Assessment of the Morphology of Selected References Sites on the Coast of Puerto Rico

November 9, 2021

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I. Summary

In this project we performed a geomorphological assessment of 58 beach units on the coast of Puerto Rico using a RTK GPS enabled Unoccupied Aerial Vehicle platform and Pix4d Mapper photogrammetry software. The total area of the coast that was covered in this project was 76.15 hectares for a total of 9.5 km of coastline covering the following municipalities: Aguada, Aguadilla, Añasco, Arecibo, Arroyo, Barceloneta, Cabo Rojo, Camuy, Carolina, Dorado, Fajardo, Guánica, Guayama, Hatillo, Humacao, Isabela, Lajas, Levittown, Loiza, Luquillo, Manatí, Maunabo, Mayaguez, Naguabo, Ponce, Rincón, San Juan, Vega Alta and Vega Baja.

The **ultimate goal** of this work was to contribute updated imagery and important data on the current state of the coastal environment of the main island of the Archipelago of Puerto Rico.

We calculated beach metrics and other important social, physical and biotic indices for each of the sites. These data are useful in the monitoring of erosion, accretion, shoreline changes and are very important for management, planning and restoration of the coast.

II. Introduction

Barreto et al. (2017) assessed the morphology of the beaches of Puerto Rico as the first stage of the creation of a "National Shoreline Changes" databank for the island using data from the 1970's and 2010. They integrated the use of remote sensing, geographic information systems (GIS) and traditional surveying techniques such as transects. The objectives of that study were to identify areas of accretion, erosion, and "no-changes" along the coast of the island. Beach sites with significant erosion problems were also identified. They also studied subaerial beach profiles and beach sediment composition in selected sites from 2015-2016. This work also validated research protocols that were used to assess coastal geomorphology at that time. It integrated the techniques mentioned above and offered recommendations that could be used in the design of coastal management plans and policy. The main goal of that work was to define a research baseline or databank that could be used to continue shoreline studies in the future.

The coast of Puerto Rico has suffered significant changes in the last four years, as a result of recent hurricanes and powerful winter storms, and there was a great need for an update on its current state.

1. Benefits of UAVs in coastal assessments.

Consumer-grade Unoccupied Aircraft Systems (UAVs), and particularly Small Unmanned Aircraft (SUA) weighing less than 20 kg, have become very common for the photogrammetric data acquisition across a wide range of applications. When compared to other more expensive remote sensing technology platforms, like the DJI Phantom series UAV that we used in this study, provide a trade-off between cost, sensor quality, functionality, and portability (Peppa et al., 2019).

The use of UAVs for low-altitude photography, combined with Pix4Dmapper's algorithms for Digital Surface Model (DSM) generation result in coastal topography datasets of very high resolution and accuracy. This allows for the quantification of even subtle changes in elevation after storm events, with clear changes observed in vegetation and sand movement at the centimeter scale across tens of hectares. The sub-five-centimeter accuracy that can be achieved in this study is comparable, and even greater, in precision to the long-term beach profile datasets usually collected using more traditional and time-consuming surveying techniques.

One of the major benefits of UAVs over satellite or plane platforms is the ability of users to define revisit times that are not hampered by cloud cover or cost-prohibitive mobilization. In this study, individual missions required a total flying time of approximately 15 minutes in addition to a small amount of preparation to design the survey plan and conduct the necessary risk assessments (< 1 hr). In addition, the data density translated into a detailed textured Triangular Irregular Network (TIN) model that allowed for an unlimited number of "virtual" oblique views from any user-defined angle or height to investigate coastal processes. Such oblique views offer advantages over the traditional aerial photogrammetric perspective (i.e. straight down) where key parameters such as the degree of notching are not apparent.

In this study we used this UAV platform to capture high resolution aerial imagery that was later analyzed using Pix4D photogrammetry software.

2. Goal

The main goal of this study was to asses the geomorphology of multiple beach units on the coast of Puerto Rico in order to generate baseline data for future geomorphological monitoring, ecological restoration planning and management of the coast.

It is our intention to provide clear data and present it in a way that is highly visual and easy to interpret in order for it to be easily understood by restoration practitioners and planners.

<u>Communicating these data in a clear and effective way is crucial for increasing the resilience of our coastal communities and primary infrastructure</u>.

3. Objectives

1. Capture and process aerial imagery of the 58 beach units on the coast of Puerto Rico using a RTK GPS enabled UAVs.

2. Determine beach morphology metrics for each of the sites using photogrammetry based on captured imagery.
3. Generate visualization products using the captured imagery (digital surface models, contour lines, beach profiles and orthomosaics).
4. Identify resilience hubs in the areas of the coast that will be studied.

III. Materials and Methods

1. Aerial imagery and geomorphic assessment of the coast –

In this study, we performed a beach geomorphological assessment of 58 beach units on the coast of Puerto Rico on 29 coastal municipalities of the main island of the Archipelago of Puerto Rico. The total area studied consisted of 76.15 hectares and a length of 9.5 km of coastline. The beach units selected are areas of open land that seem to have experienced erosion or accretion in the last four years and are suitable for resilience-building efforts. They were ranked by priority, given the level of exposure that nearby assets have to flood-related threats and the presence and abundance of fish and wildlife species within and surrounding the hub.

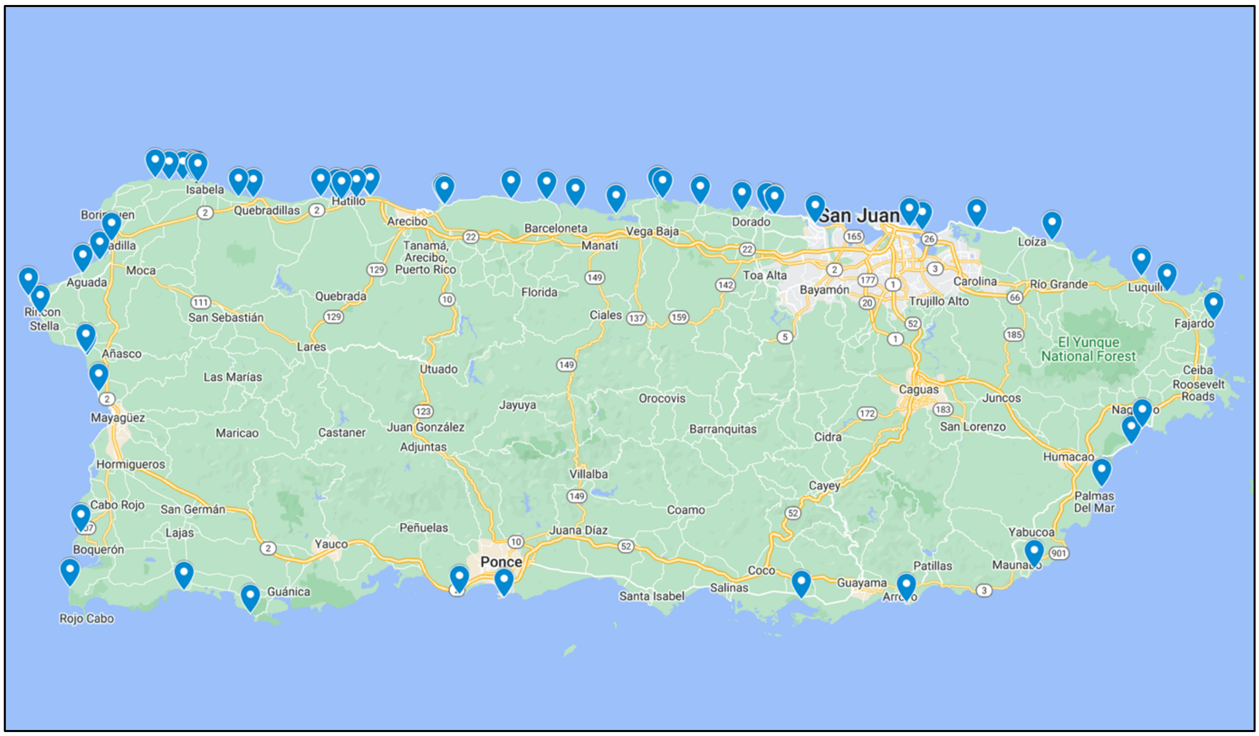

Figure 1. Map of the beach units that were studied in this assessment.

Municipality	Site	Geographical coordinates
Aguada	**Camino de La Playa**	18.39185° N 67.19468° W
Aguada	**Playa Espinal**	18.40774° N 67.17102° W
Aguadilla	**Aguadilla Pueblo**	18.43091° N 67.15505° W
Añasco	**Villa Pesquera**	18.28277° N 67.19043° W
Añasco	**Balneario Tres Hermanos**	18.28520° N 67.19138° W
Arecibo	**Playa Brava**	18.48826° N 66.60173° W
Arecibo	**Poza del Obispo**	18.48154° N 66.69676° W
Arecibo	**Jarealito**	18.48081° N 66.69343° W
Arroyo	**Playa Del Faro**	17.95745° N 66.05386° W
Barceloneta	**Playa Puerto Las Vacas**	18.48680° N 66.55245° W
Cabo Rojo	**Playa Combate**	17.97714° N 67.21237° W
Cabo Rojo	**Playa Buyé**	18.04885° N 67.19825° W
Camuy	**Finca Nolla**	18.48915° N 66.84393° W
Camuy	**Villa Pesquera**	18.49074° N 66.86609° W
Carolina	**Isla Verde**	18.44599° N 66.03173° W
Dorado	**El Unico**	18.46777° N 66.23705° W
Dorado	**El Caracol**	18.47042° N 66.24712° W
Dorado	**Balneario**	18.47294° N 66.28186° W
Dorado	**El Unico 25,**	18.46744° N 66.23711° W
Fajardo	**Desembocadura Del Rio Fajardo**	18.32859° N 65.62752° W
Guanica	**Playa La Jungla**	17.94325° N 66.96350° W
Guayama	**Bahia de Jobos**	17.96130° N 66.19961° W
Hatillo	**San Isidro Camping**	18.49232° N 66.79821° W
Hatillo	**Punta Maracayo**	18.49258° N 66.79696° W
Hatillo	**Costa Norte Center**	18.48730° N 66.83427° W
Hatillo	**Costa Azul**	18.49026° N 66.81619° W
Hatillo	**Costa Norte West**	18.48756° N 66.83645° W
Humacao	**Punta Santiago**	18.16540° N 65.74250° W
Humacao	**Secret Beach**	18.10943° N 65.78394° W
Isabela	**East Secret Spot**	18.51289° N 67.04376° W
Isabela	**Golondrinas**	18.51374° N 67.05706° W
Isabela	**Guajatacas**	18.48923° N 66.95862° W
Isabela	**Jobos**	18.51377° N 67.07555° W
Isabela	**Los Bravos**	18.51519° N 67.09486° W
Isabela	**Middles Center**	18.51241° N 67.03948° W
Isabela	**Pastillo**	18.49183° N 66.97933° W
Isabela	**Poza de Teodoro**	18.51096° N 67.03517° W
Isabela	**Pozo Brujo**	18.50803° N 67.01301° W
Isabela	**Shore Island**	18.50888° N 67.02865° W
Lajas	**La Parguera**	17.97368° N 67.05487° W
Levittown	**Playa Levittown**	18.45558° N 66.18028° W
Loiza	**Loiza Piñones Avioñes**	18.45078° N 65.95698° W
Loiza	**Parecelas Suárez**	18.43404° N 65.85250° W
Luquillo	**Corredor Ecologico Del Noreste**	18.36606° N 65.69261° W
Luquillo	**Balneario**	18.38678° N 65.72865° W
Manati	**Hacienda La Esperanza**	18.47753° N 66.51313° W
Manati	**Los Tubos de Manati**	18.46891° N 66.45594° W
Maunabo	**Limites Playa Punta Tuna**	18.00202° N 65.87646° W
Mayagüez	**Playa Sabaneta El Mani**	18.23395° N 67.17272° W
Naguabo	**Tropical Beach**	18.18766° N 65.72643° W
Ponce	**La Guancha**	17.96444° N 66.61166° W
Ponce	**Punta Las Cucharas**	17.96748° N 66.67344° W
Rincon	**Playa Lala**	18.33715° N 67.25354° W
Rincon	**Rincon Light House**	18.36135° N 67.27060° W
San Juan	**San Juan Santurce**	18.45249° N 66.04903° W
Vega Alta	**Balneario Cerro Gordo**	18.48072° N 66.34019° W
Vega Baja	**Playa de Puerto Nuevo**	18.49229° N 66.39808° W
Vega Baja	**Playa de Vega**	18.48825° N 66.39207° W

Table 1. Table of the municipalities, name of the beach unit and its geographical coordinates.

This assessment of the coast of Puerto Rico was based on aerial imagery that was captured using a **Phantom 4 RTK** and a **D-RTK 2 mobile station.** This setup provided us with real- time differential data to the Unoccupied Aerial Vehicle (UAV) making it a highly accurate surveying tool that can replace traditional on the ground surveying methods used in previous assessments of the morphology of the coast of the island.

This aircraft has a DJI Onboard D-RTK which provides data for centimeter-level positioning accuracy and has advanced anti-collision sensors and can record videos at 4K and capture 20-megapixel photos. It has a built-in DJI onboard D-RTK that provides high-precision data for centimeter level positioning when used with the DJI D-RTK 2 mobile station. It is also equipped with a 24nm wide angle camera, high precision, and anti-shake gimbal, 1-inch CMOS sensor, mechanical shutter to offer high quality aerial photo analyses. In addition to this aircraft, we will use an DJI Inspire 2 UAV with a high - resolution Zenmuse camera for capturing high-resolution images that will complement the imagery captured with the Phantom 4 RTK.

To analyze the imagery, we used the **Pix4D mapper** photogrammetry software. No traditional on-the-ground measurements were done. This software is designed to work with our Phantom 4 RTK and D-RTK 2 mobile station. With this setup we generated dense point clouds for the areas that were studied. Each point of the point cloud received the RGB value of the raster pixel that has the same location.

We created **orthomosaics** that are geometrically corrected such that the scale is uniform and are also color balanced to be visually pleasing. This allowed us to generate a digital representation of all objects in the mapped area and include natural features as well as elevated objects, like buildings.

We flew all the missions for this assessment at 30 m above the surface of the sand with 1 cm RTK horizontal and 1.5 cm RTK vertical positioning accuracy. This level of accuracy allowed us to monitor morphometric features of the beach from the imagery captured by the UAV without the need to perform the traditional, time consuming and labor intensive “on-the-ground” surveying or transects.

a. Site selection –

For this project we captured georeferenced imagery of 58 high priority beach units along the coast of the main island of the Archipelago of Puerto Rico using the equipment described above.

These areas were selected based on their levels of erosion and accretion in the last 4 years and their proximity to important primary infrastructure, areas of high population density, dunes, mangroves, and potential as resilience hubs.

b. Beach morphology –

The data captured was used to perform a geomorphological assessment of the selected sites. In order to do this we calculated a series of beach metrics and generated high resolution orthomosaic imagery and density surface models that serve as baseline data to monitor beach erosion, anthropogenic beach use patterns and changes in the location of the shoreline. Centroid coordinates for each of the beach units is included in the report.

For each beach unit we provide 3D and 2D maps, high resolution orthomosaic image and a density surface model (DSM). We also provide visual

A map with a visual representation of the metrics and data are provided in the results section for each beach unit studied. The following beach morphology metrics were calculated for the sites selected using Pix4D Mapper:

i. **Beach length** was measured as the total length of the shoreline on every beach unit studied.

ii. **Area of the beach** was defined in this work as the area of pebbly or sandy shore between high and low tide water marks. The area of the beach was measured using a polygon in the Pix4D software for every beach unit studied.

iii. **Beach volume** was calculated based on the measured beach width and height. Volume will take in consideration the whole alongshore extent of the beach. This was done using aerial orthomosaic imagery and the Pix4D mapper.

iv. **Beach elevation** was reported as the highest points in at least two elevation transects from the low water mark to the dune toe or vegetation (if there was no dune on the site). This can be determined from examining the elevation profiles included in the report.

iv. **Site elevation** was reported as the highest points in at least two elevation transects from the water to the land covering all the area that was captured by the UAV for that particular site. This can be determined from examining the elevation profiles included in the report.

v. **Shoreface extension** was reported as the area that gets wet during low and high tide, swash excursion and wave runup. This was measured using drone-captured imagery and Pix4D software.

vi. **Dune height** was be measured as the highest point in an elevation profile drawn from the fore dune to the mid dune or from the back dune to the mid dune (will depend on vegetation cover). This was reported for at least two transects for each beach unit.

v. **Dune width** was measured from at least two transects from the dune toe to the back dune using drone captured imagery.

vi. **Area and perimeter of dune** were measured using a polygon on aerial orthomosaic images of each site using the Pix4D mapper.

v. **Volume of dune** was calculated based on the measured dune width and height. Volume will take in consideration the whole alongshore extent of the dune, approximately 50 to 100 meters alongshore. This was done using aerial orthomosaic imagery and the Pix4D mapper.

vi. **Shoreline** was determined and marked visually on aerial imagery as the precise location of the boundary between land and water in each of the beach units.

vii. **Shoreline geolocation** was marked by plotting at least 2 georeferenced points along the shoreline for each beach unit. Geographic coordinates for these points is provided in the report.

viii. **Shoreline extension** was determined as the difference in shoreline position between high and low tides or the difference in the position of the shoreline in low and high tide.

ix. **Shoreline position** was measured from 15-min/mission drone-captured imagery to track the flow excursion. This was calculated as the distance between the toe of the dune (or start of vegetation if there was no dune) and the high tide mark. Shoreline position was measured in at least two transects on each beach unit. This was done using aerial orthomosaic imagery and the Pix4D mapper.

x. **Beach width** will be measured from the upper swash zone (low tide) to the dune toe. This was done using aerial orthomosaic imagery and the Pix4D mapper.

xi. **Dune width** will be measured from the foredune to the back dune on at least two transects. This was done using aerial orthomosaic imagery and the Pix4D mapper.

We also included information on the area of breaches in the primary dune line in areas where dunes are present.

In the reports for each beach unit we also include a Pix4D quality report that includes a quality check, calibration details, absolute camera position and orientation uncertainties, overlap, bundle block adjustment details, internal camera parameters, 2D keypoints table, 3D points from 2D keypoint matches, geolocation details (absolute geolocation variance and relative geolocation variance), initial processing details (system information, coordinate systems and processing options), point cloud densification details (processing options and results), DSM, orthomosaic and index details.

c. Identification of resilience hubs and other social, physical and biotic indices –

We identified the presence of **resilience hubs** along the coast by incorporating multiple indices to make informed decisions about the siting of coastal restoration and resilience projects. *Resilience hubs are areas of open space where ecological restoration projects may have the greatest potential to benefit both human community resilience and fish and wildlife*. To do this, we used the Coastal Resilience Evaluation and Siting tool (CREST) developed by the University of North Carolina - Ashville and the National Fish and Wildlife Foundation (NFWF).

The indices that we used to assess each of the beach units were: 1) community exposure, 2) community assets and threats, 3) fish and wildlife, 4) community asset inputs (population density, social vulnerability, critical facilities, critical infrastructure), 5) threat inputs (impermeable soils, soil erodibility, flood prone areas, sea level rise, storm surge, geological stressors, areas of low slope, tsunami) and 6) fish and wildlife inputs (marine and terrestrial).

We also analyzed each beach unit in terms of the level of flood-prone areas, population density, tsunami and threat index. The definitions for each of these indices are the following:

Flood-Prone Areas

Areas considered by FEMA to be in the 100- and 500-year flood zones, as well as the floodway. Frequency and occasionally flooded soil designations are used to identify areas outside of FEMA coverage. Highest values suggest areas directly in the floodway, whereas low values suggest occasionally flooded soils outside of the floodplain.

Population Density

A ranking of population density by census block groups based on the 2016 American Community Survey. Areas are ranked from low to high using the ratio of people per square kilometer.

Tsunami

Represents the potential inundation height above the ground from a tsunami in Puerto Rico. A higher rank indicates a higher inundation depth.

Threat index

Index of flood-related datasets, including storm surge scenarios and landscape characteristics that exacerbate flood potential. High values in the index represent those areas on the landscape where there are multiple high values of individual inputs.

d. Ecological restoration actions –

Some of the beach units that were studied in this work are the sites of active ecological restoration actions and we have included that information in each of the individual reports for each beach unit.

IV. Results –

The results of this study consist of imagery that includes a visual representation of the areas that were assessed and measured for each metric used. A series of elevation profiles are also included that serve as a visual and quantitative representation of the topography of every beach unit. We also include high resolution orthomosaic imagery, information on social, physical and biotic aspects of each site and information on ecological restoration projects that are active on every beach unit.

The results reported are organized in chronological order by municipality and beach unit (see table of contents).

All the data generated as part of this project were saved in a brand-new Synology 2 bay NAS DiskStation DS220+ with two Seagate IronWolf 16TB NAS Internal Hard Drive HDD – CMR 3.5 Inch SATA 6GB/S 7200 RPM 256MB Cache for Raid Network Attached Storage, with Rescue Service (ST16000VN001) that were purchased for this project and are also saved on Pix4D mapper cloud for future comparisons and monitoring of the beach units studied.

V. Discussion –

The results suggest that most of the beach units studied as part of this assessment are adjacent to highly populated areas and are unprotected from extreme weather and tsunamis as a result of degradation of natural dune systems and the reduction of stabilizing vegetation cover. We were able to capture imagery and calculate metrics for each sites studied. Some beach units did not have dune or beach therefore dune and beach metrics were not reported for those sites.

These data are very important as baseline data for monitoring the state of our coast especially after strong storm events and will allow us closely monitor changes in the shoreline as well as erosion and accretion.

VI. Future direction of work –

It is very important to do periodic updates to the photogrammetric data included in every one of the missions that we performed for each of the beach units studied. Pix4D gives us the option of repeating pre-programed missions of every of the beach units studied in order to compare metrics in different points in time for each beach unit.

This will allow us to monitor important changes on the morphology of the coast with a very cost-effective, fast and precise method. These data can be made available to planners, municipalities and ecological restoration practitioners.

We are currently discussing (with researchers from CARICOOS - Caribbean Coastal Observing System) the possibility of creating a web-based platform to make the data available to users.

It would also be useful to include more beach units on the main island of the Archipelago of Puerto Rico to this data base and to include Vieques, Culebra and Isla de Mona on future studies in order to have a complete data set for the whole archipelago.

It is also very important to add information on percent vegetation cover and identification of local flora and fauna for every beach unit. Data of anthropogenic-use of each beach unit should also be added to the data included in this report. We could not include that information as part of this work due to time-limitations.

VII. Cautionary statement –

The data included in this study were not collected by a licensed and state registered surveyor and are only for reference and scientific purposes. The data should not be used for construction or design purposes.

VIII. References –

Peppa M.V., J. Hall and J.P. Mills. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2/W13, 2019 ISPRS, Geospatial Week 2019, 10-14 June 2019, Enschede. The Netherlands.

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Appendix A.

Specifications of UAV equipment used in this study.

Aircraft

Takeoff Weight	1391 g
Diagonal Distance	350 mm
Max Service Ceiling Above Sea Level	19685 ft (6000 m)
Max Ascent Speed	6 m/s (automatic flight); 5 m/s (manual control)
Max Descent Speed	3 m/s
Max Speed	31 mph (50 kph)(P-mode) 36 mph (58 kph)(A-mode)
Max Flight Time	Approx. 30 minutes
Operating Temperature Range	32° to 104° F (0° to 40℃)
Operating Frequency	2.400 GHz to 2.483 GHz (Europe, Japan, Korea) 5.725 GHz to 5.850 GHz (United States, China)
Transmission Power (EIRP)	2.4 GHz CE (Europe) / MIC (Japan) / KCC (Korea)：< 20 dBm 5.8 GHz SRRC（China）/ FCC（United States）/NCC(Taiwan,China)：< 26 dBm
Hover Accuracy Range	RTK enabled and functioning properly： Vertical：±0.1 m；Horizontal：±0.1 m RTK disabled Vertical：±0.1 m（with vision positioning）； ±0.5 m（with GNSS positioning） Horizontal：±0.3 m（with vision positioning）； ±1.5 m（with GNSS positioning）
Image Position Offset	The position of the camera center is relative to the phase center of the onboard D-RTK antenna under the aircraft body's axis:(36, 0, and 192 mm) already applied to the image coordinates in Exif data. The positive x, y, and z axes of the aircraft body point to the forward, rightward, and downward of the aircraft, respectively.

GNSS

Single-Frequency, High-Sensitivity GNSS Module	GPS+BeiDou+Galileo（Asia)； GPS+GLONASS+Galileo（other regions)
Multi-Frequency Multi-System High-Precision RTK GNSS	Frequency Used： GPS：L1/L2； GLONASS：L1/L2； BeiDou：B1/B2； Galileo：E1/E5a First-Fixed Time：< 50 s Positioning Accuracy: Vertical 1.5 cm + 1 ppm（RMS）； Horizontal 1 cm + 1 ppm（RMS) 1 ppm means the error has a 1mm increase for every 1 km of movement from the aircraft.

Gimbal

Stabilization	3-axis (tilt, roll, yaw)
Pitch	-90° to +30°
Max Controllable Angular Speed	90°/s
Angular Vibration Range	±0.02°

Infrared

Obstacle Sensing Range	0.6-23 ft(0.2 - 7 m)
FOV	70°(Horizontal) ±10°(Vertical)
Measuring Frequency	10 Hz
Operating Environment	Surface with diffuse reflection material, and reflectivity > 8% (such as wall,trees, humans, etc.)

Mapping Functions

Mapping Accuracy **	Mapping accuracy meets the requirements of the ASPRS Accuracy Standards for Digital Orthophotos Class III ** The actual accuracy depends on surrounding lighting and patterns, aircraft altitude, mapping software used, and other factors when shooting.
Ground Sample Distance(GSD)	(H/36.5) cm/pixel, H means the aircraft altitude relative to shooting scene (unit: m)
Data Acquisition Efficiency	Max operating area of approx. 1 km² for a single flight(at an altitude of 182 m, i.e., GSD is approx. 5 cm/pixel, meeting the requirements of the ASPRS Accuracy Standards for Digital Orthophotos Class III

Vision System

Velocity Range	≤31 mph(50 kph) at 6.6 ft(2 m) above ground with adequate lighting
Altitude Range	0-33 ft(0 - 10 m)
Operating Range	0-33 ft(0 - 10 m)
Obstacle Sensing Range	2-98 ft(0.7-30 m)
FOV	Forward/Rear: 60° (horizontal), ±27° (vertical) Downward: 70° (front and rear), 50° (left and right)
Measuring Frequency	Forward/Rear：10 Hz; Downward：20 Hz
Operating Environment	Surfaces with clear patterns and adequate lighting(> 15 lux)

Camera

Remote Controller

Operating Frequency	2.400 GHz-2.483 GHz(Europe,Japan,Korea) 5.725 GHz-5.850 GHz(United States, China)
Transmission Power (EIRP)	2.4 GHz CE / MIC / KCC：< 20 dBm 5.8 GHz SRRC / FCC：< 26 dBm
Max Transmission Distance	FCC：4.3 mi(7 km)； SRRC / CE / MIC / KCC：3.1 mi(5 km) (Unobstrcted, free of interference)
Power Consumption	16 W(typical value)
Display	5.5 inch screen, 1920×1080, 1000 cd/m², Android System Memory 4G RAM+16G ROM
Operating Temperature Range	32° to 104° F (0° to 40℃)

Intelligent Flight Battery Charging Hub(PHANTOM 4 CHARING HUB)

Voltage	17.5 V
Operating Temperature Range	41° to 104℉(5° to 40℃)
Capacity	4920 mAh
Voltage	7.6 V
Battery Type	LiPo 2S
Energy	37.39 Wh
Operating Temperature	-4° to 104℉(-20° to 40℃)

Camera

Sensor	1" CMOS; Effective pixels: 20 M
Lens	FOV 84°；8.8 mm / 24 mm(35 mm format equivalent:24 mm)； f/2.8 - f/11, auto focus at 1 m - ∞
ISO Range	Video:100-3200(Auto) 100-6400(Manual)； Photo:100-3200(Auto) 100-12800(Manual)
Mechanical Shutter Speed	8 - 1/2000 s
Electronic Shutter Speed	8 - 1/8000 s
Max Image Size	4864×3648 (4:3) ； 5472×3648 (3:2)
Video Recording Modes	H.264，4K：3840×2160 30p
Photo Format	JPEG
Video Format	MOV
Supported File Systems	FAT32 (≤ 32 GB) ； exFAT (> 32 GB)
Supported SD Cards	MicroSD, Max Capacity: 128 GB. Class 10 or UHS-1 rating required Write speed≥15 MB/s
Operating Temperature Range	32° to 104° F (0° to 40℃)

Operating Temperature -4° to 104℉(-20° to 40℃)

AC Power Adapter(PH4C160)

Voltage	17.4 V
Rated Power	160 W

Intelligent Flight Battery(PH4-5870mAh-15.2V)

Capacity	5870 mAh
Voltage	15.2 V
Battery Type	LiPo 4S
Energy	89.2 Wh
Net Weight	468 g
Charging Temperature Range	14° to 104℉(-10° to 40℃)
Max charging Power	160 W