mm)	NPTs	Obs/NPT	Skew	Kurtosis	NPT RMS (mm)	Mean Pass Bias (mm)	Overlap ping NPTs	Peak to Peak (mm)
Larets	5557	5	2:31	2214	279.5	10	221	0.3	2.62				
Ajsai	1500	5	3:17	5542	266.8	15	369	0.34	2.76				
Etalon-1	525	5	3:30	276	322.3	6	46	0.12	3.07				
Starlette	1134	5	4:26	4141	240.6	7	591	0.29	2.82				
BEC	317	21	1:30	5170	282.3	27	191	0.38	2.9				
Etalon-1	525	21	1:44	18	316.2	7	2	0.08	4.4				
Ajsai	1500	21	2:59	5388	247.2	21	256	0.25	2.9				
Jason	4378	73	2:02	2109	310.5	17	124	0.43	2.84	37.5			
ERS-2	6178	73	2:54	8701	274.3	27	322	0.31	2.8	18.1			
Jason	4378	74	0:26	27011	296.1	46	587	0.43	2.91	16.4			
Lageos-2	5986	81	3:14	200	357.1	9	22	0.22	2.76	71.8			
Starlette	1134	107	1:38	10459	310.6	10	1045	0.24	2.89	10.5			
Lageos-2	5986	107	1:45	25601	294.1	8	3200	0.42	2.83	14.8			
ERS-2	6178	116	2:06	2093	287.6	17	123	0.31	2.97	30			
Larets	5557	116	3:02	4334	297.6	9	481	0.29	2.8	23.6			
Etalon-2	4146	170	0:39	299	477.4	10	29	0.12	2.5	77.5			
Envisat	6179	170	1:36	2019	341.4	22	91	0.51	2.89	38.8			
Ajsai	1500	170	1:57	23941	266.8	30	798	0.51	3.01	10.1			
Lageos-2	5986	170	3:00	12739	306.6	29	439	0.37	2.84	19.5			
Larets	5557	207	2:29	1217	288.1	9	135	0.27	2.88	26.4	-65.5	5	245.4
BEC	317	207	3:15	34684	241.9	44	788	0.17	2.87	8.5	-165.1	34	385.6
Etalon-2	525	207	3:22	3179	237.9	1	3179	0.11	2.71	3.6			
ERS-2	6178	207	2:42	9738	259.3	24	405	0.31	2.82	16.5	-97.4	19	385.1
Lageos-1	1155	207	3:48	1688	303.3	17	99	0.41	2.76	33.8			
Lageos	1155	248	0:53	294	256.1	8	36	0.39	2.82	44.8			
Envisat	6179	248	2:24	3184	240.6	11	289	0.28	2.83	21.2			

# NGSLR/LR Etalon 1 range residuals to an orbit fitted by the Global Laser Tracking Network

The observations were included in the orbit determination

The raw data RMS was 32 cm.



# Conclusions

- NGSLR/2K receiver performance has been calibrated using MOB LAS-7 transmissions
- NGSLR/2K data co-located with MOB LAS-7 agree to  $-1.1$  mm  $\pm$  3.3 mm
- NGSLR/2K transmit/receive configuration shows noise characteristics expected from eye-safe operation
- Satellite signature will affect the accuracy of orbits determined with single photon systems
- NGSLR/LR fits LEO and HEO orbits with decimeter noise and centimeter accuracy