



Joint-stock company  
«RESEARCH-AND-PRODUCTION CORPORATION  
«PRECISION SYSTEMS AND INSTRUMENTS»

# **Analysis of the LARGE campaign results in the context of a discussion about requirements for arrangement of tracking of the GLONASS satellites**

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# Requirements for SLR measurement plan

## This time we need

### (LARGE-3 GNSS Tracking Campaign):

#### 1. 9 NP per pass:

- 3 in the beginning of a pass;
- 3 in the middle of a pass;
- 3 in the end of a pass.

In each segment NP may be obtained collectively or separately, depending on how it is more convenient for a particular station/operator.

#### 2. More daytime measurements even during the sunrise and sunset.

### Definitions:

**NP length:** up to 5 min or 1000 FR points.

**Segment:** the length of a satellite's visibility period is divided by 3 segments (beginning, middle, end).

**Pass:** the whole period of time during which a satellite can be observed by a station.

Station	#	Pass/Sector/NP ratio (required is 1/3/9)		
		Pass	Sector/Pass	NP/Pass
Tahiti	7124	1	2.4	9.7
Matera	7941	1	2.4	7.6
Hartebeesthoek	7501	1	3.0	7.0
Greenbelt	7105	1	2.3	6.8
Yarragadee	7090	1	2.8	6.6
Graz	7839	1	1.9	6.4
Katziwely	1893	1	1.3	5.8
Potsdam	7841	1	1.3	5.4
Wetzell	8834	1	1.7	5.1
Shanghai	7821	1	1.3	4.9
Mount Stromlo	7825	1	1.5	4.8
Baikonur	1887	1	1.5	4.6
Komsomolsk	1868	1	1.5	4.6
Simeiz	1873	1	1.0	4.5
Altay	1879	1	1.5	4.5
Wetzell	7827	1	1.5	3.8
Brasilia	7407	1	1.5	3.6
Beijing	7249	1	1.2	3.6
Herstmonceux	7840	1	1.5	3.6
Monument Peak	7110	1	1.7	3.4
Zelenchukskaya	1889	1	1.0	3.3
Mendeleevo	1874	1	1.5	3.2
Changchun	7237	1	1.3	2.6
Arkhyz	1886	1	1.0	2.4
Zimmerwald	7810	1	1.3	2.0
Badary	1890	1	1.0	1.5

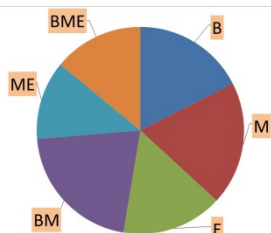
**Conclusion:** required (expected) ration of  $P/S/NP = 1/3/9$ . Actual (LARGE-4.2): min=1/1.0/1.5 (BADL), max=1/2.4/9.7 (THTL).



# Specifics of SLR measurement plan implementation

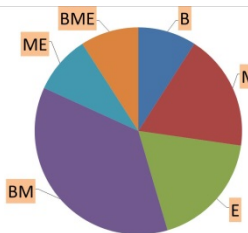
**Type 1**  
 («quasiuniform»)

1868 (KOML)



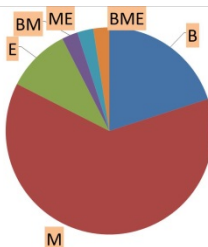
**Type 2**  
 (BM prevail)

1874 (MDVS)

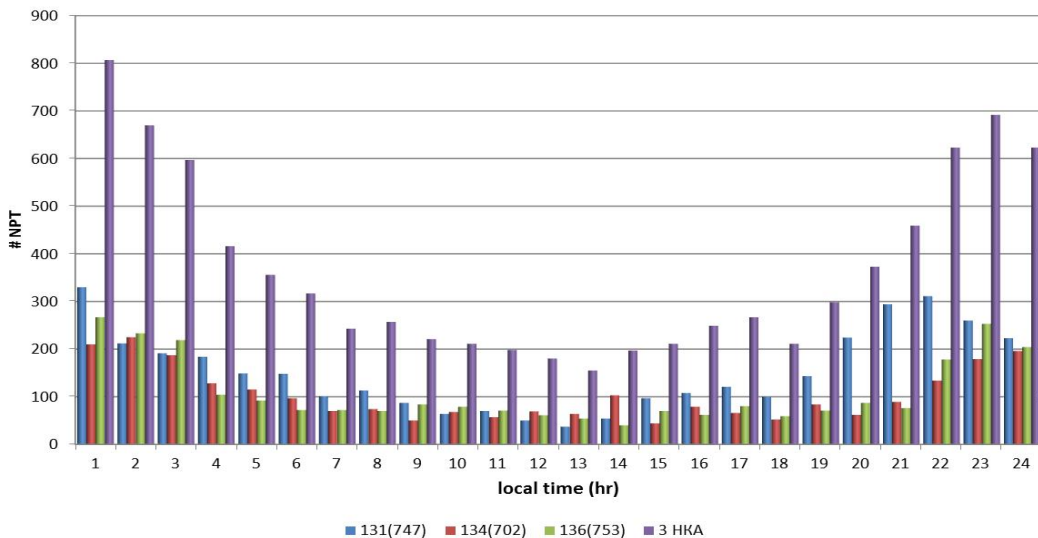


**Type 3 (M prevail)**

1889 (ZELL)



Зависимость SLR-наблюдений от местного времени



Station	#	Sectors, %						
		B	M	E	BE	BM	ME	BME
Altay	1879	25	15	11	0	38	11	0
Arkhyz	1886	6	76	18	0	0	0	0
Badary	1890	0	0	0	0	0	0	0
Baikonur	1887	18	43	3	0	23	6	9
Beijing	7249	9	72	0	0	19	0	0
Brasilia	7407	20	23	19	0	20	11	7
Changchun	7237	40	30	6	0	17	3	4
Graz	7839	18	15	5	0	24	12	25
Greenbelt	7105	27	41	14	0	8	9	0
Hartebeesthoek	7501	25	52	17	0	4	2	0
Herstmonceux	7840	18	32	4	0	27	9	9
Katzively	1893	6	53	12	0	24	6	0
Komsomolsk	1868	24	32	3	0	24	11	5
Matera	7941	20	53	14	0	7	6	0
Mendeleevo	1874	28	50	11	0	11	0	0
Monument Peak	7110	17	59	24	0	0	0	0
Mount Stromlo	7825	11	53	1	0	22	4	10
Potsdam	7841	6	69	0	0	25	0	0
Shanghai	7821	8	63	13	0	4	13	0
Simeiz	1873	0	0	0	0	0	0	0
Tahiti	7124	6	59	21	0	9	6	0
Wetzell	7827	32	20	4	0	26	7	10
Wetzell	8834	17	31	8	0	15	11	17
Yarragadee	7090	25	46	24	0	2	4	0
Zelenchukskaya	1889	10	80	10	0	0	0	0
Zimmerwald	7810	2	33	39	0	5	19	2
	26	21	43	15	0	11	6	4

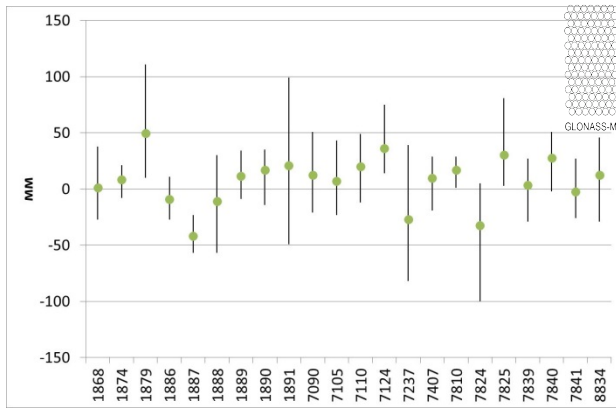
Note: B – beginning of a pass, M – middle of a pass, E – end of a pass.

**Conclusion:** it is necessary to aim for «quasiuniform» distribution of SLR measurements, regardless of the local time.

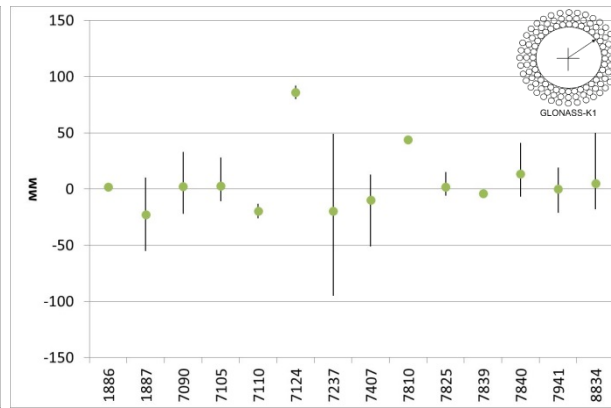


# Accuracy of laser measurements (LARGE-3, in relation to the «laser» orbit)

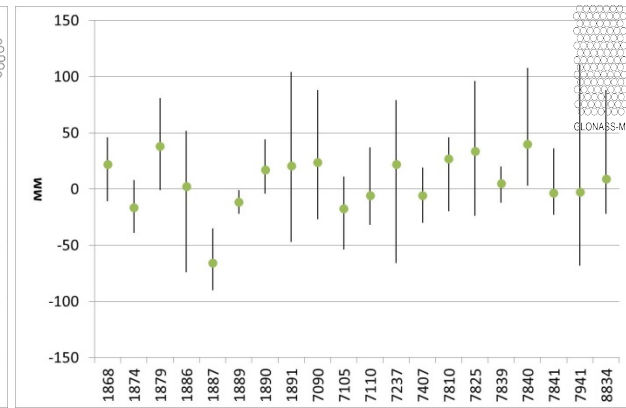
## GLONASS-123



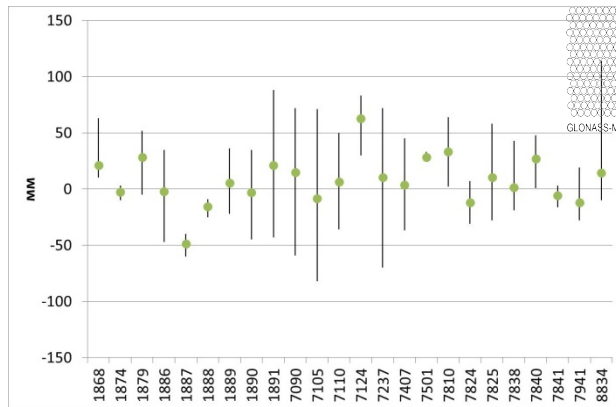
## GLONASS-125



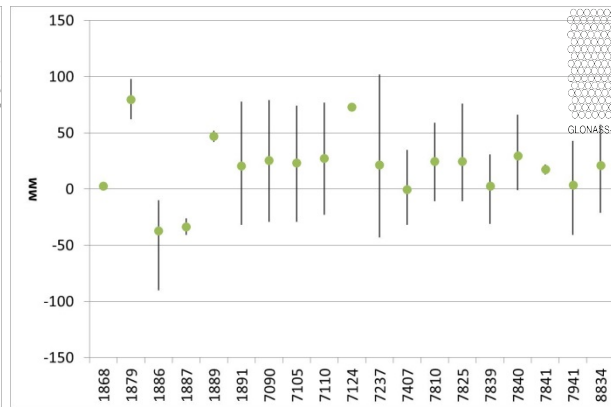
## GLONASS-128



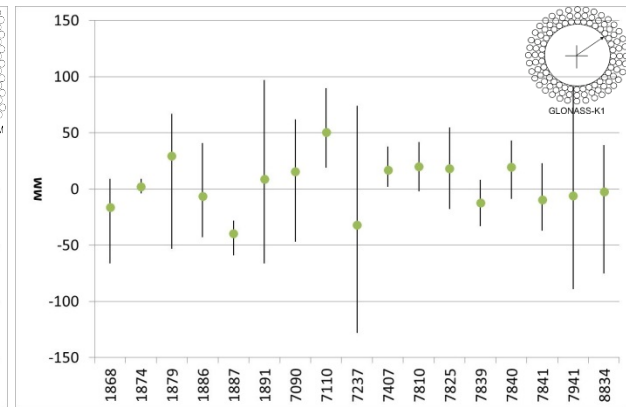
## GLONASS-129



## GLONASS-133



## GLONASS-134



**Conclusion:** the average residual error value with a probability of 0.95 does not exceed **48.7 mm**, its dispersion is from -65.8 up to 86.0 mm ( $\sigma \leq 33.7$  mm). It is necessary to aim for reduction of systematic errors of laser measurements by at least an order. **4**



# Helmert transformation parameters (LARGE-1)

Helmert transformation parameters for reference frames fixed by SLR-station coordinates and transferred by a posteriori ephemerides of analysis centers

HTP	Factor	$\Delta X$	$\Delta Y$	$\Delta Z$	$\omega_X$	$\omega_Y$	$\omega_Z$	m, ppb
		cm			mas			
pmk	ME	0.5	-0.4	-1.9	-0.3	0.0	0.0	2.4
	RMS	0.1	0.1	0.2	0.1	0.0	0.0	0.6
cod	ME	0.1	-0.3	-1.6	-0.4	0.0	0.0	1.1
	RMS	0.2	0.0	0.1	0.0	0.0	0.0	0.6
iac	ME	0.4	-0.5	-1.8	-0.3	0.0	0.0	2.3
	RMS	0.2	0.2	0.2	0.0	0.0	0.0	1.1
esa	ME	0.2	-0.3	-1.6	-0.3	0.0	0.0	2.1
	RMS	0.2	0.1	0.1	0.0	0.0	0.0	0.6

**Conclusin:** we see the **Z** offset by a value of the order of **2 cm**, which can be explained by a larger number of SLR-stations located in the Northern hemisphere (Z offset). It is necessary to aim for geographically quasiuniform SLR data collection through increasing the number of station in the Southern hemisphere.



## LARGE goals

- 1. Comparison of potential accuracies of the SLR and GNSS techniques. Goal achievement conditions: 1) having from 8 to 10 quasiuniformly distributed SLR-stations in the Northern and Southern hemispheres; 2) collecting no less than 60 sessions on 4-day measuring intervals (8 passes, up to 24 segments and up to 540 NP in total from all involved); 3) nearly uniform number of measurements obtained at a site within 24 hours.**
- 2. Comparison of coordinates of SLR-stations generated using different techniques (SLR and GNSS).**
- 3. SC listed as the LARGE mission priority ones are also observed in Russia within the scope of an experiment on SLR, GNSS and VLBI colocation. In case of a positive outcome, it will be the first time when there is an opportunity to compare the accuracies of the SLR, GNSS and VLBI techniques.**
- 4. Evaluation of parameters of a new model of math interpretation of measurements on the SC «Glonass-K» in the SLR interests.**



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