Trimble UX5 Aerial Imaging Solution

Overview

What is UAS?

- An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot on board. Its flight is controlled either autonomously by computers in the vehicle, or under the remote control of a pilot on the ground or in another vehicle.

- The term unmanned aircraft system (UAS) emphasizes the importance of other elements beyond an aircraft itself. A typical UAS consists of the:
  - unmanned aircraft (UA)
  - control system, such as Ground Control Station (GCS)
  - control link, a specialized datalink
  - other related support equipment.

Credit: Wikipedia.org

Why UAS Aerial Imaging?

- New emerging technology well suited for geospatial professionals
- Complementary to traditional surveying technologies and to traditional photogrammetry
- Many UASs, but not many targeting the geospatial industries

History of Geospatial UAS Aerial Imaging Solutions in Trimble

2013
- Trimble Business Center Photogrammetry Module released
- Trimble UX5 Aerial Imaging Solution released

2012
- Gatewing acquired by Trimble

2011
- First desktop image processing software for UAS surveying from Gatewing

2010
- Gatewing X100 released

2009
- First Gatewing prototype for surveying

2008
- Gatewing founded
- First idea for a surveying UAS within Gatewing

2007
- Inpho GmbH acquired by Trimble

Definitions

- AGL - above ground level
- CAA - Civil Aviation Authority
- COA - Certificate of Authorization
- FAA - Federal Aviation Authority
- GCP - ground control point
- GCS - ground control station
- GSD - ground sample distance
- UA - unmanned aircraft
- UAS - unmanned aircraft system
- UAV - unmanned aerial vehicle

Applications & Benefits

UAS Aerial Imaging Solutions

Benefits of Aerial Imaging Solutions

- **Economic solution – enables aerial mapping technology, once reserved for the largest surveying & engineering firms, to be used by the masses**
- **Safety – enables surveying of rugged, hazardous, hard-to-reach or unhealthy areas without risking injury (or worse) to them or individuals in the area**
- **Efficient process – ability to collect and process data faster than often achievable with terrestrial-based survey technology**
- **Rapid workflow – system is designed to quickly plan a flight and collect data, allowing rapid response to your customer's needs (traditional photogrammetry processes**
- **Versatile – a technology that can be used to serve numerous professional markets and applications**

Target Markets

- Engineering & Surveying
- Mining
- Civil & Heavy Earthworks Construction
- Oil & Gas
- Environmental & Landfill
- Public Agencies
- Agriculture & Forestry

Target Applications

	Boundary Surveys	Topographic Surveys	Site Planning	Route Planning	Progress Monitoring	As-Builts	Resource Mapping	Volume Calculation	Disaster Analysis	Vegetation Health
Engineering & Surveying	✓	✓			✓			✓		
Mining	✓	✓	✓	✓	✓	✓		✓		
Civil & Heavy Earthworks Construction	✓	✓	✓		✓					
Oil & Gas	✓	✓	✓	✓	✓	✓	✓	✓		
Environmental & Landfill	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Public Agencies	✓	✓	✓	✓	✓		✓		✓	✓
Agriculture & Forestry	✓		✓		✓		✓		✓	✓

UAS Aerial Imaging Benefits

	Problem	UAS Feature	Benefit
Boundary Surveys	• Large area to be surveyed	• Up to 7.5 km^2 coverage per flight	• Reduced time & cost to collect data
	• Numerous interests to be mapped (roads, structures, fences, etc.)	• Scaled, geo-referenced orthophotos created	• Accurate and current representation of the land use and features
Topographic Surveys	• Slow data collection	• Up to 7.5 km^2 coverage per flight	• Reduced time & cost to collect data
	• Typically low or inconsistent density of measurements	• Fixed ground sampling of measurements down to 2.4 cm	• More accurate representation of topography
	• Numerous interests to be mapped (roads, structures, fences, etc.)	• Scaled, geo-referenced orthophotos and surface models created	• Accurate and current representation of the terrain, land use and features

Topographic Survey Example

Switzerland
510 Images
400 m Flight Height
11 cm GSD
3.12 km^2

UAS Aerial Imaging Benefits

	Problem	UAS Feature	Benefit
Site Planning	• Numerous interests to be mapped (access roads, drill rig pads, structures, drainage areas, etc.)	• Scaled, geo-referenced orthophotos and surface models created	• Reduced time & cost to collect data and generate feature maps
	• Availability of accurately geo-referenced imagery	• Scaled, geo-referenced orthophotos created	• Accurate and current representation of the land use and features
Route Planning	• Large area to be surveyed	• Up to 7.5 km^2 coverage per flight	• Reduced time & cost to collect data
	• Numerous interests to be mapped (roads, structures, fences, etc.)	• Scaled, geo-referenced orthophotos created	• Accurate and current representation of the land use and features
	• Availability of accurately geo-referenced imagery	• Scaled, geo-referenced orthophotos created	• Accurate and current representation of the land use and features

Route Planning Example

Belgium
462 Images
150 m Flight Height
5 cm GSD
0.8 km^2

UAS Aerial Imaging Benefits

	Problem	UAS Feature	Benefit
Progress Monitoring	• Lack of current overview view of site	• Scaled, geo-referenced orthophotos created	• Easy to visualized and understand progress by all stakeholders
	• Possibility of leaving the site with incomplete measurements	• “Over-flight” ensures the entire site is measured	• Eliminate the time & costs associated wit having to send a crew out to fill-in missing measurement
	• Traditional methods often interrupt site operations	• Remote sensing measurements keep operators away from job activity	• Delays in site productivity can lead to unplanned costs and schedule delays

Progress Monitoring Example

United Kingdom
150 m Flight Height
5.7 cm GSD
2.4 km^2

UAS Aerial Imaging Benefits

	Problem	UAS Feature	Benefit
Volume Calculation	• Large area to be surveyed	• Up to 7.5 km^2 coverage per flight	• Reduced time & cost to collect data
	• Typically low or inconsistent density of measurements	• Fixed ground sampling of measurements down to 2.4 cm	• More accurate representation of topography
	• Slow data collection	• Up to 7.5 km^2 coverage per flight	• Reduced time & cost to collect data
	• Individuals often work in hazardous conditions (terrain, vehicles, equipment, etc.)	• Remote sensing measurements keep operators in safe locations	• Reduce the potential for unforeseen costs and delays
	• Traditional methods often interrupt site operations	• Remote sensing measurements keep operators away from job activity	• Delays in site productivity can lead to unplanned costs and schedule delays

Volume Calculation Example

Open Pit Mine
641 Images
150 m Flight Height
5.6 cm GSD
0.12 km^2

UAS Aerial Imaging Benefits

	Problem	UAS Feature	Benefit
Resource Mapping	• Large area to be surveyed	• Up to 7.5 km^2 coverage per flight	• Reduced time & cost to collect data
	• Numerous interests to be mapped (roads, structures, fences, etc.)	• Scaled, geo-referenced orthophotos created	• Accurate and current representation of the land use and features
	• Lack of overview view of area of interest	• Scaled, geo-referenced orthophotos created	• Easy to visualized and understand land utilization
As-Builts	• Numerous interests to be mapped (roads, structures, fences, etc.)	• Scaled, geo-referenced orthophotos created	• Accurate and current representation of the land use and features
	• Typically low or inconsistent density of measurements	• Fixed ground sampling of measurements down to 2.4 cm	• More accurate representation of topography
	• Slow data collection	• Up to 7.5 km^2 coverage per flight	• Reduced time & cost to collect data

Resource Mapping Example

Namibia
288 Images
100 m Flight Height
5 cm GSD
1.5 km^2

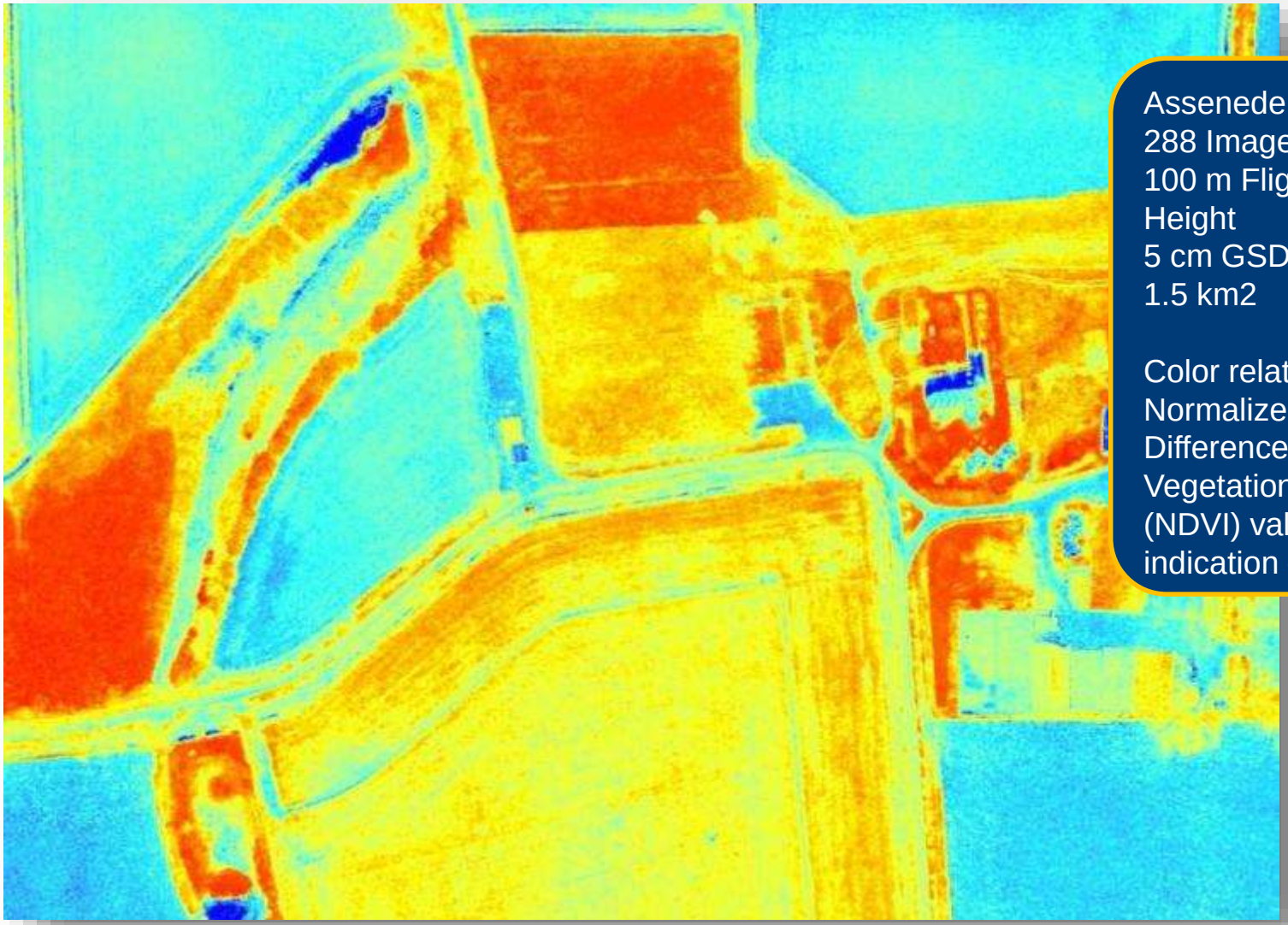
UAS Aerial Imaging Benefits

	Problem	UAS Feature	Benefit
Disaster Analysis	• Large area to be surveyed	• Up to 7.5 km^2 coverage per flight	• Reduced time & cost to collect data
	• Numerous interests to be mapped (roads, structures, fences, etc.)	• Scaled, geo-referenced orthophotos created	• Accurate and current representation of the land use and features
	• Lack of current overview view of site	• Scaled, geo-referenced orthophotos created	• Easy to visualized and understand progress by all stakeholders
	• Individuals often work in hazardous conditions (terrain, downed powerlines, standing water, etc.)	• Remote sensing measurements keep operators in safe locations	• Reduce the potential for unforeseen costs and delays

UAS Aerial Imaging Benefits

	Problem	UAS Feature	Benefit
Vegetation Health	• Large area to be surveyed	• Up to 7.5 km^2 coverage per flight	• Reduced time & cost to collect data
	• Traditional survey technologies to not offer the ability to determine health of vegetation	• NIR camera provides visual indication of different types and health of vegetation	• Clear understanding of health of vegetation to make the appropriate decisions for operations

Vegetation Health Example



Assenede
288 Images
100 m Flight Height
5 cm GSD
1.5 km2

Color relates to Normalized Difference Vegetation Index (NDVI) value - indication of health

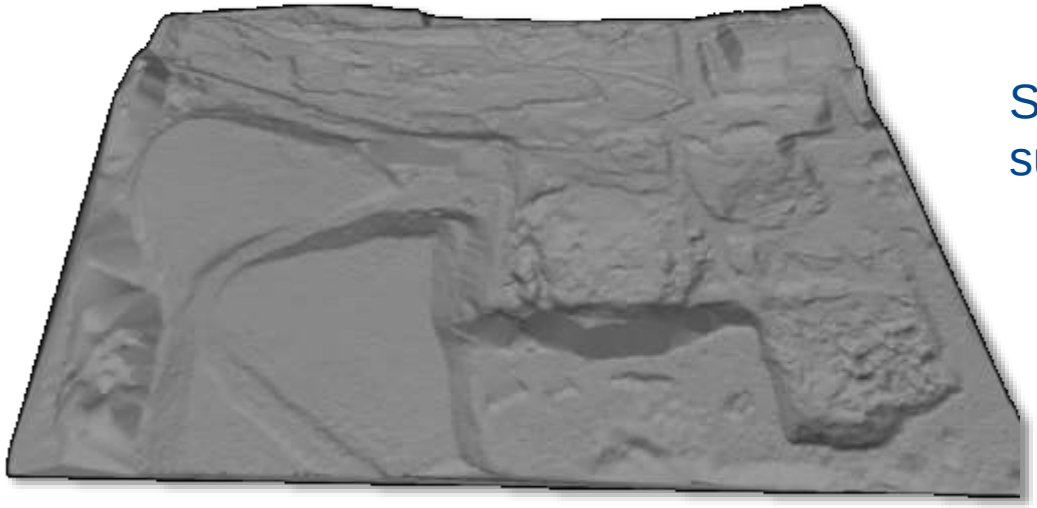
Topographic Survey Example

Aerial Imaging vs. Traditional Surveying

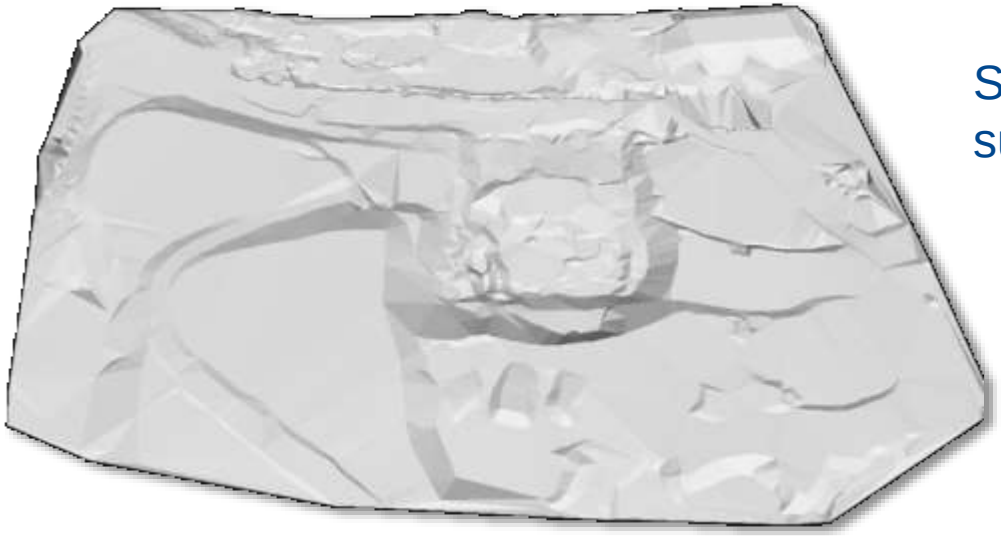
Topographic Survey Example

	UAS	GNSS	Comments
Area	1.5 km^2	1.5 km^2	
Ground control setup & measurement	1 ¼ hr	---	Ground control not required for all applications
Setup time	15 min	15 min (per day)	
Survey time	45 min	30 ½ hr (4 days)	
Tear-down time	15 min	15 min (per day)	
Data processing time	4 hrs (2.80 GHz Intel Core i7, 16 GB RAM)	---	Data can be processed overnight
Total time	6 hr 30 min	32 hr 30 min	5x faster than GNSS
Measurement sampling	3.8 cm (at 120 m flight altitude)	15 m	Minimum sampling size is 2.4 cm
Horizontal accuracy	2 cm	1 cm	
Vertical accuracy	4 cm	2 cm	

Topographic Survey Example



Surface model generated from UAS survey (300,000 measurements)



Surface model generated from GNSS survey (100,000 measurements)

Flight Calculator Table

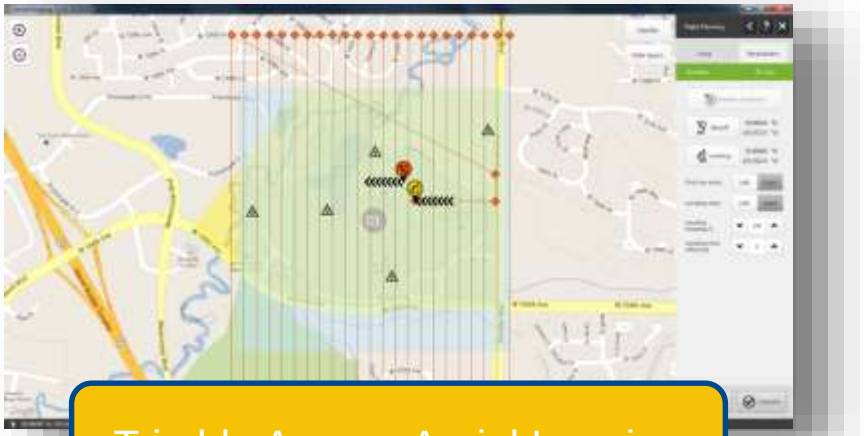
Height (m)	GSD (cm)	Flight Lines	Coverage / Flight (km^2) 70%	80%	90%	Coverage / Day (km^2) 70%	80%	90%
75	2.4	40	1.14	0.76	0.38	6.82	4.55	2.27
100	3.2	30	1.80	1.20	0.60	10.79	7.19	3.60
120	3.8	25	2.32	1.55	0.78	18.72	12.48	6.24
150	4.8	20	3.12	2.08	1.04	18.72	12.48	6.24
200	6.4	15	4.44	2.96	1.48	26.65	17.77	8.88
250	8	12	5.76	3.84	1.92	34.58	23.05	11.53
300	9.6	10	7.09	4.72	2.36	42.51	28.34	14.17
400	12.8	7.5	9.73	6.49	3.24	58.37	38.92	19.46
500	16	6	12.37	8.25	4.12	74.24	49.49	24.75
750	24	4	18.98	12.65	6.33	113.89	75.93	37.96

** 80% overlap is the default in Trimble Access Aerial Imaging Module*

System Overview

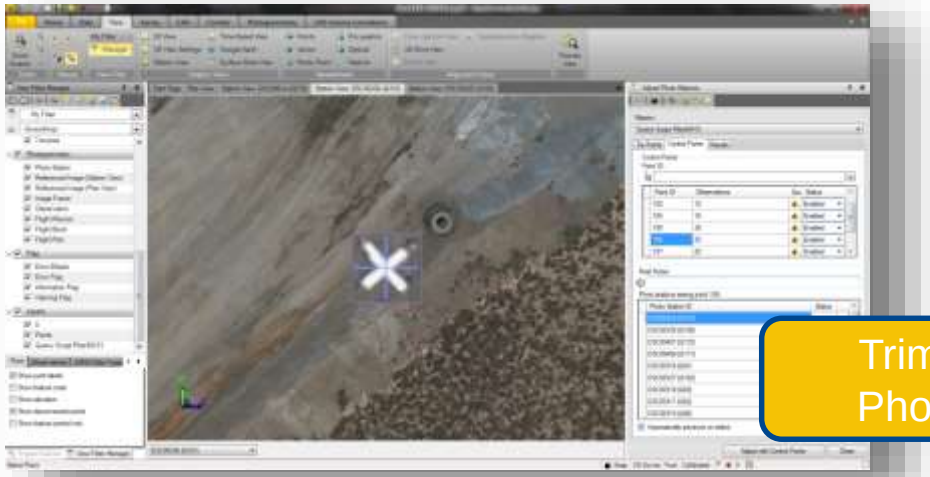
Trimble UX5 Aerial Imaging Solution

Trimble UX5 Aerial Imaging Solution



Trimble Access Aerial Imaging

Trimble UX5 Aerial Imaging Rover & Trimble Tablet

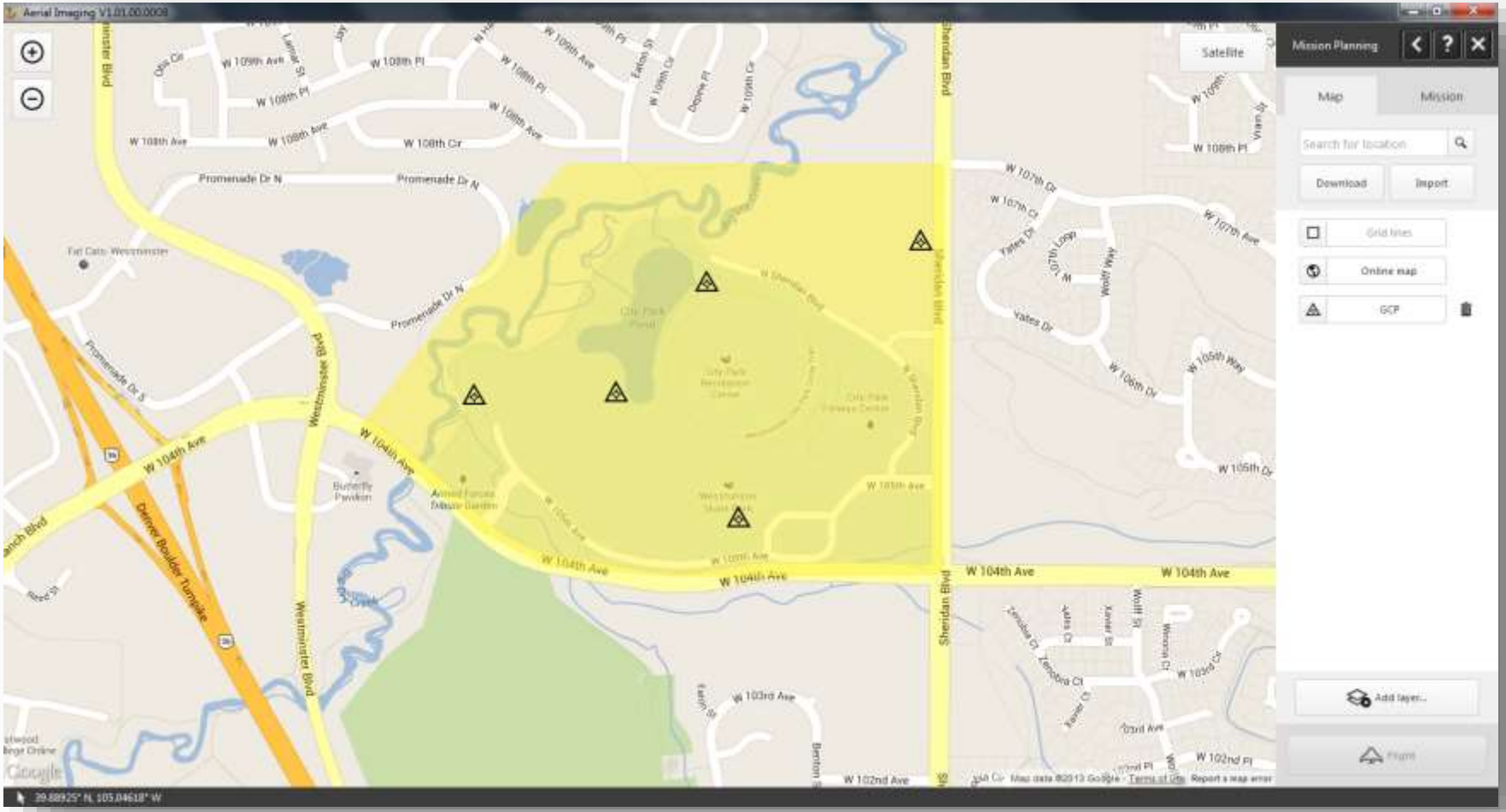


Trimble Business Center Photogrammetry Module

Trimble Access Aerial Imaging Application

- Mission planning
  - Create background map and add optional layers
  - Define mission area and avoidance zones
  - Define GSD, height and overlap
  - In the office or in the field
- Flight planning
  - Calculate and plan multiple flights for a mission
  - Define wind direction, takeoff location, and landing location
  - In the field
- Flight monitoring
  - Monitor the flight
  - Trigger emergency actions when needed
  - In the field
- Analysis
  - Check completeness of data
  - In the office or in the field

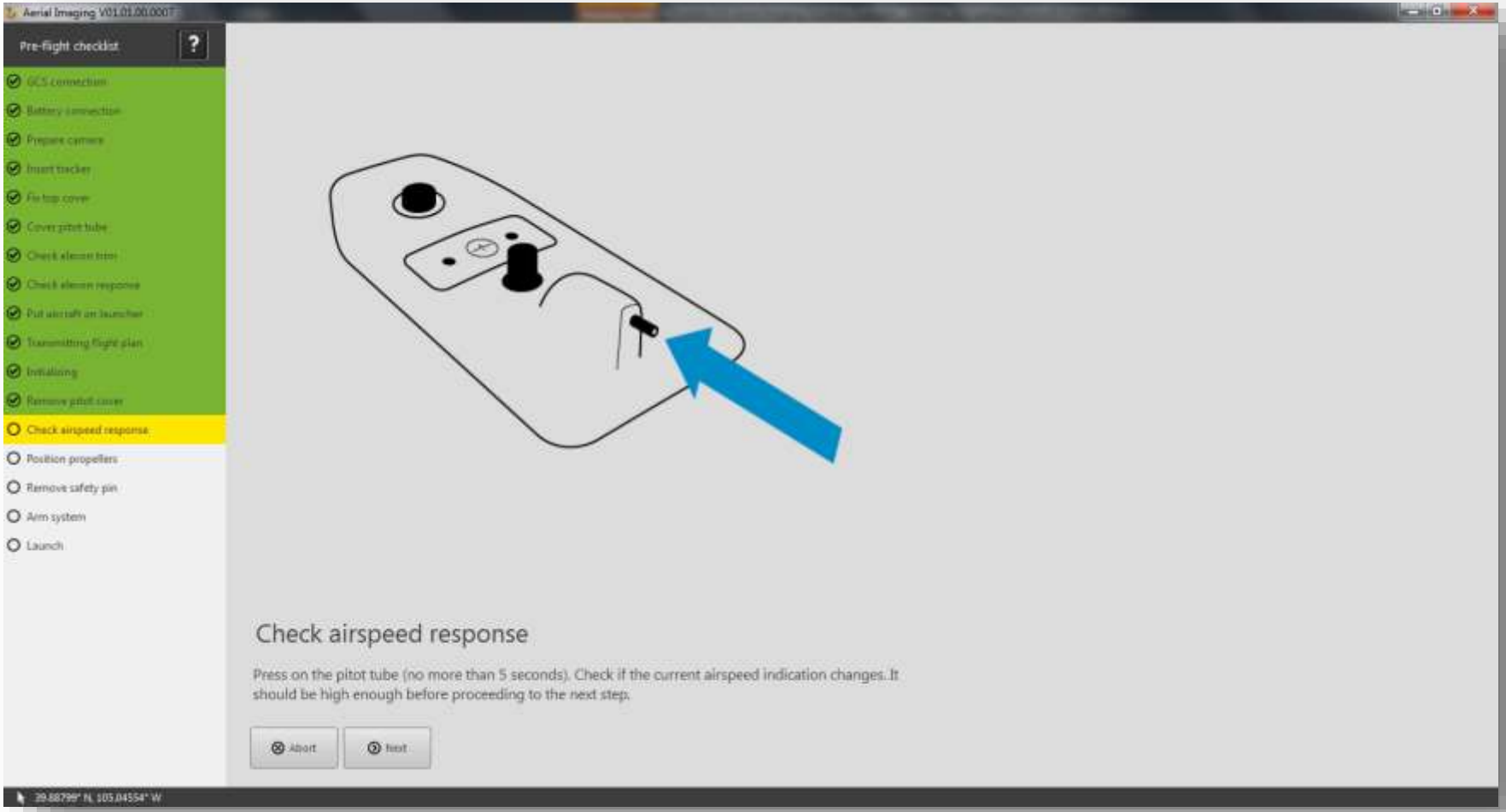
Defining the Project Area



Defining the Flight

Flight Simulation

Flight Checklist



Flight Monitoring

- Flight is controlled by the autopilot system
  - Based on the mission & flight plan from Trimble Access Aerial Imaging application
- Flight parameters & performance displayed
  - Virtual horizon
  - GPS lock
  - Communication link strength
  - Battery level
  - Aircraft height & speed (actual & planned)
  - Aircraft location & flight lines (on map)
- Manual evasive maneuvers available (if necessary)
- Landing confirmation

Flight Monitoring

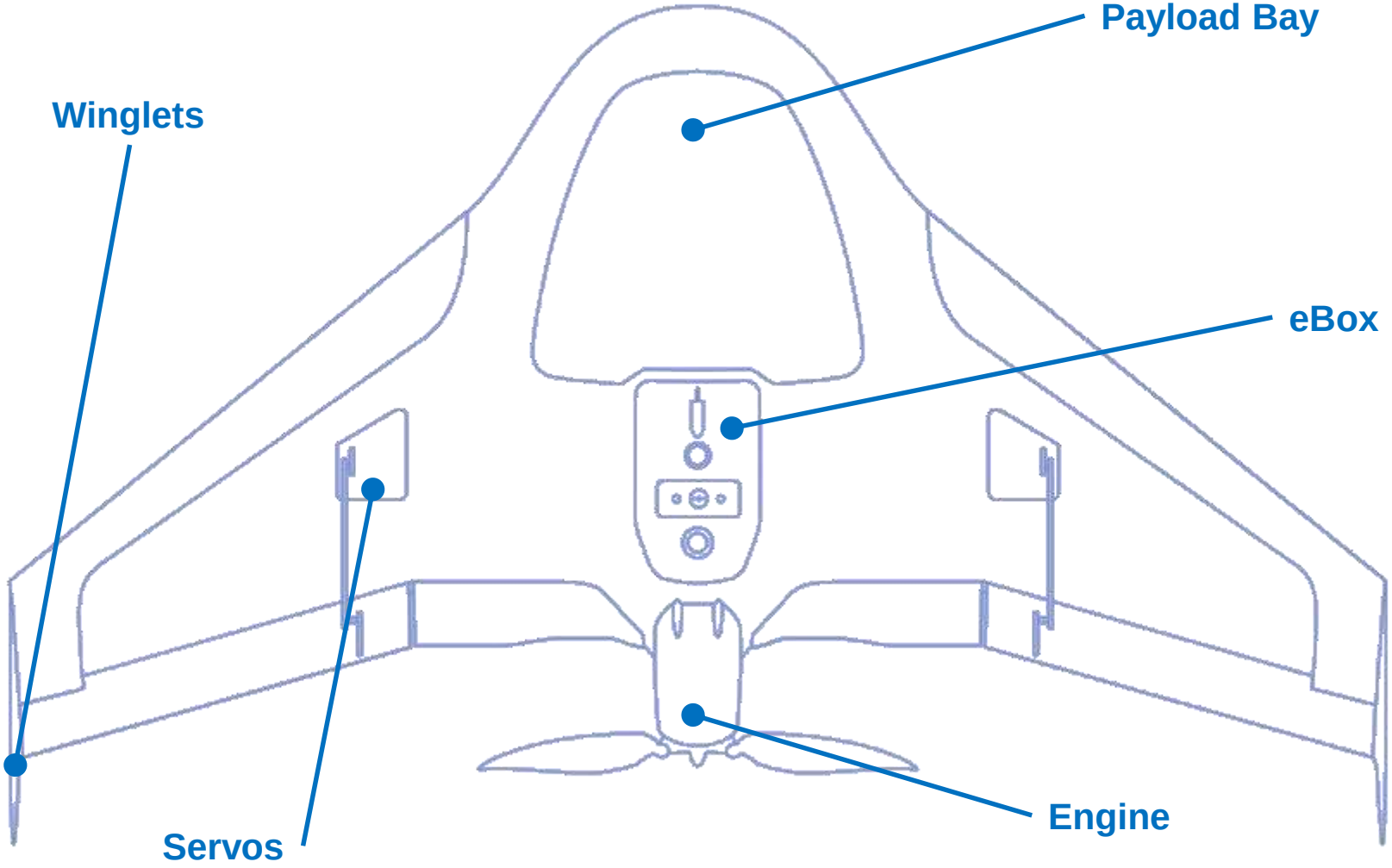
Safety Maneuvers

- **Land**
  - Instruct aircraft to follow land circuit before flight path is finished
- **Fly To**
  - Fly to a user-specified location on map and circle
- **Hold**
  - Circle at current position
- **Here**
  - Fly to location of pilot/GCS and circle
- **Right**
  - Fly 300 m to the right of current heading and circle
- **FTS (Flight Termination System)**
  - Abort flight immediately and spiral downward
- **Up (not shown)**
  - Instruct UA to increase altitude by 10 m
  - Available once a flight maneuver is enacted
- **Down (not shown)**
  - Instruct UA to decrease altitude by 10 m
  - Available once a flight maneuver is enacted

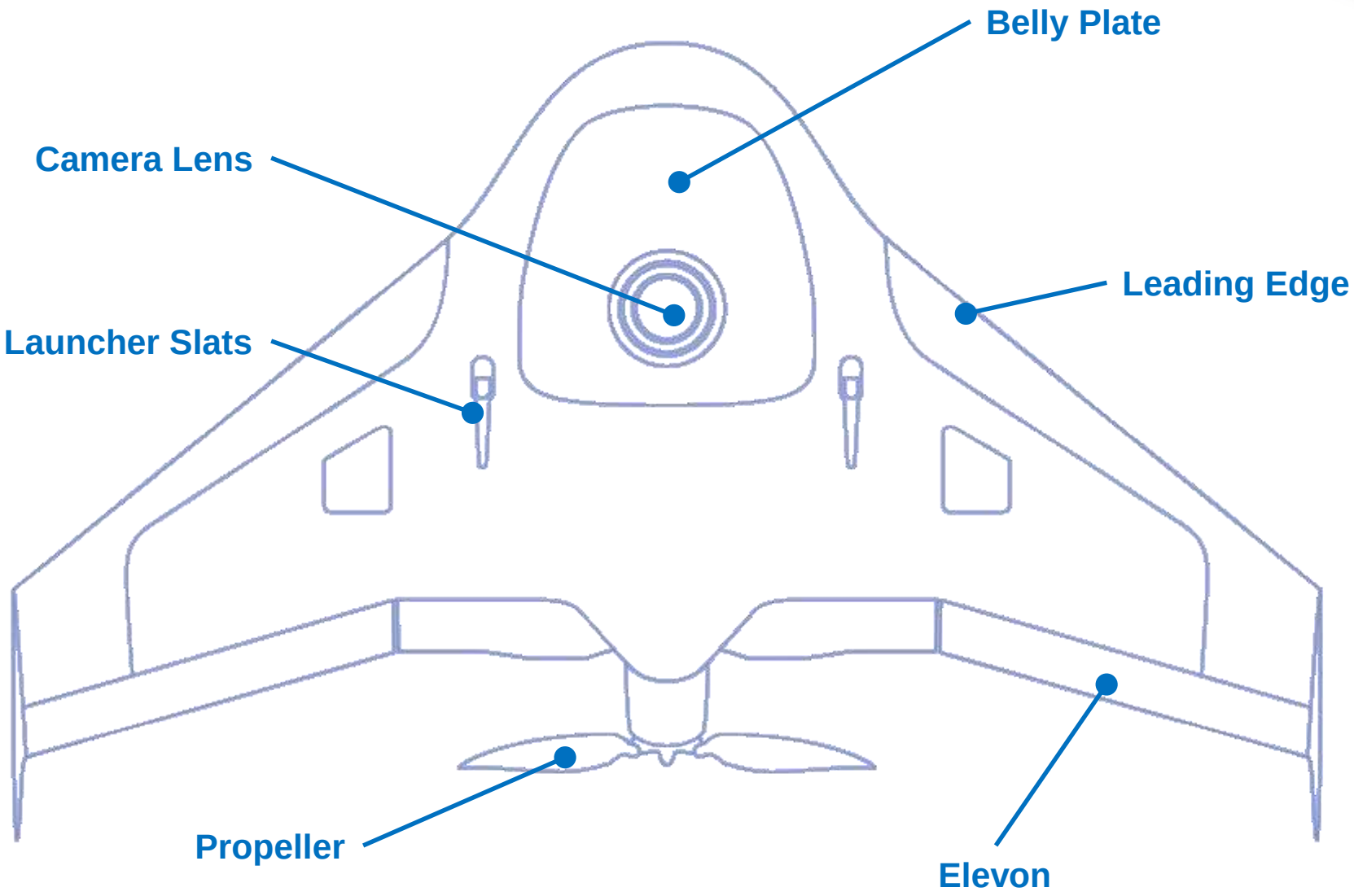
Trimble UX5 Aerial Imaging Rover

- **Airframe**
  - Internal carbon frame
  - Expanded polypropylene foam body
  - Engine & propeller
  - Servo-controlled elevons
- **Payload Bay**
  - Battery
  - Camera
  - Tracking beacon
- **eBox**
  - GPS & orientation sensors
  - 2.4 GHz radio
  - Autopilot

UX5 Top



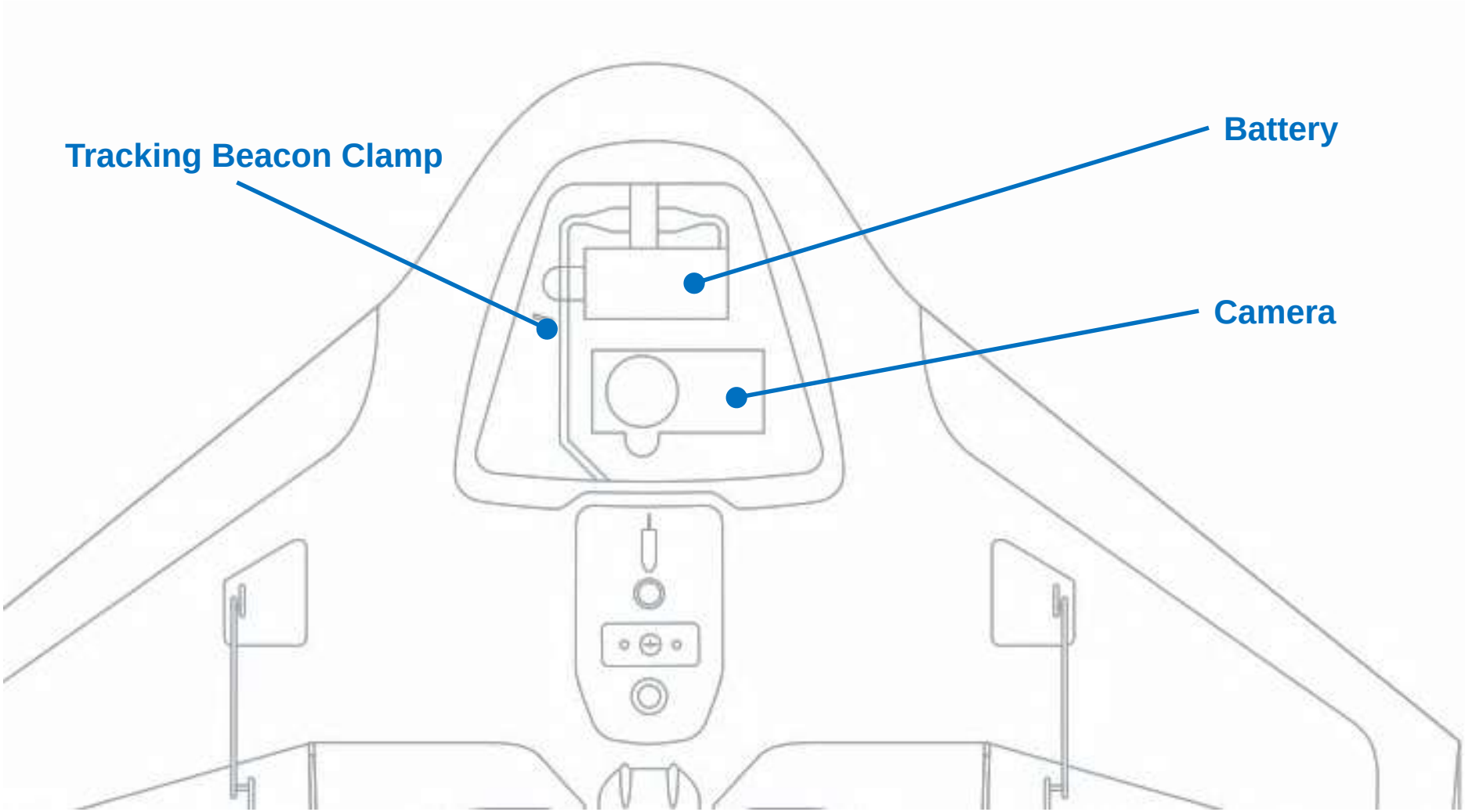
UX5 Belly


Belly Plate
Camera Lens
Leading Edge
Launcher Slats
Propeller
Elevon

UX5 Airframe

- Internal carbon frame
- Expanded polypropylene foam
- Impact resistant plastics
  - Motor assembly
  - eBox
  - Servos
- Composite fiber parts
  - Elevons
  - Vertical winglets
  - Belly plate

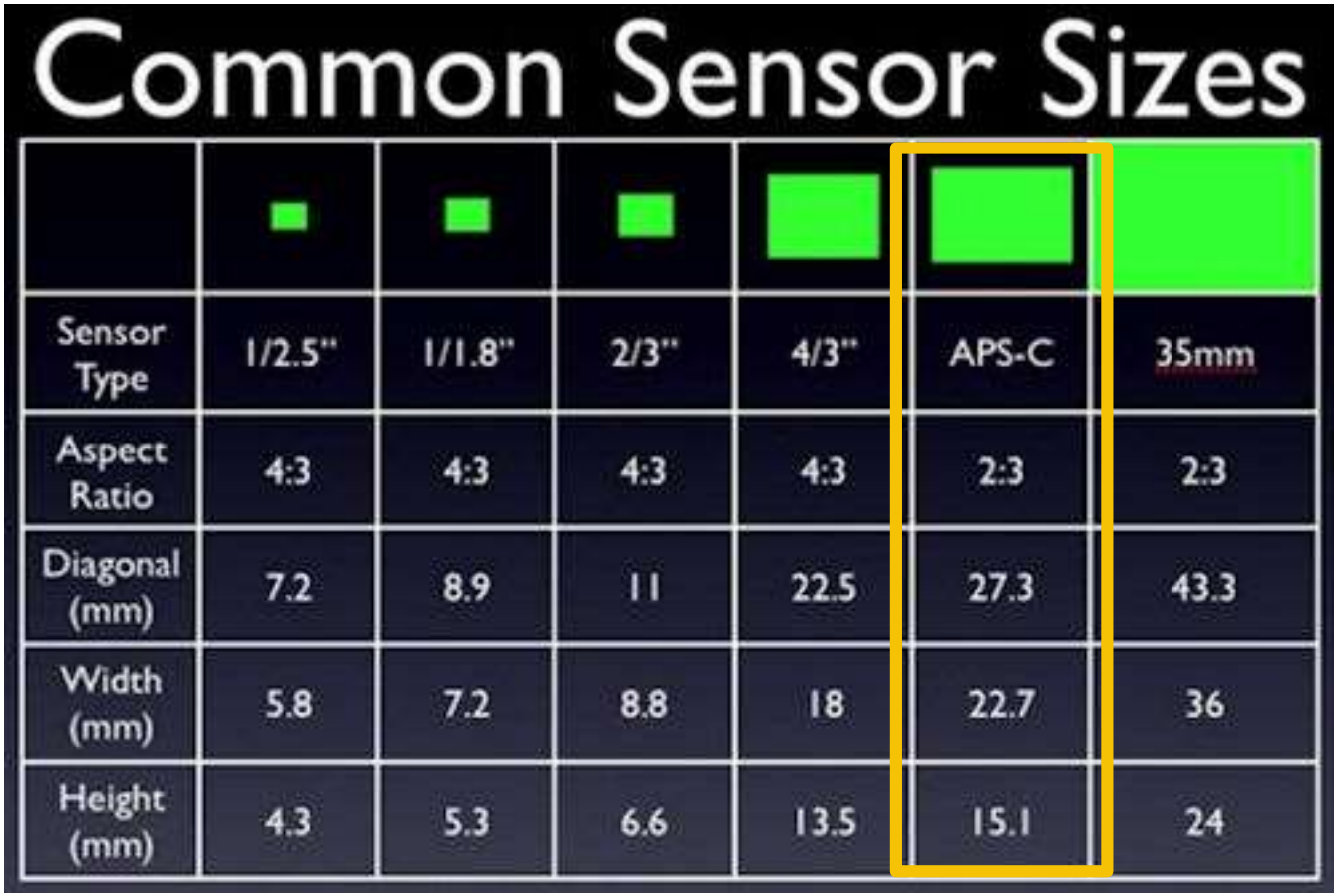
UX5 Payload Bay



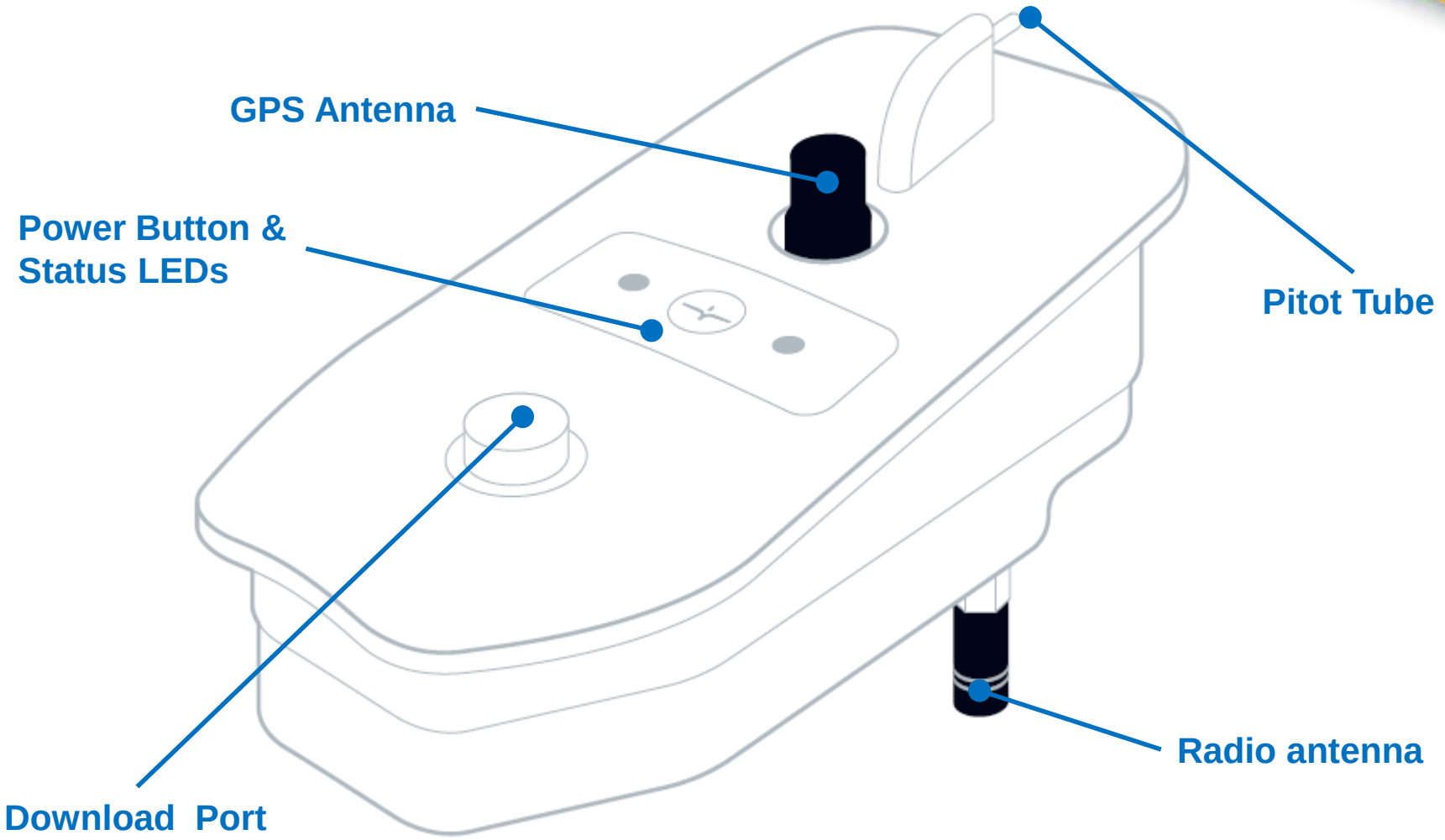
UX5 Camera

- Sony NEX-5T digital SLR
- 16.1 MP (APS-C) sensor
- Custom mounted Voigtlander fixed-optics lens
  - Increases the stability of the camera internal geometry
- Image size 4912 x 3261 px
  - (156.67 x 104.67 m @ 100 m flight height)
- RGB & NIR (Near Infra-Red) versions

UX5 Camera Sensor Size



UX5 eBox


GPS Antenna
Power Button &
Status LEDs
Pitot Tube
Download Port
Radio antenna

UX5 Tracking Beacon

- Tracking beacon for recovering lost aircraft
- 433 MHz tracker approved for use in Europe, Africa, Russia, Australia
- Trackers for North America and Brazil are not yet available

Trimble UX5 Specifications

- Weight: 2.5 kg
- Wingspan: 100 cm
- Launch Type: Catapult
- Cruise Speed: 80 km/h
- Endurance (flight time): 50 min
- Flight Height (AGL): 75-750 m
- GSD: 2.4-24 cm
- Coverage (@ 5 cm GSD): 2.19 km^2
- Coverage (@ 10 cm GSD): 4.94 km^2
- Flight Ceiling: 5000 m
- Wind Speed: 65 km/h
- Landing Type: Belly
- Camera: Sony NEX5R (16.1 MP)

Launcher Components

- Ramp
  - Bungee
  - Winching tool
  - Release handle
  - Safety pin
- Launcher Dock
- Support

Launcher Benefits

- Consistent launch
  - Speed
  - Launch angle
  - No risk of stall
  - Short learning curve for operator
  - Less stressful (user has to control speed & angle with a hand launch)
- Safety
  - Consistent & controlled launch sequence
  - User not exposed to running motor
  - Complies with Machinery Directive 2006/42/EC

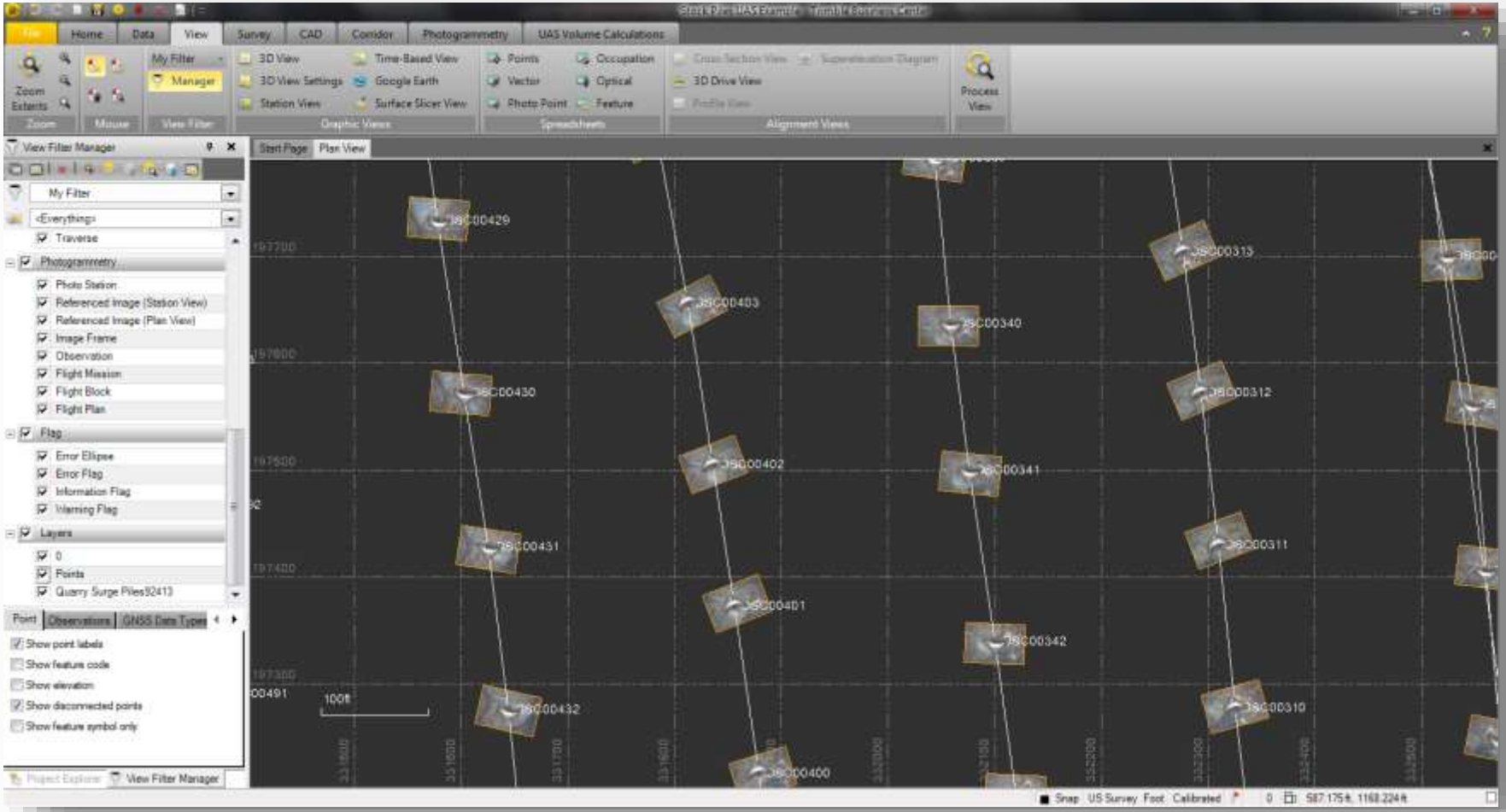
Ground Control Station

- Rugged Tablet
- Flight Planning & Control Software
- Communications Link
- Download Connector

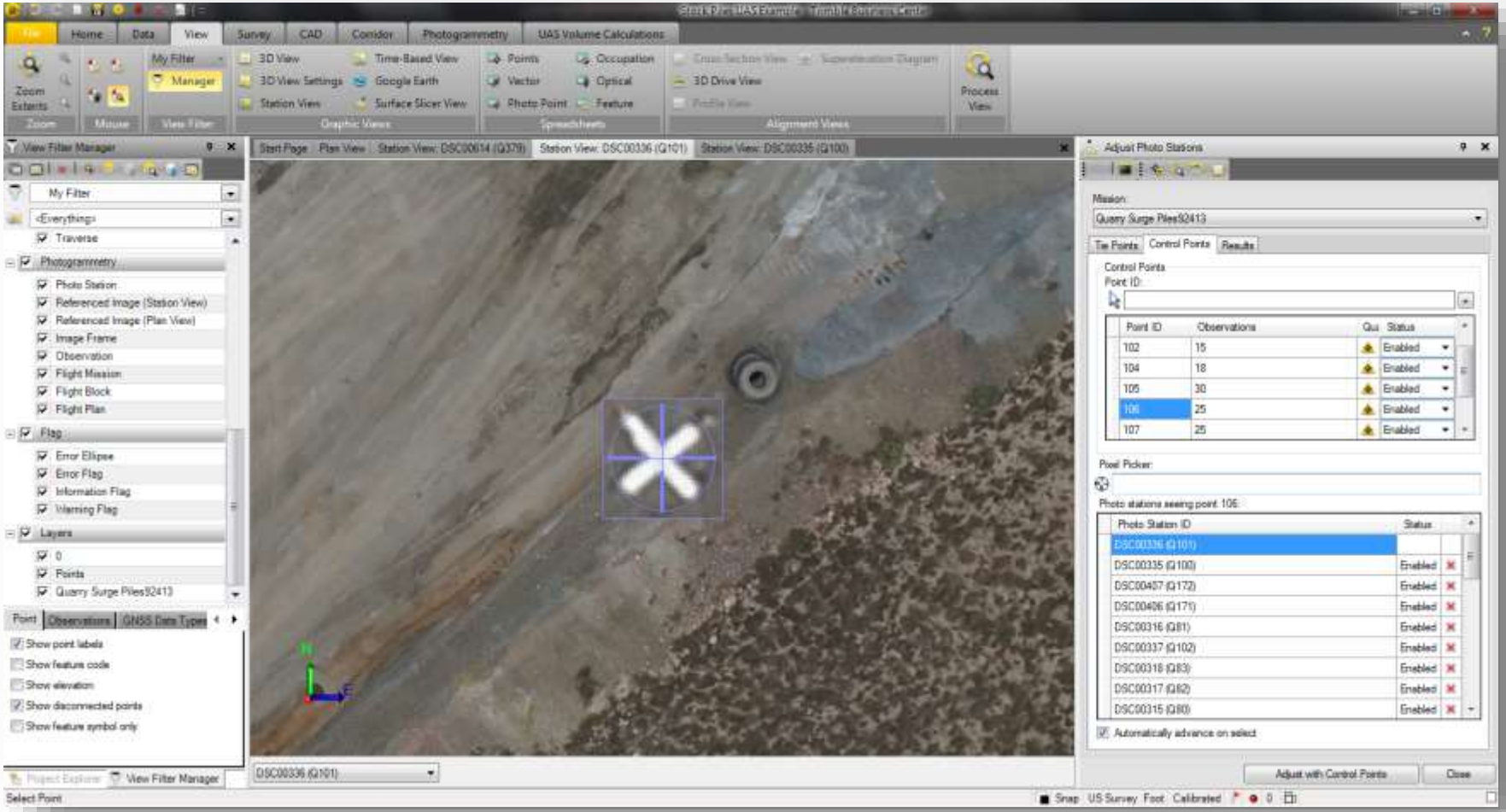
Trimble Business Center Photogrammetry Module

- Office application for processing traditional and Trimble UAS survey data
- 64-bit processor / operating system requirement
- Photogrammetry processing using technology from Inpho
- Simple workflows for importing flight data, stitching images, identifying ground control points, producing deliverables, and measuring features

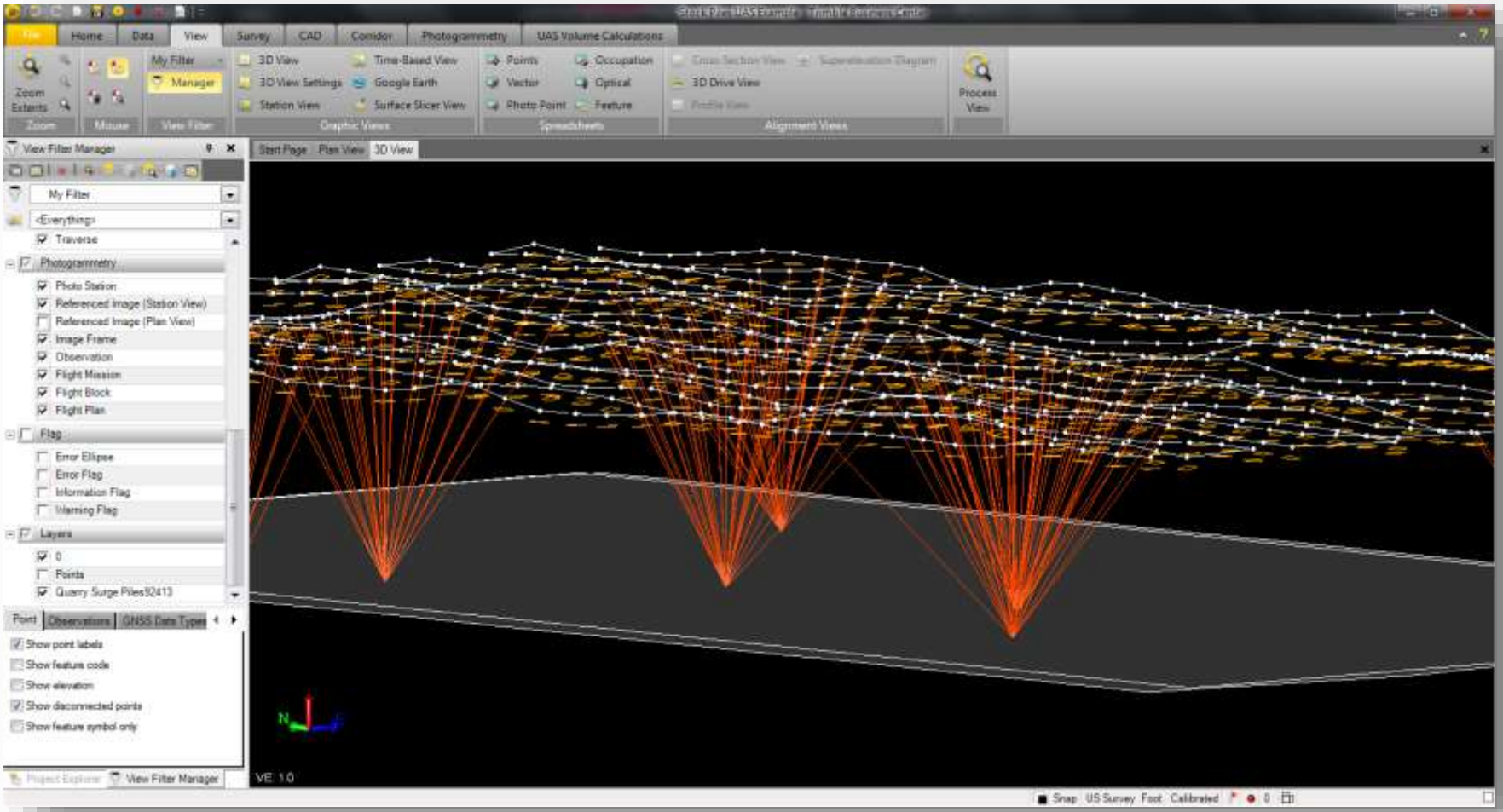
Visualize the Flight



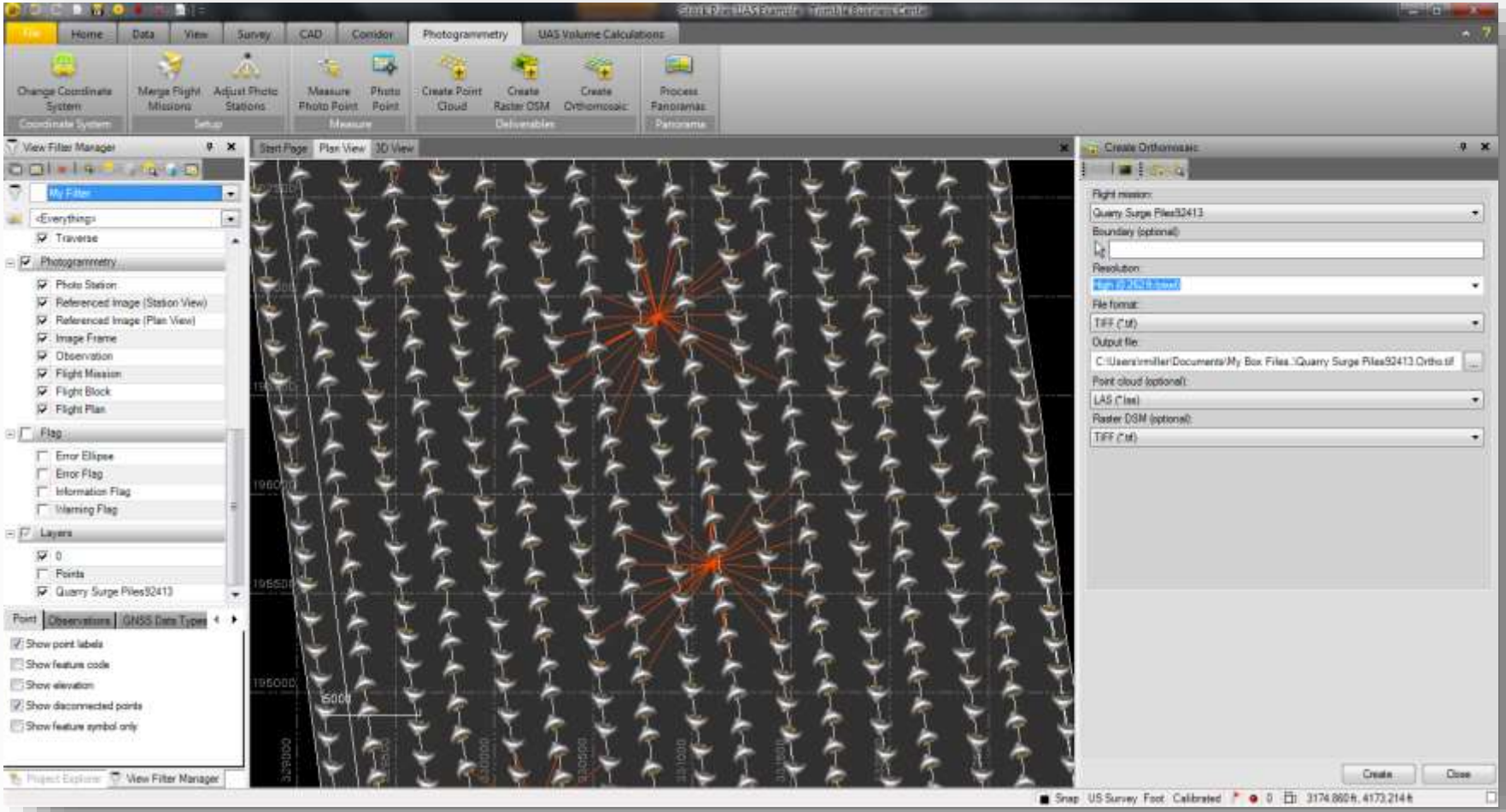
Measure Ground Control Points



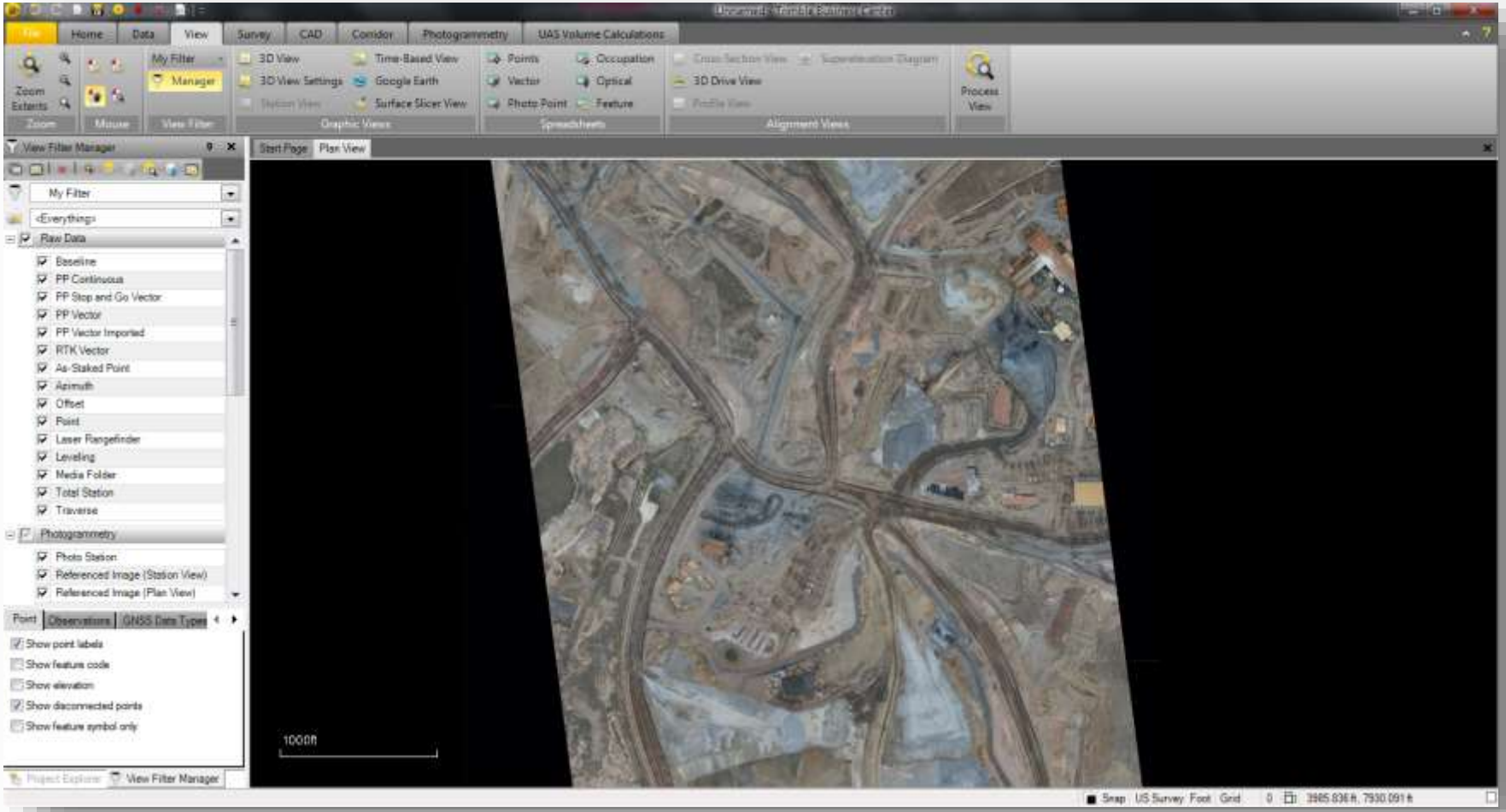
View Ground Control Point Relationships



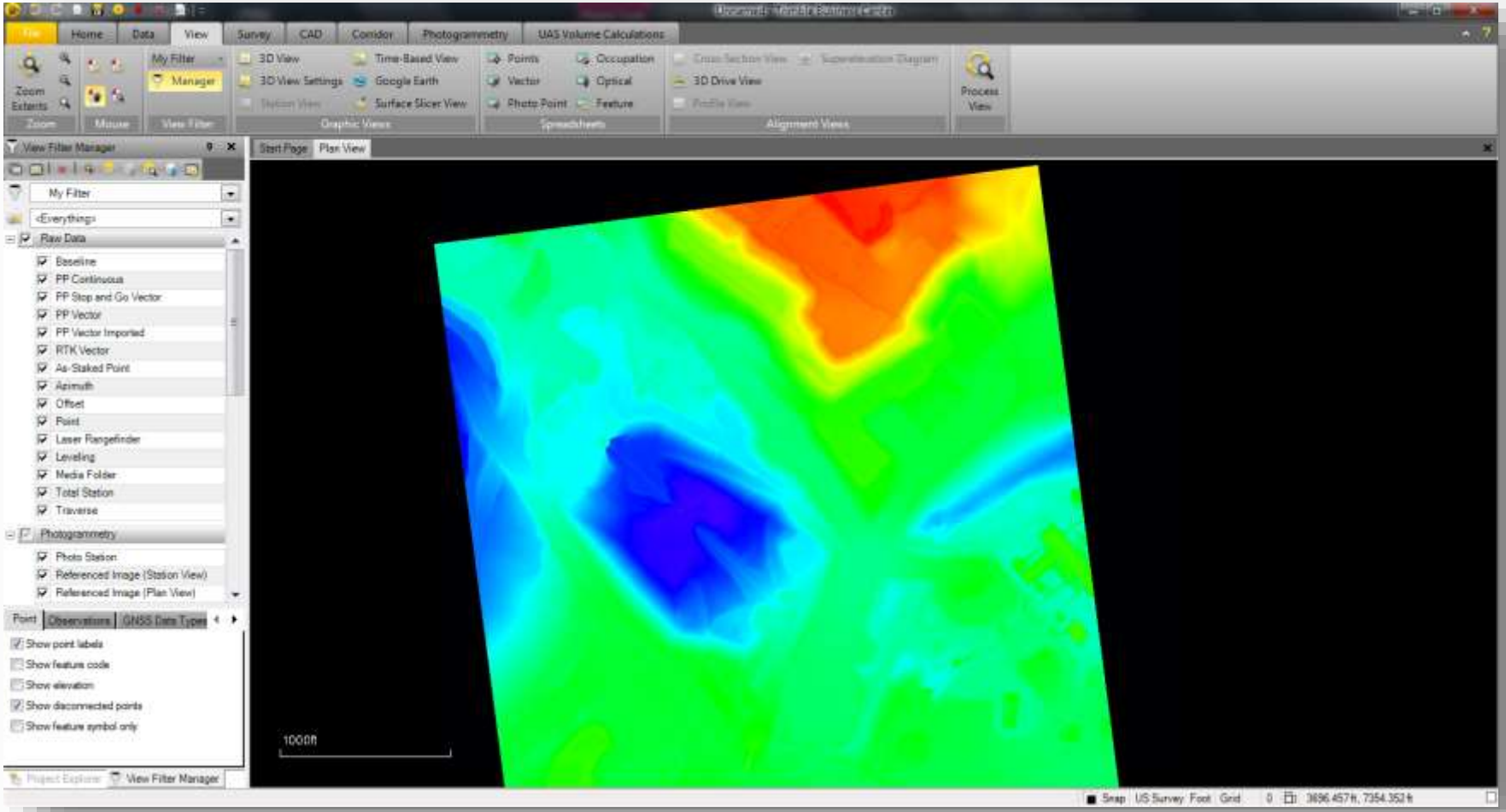
Create Deliverables



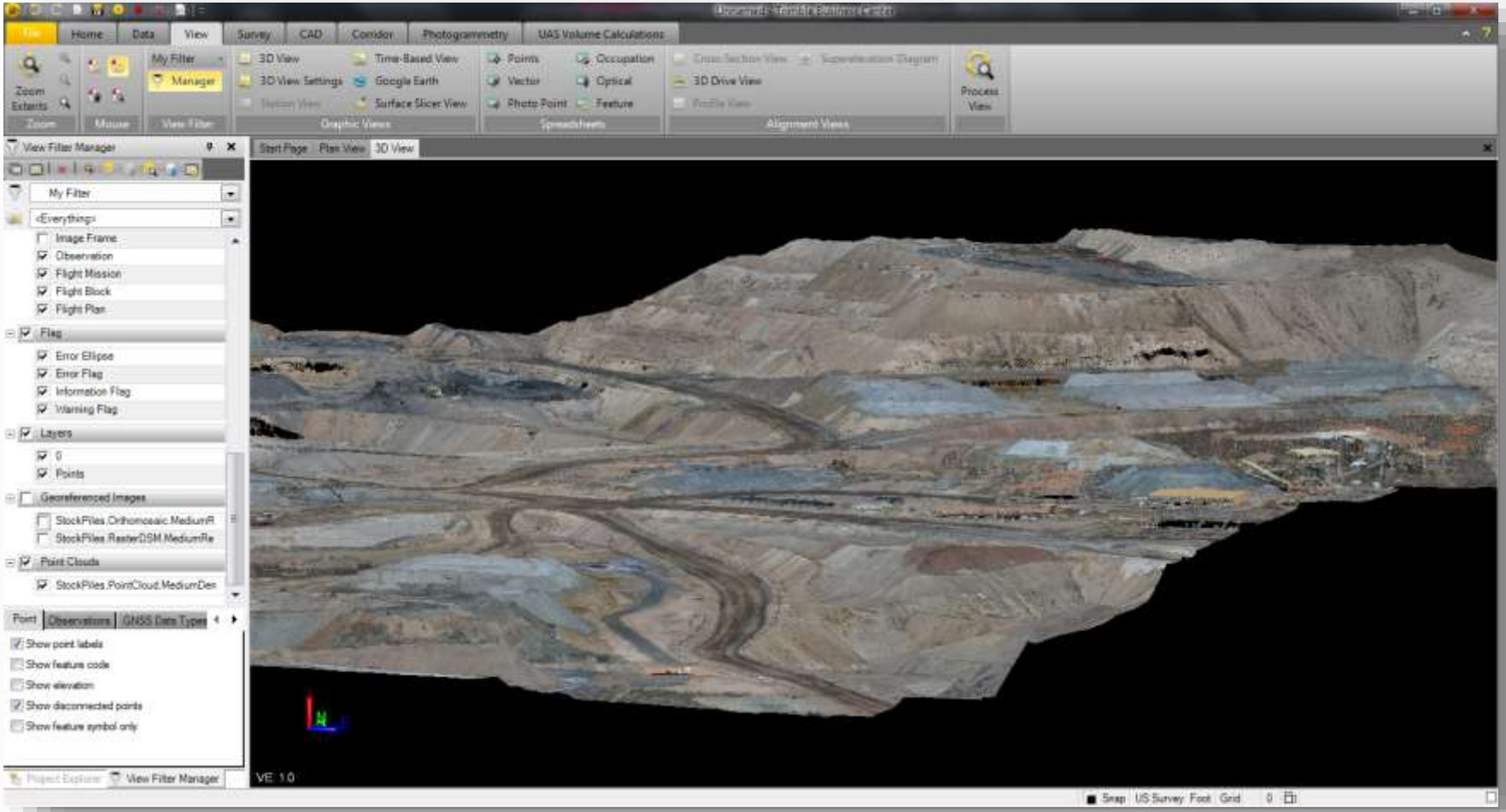
Create Orthomosaics



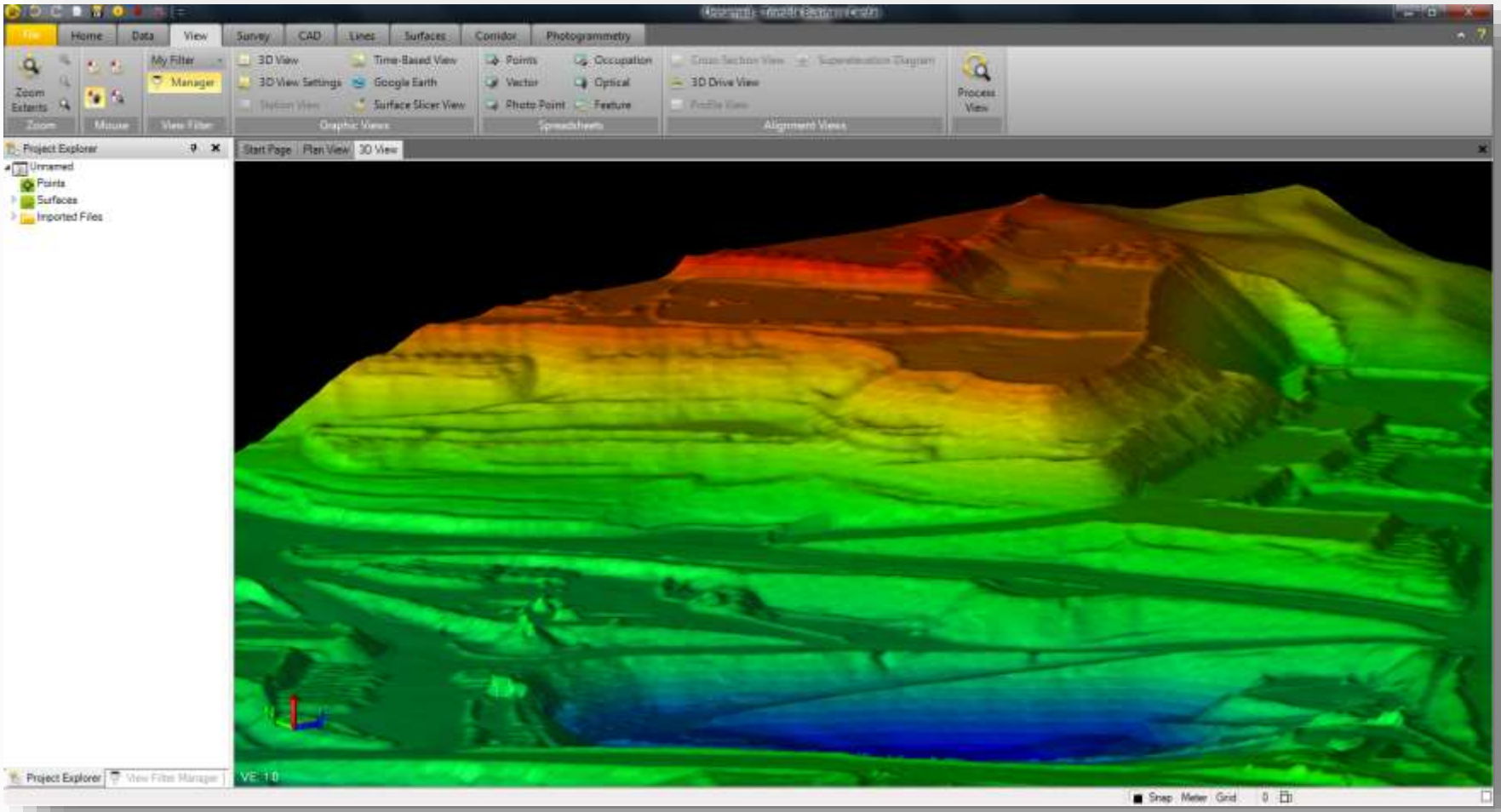
Create Digital Surface Models



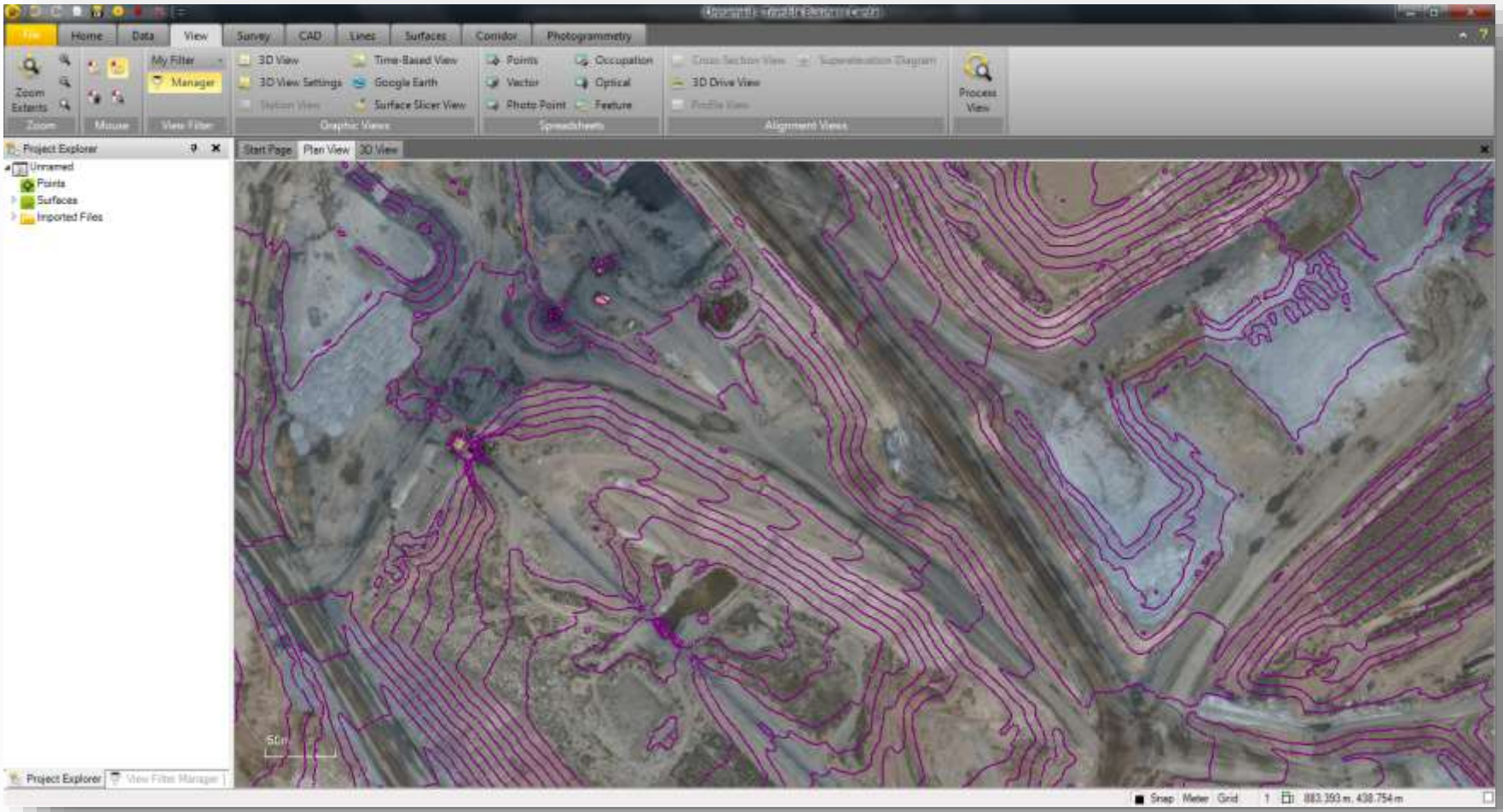
Create Point Clouds



Create Surface



Create Contours



Orthomosaic Examples

Trimble UAS & Trimble Business Center Photogrammetry Module

Questions?

Trimble UX5 Aerial Imaging Solution