

Low-altitude aerial imagery of Coast Guard Beach, Nauset Spit, and Nauset Marsh, Cape Cod National Seashore, MA

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23 March 2016

Abstract

Low-altitude (approximately 120 meters above ground level) digital images were obtained from cameras in a fixed-wing unmanned aerial system (UAS) flown from the lawn adjacent to the Coast Guard Beach parking lot on 1 March, 2016. The UAS was a Skywalker X8 flying wing operated by Raptor Maps, Inc., contractors to the U.S. Geological Survey. U.S. Geological Survey technicians deployed and mapped 28 targets that appear in some of the images for use as ground control points. All activities were conducted under a National Park Service Scientific Research and Collecting Permit, study number CACO-00285, permit number CACO-2016-SCI-003. Two consecutive UAS missions were flown, each with two cameras, autopilot computer, radios, and a Global Navigation Satellite System (GNSS) positioning system as payload. The first flight (f1) was launched at approximately 1112 EST, and followed north-south flight lines, landing at about 1226 EST. Two Canon SX280 digital cameras, designated rgb1 and rgb2 made images during this flight. The second flight (f2) was launched at 1320 EST and followed east-west flight lines, landing at 1450 EST. Prior to f2, rgb2 was replaced with a Canon SX280 modified with a Schott BG 3 filter to emphasize light at near-infrared wavelengths, designated nir1. Rgb1 and nir1 made images during this second flight. Low tide on the ocean beaches was forecast for approximately 1130 EST, and estimated low tide on the marsh was at least an hour later. Weather conditions were clear and sunny during the first flight. During the second flight, there were periods with high clouds. Winds (estimated by experienced observers) during the first flight were from the north-northeast at ~15 mph, with gusts to ~20 mph. Winds decreased beginning in early afternoon, and at the end of the second flight, estimated winds were 5 – 10 mph with gusts to 15 mph. Images are contained in four directories, designated f1_rbb1, f1_rgb2, f2_rgb1, and f2_nir1.

Surveying

A differential GPS base station was established over a reference point on the lawn of the NEED building at Coast Guard Beach (Figure 1). The coordinates of the reference point (named CGB_OPUS) were determined from an ultra-rapid precise orbit On-line Positioning User Service (OPUS) solution based on GPS data from a five-hour occupation on January 11, 2016. (Appendix A). Coordinates in NAD83 2010(2011) UTM Zone 19, elevation NAVD88 (ellipsoid 12a) for the reference point are: Northing (m) 4632792.698 (± 0.002), Easting (m) 421296.521 (± 0.003), Orthometric elevation (m) 12.880 (± 0.012). The uncertainties in parentheses represent peak-to-peak values.

Two differential GPS rover instruments were used by field crews to map targets for ground control points and to map points along several beach profiles for later comparison with photogrammetry products. These instruments were used to stake three reference points established near the base station at the beginning and end of the day. The average absolute deviation largest vertical difference measured was +0.03 m.

Ground Control Points

Twenty-eight ground control points were used to constrain the photogrammetry (Figure 1). Most (24) were targets placed by the USGS field crew but four were man-made features already in place. Targets included commercial targets (4 ft x 4 ft x 4-mil thick PVC plastic sheets with black and white diamond patterns and grommets in corners; Berntsen International, Inc. product number AT48IC-STK), plywood targets (2 ft x 2 ft x ½-inch thick plywood boards painted with black and white squares), and black plastic trash bags. The commercial targets were designated Tnn and the plywood targets were designated Pnn, where nn is the target number. The trash bags were designated Bxx or BNxx, where xx is the order in which they were deployed. One target (B1) was removed and two targets (P6 and T2) were moved between flight 1 and flight 2 in advance of the rising tide. In-place features included BE, BW, FLAGSTONE, and MAN-SW. Photos of these features are included so that they Three additional in-place features were mapped, but not used in the photogrammetry; these include points designated ASPHALT, CANAL, T-BOARD. Ground control points are listed in file gcp_points_new.txt and locations are shown in Figure 2.

Two additional points (FAKE_1 and FAKE_2) were used to constrain photogrammetry in western portion of Nauset Marsh, where no GCPs were deployed. These points were established by picking flat but distinctive locations in the orthophotomosaic and determining their elevations from the 2013 USGS Lidar data. Without these points, photogrammetry produced marsh elevations about 0.6 m higher than the Lidar elevations. When these points were included as ground control points, close agreement with Lidar elevations resulted.



Figure 1. Photos of reference point GCB_OPUS, on the southwest rim of the northeast manhole on the lawn of the NEED building, Coast Guard Beach, Cape Cod National Seashore, MA.

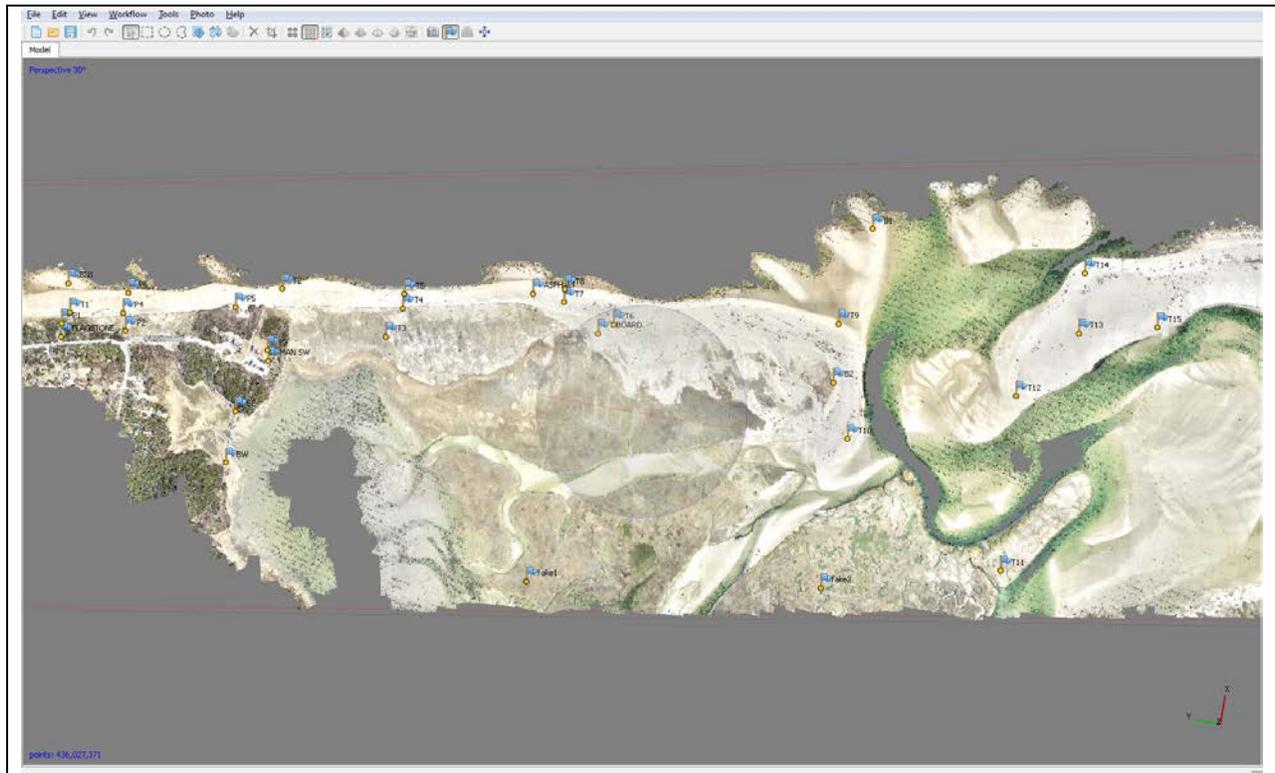


Figure 2. Dense point cloud constructed from f1_rgb2 images, with blue flags indicating the location of ground control points.



Figure X. Photos showing the location of ground control point FLAGSTONE.



Figure X. Photos showing the location of ground control point MAN SW on the NEED building lawn east of the parking lot.



Figure X. Photo showing the location of ground control point BW at the west end of the bike-path boardwalk over the marsh west of the parking lot.

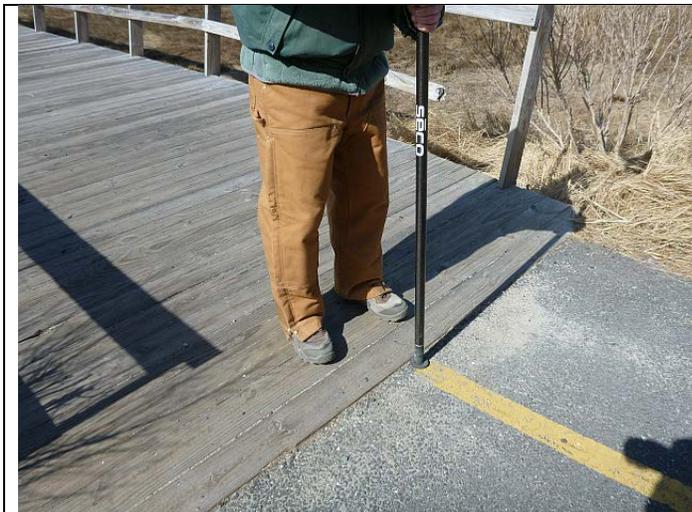


Figure X. Photo showing the location of ground control point BE at the east end of the bike-path boardwalk over the marsh west of the parking lot.



0 m 20 m 40 m 60 m 80 m



0.0 m 1.0 m 2.0 m 3.0 m 4.0 m 5.0 m 6.0 m

Figure X. Orthophotomosaic from f1_rgb1 showing location of FAKE_1 (lower panel is zoomed for closer view)

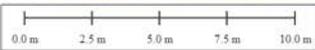
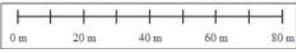


Figure X. Orthophotomosaic from f1_rgb1 showing location of FAKE_2 (lower panel is zoomed for closer view)

Table 1. Ground control points deployed 1 March 2016. Fix numbers are from two different GPS data collectors: fixes 101 – 260 were recorded by Irwin; fixes 100 – 119 were recorded by Brosnahan. Northings and Eastings are NAD83 2010(2011) UTM Zone 19. Elevations are NAVD88 (geoid 12b). Latitudes and longitudes are also NAD83. Time is Eastern Standard Time.

Fix	Northing (m)	Eastings (m)	Elevation (m)	Name	Latitude	Longitude	Time (EST)
101	4633304.634	421295.1887	14.4724	P1	41.847731	-69.94807733	08:26:05
102	4633300.754	421264.4885	15.5644	FLAGSTONE	41.847693	-69.94844658	08:28:01
103	4633150.656	421303.4784	3.8502	P2	41.84634515	-69.94795702	08:33:33
104	4633163.158	421345.3863	3.8931	P4	41.8464619	-69.94745393	08:36:03
105	4633161.461	421393.651	0.1461	P6	41.84645142	-69.9468724	08:38:07
106	4633295.376	421323.9188	3.3805	T1	41.84765048	-69.94773007	08:44:59
107	4633312.225	421392.3687	-0.2037	BN1	41.84780902	-69.94690787	08:50:59
205	4632202.431	421547.2067	3.0415	ASPHALT	41.83782992	-69.94489587	09:46:05
253	4632070.765	421306.8785	0.634	CANAL	41.83662033	-69.94777253	10:00:53
254	4632038.133	421482.082	2.0444	T BOARD	41.83634385	-69.94565835	10:05:13
256	4632796.444	421316.2566	13.1264	P3	41.8431565	-69.94775603	11:34:25
257	4632790.728	421292.3646	12.8735	MAN SW	41.84310265	-69.94804302	11:37:40
258	4632856.524	421039.0632	1.6585	BW	41.84366997	-69.95110243	11:43:52
259	4632852.457	421161.307	1.7247	BE	41.84364552	-69.94962963	11:46:33
260	4633162.1	421384.4323	1.1631	P6 MOVED	41.84645625	-69.94698352	13:33:21
100	4632893.741	421403.5623	4.1019	P5	41.84404118	-69.94671752	08:25:30
101	4632791.415	421463.0803	0.6971	T2	41.84312557	-69.94598712	08:28:22
102	4632525.587	421394.0306	3.2533	T3	41.84072476	-69.94678343	08:37:21
103	4632496.014	421464.9579	6.3036	T4	41.84046547	-69.94592533	08:44:12
104	4632500.29	421498.3601	0.6326	T5	41.84050729	-69.94552363	08:48:02
105	4632132.01	421568.4215	0.125	T8	41.83719761	-69.9446311	08:58:54
106	4632128.394	421539.8443	2.919	T7	41.83716222	-69.94497476	09:02:34
107	4632006.658	421507.8405	3.1684	T6	41.83606272	-69.94534402	09:08:32
108	4631506.754	421592.6454	0.3412	T9	41.83156915	-69.94425661	09:23:33
109	4631468.972	421814.0865	-0.1674	B1	41.83125078	-69.94158516	09:30:39
111	4631496.437	421461.689	4.5234	B2	41.83146326	-69.94583213	09:40:39
112	4631444.88	421341.7187	1.003	T10	41.83098704	-69.94726989	09:45:11
114	4631065.481	421112.7569	0.9363	T11	41.82754752	-69.94997636	10:02:24
115	4631096.898	421498.8983	0.6899	T12	41.82786881	-69.94533114	10:14:27
116	4630988.903	421656.7336	1.8461	T13	41.82691187	-69.94341642	10:17:51
117	4630998.403	421789.0068	1.568	T14	41.82701049	-69.94182503	10:20:47
118	4630826.805	421697.4221	1.6539	T15	41.82545608	-69.94290508	10:25:57
119	4632789.621	421448.9453	2.0012	T2_MOVED	41.84310801	-69.94615712	13:35:19
998	4632105.155	420895.455	0.826	FAKE_1			
999	4631446.181	421002.557	0.817	FAKE_2			

Appendix A. OPUS solution report for reference point CGB_OPUS

FILE: 01220112.16o OP1452608407456

2005 NOTE: The IGS precise and IGS rapid orbits were not available
2005 at processing time. The IGS ultra-rapid orbit was/will be used to
2005 process the data.
2005

NGS OPUS SOLUTION REPORT =====

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: <http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy>

USER: birwin@usgs.gov
RINEX FILE: 0122011o.16o

DATE: January 12, 2016
14:21:21 UTC

SOFTWARE: page5 1209.04 [master52.pl](#) 022814 START: 2016/01/11 14:47:00
EPHEMERIS: igu18791.eph [ultra-rapid] STOP: 2016/01/11 20:05:00
NAV FILE: brdc0110.16n OBS USED: 12897 / 13396 : 96%
ANT NAME: SPP91564_2 NONE # FIXED AMB: 53 / 53 : 100%
ARP HEIGHT: 2.25 OVERALL RMS: 0.012(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) IGS08 (EPOCH:2016.0293)

X:	1631605.378(m)	0.002(m)	1631604.509(m)	0.002(m)
Y:	-4470169.947(m)	0.004(m)	-4470168.506(m)	0.004(m)
Z:	4232628.705(m)	0.003(m)	4232628.697(m)	0.003(m)
LAT:	41 50 35.23448	0.006(m)	41 50 35.26999	0.006(m)
E LON:	290 3 7.22484	0.001(m)	290 3 7.21088	0.001(m)
W LON:	69 56 52.77516	0.001(m)	69 56 52.78912	0.001(m)
EL HGT:	-14.975(m)	0.002(m)	-16.210(m)	0.002(m)
ORTHO HGT:	12.880(m)	0.012(m)	[NAVD88 (Computed using GEOID12B)]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 19)	SPC (2001 MA M)
Northing (Y) [meters]	4632792.698	844817.482
Easting (X) [meters]	421296.521	328891.115
Convergence [degrees]	-0.63243226	1.04252754
Point Scale	0.99967622	0.99998391
Combined Factor	0.99967857	0.99998626

US NATIONAL GRID DESIGNATOR: 19TDG2129632792(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DO9475	MATU TRURO CORS ARP	N415851.708	W0700236.891	17249.0
DO9467	MADA DARTMOUTH CORS ARP	N413822.848	W0710141.393	92650.4
DO9471	MAPL PLYMOUTH CORS ARP	N415619.314	W0703918.243	59633.7

NEAREST NGS PUBLISHED CONTROL POINT

UT0682 STATION SOUTH OF NAUSEAT LIGHT N415110.677 W0695658.640 1104.3

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.