TLRS-3 Return To Operations

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Abstract

The Transportable Laser Ranging Station 3 (TLRS-3) tracked from the Arequipa, Peru site for almost twelve years when the station was decommissioned in January of 2004. Replacing the SAO-2 in 1992 in a partnership between NASA and the Universidad Naciaonal De San Agustin, the TLRS-3 had travelled between Cerro Tololo, Chile and Arequipa, Peru after beginning its first operations in 1988 visiting the Mojave site in Goldstone, California. This paper will discuss the repairs, upgrades, and modifications accomplished at the TLRS-3 as well as the results of the first data collected.

History of TLRS-3 in Arequipa, Peru

The TLRS-3 replaced the SAO-2 system as the primary tracking station in Arequipa, Peru on August 7, 1992 with the tracking of an ERS-1 pass. In an agreement between NASA and the Universidad Naciaonal De San Agustin (UNSA), UNSA provided the operational crew while HTSI provided engineering support. TLRS-3 operated very well for almost twelve years until NASA budget reductions necessitated the closing of TLRS-3. On January 27, 2004 TLRS-3 tracked its last pass, a Starlette. In the fall of 2005, NASA tasked HTSI to return TLRS-3 to operational status. The UNSA crew returned to the station on December 12, 2005 to begin the task of reinitializing the system. HTSI working, with NASA and UNSA, began restoring the TLRS-3 to full operations, returning to the station in January 2006. The task of returning TLRS-3 to operations was done concurrently with the TLRS-4 Return to Operations effort.

TLRS-3 Return to Operations Strategy

With the TLRS-4 Return to Operations effort preceding the TLRS-3 effort by a few months, the TLRS-3 effort was able to take advantage of the multiple enhancements, upgrades and repair strategies used to quickly bring TLRS-4 back to operational status. Unlike the TLRS-4 though, the TLRS-3 had been without power and had not seen any type of maintenance for two years. Scheduled for TLRS-3 would be a full system inspection, implementation of the software and hardware improvements made to TLRS-4, a full system characterization using the System Operational Verification Test (SOVT) process, and a full validation of system performance prior to release of data to the ILRS.

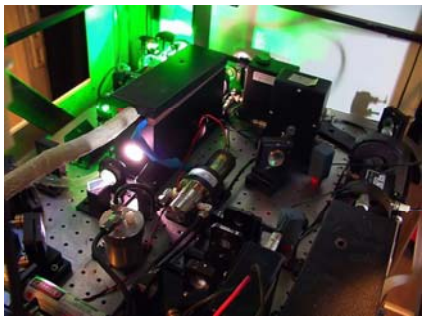
Significant Engineering Issues

The TLRS-3 was off line for over 2 years with no HVAC control, no humidity control, and no air filtration. The system had not been exercised in any way. As a result the integrity of the station computers, system electronics, telescope optics, laser system, and

gimbal were of concern. With the lack of humidity control, corrosion issues were of concern as well, especially with the wire wrap boards, ICs and IC sockets, connectors, switches, etc. and the metal surfaces within the system, especially the laser. Because of the uncontrolled atmosphere within the trailers, temperature cycling presented a connection issue with wire wrap boards, connectors, etc. also. Maintenance of the site and main power system had not been performed either.

Planned and Implemented Upgrades

Upgrades planned for the TLRS-3 had already been implemented and proven to the TLRS-4. The Upper Deck received several enhancements to reduce maintenance and improve lifetime of the optics, improve the accuracy of the star calibration and reduce the time required to accomplish the calibration, and to improve throughput of the daylight filter. The optical system of the entire Upper Deck was enclosed to assist in keeping the optics clean, improve daylight tracking, and provide additional operator safety. A camera system was installed to increase the accuracy of the star calibrations. The optics layout was also redesigned so that optics did not have to be removed to perform the star calibration and so that the laser and star image could be easily co-aligned. The 10 angstrom daylight filter was replaced with a unit that has a 68% throughput and is quite temperature stable. The telescope was returned to NASA SLR Engineering in the USA and was completely disassembled, inspected, cleaned, and realigned. Throughput increased from ~ 50% to 87%. The T/R Switch was upgraded to an improved stepper motor design which was much more temperature stable than the old design. The Photek MCP Upgrade was installed replacing the failing ITT MCP. The upgrade included a newly calibrated CFD as well. The Controller Computer received improved Sattrk and Monitor programs. With these improvements came the Window/Window Upgrade, Mode Change Bias Reset, enhanced “Record All frames” function, 5pps and 4pps Thread Matching and Automated Switching, Sun Avoidance, Horizon Mask, the new Go/No Go software, and the high voltage power supply scaling upgrade. The new TLRS-4 microprocessor based Trackball was installed as well. Maintenance to site power was performed which included refurbishing the site power transformer.



Current Status

The TLRS-3 is producing high quality data. Over 90 pass segments have been acquired with a data quality of <10mm RMS on Lageos and Starlette and <20 mm RMS on Ajisai. CHAMP and Grace B have been tracked. Average ground calibration is excellent at the 5.4 mm level.

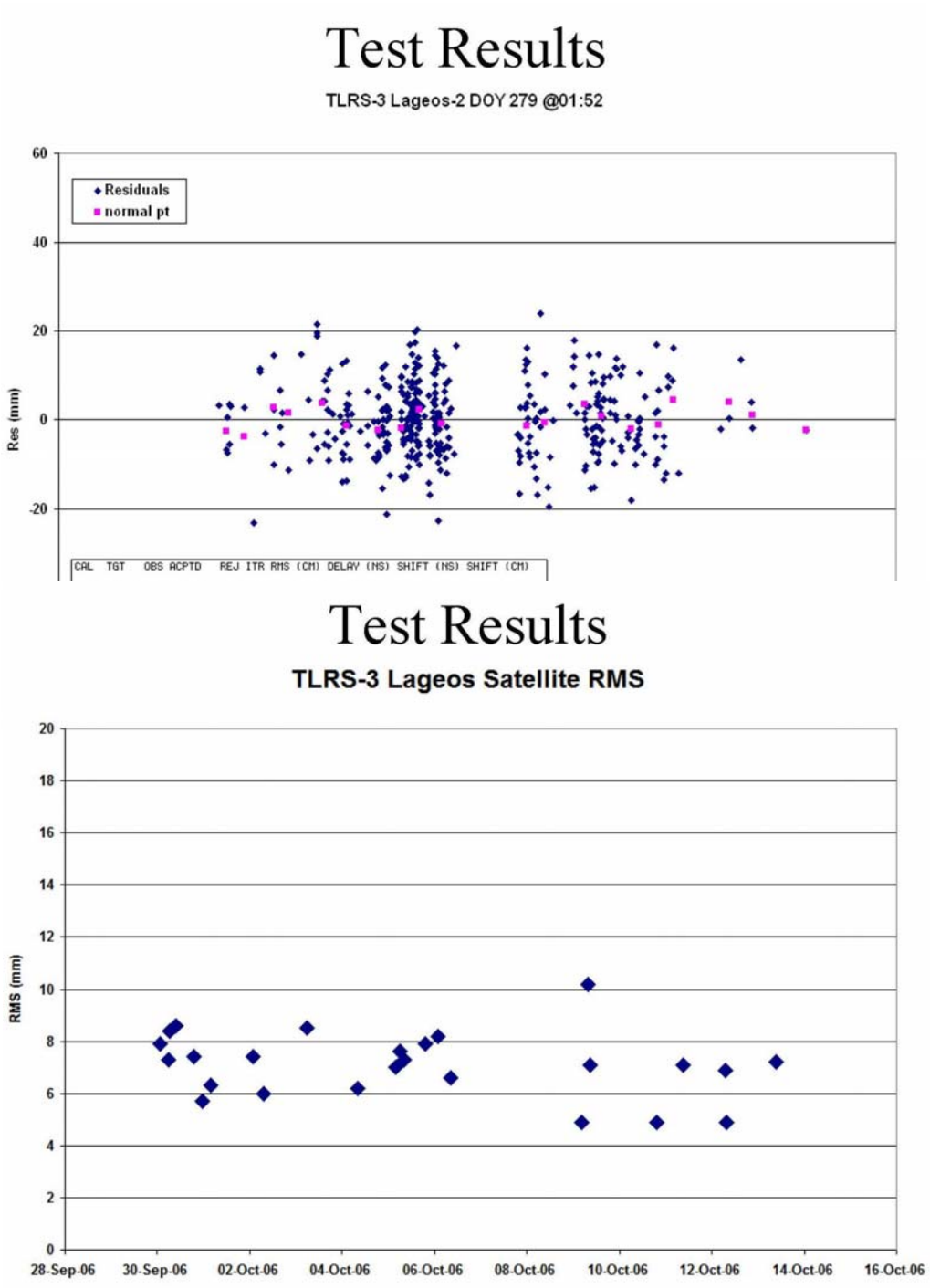
Future Plans

Though significant progress has been made in bringing the TLRS-3 back to operational

status, there are still some unfinished tasks. Optimization of gimbal tracking performance, completion of the 4pps upgrade, completion of the Controller and Processor software upgrades and testing, calibration of system test equipment, restocking of system spares, completion of a site safety inspection and the performance of the site survey.

Test Data

Graphical examples of the Lageos satellite data and a listing of all the passes acquired by TLRS-3 during the upgrade are provided below. Included in the pass listing are calibration RMS, satellite RMS, system delay shift, calibration observation count, and satellite observation count.



Test Results

PASS DATE	OCC NUM	SATID	TARGET	TARGET DISTANCE	# CAL OBS	# CAL REJ	CAL RMS (mm)	APPLIED DELAY	SHIFT (mm)	# SAT OBS	# SAT REJ	SAT RMS (mm)	MEAN TEMP ©	MEAN PRESS (mbars)	HUMIDITY (%)	NUM NP DATA BINS	NUM NP
29-Sep-06 00:53	03	1500	BC	105981	1948	14	4.5	3637.2	-1.07	93	15	22.2	13.32	761.2	51	30	18
30-Sep-06 01:21	03	5986	BC	105981	2188	9	5.9	3643.9	6.16	92	0	7.9	12.31	760.5	46	4	4
30-Sep-06 01:43	03	4378	BC	105981	2188	9	5.9	3643.9	6.16	19	6	4.2	11.73	760.6	45	28	6
30-Sep-06 02:03	03	1500	BC	105981	2188	9	5.9	3643.9	6.16	341	23	17.3	11.57	760.7	45	20	19
30-Sep-06 05:51	03	5986	BC	105981	2046	5	6.4	3643.5	-1.46	10	0	7.3	10.27	759.7	43	2	2
30-Sep-06 06:11	03	1155	BC	105981	2046	5	6.4	3643.5	-1.46	224	1	8.4	10.29	759.5	42	13	13
30-Sep-06 06:56	03	317	BC	105981	2034	4	6.4	3644.6	0.65	343	23	14.2	9.88	759.5	41	27	19
30-Sep-06 08:05	03	1134	BC	105981	2065	10	5.9	3646.7	1.72	100	7	8.4	8.91	759.6	45	5	5
30-Sep-06 08:52	03	643	BC	105981	2014	1	5.8	3646.2	-0.95	67	3	10	9.51	759.7	42	4	4
30-Sep-06 09:52	03	5986	BC	105981	2043	1	6.4	3646.4	1.37	159	1	8.6	9.15	760	39	14	10
30-Sep-06 18:58	03	1155	BC	105981	2249	10	5	3646.2	-0.35	132	1	7.4	23.14	760.5	15	6	6
30-Sep-06 23:04	03	1134	BC	105981	2022	3	5	3644.5	2.06	372	63	8.9	16.08	761.7	28	19	13
30-Sep-06 23:31	03	5986	BC	105981	2022	3	5	3644.5	2.06	38	1	5.7	14.37	762.1	32	10	8
01-Oct-06 01:11	03	1500	BC	105981	2233	16	4.7	3640	2.66	1063	231	21.7	11.35	762.5	39	17	17
01-Oct-06 02:37	03	6179	BC	105981	2015	32	4.4	3641.1	2.11	43	0	19.9	10.51	762.6	36	5	5
01-Oct-06 03:05	03	6178	BC	105981	2015	32	4.4	3641.1	2.11	127	14	22.4	10.7	762.6	32	6	6
01-Oct-06 03:13	03	5557	BC	105981	2015	32	4.4	3641.1	2.11	109	12	6.1	10.55	762.5	31	7	7
01-Oct-06 03:33	03	5986	BC	105981	2015	32	4.4	3641.1	2.11	109	3	6.3	8.9	762.3	36	13	11
02-Oct-06 00:34	03	4378	BC	105981	2131	39	4.6	3638.1	-0.65	192	3	7.3	12.12	761.9	35	27	23
02-Oct-06 01:13	03	8004	BC	105981	2157	60	4.7	3637.3	-1.4	402	22	14.6	11.46	762.2	35	45	34
02-Oct-06 01:31	03	5986	BC	105981	2157	60	4.7	3637.3	-1.4	405	4	7.4	10.85	762.2	36	21	18
02-Oct-06 02:36	03	6178	BC	105981	2455	66	4.8	3636.3	1.11	59	8	8	10.9	762.2	32	11	10
02-Oct-06 05:14	03	8501	BC	105981	2059	43	5.3	3639.4	-1.09	44	1	6.8	8.48	761.1	37	7	6
02-Oct-06 05:28	03	317	BC	105981	2059	43	5.3	3639.4	-1.09	192	15	14.3	8.69	760.8	35	26	12
02-Oct-06 06:53	03	8501	BC	105981	2083	28	5.3	3638.1	-0.4	8	0	10.1	8.2	760.2	34	2	2
02-Oct-06 06:55	03	1134	BC	105981	2083	28	5.3	3638.1	-0.4	168	10	10.7	8.18	760.2	34	10	10
02-Oct-06 07:05	03	1155	BC	105981	2083	28	5.3	3638.1	-0.4	38	0	6	8.29	760.1	36	3	3
02-Oct-06 07:19	03	317	BC	105981	2083	28	5.3	3638.1	-0.4	371	40	9.3	7.7	760.1	34	34	21
02-Oct-06 07:59	03	643	BC	105981	2025	19	5.4	3638.4	0.16	13	0	5.7	7.41	760.1	36	3	3
02-Oct-06 08:48	03	1134	BC	105981	2035	7	5.5	3640.3	0.91	30	3	7.9	7.8	759.9	34	4	4
02-Oct-06 12:57	03	1500	BA	105981	1018	8	6.3	3645.6	0	460	65	16.3	18.1	761.4	18	12	12
03-Oct-06 01:32	03	1500	BB	105981	1007	32	4.8	3636.8	0	182	5	14.8	10.52	761.4	41	4	4
03-Oct-06 02:48	03	5557	BC	105981	2031	139	5.3	3638.3	-0.94	99	6	7.6	10.69	761.7	40	10	8
03-Oct-06 04:45	03	317	BC	105981	1837	27	5.2	3639.4	-1.4	157	6	9.9	9.58	760.6	40	21	18
03-Oct-06 05:32	03	1155	BC	105981	2034	37	5	3638.3	1.67	243	3	8.5	9.13	760.3	41	12	12
03-Oct-06 06:19	03	8501	BC	105981	2039	41	5	3639.6	-0.1	129	15	16.9	9.6	759.8	36	4	4
03-Oct-06 06:40	03	317	BC	105981	2039	41	5	3639.6	-0.1	119	2	8.5	8.85	759.5	36	11	11
03-Oct-06 07:16	03	1134	BC	105981	2017	34	5.3	3640.5	2.09	17	0	6.9	9.2	759.3	32	1	1
04-Oct-06 05:48	03	8501	BC	105981	2031	6	5.1	3644.3	1.81	165	7	7.2	9.8	759.4	33	9	9
04-Oct-06 07:38	03	1134	BC	105981	2040	8	5.1	3643.3	-0.55	272	8	7.9	8.42	758.6	32	7	7
04-Oct-06 07:49	03	317	BC	105981	2040	8	5.1	3643.3	-0.55	26	0	7.1	8.99	758.5	30	7	7
04-Oct-06 07:53	03	1155	BC	105981	2040	8	5.1	3643.3	-0.55	12	0	6.2	8.61	758.6	34	6	5
05-Oct-06 02:11	03	6179	BC	105981	1237	15	5	3643.2	-1.85	249	55	7.9	10.57	760	41	22	20
05-Oct-06 02:29	03	5557	BC	105981	1237	15	5	3643.2	-1.85	23	1	9.7	10.5	760.1	40	2	2
05-Oct-06 02:40	03	6178	BC	105981	1237	15	5	3643.2	-1.85	346	23	8.9	10.61	760.2	39	20	19
05-Oct-06 02:47	03	8002	BC	105981	1237	15	5	3643.2	-1.85	109	6	10.8	10.47	760.2	39	16	11
05-Oct-06 03:54	03	5986	BC	105981	2277	59	5.5	3642.8	1.2	119	1	7	9.88	759.6	39	17	17
05-Oct-06 05:10	03	317	BC	105981	2046	10	5.5	3643.1	1.29	59	3	10.3	9.7	758.9	34	18	8
05-Oct-06 06:12	03	1155	BC	105981	2146	8	5.5	3647.4	0.67	109	0	7.6	9.37	758.3	22	12	4
05-Oct-06 07:04	03	317	BC	105981	2146	8	5.5	3647.4	0.67	306	20	11.1	8.84	758.1	21	19	19
05-Oct-06 07:54	03	1134	BC	105981	2143	8	5.5	3647.9	1.36	405	51	11.1	9.59	757.8	18	11	11
05-Oct-06 08:20	03	643	BC	105981	2143	8	5.5	3647.9	1.36	130	11	6.7	9.38	757.7	17	6	6
05-Oct-06 08:28	03	5986	BC	105981	2143	8	5.5	3647.9	1.36	54	0	7.3	9.31	757.6	17	8	6
05-Oct-06 18:05	03	8501	BC	105981	2060	10	6.7	3655.7	-7.68	47	2	5.9	23.44	758	16	6	6
05-Oct-06 19:22	03	1155	BC	105981	1687	20	5.5	3654.1	1.19	15	1	7.9	23.11	757.5	17	3	2
05-Oct-06 22:41	03	1500	BC	105981	2064	11	5.6	3654.2	1.87	700	91	21.9	18.21	758.7	22	19	19
06-Oct-06 01:53	03	5986	BC	105981	2590	23	5.3	3646	5.19	417	0	8.2	12.35	760.9	33	24	20
06-Oct-06 03:03	03	5557	BC	105981	2174	5	5.4	3649.3	-1.43	33	3	6.1	10.5	761	35	3	3
06-Oct-06 03:19	03	6179	BC	105981	2174	5	5.4	3649.3	-1.43	127	9	7	11.17	761.1	33	9	9
06-Oct-06 06:16	03	317	BC	105981	2063	5	5.6	3650.2	-0.2	450	19	13.1	10.39	759.9	34	27	25
06-Oct-06 06:28	03	1134	BC	105981	2063	5	5.6	3650.2	-0.2	202	41	9.4	10.33	759.9	33	5	5
06-Oct-06 08:14	03	1155	BC	105981	2021	6	5.6	3652.2	0.49	110	0	6.6	10.14	759.2	30	22	15
08-Oct-06 21:59	03	1500	BC	105981	2026	54	4.7	3655.6	0.51	1417	260	17.7	19.89	760.3	24	25	24
08-Oct-06 23:21	03	4378	BC	105981	2192	106	5.2	3653.8	2.72	116	11	7.5	15.79	761	33	20	14
09-Oct-06 04:10	03	317	BC	105981	1527	175	5.7	3649.4	-1.07	11	0	6.5	11.4	761.6	34	2	2
09-Oct-06 04:30	03	1155	BC	105981	1527	175	5.7	3649.4	-1.07	44	5	4.9	11.34	761.4	32	8	7
09-Oct-06 05:37	03	1134	BC	105981	1540	151	5.5	3647.1	-0.87	134	25	6.9	11.5	760.8	29	5	5
09-Oct-06 07:46	03	1155	BC	105981	2063	181	5.4	3647.1	1.83	39	1	10.2	10.03	760	29	6	4
09-Oct-06 08:15	03	643	BC	105981	2063	181	5.4	3647.1	1.83	33	5	6.5	9.1	759.9	25	2	2
09-Oct-06 08:56	03	5986	BC	105981	2044	259	5.4	3647.1	-2.6	272	23	7.1	9.24	760	23	20	14
10-Oct-06 19:01	03	1134	BC	105981	1234	3	6	3660.7	5.77	241	19	7.1	22.35	761.9	20	20	12
10-Oct-06 19:35	03	1155	BC	105981	1234	3	6	3660.7	5.77	60	1	4.9	22.97	761.8	20	5	5
11-Oct-06 09:10	03	5986	BA	105981	1020	1	5.3	3658.7	0	56	0	7.1	12.22	760.9	17	17	6
12-Oct-06 04:42	03	1134	BC	105981	2048	6	5.1	3660	0.29	156	6	5.9	11.84	762.6	29	14	5
12-Oct-06 06:39	03	8501	BC	105981	2023	5	5	3660.5	-0.34	10	0	8.4	11.4	761.5	31	2	2
12-Oct-06 07:11	03	1155	BC	105981	2124	5	4.8	3661.4	-0.14	108	0	6.9	11.57	761.2	30	6	6
12-Oct-06 07:34	03	1155	BC	105981	2124	5	4.8	3661.4	-0.14	32	0	4.9	11.96	761.2	29	6	6
12-Oct-06 08:31	03	643	BC	105981	2092	9	4.5	3659.8	-0.08	96	12	9.5	11.16	761.1	30	4	4
12-Oct-06 10:03	03	1500	BC	105981	2051	8	5	3658.9	-0.77	1083	111	17	11.35	761.6	30	17	17
12-Oct-06 10:56	03	4378	BC	105981	2019	6	5.6	3662.9	2.36	24	0	6	11.6	762	30	6	6
12-Oct-06 17:52	03	1134	BC	105981	1926	17	5	3666.7	-0.02	133	7	7	24.29	761.1	16	14	10
13-Oct-06 08:09	03	643	BB	105981	1041	47	7.3	3654	0	48	3	16.5	9.6	761.1	36	4	2
13-Oct-06 09:39	03	5986	BC	105981	2085	46	6.3	3656.2	-0.8	377	2	7.2	9.03	761.4	36	14	13