NASA HALEAKALA TLRS4
POST-MAINTENANCE FINAL GEODETIC SURVEY REPORT

MAUI, HAWAII

Strategic Services Subcontract

2712-12-15 Task 22-2

Support of ITT Exelis NNG09DA01C

` **Dates of Survey: March/May 2013**

Date of Report: May 24, 2013

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Survey equipment at Haleakala site primary survey control monument "KOLEKOLE Reset 1950" New PanSTARRS facility in background

1. Introduction

This is the final report covering the geodetic survey of the TLRS4 system and selected survey control monuments and calibration piers at the NASA SLR site on Haleakala, Maui, Hawaii in March and May 2013**.**

The report augments the TLRS4 pre-maintenance geodetic survey report dated March 24, 2013 and updates the geodetic positions and heights of the site survey control monuments, calibration piers, SLR and GPS systems.

2. Survey Description

The survey work was completed by Troy Carpenter, Geodetic Surveyor of Strategic-Services, Inc. under the ITTEXELIS Corporation NASA SCNS contract NNG09DA01C and TO-22 (Operations, Maintenance, and Sustainment). The field survey data was collected during March and May 2013 for a re-survey of the TLRS 4 Haleakala site survey control monuments, the existing Global Positioning system and, and the TLRS 4 calibration piers. In addition Global Positioning System (GPS) data was collected to upgrade and reference the site geodetic coordinates to the ITRF2008 epoch 2005 International terrestrial Reference Frame. The field survey consisted of two phases, one in March and one in May 2013. The March 2013 phase was conducted as a re-survey of the NASA TLRS4 system prior to scheduled system mount maintenance. The May 2013 phase was conducted of the NASA TLRS4 system as a post-maintenance survey to confirm the TLRS4 system coordinates, eccentricities, and calibration ranges.

2.1 Instruments and Equipment

The majority of the survey instruments and equipment utilized for this project is owned by NASA and administered by ITTEXELIS under the SCNS TO-22 Contract. In addition, a second Leica DI2002 DME was on loan from the National Geodetic Survey and utilized during the post-maintenance survey.

The following are the primary survey instruments utilized:

a. Leica electronic theodolite T3000, with an angular accuracy standard deviation of 0.5 arc seconds, were used to measure horizontal directions and zenith distances.

b. Two Leica electronic distance measurement (EDM) instruments (DI2002 180595/180468), with an accuracy standard deviation of 1 mm + 1 ppm were used to measure the slope distances.

c. Leica electronic level NA3003 (93769), with an accuracy standard deviation of 1.2 mm was used for the differential level measurements.

d. Two Trimble 4000SSE GPS receivers with Trimble choke ring antennas, with a horizontal accuracy standard deviation of 5mm + 1ppm and a vertical accuracy standard deviation of 10 mm + 1 ppm were used to collect the GPS data.

Other survey accessory equipment included:

a. Leica optical plummet/w compensator
b. Wild T2 targets
c. Tripods
d. Trivet plates, tribrachs, and tribrach adapters
e. Calibrated 40 mm mini-prisms

The calibration constant of the Leica DI2002 (180595) had been compared with several Leica TS30 robotic theodolite measurements at the Goddard Space Flight Center (GGAO) in November 2012. The Leica TS30 robotic theodolite was calibrated at the NGS precise baseline in Corbin, Virginia in April 2010. This calibration confirmed the manufactures published calibration value. The Leica DI2002 had been calibrated at the National Geodetic Survey (NGS) precise baseline in Corbin, Virginia (CBL) in May 2009. The Leica DI2002 (180468) was compared to the Leica TS30 robotic theodolite at the Goddard Geophysical Astronomic Observatory (GGAO) in Greenbelt, Maryland just prior to use on this survey.

2.2 Survey Network and Strategy

For the March 2013 pre-maintenance survey, the majority of the inter-visible lines-of-sight between the survey stations were observed. Horizontal directions where observed in sets of four observations with each set consisting of an observation in both the direct and reverse theodolite telescope pointing. Zenith distances where observed in sets of three observations, both direct and reverse theodolite telescope pointing. Zenith distance observations where observed across most of the lines from each of the occupied stations.

The distance measurements where made from each station standpoint with the Leica DI2002 to the majority of the inter-visible target points. The atmospheric pressure and temperature data were recorded at the beginning and end of each distance measurement.

Direct differential levels where observed to determine orthometric height differences between the survey control stations located in the vicinity of the TLRS4 system. These included direct differential level observations to the MAUI station GPS antenna ARP. All observations where double run: forward run and backward run. The differential level observation to the TLRS4 system where made to the top of the TLRS4 special survey plate and the fixed height difference of -0.174 meters applied to these observations to reduce them to the TLRS4 physical intersection of the horizontal and vertical axis of rotation. The exceptions to this where the observations to Calibration Pier A, Calibration Pier B, and KOLEKOLE Reset 1950. The heights of these control points where determined by a combination of zenith distance observations and Global Positioning System (GPS) collected data.

The Global Positioning System (GPS) antenna at station MAUI could not be removed. To provide the survey tie to this system, it was necessary to use survey intersection methods. The survey intersection observations consisted of horizontal directions from several of the control monuments in the site survey scheme. In addition, this station was connected to the survey control network with five separate sessions of GPS data.

The conventional reference point for the SLR telescope is the intersection of the horizontal and vertical axis of rotation. This reference point is not accessible and cannot be measured directly. A special survey plate has been designed to rotate above the actual center of rotation of the TLRS4 reference point. For the March 2013 survey this reference point has been designated T413 and for the May 2013 it is designated as TLRS4. The SLR reference point is horizontally and vertically eccentric from the station mark, which is designated as 7119.

All the survey observations into the TLRS4 system special survey plate where made from six of the site survey control stations on the existing site survey control network. A set of check distances where measured from survey control monument UH HIG to the TLRS4 system special survey plate. Four separate measurements where made with the TLRS4 mount rotated 90 degrees for each measurement. This was accomplished to ensure that the survey plate was set at the TLRS4 system center of rotation.

To update the site survey control network orientation and to update the network to the ITRF2008 (epoch 2005) reference frame, Global Positioning System (GPS) data was collected. This GPS data was collected at survey control stations KOLEKOLE Reset 1950 and Calibration Pier A. The GPS observations consisted of three separate sessions over three separate days. The GPS data was collected with two Trimble 4000SSE receivers and two Trimble choke ring antennas.

For the May 2013 post-maintenance survey, the same procedures and methods where used as during the March 2013 pre-maintenance survey. During this survey only selected additional observations where made between the existing site survey monuments. These where made to strengthen the survey ties across the existing survey control scheme. In addition, two sessions of GPS data was collected across the existing survey scheme. These sessions connected survey control monuments where a conventional line of sight did not exist.

The distances to and from the TLRS4 survey plate where measured with two DI2002 DME's when possible. The TLRS4 system mount was rotated 180 degrees between each separate measurement at a particular survey control monument. This was also done during the distance measurements from the TLRS4 survey plate. The TLRS4 mount was rotated to eliminate any eccentricity of the TLRS4 survey plate, and to determine the TLRS4 physical center of rotation during the adjustment process. A total of eight separate distances where measured between the TLRS4 survey plate and both Calibration piers A and B.

Horizontal directions where observed to targets on the TLRS4 survey plate from stations "KoleKole Reset 1950", Calibration Pier A, Calibration Pier B, UH-HIG, and T4 RM1. Zenith distance observations where also observed across selected lines on the survey control scheme and the TLRS4 survey plate.

Differential level observations where again observed between survey control monuments in the vicinity of the TLRS4 system. The observations where made to the top of the TLRS4 survey plate and a fixed height difference of –0.174 applied to these observations to reduce them to the TLRS4 physical intersection of the horizontal and vertical axis of rotation.

3. Survey Computations

The conventional electro-optical survey data recorded in the filed (distances, horizontal directions, zenith distances, and direct differential levels) was reduced and organized in abstract form for subsequent input into a least-squares adjustment. The distance measurements were corrected for the deviations in atmospheric pressure and temperature.

The collected Trimble GPS data was post processed with the Trimble software GPSurvey, version 2.35,

along with the downloaded RINEX GPS data for MAUI. The RINEX GPS data for station MAUI was downloaded from the National Geodetic Survey (NGS) CORS web site. Since all of the collected GPS data covered a small area of 200 meters or less, only the broadcast ephemeris orbits for the GPS satellites were utilized during the post processing.

The software adjustment program HAVAGO and the MicroSearch software program GeoLab32v3 was used for the least-squares adjustment of both the conventional and collected GPS data. The original input data files where developed from the reduced conventional survey observation data. The geodetic coordinates for station MAUI were constrained to the published ITRF2008 (epoch 2005) X, Y, Z Cartesian coordinates.

The May 2013 collected survey data was incorporated into the original March 2013 survey data files. This produced a final site adjustment of the data collected during the pre-maintenance and post-maintenance surveys.

4. Results

The final comprehensive least-squares adjustments where completed with the HAVAGO and GeoLab32v3 software, and is a combination of the survey control network observations and the collected GPS data. The conventional survey observations where used to develop the ground survey net GeoLab .iob input file. This was then combined with the GPSurvey GPS post-processed (vector coordinate values and extracted covariance matrix) for the processed baselines. The coordinates for the MAUI station were constrained at 1 mm to the ITRF2008 epoch 2005 values.

The final HAVAGO and Geolab least squares adjustments includes stations T406 and 7119. The geodetic positions and heights for these stations where obtained from the final 2006 Geolab least squares adjustment and where included to provide a comparison between the 2006 and 2013 surveys Geolab adjusted geodetic positions and heights.

4.1 Summary Results of Final Adjustment

The summary of the adjusted coordinates from the GeoLab (glab32v3) adjustment and the HAVAGO adjustment are shown below, after Table 1.

Table 1 is a translation table provided to assist in coordinating the survey point description and the names used in the adjustment for selected points of interest.

Table 1. Translation Table for Survey Point Names

Survey Point Description	DOMES Number	Adjustment Name
GNSS MAUI	40445S008	MAUI
SLR 7119	40445M004	7119/T4 Disk (2006)
KOLEKOLE RESET 195	None	KOLE
Calibration Pier A	None	CALA
Calibration Pier B	None	CALB
TLRS4 (2006)	None	T406
TLRS4 (March 2013)	None	T413
TLRS4 (May 2013)	None	TLRS4

GeoLab Adjusted Coordinates

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================================================================================
                          MAUI TLRS4 SITE SURVEY 2013
GeoLab V3.65                 GRS 80             UNITS: m,DMS
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Adjusted PLH Coordinates:
                                 LATITUDE          LONGITUDE   ELIP-HEIGHT
 CODE FFF STATION              STD DEV            STD DEV       STD DEV
 ---- --- ------------ ----------------- ----------------- ------------
 PLH  111 7119     N 20 42 23.360460 W156 15 24.915160    3056.2720 m
                               0.0000            0.0000       0.0000
 PLH  000 CALA     N 20 42 26.146978 W156 15 24.168194    3067.1503 m
                               0.0007            0.0009       0.0008
 PLH  000 CALB     N 20 42 26.686700 W156 15 22.445143    3072.5801 m
                               0.0010            0.0010       0.0011
 PLH  000 HIG      N 20 42 23.786628 W156 15 24.645913    3058.8419 m
                               0.0007            0.0008       0.0006
 PLH  000 KOLE     N 20 42 26.353339 W156 15 22.324285    3070.2828 m
                               0.0010            0.0009       0.0008
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PLH	000	KOLE1	N	20	42	23.008497	W156	15	23.432756	3058.7736 m
						0.0009			0.0014	0.0007
PLH	111	MAUI	N	20	42	23.956230	W156	15	25.286660	3062.1013 m
						0.0000			0.0000	0.0000
PLH	000	T4 RM3	N	20	42	23.506818	W156	15	25.305424	3056.4946 m
						0.0012			0.0010	0.0008
PLH	111	T406	N	20	42	23.360540	W156	15	24.915130	3058.9040 m
						0.0000			0.0000	0.0000
PLH	000	T413	N	20	42	23.360619	W156	15	24.914996	3058.9039 m
						0.0008			0.0010	0.0007
PLH	000	T4R1	N	20	42	23.010789	W156	15	23.077663	3059.0017 m
						0.0009			0.0010	0.0008
PLH	000	TLRS4	N	20	42	23.360556	W156	15	24.915051	3058.9025 m
						0.0007			0.0010	0.0007

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MAUI TLRS4 SITE SURVEY 2013

GeoLab V3.65 GRS 80 UNITS: m,DMS

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Adjusted XYZ Coordinates:

CODE	FFF	STATION	X-COORDINATE STD DEV	Y-COORDINATE STD DEV	Z-COORDINATE STD DEV	
XYZ		7119	-5466065.4933	-2404338.3319	2242108.2341	m
			0.0000	0.0000	0.0000	
XYZ		CALA	-5466038.3509	-2404350.0175	2242192.2790	m
			0.0008	0.0009	0.0007	
XYZ		CALB	-5466017.5400	-2404395.3592	2242209.7327	m
			0.0010	0.0011	0.0010	
XYZ		HIG	-5466060.3113	-2404344.5682	2242121.4083	m
			0.0006	0.0008	0.0007	
XYZ		KOLE	-5466017.4840	-2404399.1571	2242199.3259	m
			0.0008	0.0009	0.0010	
XYZ		KOLE1	-5466053.8603	-2404380.0998	2242098.9887	m
			0.0009	0.0012	0.0009	
XYZ		MAUI	-5466068.8820	-2404328.0729	2242127.4420	m
			0.0000	0.0000	0.0000	
XYZ		T4 RM3	-5466068.7756	-2404327.4326	2242112.5251	m
			0.0008	0.0010	0.0012	
XYZ		T406	-5466067.7457	-2404339.3237	2242109.1670	m
			0.0000	0.0000	0.0000	
XYZ		T413	-5466067.7433	-2404339.3268	2242109.1692	m
			0.0007	0.0009	0.0007	
XYZ		T4R1	-5466049.8935	-2404389.5857	2242099.1353	m
			0.0009	0.0009	0.0009	
XYZ		TLRS4	-5466067.7433	-2404339.3251	2242109.1669	m
			0.0007	0.0009	0.0007	

HAVAGO Adjusted Coordinates

ADJUSTED DATA: STATIONS

STATION	LATITUDE	SIGMA	LONGITUDE	SIGMA	HEIGHT	SIGMA
KOLE KOLE 1950 USC&GS	20 42 26.35332	.00003	156 15 22.32430	.00003	3070.284	.001
UH HIG 2013	20 42 23.78662	.00003	156 15 24.64592	.00003	3058.842	.001
GPS MAUI 2013	20 42 23.95623	.00003	156 15 25.28666	.00003	3062.101	.001
T4 DISK (2006)	20 42 23.36046	.00003	156 15 24.91516	.00003	3056.272	.001
CAL PIER A (TLRS4) 2013	20 42 26.14697	.00003	156 15 24.16821	.00003	3067.151	.001
CAL PIER B (TLRS4) 2013	20 42 26.68668	.00003	156 15 22.44515	.00004	3072.581	.001
T4 RM1 (2013)	20 42 23.01078	.00003	156 15 23.07768	.00004	3059.002	.001
T4 RM3 (2013)	20 42 23.50682	.00004	156 15 25.30544	.00004	3056.494	.001
KOLE NO. 1	20 42 23.00849	.00004	156 15 23.43277	.00005	3058.774	.001
TLRS-4 (2006)	20 42 23.36054	.00003	156 15 24.91513	.00003	3058.904	.001
TLRS-4 (Pre13)	20 42 23.36062	.00003	156 15 24.91502	.00004	3058.904	.001
TLRS-4 (Post13)	20 42 23.36055	.00003	156 15 24.91507	.00004	3058.902	.001

ADJUSTED CARTESIAN COORDINATES

STATION	X	Y	Z
KOLE KOLE 1950 USC&GS	-5466017.485	-2404399.157	2242199.326
UH HIG 2013	-5466060.312	-2404344.568	2242121.408
GPS MAUI 2013	-5466068.882	-2404328.073	2242127.442
T4 DISK (2006)	-5466065.493	-2404338.332	2242108.234
CAL PIER A (TLRS4) 2013	-5466038.352	-2404350.017	2242192.279
CAL PIER B (TLRS4) 2013	-5466017.541	-2404395.360	2242209.732
T4 RM1 (2013)	-5466049.894	-2404389.586	2242099.135
T4 RM3 (2013)	-5466068.776	-2404327.432	2242112.525
KOLE NO. 1	-5466053.861	-2404380.100	2242098.989
TLRS-4 (2006)	-5466067.746	-2404339.324	2242109.167
TLRS-4 (Pre13)	-5466067.744	-2404339.326	2242109.169
TLRS-4 (Post13)	-5466067.743	-2404339.325	2242109.167

4.2 SLR Reference Point Eccentricity

Table 2. Values for the Eccentricity of the SLR (TLRS4) Conventional Reference Point from Survey Control Monument 7119 (DOMES Number: 40445M004) in meters.

March 2013 TLRS4 Pre-maintenance

DN (m) +0.005	DE (m) +0.005	DU (m) +02.632
DX (m) -02.250	DY (m) -00.995	DZ (m) +00.935

May 2013 TLRS4 Post-maintenance

DN (m) +0.003	DE (m) +0.003	DU (m) +02.630
DX (m) -2.250	DY (m) -00.993	DZ (m) +00.933

4.3 TLRS4 4 System Calibration Pier Results

Table 3. TLRS4 System Calibration Pier Data

Target:	Prism SN:	Prism Constant Applied
Cal Pier A	**LTN 90-K**	**+0.0319**
Calibration Distance:	88.840 meters	
Elevation Angle:	+05.3699 Degrees	
Geodetic Azimuth:	14.1547 Degrees	

Target:	Prism SN:	Prism Constant Applied
Cal Pier B	**89-3**	**+0.0325**
Calibration Distance:	125.633 meters	
Elevation Angle:	+6.2806 Degrees	
Geodetic Azimuth:	34.9418 Degrees	

Conclusions and Remarks

On this final May 2013 HAVAGO and Geolab data adjustments the geodetic positions and heights of the survey control monuments and the TLRS4 system have changed by small amounts when compared to the March 2013 Geolab adjustment. This is due to the inclusion of additional conventional measurements across identical lines on the survey control scheme and also the addition of two more GPS data sessions.

Mr. Dan O'Gara, the TLRS4 supervisor informed me that Mr. Dennis McCulloms (ITTEXELIS) and himself had re-leveled the TLRS4 system mount once the system maintenance had been completed.

The March 2013 Geolab adjustment on measurements to the TLRS4 calibration pier B (prism 94-3) produced higher than normal residuals. Based upon these and the results of a check measurement comparison in May 2013 I decided it would be advisable to replace the prism (94-3) on that pier with one of the survey prisms. I selected one (89-3) that had an identical calibration constant of –0.0325. Prior to departure, I applied plumbers teflon tape to the steel plate studs on both of the TLRS4 calibration piers. This ensured that the prisms where set firm and would remain stable even in the Haleakala high winds.

My thanks to Mr. Dan O'Gara and the TLRS4 operations team for their assistance and support on both the March and May 2013 survey projects.

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May 2013