Anguilla

Data Report

December 2023

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This report was prepared by The PLACE Team who wishes to thank the Department of Lands and Surveys, especially Director Leslie Hason Hodge, as well as the entire project team. Specials thanks to the Anguilla Air Traffic Control in granting permission and coordinating during the data collection operations.

Executive Summary

In July 2023, The Government of Anguilla, as represented by the Department of Lands and Surveys (herein "L&S") within the Ministry of Home Affairs, Immigration, Labour, Information and Broadcasting and Physical Planning entered into a Memorandum of Understanding with ThisIsPlaceFoundation (PLACE) to pursue the collection of geo-referenced aerial images captured from an Unmanned Aerial Vehicle or UAV (herein "PLACE Aerial") and geo-referenced street camera imagery (herein "PLACE Ground"). These data are essential primary sources needed by the Government of Anguilla for land management - including management of the registry and cadastre, land valuation, land use planning, climate mitigation and resilience and environmental stewardship. These data will also be available to members of the PLACE Community.

Following the execution of the Memorandum of Understanding (MOU), PLACE and the Lands and Surveys Department, finalized a work plan with PLACE mobilizing in country on August 16th, 2023, to begin training and the initial capture of PLACE Aerial and PLACE Ground data.

Overviews of the PLACE data collection tools, our approach and the resulting data outputs were held with a broad range of stakeholders and followed by hands on training for technical members of the Lands & Surveys Department engaged in the data collection program. This technical training quickly transitioned into on-the-job training as the L&S team proved more than capable of managing all aspects of the data collection process – from driving and street navigation, to coordinating with Air Traffic Control and assisting with the design of flight plans and conducting missions.

Initial PLACE Aerial capture comprised two production flights before mechanical difficulties grounded the UAV. For the remainder of the ten-day mission, PLACE Ground collection continued resulting in all roads of Anguilla being mapped.

On October 29th, the PLACE Team returned to continue PLACE Aerial capture completing six flights over the course of a week, also spending time with the Lands & Survey Department to identify technical needs and possible software architecture approaches that will maximize the ability to share data, while also ensuring coordination of software acquisition between departments to reduce overall government spend on architecture.

On November 12th, the PLACE Team returned for a final time completing an additional twelve (12) production flights and ensuring complete capture of the main island of Anguilla, as well as Angualita, Sandy Island and Scrub Islands.

The results of data collection are as follows:

- 100% of Anguilla flown in October and November, covering an area of 85 square kilometres comprising sixteen (16) flights flown at 1000 feet, captured at 5cm ground sample distance (GSD)[1] and made-up pf 6878 JPEG images;
- 100% of Scrub Island flown covering 12.5 square kilometres, acquired in a single flight flown at 2000 feet captured at 10cm ground sample distance and made up of 61 JPEG images;
- 100% of Sandy Island flown, covering 0.4 square kilometres (and surrounding reef), flown at 500 feet and captured at 2.5cm GSD and made up of 112 JPEG images;

[1] *"In remote sensing, **ground sample distance** (**GSD**) in a digital photo (such as an orthophoto) of the ground from air or space is the distance between pixel centers measured on the ground. For example, in an image with a one-meter GSD, adjacent pixels image locations are 1 meter apart on the ground.[1] GSD is a measure of one limitation to spatial resolution or image resolution".*
https://en.wikipedia.org/wiki/Ground_sample_distance

- 100% of primary and secondary roads, and most tertiary roads were captured, totalling 325 kilometres of roadway;
- Total volume for all imagery to date is approximately 460GB;
- An ortho and digital surface model (DSM) of Sandy Island and of Scrub Island, as well as the Valley, was prepared the week of November 27th, 2023;
- An ortho image and DSM for the remainder of Anguilla were delivered the week of December 20th, 2023, however this dataset will be further refined, and.
- A number of data products developed for the Lands & Surveys Team in order to help catalyse data use, this includes the development of 3D models of the Valley, initial application of machine learning models for specific needs, analysis of flood risk within The Valley, and demonstrations of the utilization of street view imagery.

While the PLACE data has been delivered as planned, we long forward to ongoing engagement with the Government of Anguilla and the Lands & Surveys Department as members of the PLACE Community and will continue to provide support on as needed basis and begin to look ahead to data collection in 18-24 months.

Acknowledgements

The PLACE team would like to extend particular thanks to Honourable Minister Kenneth Hodge, and Director Leslie J. Hodge of the Department of Lands and Surveys for their trust and belief in a partnership with PLACE. Their pursuit of a bold vision of an improved geodetic and geospatial data infrastructure has laid the groundwork for a long-term successful partnership allowing them and the Government and people of Anguilla to have access and use of up to date, detailed information that can be used for planning, investment, and environmental stewardship among many others.

Many thanks to the technical team within the Lands and Survey Department for their time and dedication over the course of the activity, recognizing that in certain cases it meant working over weekends and long days starting at 7am and working through to sundown. Mr. Maikol Rivas and Mr. Ricardo Rock did an exceptional job managing the capture of Ground Control Points (GCPs) which has ensured a high level of positional accuracy of the data. Mr. Wayne Hodges ensured all roads were captured during the PLACE Ground exercise. Many thanks to the rest of the team who helped.

Collaboration with staff from the Physical Planning Department, The Disaster Management Office and the Inland Revenue Department in assisting with data collection and providing valuable feedback on the data applications ensured that the data will be useful to a wide range of users across Anguilla.

Many thanks to the Anguilla National Trust for working to get the PLACE and Lands & Surveys Team to out to Prickly Pear and Dog Islands, even if rough seas didn't allow us to disembark and collect data.

Lastly, a thank you to Mr. Jabari Harrigan, Airport Manager at the Clayton Lloyd International Airport, and his team within Air Traffic Control for their collaboration over the course of the data collection. With their help, we were able to work quickly and efficiently from airport grounds, ensuring minimal disruption to other air traffic.

Introduction

The Government of Anguilla, like many small island states, suffers from a lack of up-to-date geospatial information. Recognizing the ability for PLACE to help resolve this issue in a timely manner while at the same time building capacity within the Land Agencies, PLACE and the Ministry of Home Affairs, Immigration, Labour, Information and Broadcasting and Physical Planning of Anguilla executed a Memorandum of Understanding (MOU) in early July 2023. PLACE and the Government of Anguilla agreed to collaborate in collecting data that is critical to further development of the national geospatial data infrastructure.

The MOU lays out the responsibilities of the parties. In the case of PLACE this means providing the needed expertise and hardware, in the form of 360 Degree Streetview camera, and an e400 Unmanned Aerial Vehicle from Event 38, to allow for the capture of data across Anguilla.

Insta360 Pro II

E400 from Event 38

Figure 1 - Platform for Collection of PLACE Ground and PLACE Aerial Data

The collected dataset, an inventory of geo-referenced aerial (PLACE Aerial) and Streetview imagery (PLACE Ground), is owned by the government, with a use license to be shared with the PLACE legal Data Trust in the UK (PLACE UK). The aerial data (2.5 to 10cm ground sample distance (GSD), in 24-bit RGB color) is geolocated to within 20 cm absolute positional accuracy making it suitable for engineering purposes and more. The PLACE Ground system captures 360 degree, geolocated imagery, that together with the aerial data create a seamless dataset of Anguilla.

Results include a complete dataset for PLACE Ground collected across the island, processed to include data standardization, and deidentification (in the form of blurring of faces and number plates), along with PLACE Aerial for all of Anguilla and the islands within 2 kilometres of the shore.

Logistics and Coordination

Prior to the start of field activities, L&S and PLACE developed a checklist of pre-mobilization tasks designed to optimize time in the field. These included:

- Approval of PLACE unmanned aircraft vehicle insurance for the Lands & Surveys Department
- Coordination with Air Safety Support International (ASSI) UK (responsible for Air Safety in British Overseas Territories) for flight approvals;
- Coordination with Airport Control Tower at Clayton Lloyd International Airport;
- Capture of Ground Control Points across the island;
- All import clearance letters provided for all PLACE equipment and personnel.
- Vehicles for local travel and data collection confirmed.

- Provision of housing and meals for PLACE staff, and
- Internal travel arrangements (for Dog and Prickly Pear Islands).

Field Activities

On Thursday, August 17th, 2023, an introductory presentation by PLACE was facilitated by the Lands & Surveys Department and hosted by the Ministry of Public Works was held. With attendees from the L&S Department, the Physical Planning Department, The Disaster Management Office, Air & Sea Ports Authority, the Inland Revenue Department and the Ministry of Public Works in attendance, most anticipated governmental users of the resulting geospatial data were included.

The intent of the presentation was to:

- Provide an overview of the PLACE mapping tools, their operation and the technical output;
- Share plans for the data capture campaign, set expectations and representative data examples;
- Gather information regarding the current software tools used for managing spatial data, plans for future spatial data management, and potential uses cases of the PLACE data.

With over a dozen representatives present, clear interest in the data was expressed, with a further detailed discussion regarding how the different government agencies might efficiently access and share the data. Use cases were identified around the need for mapping impact from storms, to identifying road hazard, developing flood models and planning for disasters.

PLACE Ground

Given unfavourable weather (rain and wind), initial data capture was focused on PLACE Ground. Over the course of ten days, almost 325 kilometres of roadway were captured, including many miles of unpaved roadway. The team captured six (6) images, capturing the full 360 degrees, every 3, 4 or 5 seconds, depending on the speed the vehicle was travelling – with speeds always kept under 30 miles per hour. L&S and the PLACE team even worked to capture roads that seemed initially impassable, identifying informal access roads across the island.

The approach taken was to have a driver from the L&S Department supported by a navigator from PLACE working to both monitor the streetview camera ensuring pictures are being taken and geo-tagged, as well as to provide direction to the driver as to what roads to take. It was critical for the navigator to have a large screen tablet to monitor the road network and track which roads have been covered, ensuring a minimum of duplication as well as full coverage of each community.

Figure 2 - PLACE Ground Setup on an Inland Revenue Department Vehicle

Staff from L&S Dpartment proved critical to data collection, particularly in identifying which roads might in fact be on Private or Family Roads, as well as to assuage any concerns residents might have. The L&S staff ensured every road which could be considered passable, was covered with the street view. Daily data processing allowed the team to identify streets that might have been missed and that would need to be covered again, ensuring complete data capture.

Once collected the data was returned to the PLACE team to work on the de-identification process, blurring faces and number plates in images, before making the entire imagery collection available to the Government of Anguilla.

PLACE Aerial

The Lands & Surveys team, working with PLACE, made the decision to fly the entirety of the island at 1000 feet, apart from Scrub Island, which would be flown at 2000 feet. Flying at 1000 feet ensures a resolution of 5 cm/pixel on the unprocessed imagery, while at 2000 feet we achieve a resolution of 10 cm/pixel. With GCPs, this ensures the data can be processed in to a single ortho-photo with an approximate positional accuracy of 1 – 1.5 times GSD.

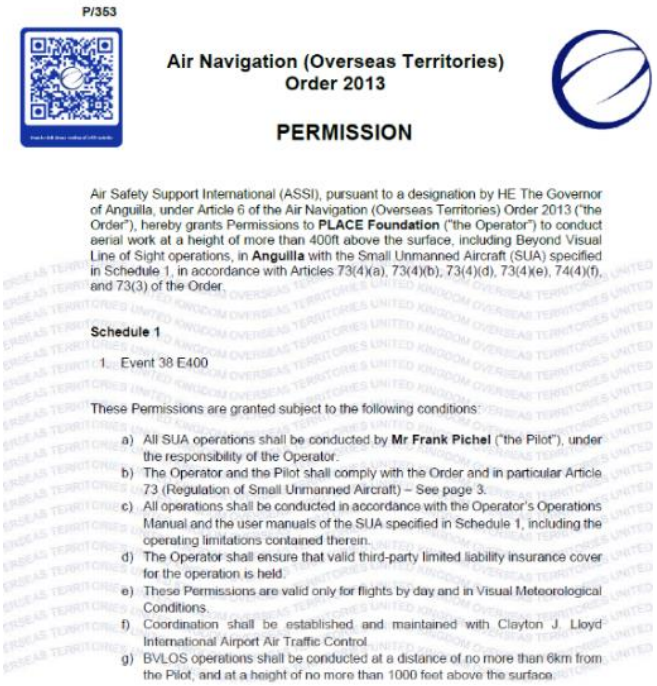
Preparations

Flight Clearances

Prior to travel to Anguilla, the PLACE team provided detailed specifications on the UAV we planned to operate, our proposed flight plans, and the qualifications of the PLACE UAV pilots. These were reviewed by the Anguilla Air Traffic Control, who, once satisfied, passed on our request to Air Safety Support International (ASSI), a subsidiary United Kingdom Civil Aviation Authority responsible for civil aviation safety regulation in the UK Overseas Territories.

On August 17th, an in-person meeting was held with the leadership of the Anguilla Air and Sea Ports Authority, as well as a Flight Operations Inspector from ASSI (via video conference) to review the flight plans, discussed options for diversion in the event of air traffic, and established an operational approach to communications with the flight tower. When operating in the vicinity of the airport a strict operational protocol was followed including clearance from ATC prior to each UAV flight and confirmation from PLACE to ATC that all UAV flights were safely completed, always ensuring safe and controlled airspace. All aerial imagery collection in the vicinity of the airport and flight paths took place during the early morning (7 am – 10 AMam) prior to commercial flights, minimizing disruption to flight operations. All aerial flights in the vicinity of the airport were also made from within the airport compound, and while accompanied by a member of the ATC team, ensuring continuous communication with the flight tower during operations. As needed, the PLACE team moved the e400 UAV into a loiter mode outside of flight lines to allow in bound and out bound air traffic to proceed.

Based on the review from ASSI and Anguilla Air and Sea Ports, a permission was subsequently granted to allow for PLACE to operate in Anguilla.



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Air Navigation (Overseas Territories) Order 2013

PERMISSION

Air Safety Support International (ASSI), pursuant to a designation by HE The Governor of Anguilla, under Article 6 of the Air Navigation (Overseas Territories) Order 2013 ("the Order"), hereby grants Permissions to **PLACE Foundation** ("the Operator") to conduct aerial work at a height of more than 400ft above the surface, including Beyond Visual Line of Sight operations, in **Anguilla** with the Small Unmanned Aircraft (SUA) specified in Schedule 1, in accordance with Articles 73(4)(a), 73(4)(b), 73(4)(d), 73(4)(e), 74(4)(f), and 73(3) of the Order.

Schedule 1

1. Event 38 E400

These Permissions are granted subject to the following conditions:

a) All SUA operations shall be conducted by **Mr Frank Pichel** ("the Pilot"), under the responsibility of the Operator.
b) The Operator and the Pilot shall comply with the Order and in particular Article 73 (Regulation of Small Unmanned Aircraft) – See page 3.
c) All operations shall be conducted in accordance with the Operator's Operations Manual and the user manuals of the SUA specified in Schedule 1, including the operating limitations contained therein.
d) The Operator shall ensure that valid third-party limited liability insurance cover for the operation is held.
e) These Permissions are valid only for flights by day and in Visual Meteorological Conditions.
f) Coordination shall be established and maintained with Clayton J. Lloyd International Airport Air Traffic Control.
g) BVLOS operations shall be conducted at a distance of no more than 6km from the Pilot, and at a height of no more than 1000 feet above the surface.

Figure 3 - Clearance from ASSI to operate in Anguilla.

Ground Control Points

Ground Control Points or GCPs, are needed to validate the accuracy of the map and to provide for some contingency for geo-referencing in case accurate GNSS Post Processed Kinematic (PPK)positions of the camera exposure positions are not available (meaning the position is processed against other stations data). GCPs, also at times referred to as validation points, are also used to verify the spatial accuracy of ortho-mosaics and surface models. Prior to the PLACE Team mobilizing to Anguilla, the L&S worked with PLACE to design a GCP data collection plan that would ensure a high level of positional accuracy for the resulting Ortho mosaic.

Figure 4 - GCPs in Anguilla using existing features (at left) and new targets (at right)

Over the course of August 2023, the L&S team identified, or created, approximately 66 GCPs across the island, measuring each multiple times to gather precise coordinates. In most cases GCPs were **existing features** on the ground, minimizing the need to create targets which would then need to be maintained for the duration of the image acquisition campaign. Where no existing target feature was available, the L&S team created a GCP marker by painting a clearly visible cross on a flat surface, visible from the air.

Base Station

In combination with the GNSS on the Event38 E400 unmanned aerial vehicle (UAV) used by PLACE for mapping, is a GNSS receiver on the ground serving as a Base Station. That data logged by the UAV and the base station must then be post processed by applying a correction method known as Post Processing Kinematic (PPK) which yields fixed or float solutions. This ensures that the final processed data is precisely positioned, and further refined by the GCPs captured earlier.

Figure 5 - Base Station on a known Control Point

Given the size of Anguilla, a single base station located centrally at the L&S office on an existing control point which could be monitored throughout the day, was sufficient to cover all planned flights. Each morning started with setup of the base station on the control point, with the stations left running for ongoing data collection and eventual processing of the collected imagery.

In addition, PLACE utilized the newly established Trimble Continuously Operating Reference Station (CORS) installed earlier this year. These two data sets ensured the PLACE team has multiple ways to process the data.

PLACE Aerial Data Collection Details

August 2023 Data Collection

An initial test flight was completed on Tuesday August 22nd, 2023, in order to ensure that the UAV had arrived unscathed from the travel from Washington DC. This test flight, captured by the communications team of the Government of Anguilla, and shared on their Facebook page[2], was a success. The flight, while short allowed the technical team at PLACE to have an initial dataset to work with, which included much of the central business district of the island.

Figure 6 - The initial test flight was captured by the Ministry Communications Team and shared via the Govt. Facebook page

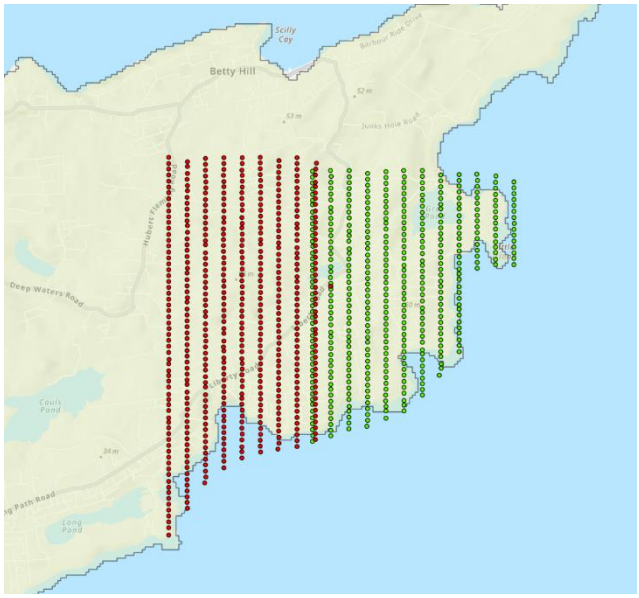


Figure 7 - Flight Paths of August Production Flights

On August 23rd, two Production flights were flown from the basketball court at the Morris Vanterpool Primary School in East End Village. These flights, longer than the initial test flight flow on the day prior, were full production flights intended to capture the East End of the island, as depicted in the image at left. Both data collections were completed successfully. Unfortunately, an error with the landing resulted in a need to fix the e400 from Event38, which could only be done at the home office.

Flight #	Date	Time	Duration	Area Covered	Altitude	Overlap	Sidelap	# Images
1	Aug. 22 '23	4:15 PM	9:25	.75 km2	1000 ft	80%	60%	27
2	Aug. 23 '23	12:15 PM	33:12	4.63 km2	1000 Ft	80%	60%	426
3	Aug. 23 '23	1:30 PM	44:04	5.57 km2	1000 ft	80%	60%	487
Total			1:26:41	10.95km2				940

Figure 8 – Summary of August Flights

[2] https://www.facebook.com/watch/?v=1532379854257348&ref=sharing

October 2023 Data Collection

The PLACE Team returned to complete the data collection on October 29th, and following initial testing, immediately proceeded to continue data collection on the East End of the Island. The L&S team had identified a vacant lot, which after some clearing of brush by the team, was a well-situated location for flights.

Over the course of the afternoon of the 30th, an initial test flight of seven minutes was flown, followed by two production flights allowing us to capture the Northeastern Coast of the Island.

On the 31st of October, we coordinated closely with the Airport Authorities to collect data over the airport, as well as to the east and west of the runway. Tuesday the 31st was selected specifically due to the low traffic, and the intent was to complete our flights before any known inbound traffic. Following a security review, badging, and ensuring proper safety equipment was available, the PLACE team was permitted to operate from the executive terminal parking lot, while escorted with a member of the ATC team dispatched from the tower.

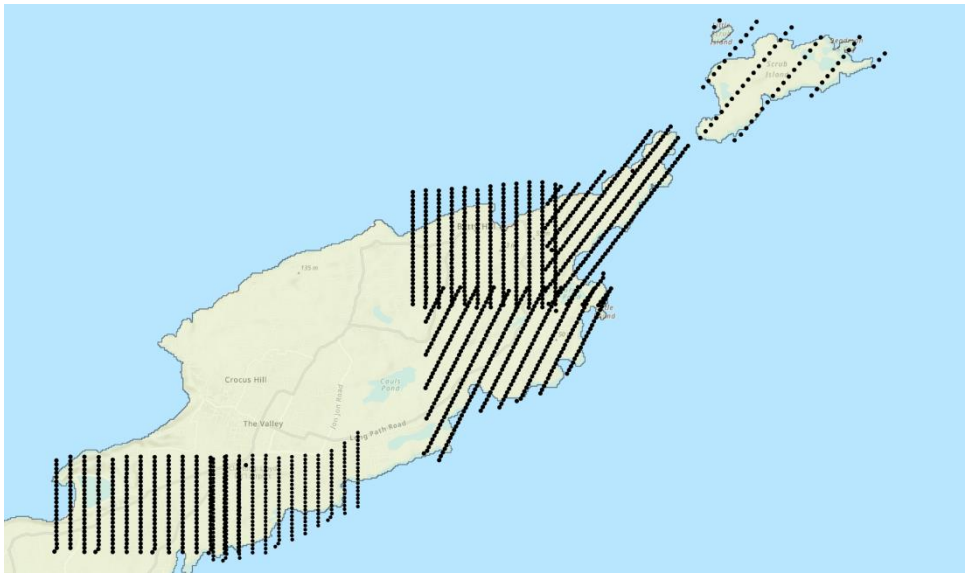
Figure 9 - PLACE UAV at the Airport parked next to other private planes.

While a small airport, it is quite busy to traffic from small planes operating under visual sight rules, and which may not have transponders. Given the proximity to St. Maarten and other islands, these planes often do not announce their intentions to land until minutes before the planned landing. Consequently, the close coordination with ATC was appreciated, and the PLACE team successfully transitioned into loiter mode while waiting for airspace to clear and the mission to continue.

In the late morning, PLACE shifted to an unused cricket pitch on the southeast end of the island to complete data capture in the east end.

On the afternoon of the 31st, the PLACE and L&S Team moved to the far northeastern tip of the island to review previously identified take-off and landing locations, with the intent to fly across to capture Scrub Island. Those previously identified take off locations proved to be too exposed to the wind, and thus dangerous for take-off and landing. A small depression on the Northern (leeward) side of the island was identified as a possibility, and following review with the anemometer to ensure that the wind was sufficiently broken by the ridge to allow for landing, it was deemed safe to proceed. Flying at 2000 feet, given the lower resolution required as the island is undeveloped, the team was able to successfully acquire imagery for the entirety of Scrub Island

In the course of preparing for flights on November 1st, it was revealed that the UAV has suffered from a power surge and would thus need to be repaired before we could finalize image acquisition, thus concluding our data collection in October.



Flight #	Date	Time	Duration	Area Covered	Altitude	Overlap	Sidelap	# Images
1	Oct. 30 '23	12:45 PM	41:38	6.44 km2	1000 ft	70%	30%	251
2	Oct. 30 '23	2:30 PM	50:26	8.79 km2	1000 ft	70%	40%	357
3	Oct. 31 '23	8:00 AM	47:40	9.39 km2	1000 ft	70%	35%	333
4	Oct. 31 '23	9:30 AM	39:08	7.49 km2	1000 ft	70%	35%	279
5	Oct. 31 '23	11:55 AM	53:43	11.47 km2	1000 ft	70%	30%	338
6	Oct. 31 '23	2:15 PM	31:46	7.24 km2	2000 ft	70%	30%	62
TOTAL			4:24:21	50.83				1620

Figure 10 – Summary of October 2023 Flights

November 2023 Data Collection

While reviewing the previously collected data, it was noted that the overlap between adjacent images within a flight line, and sidelap (the overlap between images on adjacent flightline) used for data capture in previous missions proved adequate for the creation of an ortho image, however it did not allow for high quality 3D renderings of the images, with resulting distortion in built up areas. As a result, we decided to re-fly some areas, and capture with a greater side and overlap to allow for an improved final product.

On November 13th, 2023, we commenced flying from the cricket pitch located in the Valley. The pitch provides plenty of space, as well as a wind break in the form of the score board. The Valley is so named however, because it is indeed in a valley between two ridgelines, which impact our two initial flights. While the flights were within typical operating distance, we were obscured by a ridge with buildings upon it on the outer limits of our flights. As a result, both flights ended with the UAV going out of communications range and initiating a return. Following a modification of our flight plans, and an adjustment of the radio, we were able to successfully complete the planned missions in the afternoon.

On the 14th of November, with permission from the Lake family, we operated from the Albert Lake Mausoleum close to Shoal Bay. A private, well-situated area on top of a hill, the site proved ideal for flight operations. From the mausoleum we were able to complete two flights, before shifting to Blowing Point in the afternoon. At Blowing Point, we were able to complete two flights covering the South End of the island, despite a steadily rising wind.

Figure 11 - The Team Setup at West End Elementary School

On November 15th, the data collection team was back at the airport for two flights which would allow us to recapture a portion of the island with greater overlap, and ensure we captured all imagery with the flight lines. During the second flight of the day, covering Sandy Ground, we lost radio communication and subsequently aborted the mission. Further investigation with the L&S team revealed that our communications were being disrupted only when flying over a high powered Am/Fm radio tower. Following a modification of the flight plan, this mission was reflown, allowing us to compete operations at the airport just after 10 AM.

In the afternoon of the 16th, the data collection team relocated to the West End Primary School, to complete data collection the West End of the Island. Over the course of the afternoon, two flights were successfully completed, allowing the team to close out most of the island.

On the 17th of November, we completed a short final flight from the Cricket Pitch to close a small gap between flight lines that was identified during initial processing. Subsequently, the Anguilla National Trust took the team out to Dog and Prickley Pear Islands, with the intent to complete an imagery capture of the islands, however rough seas prevented the team from disembarking with the equipment. In the early afternoon, a final flight from the new dock terminal at Sandy Ground was launched to fly across 3.5km of open water to Sandy Island. Sandy Island was successfully captured while flying at 500 feet at a resolution of 2.5 cm, thus concluding the aerial imagery acquisition component for the year.

Figure 12 - Sandy Key

Flight #	Date	Time	Duration	Area Covered	Altitude	Overlap	Sidelap	# Images
1	Nov. 13 '23	11:00 AM	15:00	*No data produced*				
2	Nov. 13 '23	12:00 PM	20:00	*No data produced*				
3	Nov. 13 '23	1:30 PM	59:47	7 km2	1000 feet	80%	60%	643
4	Nov. 13 '23	3:15 PM	52:54	6 km2	1000 feet	80%	60%	501
5	Nov. 14 '23	9:40 AM	51:53	7.2 km2	1000 feet	80%	50%	494
6	Nov. 14 '23	11:20 AM	51:26	8.7 km2	1000 feet	80%	50%	566
7	Nov. 14 '23	1:45 PM	50:06	8.4 km2	1000 feet	80%	50%	540
8	Nov. 14 '23	3:35 PM	52:13	8.6 km2	1000 feet	80%	50%	602
9	Nov. 15 '23	7:30 AM	24:39	2.4 km2	1000 feet	80%	50%	157
10	Nov. 15 '23	8:35 AM	*20:00*	*No data produced*				
11	Nov. 15 '23	9:25 AM	37:45	5.7 km2	1000 feet	80%	50%	373
12	Nov. 15 '23	12:30 PM	50:06	8.3km2	1000 feet	80%	50%	540
13	Nov. 15 '23	3:05 PM	46:00	6.9km2	1000 feet	80%	50%	444
14	Nov. 16 '23	7:55 AM	16:07	1.3 km2	1000 feet	80%	60%	126
15	Nov. 16 '23	12:45 PM	22:00	340m2	500 feet	80%	60%	116
TOTAL			10:17:28	84.8 km2				6306

Figure 13 – Summary of November Flights

Data Collection Summary

PLACE Ground Summary

Data was captured across over 325km of roadway in August of 2023. The details of the data collection timing detailed and depicted in the figures below.

Date of Capture	Length in km
18-Aug-23	50.90
19-Aug-23	2.94
21-Aug-23	21.47
22-Aug-23	31.57
24-Aug-23	15.86
25-Aug-23	49.08
26-Aug-23	50.99
28-Aug-23	46.88
29-Aug-23	44.35
30-Aug-23	10.83
TOTAL (Km)	**324.86**

Figure 14 – Roads and Distances Covered in the Capture of PLACE Ground

PLACE Aerial Summary

Over the course of 24 flights, with a total of approximately 18 flight hours, a total of 97 square kilometres were captured, covering the entirety of Anguilla. Some areas were flown multiple times to ensure sufficient overlap and high-quality images, resulting in an area flown exceeding the total area of the island. The figure below depicts all the production flights flown over the duration of the data collection exercise. All the raw imagery was delivered to the L&S Department on a hard disk prior to the departure of the PLACE Team in November 2023.

Figure 15 – Flightlines for all PLACE Aerial Production Flights

Data Collection and Data Processing Overview

Over the course of the data collection exercise, the PLACE team would collect the relevant datasets from each flight – the GNSS files from the UAV (rover), the GNSS files from the base station and the CORS, as well as images captured with an initial geotag. The PLACE Technical team then processed the data to ensure it met our technical requirements, before the team returned to the outputs to L&S.

Post processing generated fixed and float image collections with carrier phase differential GNSS and exposure event marking. These collections were delivered to the L&S and PLACE Private Cloud[3] where they were used as inputs for generating ortho-mosaics and digital surface models for some of the islands flown.

This section outlines the data processing methodology applied to aerial imagery acquired for Anguilla. It can be replicated as new imagery is acquired.

[3] A cloud infrastructure for the storage and sharing of PLACE image data.

Background

GNSS data logged by the UAV and its EMLID Reach Base Station must be post processed on completion of sorties for aerial imagery to meet the specification for PLACE Aerial (see box). By applying a correction method known as Post Processing Kinematic (PPK) which yields fixed or float solutions, imagery can be accepted into the PLACE Data Trust. On acceptance imagery undergoes further processing in the cloud (e.g. generating ortho mosaics).

PPK was performed each day as the PLACE and L&S Team were collecting new aerial imagery. Results show post processed imagery meets accuracy standards required by the surveying profession.

Product Definition: PLACE Aerial is a collection of RGB, nadir aerial images. An image collection is a set of individual images (e.g. a flight line, a project area or a city) acquired with a specialized aerial mapping UAV using a mirrorless digital camera with fixed focal lens. Images have at least 60% forward-lap and 60% side-lap, a GSD of 5 - 10cm and a radiometric resolution of 24-bit (3 x 8 bits per band). Images are geo-tagged by means of carrier phase differential GNSS and exposure event marking yielding fixed and float solutions with an average positional accuracy of 20cm. Image collections are delivered in cloud optimized GeoTIFF (COG) format with associated metadata.

Accuracy Levels

There are different levels of image accuracy dependent on the level of processing described below. Post processing PLACE imagery is accurate within a range of 20- 30 cm:

1. When the UAV is airborne, the position of each camera exposure (an event) is recorded whenever a picture is taken. Camera exposure events are logged by an on-board dual frequency (L1/L2) GNSS receiver yielding immediate positional accuracies of +/- 5m.

2. Post flight, accuracy is improved by PPK. PPK is always performed on the data PLACE collects ensuring the highest accuracy standards. PPK was performed using Event38 utilities and RTKLib[4], an open source GNSS software package. By including base station readings (corrections), recorded while the UAV is airborne with the UAV's on-board GNSS readings (positions), PPK yields positional accuracies of 20 – 30cm[5].

   During each flight the EMLID Reach base station was positioned on known fixed or observed locations. Typically, the base station logged readings at least 30 minutes prior to, and 30 minutes after a flight[6]. The EMLID base station was then positioned on the observed control for the duration of the flight. Base station coordinates in Anguilla are recorded in ITRF2014/UTM Zone 20N. For post processing coordinates were converted to WGS84 (lat/long).

3. To achieve the highest positional accuracy PPK can be supplemented with Ground Control Points (GCPs). Including GCPs will yield positional accuracies of between 1-1.5 times an image's Ground Sample Distance (GSD)[7]. A GCP campaign was undertaken by L&S which to achieve higher accuracy of the ortho image.

[4] These utilities are available for download from the Event38 website.
[5] PPK produces a quality reading from Q1 to Q5, where Q1 is a fixed solution with centimeter precision, Q2 is a float solution with accuracy at the sub meter level and Q5 is single precision and usually at the several meter level. A low number of visible satellites, satellite constellation geometry, interrupted or low signal strength may prevent realizing a fixed solution.
[6] A 30 minute 'warm up' period for the base station is recommended before the UAV (rover) begins recording.
[7] At 5cm GSD accuracies will be between 8 – 10cm.

Post Processing Results

This section describes flights and the PPK solutions for the imagery collected."

Centimeter level solutions (Q=1) were achieved using PPK. Also known as a fixed solutions these equate to the highest quality position solution with precision at the centimeter level. Where this was not the case, it was most likely due to interrupted GNSS signals and not something the L&S can control. Float solutions (Q=2), achieved for some flights are perfectly acceptable (equating to sub-meter accuracies) yielding positionally accuracies of between 20-30 centimeters across the extent of the true ortho[8].

A copy of all data has been provided to the Lands & Surveys Department[9].

The following flights were completed across the entirety of Anguilla, refer to the Quality Readings column for an accuracy assessment.

Date	Flight #	Area	Solution
Oct. 30 '23	1	-	NA
Oct. 30 '23	2	-	Q1
Oct. 31 '23	3	Airport West	NA
Oct. 31 '23	4	Airport East	Q1
Oct. 31 '23	5	FIFA Field SE End	Q2
Oct. 31 '23	6	Scrub Island	Q2
Nov. 13 '23	1	Cricket Pitch West	Q1
Nov. 13 '23	2	Cricket Pitch East	Q1
Nov. 14 '23	1	NW Island	Q1
Nov. 14 '23	2	NE Island	Q1
Nov. 14 '23	3	Blowing Point East	Q2
Nov. 14 '23	4	Blowing Point West	Q1
Nov. 15 '23	1	Airport East	Q1
Nov. 15 '23	2	Airport West	Q1
Nov. 15 '23	3	West End Elem West	Q1
Nov. 15 '23	4	West End Elem East	Q2
Nov. 16 '23	1	Cricket Pitch Gap	Q1
Nov. 16 '23	2	Sandy Island	Q2

Figure 16 - Anguilla Flights by date, control and solution

Anguilla Base Station

Anguilla is in UTM Zone 20N. The following base stations were used as controls:

ID	E (m)	N (m)	Lat	Long
W6065	783982.003	2410858.752	21.780488683	-72.253429909

[8] Initial orthomosaic processing did not use ground control points.

[9] The L&S have been given access to PLACE's image repository so they can download ortho-mosaics and other derived datasets.

Data Outputs

True Ortho

The PLACE Team developed a true ortho of Sandy Island (2.5cm GSD), Scrub Island (10cm GSD) and portions of The Valley (5cm GSD) for initial analysis. These orthomosaics were delivered to L&S the week of November 27th, 2023. A Digital Surface Model (DSM) for each location was developed. These datasets have been provided electronically as TIFF files via a shared folder.

Figure 17 - Samples of Digital Surface Model for Anguilla

Figure 18 - Sample of Processed Imagery for Anguilla

Machine Learning Models

PLACE identified several deep learning models, drawing from the Esri library of existing pre-trained models, which might be relevant as demonstrative datasets. Using these models, trees, cars and buildings were identified in The Valley.

L&S staff noted that some buildings were not captured in the initial processing of building outlines. Upon review it was realized by the staff that it was buildings with concrete roofs were not captured. In reviewing the training model, it was revealed it was trained with US datasets. Concrete roofs are less common in the US, and are more often parking lots, while in the Caribbean, concrete roofs are common due to tropical storms.

Each of these models can be extended island wide, and through refinement, the models can be improved. We look forward to members of the PLACE Community sharing models refined for their own respective work and regions.

Figure 19 - Building Outlines Identified Using Machine Learning Models

Figure 20 - Trees Identified Using Machine Learning Models

Figure 21 - Car Outlines Identified Using Machine Learning Models

Oriented Imagery Catalog Demonstration

Street imagery, once deidentified by PLACE was used to create an orientated image catalog (OIC) in ArcGIS Pro, and subsequently published to ArcGIS Online for sharing with invited users. OIC's allow viewing of a range of imagery acquired from cameras at locations selected on a map – whether car mounted cameras, aerial cameras, or those at fixed locations. The OIC uses camera information (field of view, direction, etc) to create a 360-view port side by side with a true ortho. This allows users to navigate using the aerial imagery, and then select a specific point for which the street view is of interest.

Integrating the two data sets allows both to act as material for machine learning, measurement, and analysis. In the graphic below the red cross in the map relates to the exact position of the vehicle. Any object in the street view imagery can be measured – height, area etc. and any object can be digitized as a database information set. For example, we can see that the store yellow building with the concrete roof is one story and appears to be a residence. We can measure the height and calculate the cubic area of the building, and confirm key aspects of the dwelling, including that the roof is prepared for an addition. It is the combination of the two data sets that provides such a wealth of information for many applications.

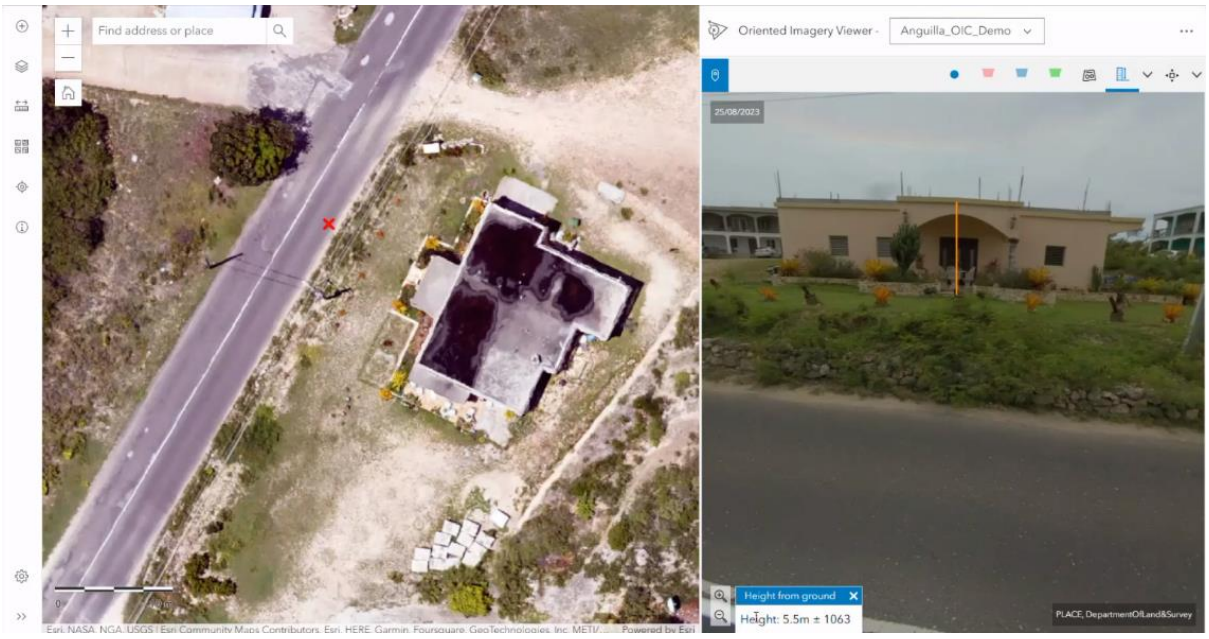


Figure 22 - Oriented Imagery Catalog Aerial View While Using PLACE Ground for Measurements

3D Model Demonstration

A 3D Model of the city allows users to interact with data in new ways and provides unparalleled perspectives for visualizing the city. For those users not used to working with spatial data – particularly policy makers and the public – the 3D model is a powerful tool in conveying information.

PLACE Aerial was purposely collected with a high degree of overlap between images – 80% forward overlap (between successive images in a line) and 50% to 70% sidelap (between flight lines) depending on the level of development in our area of capture. For The Valley, we ensured a 70% sidelap, allowing PLACE to effectively process a 3d point cloud, even without the use of LiDAR.

Figure 23 - 3D Model of The Valley

This 3D model of The Valley could be further refined by extracting PLACE Ground images captured in the field and overlaying them upon building façade if required. The 3D Model, because of the imagery being precisely geopositioned can be used for measurements, and the analysis of heights, making it particularly useful in analysing the Digital Surface Model (detailed further below).

Valley Flooding Use Case

A short video, showcasing how PLACE imagery can be used for flood risk analysis has been developed for the Valley. This use case highlights several different data products, and how they can be used together for analysis and the creation of a derived product. In this use case, using Structure from Motion (SfM) a digital surface model (DSM) was first created. A DSM is an elevation model representing all above ground features (e.g. trees, buildings, etc). With this elevation information,

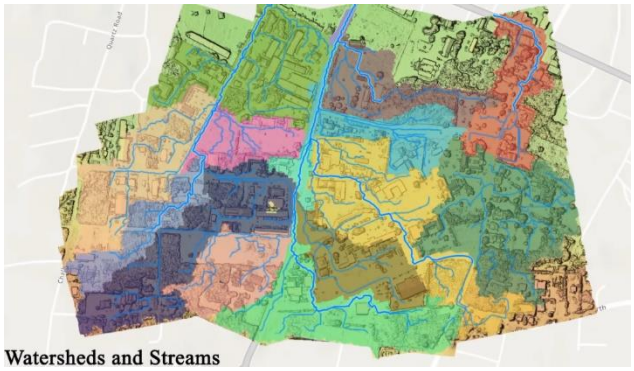


Figure 24 - Watersheds of The Valley, Anguilla

Figure 25 - Drainage Paths, Building Outlines and Highlights Buildings at Risk of Flooding

catchment areas or natural boundaries defined by ridges or hills and within which surface water will drain into a common channel to form a river or stream, can be mapped (see below left).

After creating the DSM and watershed map, a number of Esri's pre-trained deep learning models for building detection were applied. With this, it is now possible to see which buildings are in likely water channels and apply buffers from channels to identify those within a certain distance and thereby ranking their risk of inundation. As buildings are often underwritten by loans and insurance recording

building characteristics, a task facilitated by combining PLACE street imagery, coupled with their location means it is quite possible to decide of the financial impact of flooding. This dataset can also be immediately used by The Planning Department in assessing building approvals, as well as for flood mitigation activities based on likely road coverage, etc.

Conclusion

The initial data collection in Anguilla over the course of August – November 2023 proved effective with the entirety of Anguilla captured, as well as those small islands within three kilometres of the main island, totalling 85 square kilometres of imagery at 5cm resolution, replacing outdated imagery of much lower resolution. Additionally, streetview for the entire island, totalling 325 kilometres of linear road across the island, has been captured.

All imagery has been processed, and the use of Ground Control Points (GCPs) captured by the Lands & Surveys Department ensures a positional accuracy of 10-20 centimetres across the orthomosaic.

Next Steps

Image data will be processed further and reviewed for quality control purposes, with all revised datasets made available to the Department of Lands & Surveys for download. PLACE Ground Imagery will be anonymised and shared in late January 2023. Once processing is complete all data will be delivered via the transfer of an external hard drive (expected to be in mid-March 2023). In mid-February 2023, Mr. Nigel Edmead will visit TCI for approximately three weeks to supervise additional UAV flights, provide training on processing and use of the data and validate the accuracy of the orthophotos.

Ongoing Support

PLACE, and members of the PLACE Community, remain available to support the Government of Anguilla in the use of the PLACE Data captured, including through exploration of additional use case development, training, and technical support.

Annexes

Annex A: PLACE Staffing Summary

Over the course of the activity period, members of the PLACE Team supported the data collection and training. Short bios are below.

Peter Rabley is the **Managing Director of PLACE**, and is a technology executive, investor, and geographer. He has spent the last thirty years creating and operating geospatial businesses that map the earth to improve lives and protect the resources of our planet. His latest venture is PLACE, a non-profit data trust, which he founded to make mapping more accessible and affordable so that decision makers have the data they need to improve the places around them. At PLACE, Peter is responsible for strategy and managing the organization's investment portfolio. Peter has built various businesses including ILS, an enterprise software firm that provided property taxation, registration, and mapping solutions to governments globally. After its acquisition by Thomson Reuters, he became Vice President for Global Business Development and Strategy at Thomson Reuters. Peter is a Fellow of the Royal Geographical Society and the Royal Society of Arts and graduated from the University of Miami with a B.A. in Geography and Economics and an M.A. in Geography.

Frank Pichel is the Partner for Field Operations, and as an **FAA Certified Pilot** is a **Trainer on PLACE Aerial and PLACE Ground Platforms**. Frank is a land information specialist with experience designing, managing, and implementing projects around the globe. Frank started his career working to deliver technologically appropriate solutions for land management in the US, Caribbean, and Africa, implementing tools for use by local and national governments. Following his time at USAID, and recognizing the need to move beyond data collection, and into localized management, use and ownership of data, Frank helped establish Cadasta Foundation, serving as the Chief Programs Officer. Frank led the definition of the technical needs of the Cadasta Foundation platform and managed partnerships and program implementation, working with over 100 partners in more than 40 countries to strengthen their land and resource rights. Frank holds a B.A. in International Business from Virginia Tech, and a MSc in Land Management and Geospatial Science from the Technical University of Munich.

Nigel Edmead is the ***Technical Lead*** for PLACE and is a learning development specialist focusing on geospatial data and applications, with over 30 years' experience in the geo-spatial sector. He has worked on donor-funded programs in Southeast and Africa as well as for Esri (UK) and Thomson Reuters. Specializing in field of training and documentation he has applied GIS to improve urban and environmental planning in Indonesia and the Philippines, worked on introducing new computerized land administration systems in Nigeria, Uganda and Zambia and supported the launch of new geospatial products and solutions to the market in the UK. Through his professional experience Nigel has developed strong connections with the donor, NGO, academic and commercial communities. He is conversant with learning technology, learning management systems and eLearning authoring tools. Nigel is a Fellow of the Royal Geographical Society and graduated from the University of St Andrews with B.Sc. in Geography and an MSc. in Land Resource Management from Cranfield University.

Waddah Hago is a UAVs pro-user with multidisciplinary utilization of the technology for several industries. With focus on GIS and remote sensing, he pioneered in the utilization of drone technology in multiple fields such as; agriculture, water resources, topographical survey, morphological studies, and land use analysis. Waddah holds a civil engineering degree and an MSc in Water Resources Engineering which allowed him to gain multi-disciplinary skills working in several consultancy and engineering firms. In addition to Sudan, his professional experience included working in Ethiopia,

Nigeria, Rwanda, Uganda and other countries in east and west Africa. Waddah pioneered in introducing UAV technology in the agriculture industry in Sudan focusing on two key-areas which found to directly affect crop yields and boost farmers revenue. First: crop monitoring and Crop Spraying using agricultural drones. And second: land development; starting with topographical survey to irrigation and drainage design utilizing AI based optimization techniques.

Name	Role	Date of Arrival	Date of Departure
Peter Rabley	Data Collection and Management	Oct. 29, 2023 Nov. 12, 2023	Nov. 4, 2023 Nov. 18, 2023
Frank Pichel	FAA Pilot, Training & Data Collection	Aug. 15th, 2023 Oct. 29, 2023 Nov. 12, 2023	Aug. 30th, 2023 Nov. 4, 2023 Nov. 18, 2023
Nigel Edmead	Data Review and Processing	Throughout	
Waddah Hago	Data Processing and Use Case Dev.	Throughout	

Figure 25 - Activity Staffing

Annex B: Equipment List

DESCRIPTION
Event 38 E400 UAV (Serial Number 400216) inclusive of: • Sony A7R IV camera, • PPK GNSS integrated into UAV, • Emlid Reach RS2 Base Station, • Long range radio, • Radio antenna mast MFJ 1919EX, • Hard shell transport case, • Ping 1090, • Fast charger upgrade, • 8 2S 12Ah battery components spare batteries, • Standard Battery, • Anemometer, and • HP Tablet Computer. Autel Evo Nano+ • 2 spare batteries • Carrying Case and Spare Propellors • Controller Insta360 Pro 2 Streetview Camera • Spare battery • Extended range radio connection • Roof Mount system