

Drones and Computer Vision

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Co-Founder and CTO, Clobotics

June 24, 2017


Clobotics



About Me



**Carnegie
Mellon
University**

B.S. Computer Science, 2001

M.S. Electrical and Computer Engineering, 2002

Ph.D. Computer Vision, 2008



Principal Development Manager, 2016

Bing Search

Web Index Selection

Knowledge Graph

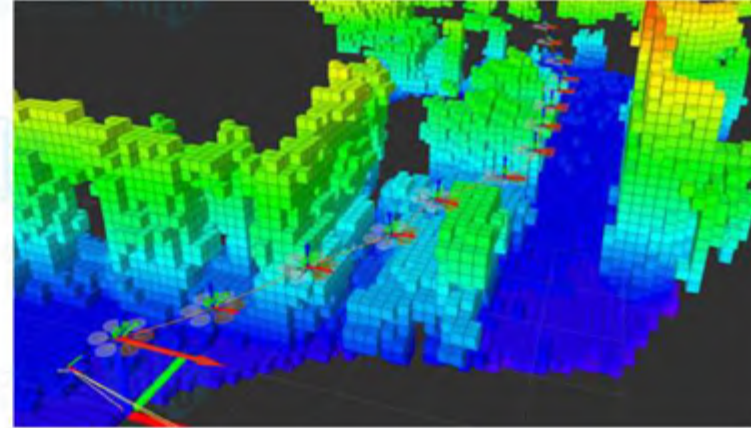
Question Answering



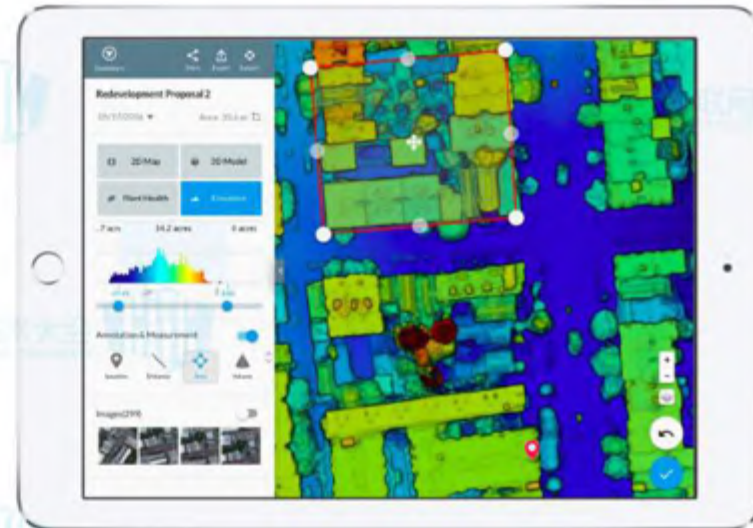
Clobotics

Overview

- Industry overview
- Computer vision on drones
- Computer vision on collected data



ETH Zurich / Ascending Technologies



DroneDeploy



Drone Imagery



Drones in the News



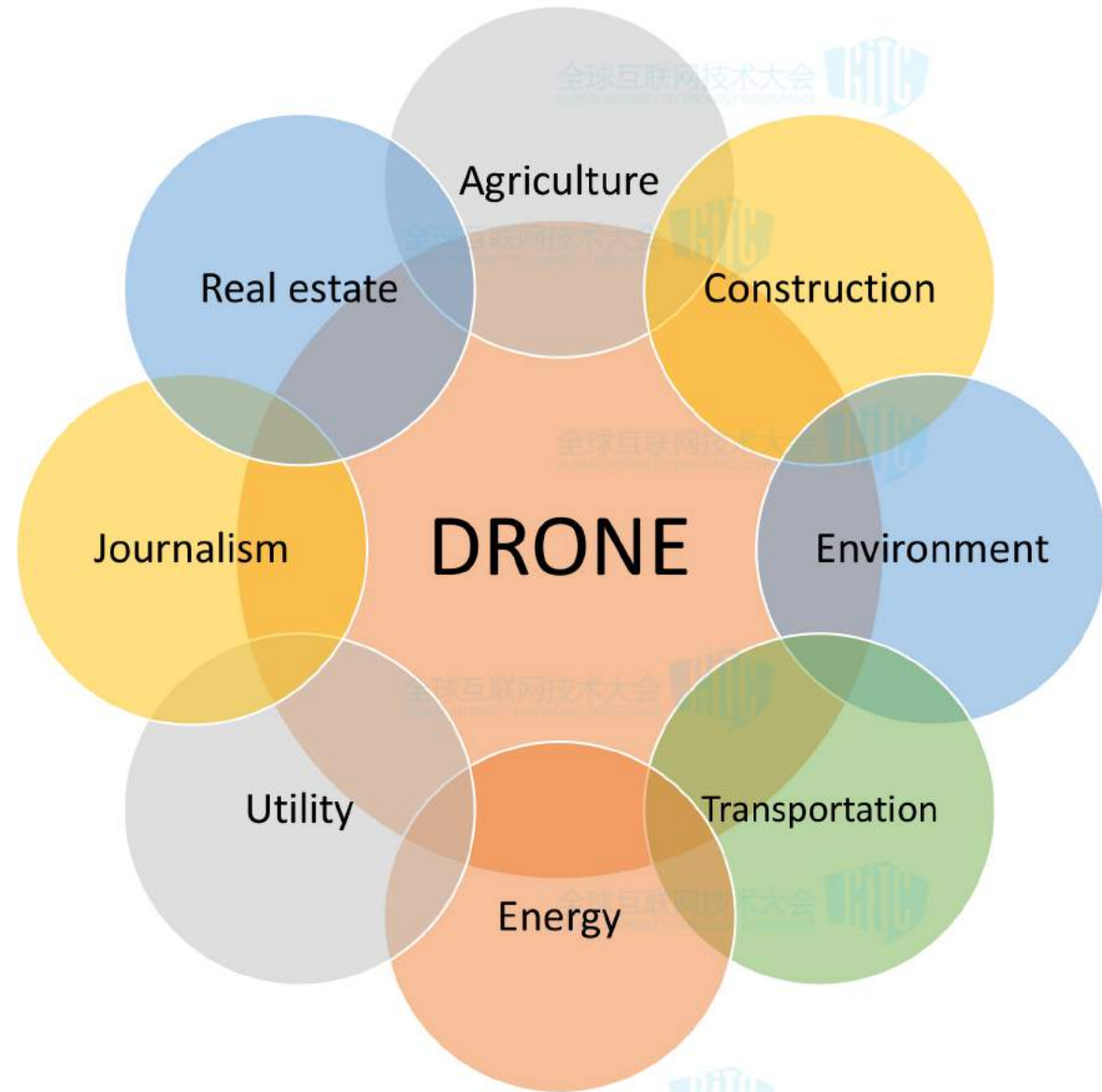
"25 near-misses between planes and objects identified as drones at Heathrow in 2016"

"Drones have near-misses with airplanes over three times a day (US)"

<http://news.sky.com/story/drone-and-plane-in-near-miss-close-to-heathrow-10379797>

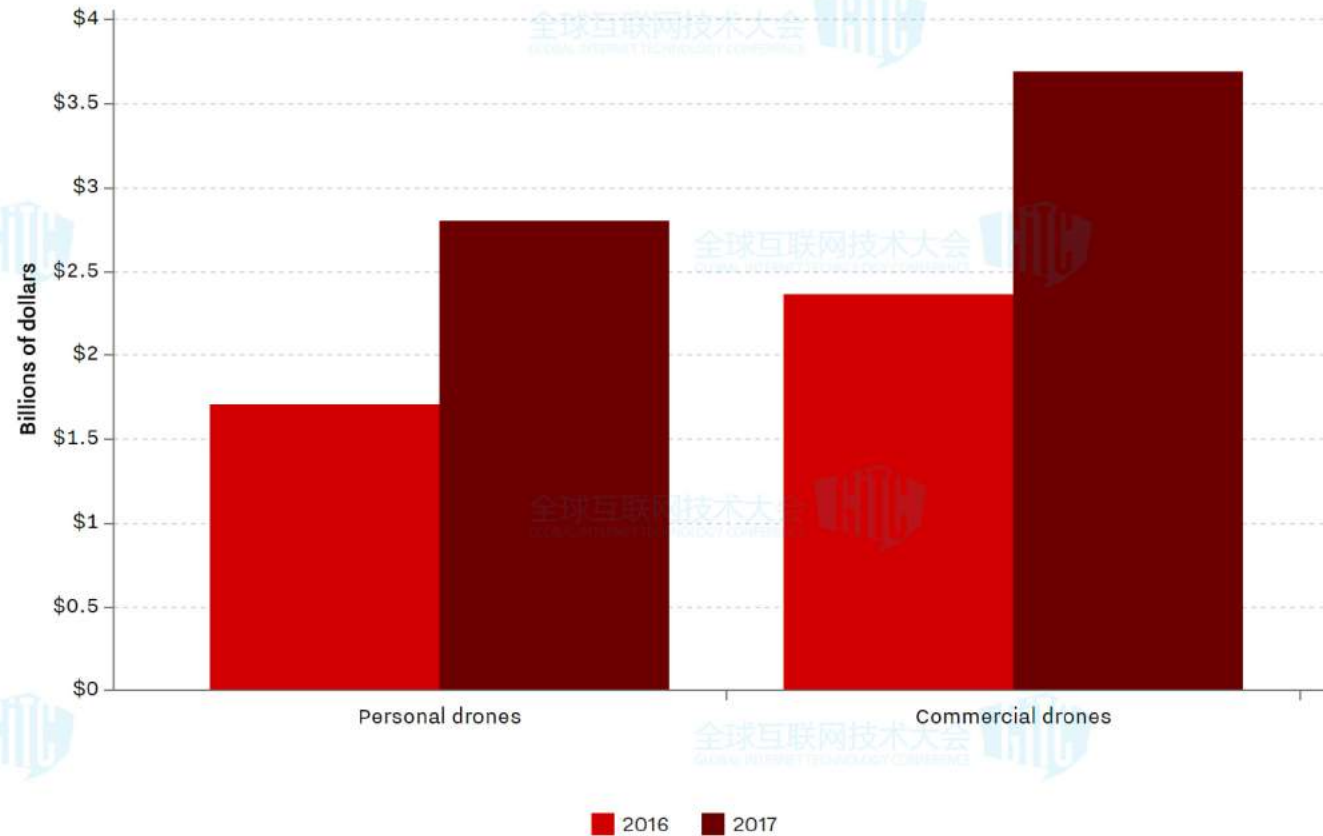
<http://nypost.com/2016/03/29/drones-have-near-misses-with-airplanes-over-three-times-a-day/>

<http://www.irishnews.com/magazine/technology/2017/04/03/news/the-number-of-drone-near-misses-at-heathrow-has-more-than-tripled-in-a-year-986572/>



How big is the industry?

Global drone revenue forecast



Source: Gartner
Credit: Reporting by April Glaser

recode

\$100 billion by 2020

Goldman
Sachs



THE OPPORTUNITY AHEAD

Between now and 2020, we forecast a \$100 billion market opportunity for drones—helped by growing demand from the commercial and civil government sectors.

Source: Goldman Sachs Research



<http://www.goldmansachs.com/our-thinking/technology-driving-innovation/drones/>

Clobotics

Cost of Data Acquisition



Hundreds of Millions



Satellites

\$50M - \$400M to build and launch
Millions per year to operate



Hundreds of Thousands



Planes

\$300K+ to buy
\$100K per year to hire a pilot



Thousands



Drones

\$1000 - \$10,000 to buy
Autonomous



Computer Vision on Drones



Safe and Autonomous

- Goals

- Obstacle Avoidance
- Visual Navigation (No GPS)
- Tracking
- Precise Landing

- Requirements

- Real time
- Low weight
- Low power



Drones Are Not Toys



Obstacle Avoidance



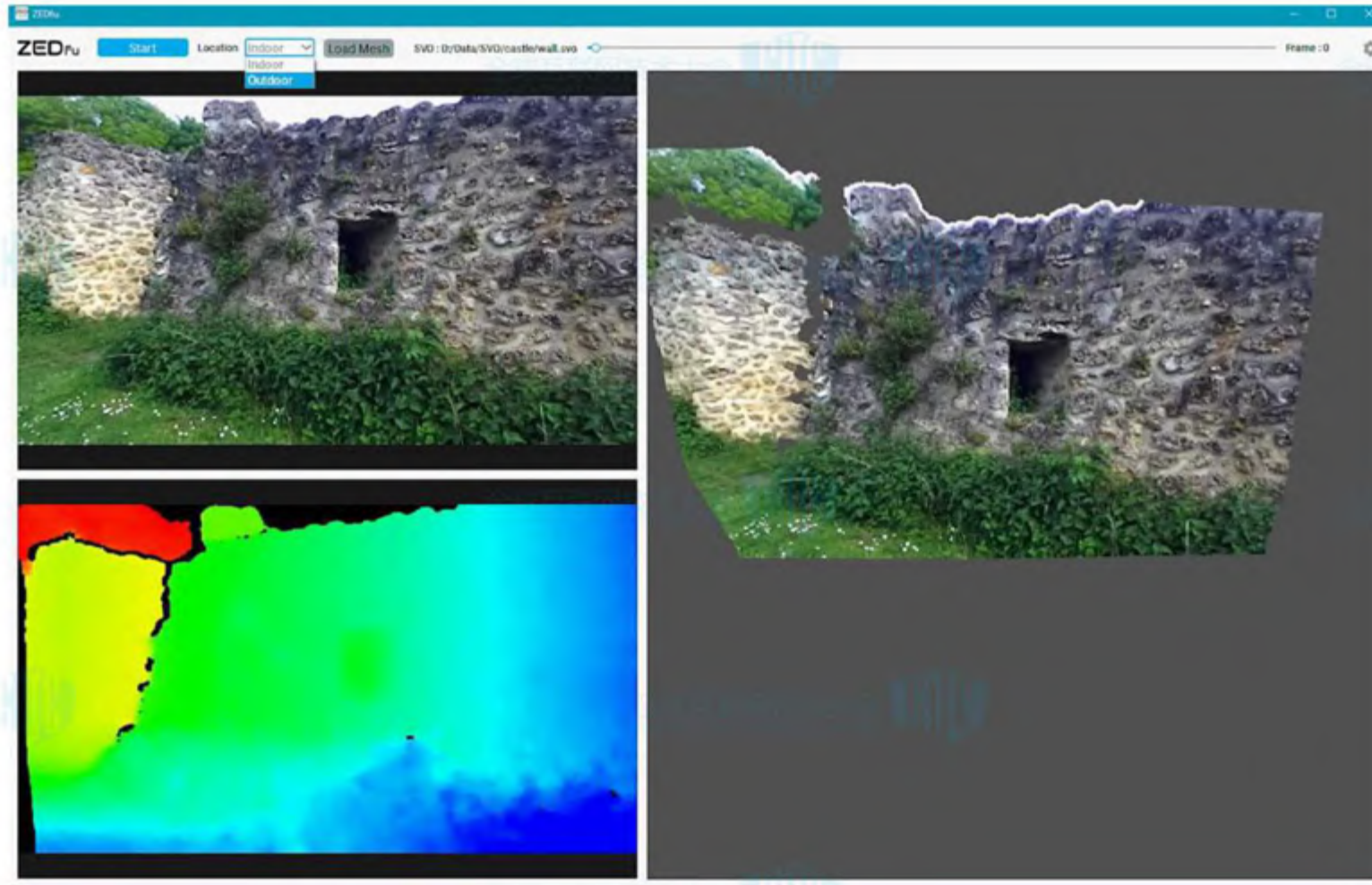
YUNEEK



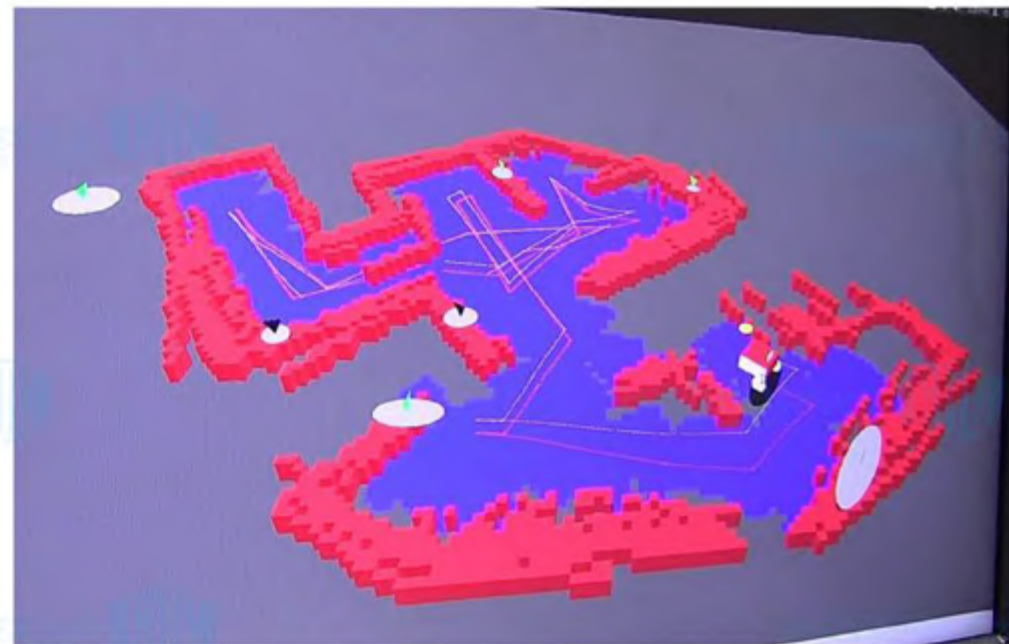
DJI Obstacle Avoidance



ZED Stereo Camera Output



SLAM - Simultaneous Localization and Mapping



University of Michigan

Visual Odometry

University of Zurich – Robotics and Perception Group



Tutorial: https://www.researchgate.net/publication/284136264_An_Overview_to_Visual_Odometry_and_Visual_SLAM_Applications_to_Mobile_Robots

Tracking – TLD, CMT



Fig. 1. Given a single bounding box defining the object location and extent in the initial frame (LEFT), our system tracks, learns and detects the object in real-time. The red dot indicates that the object is not visible.

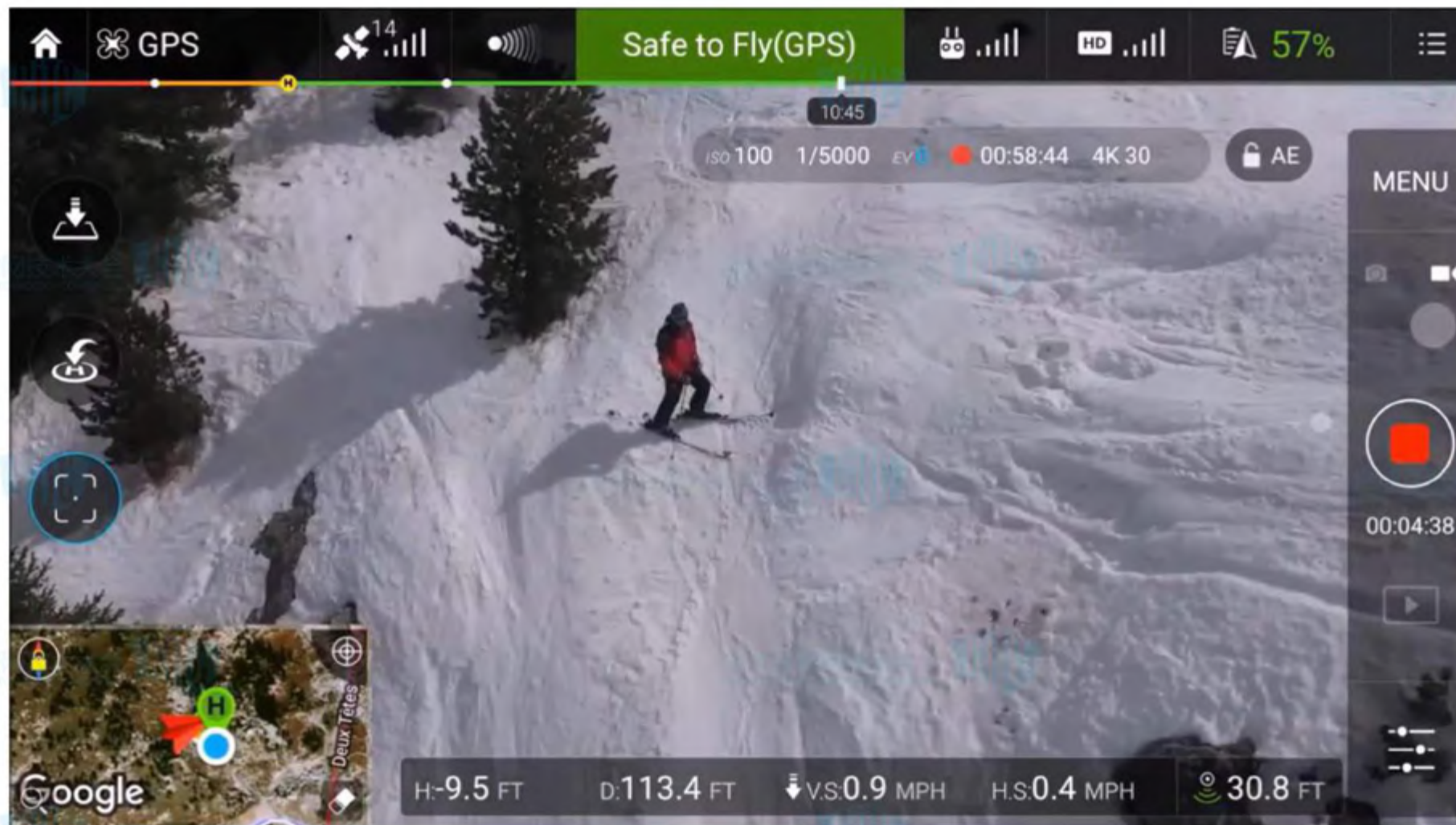
<http://personal.ee.surrey.ac.uk/Personal/Z.Kalal/tld.html>

http://kahlan.eps.surrey.ac.uk/featurespace/tld/Publications/2011_tpami

<https://www.gnebehay.com/tld/>

<https://www.gnebehay.com/cmt/>

DJI Active Track



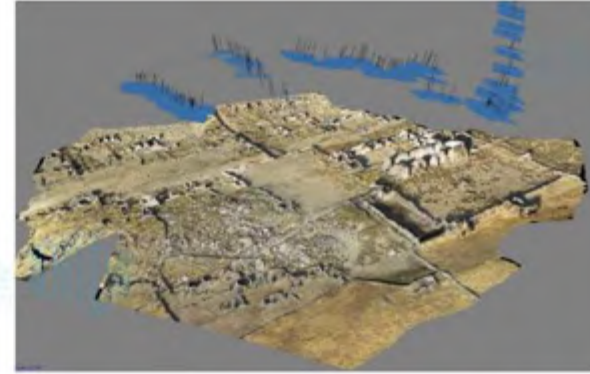


@Matt:
Can you confirm site #A1523
is ready for blasting tomorrow?

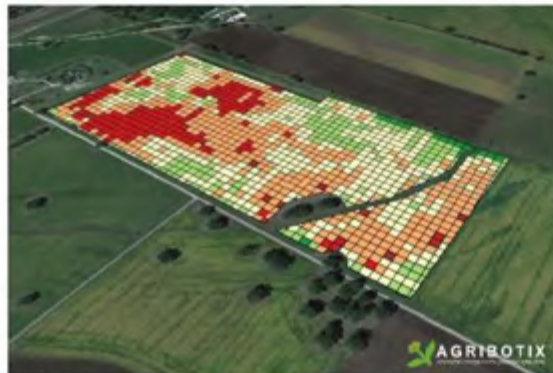
Computer Vision on Drone Data

Underlying Technologies

- Image Stitching
- 3D Reconstruction
- Multispectral Analysis
- Object Detection



Steve Wernke / Vanderbilt University



Agribotics



Pro Aerial Services



Image Stitching

- Many overlapping high resolution photos
- Image registration (with keypoints)
- Calibration
- Blending
- Georeference



<http://www.mdpi.com/1424-8220/12/12/17504/htm>

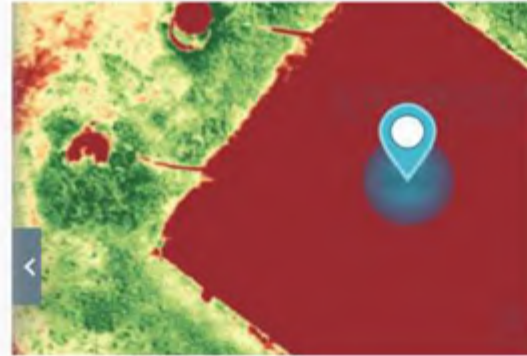
Point, Length, Area Measurements



Location Distance Area Volume

Title
Barn

Coords 44.21978, -78.52836



Data Share Export Support

Annotation & Measurement

Location Distance Area Volume

Title
Barn

Area 5.8 acres

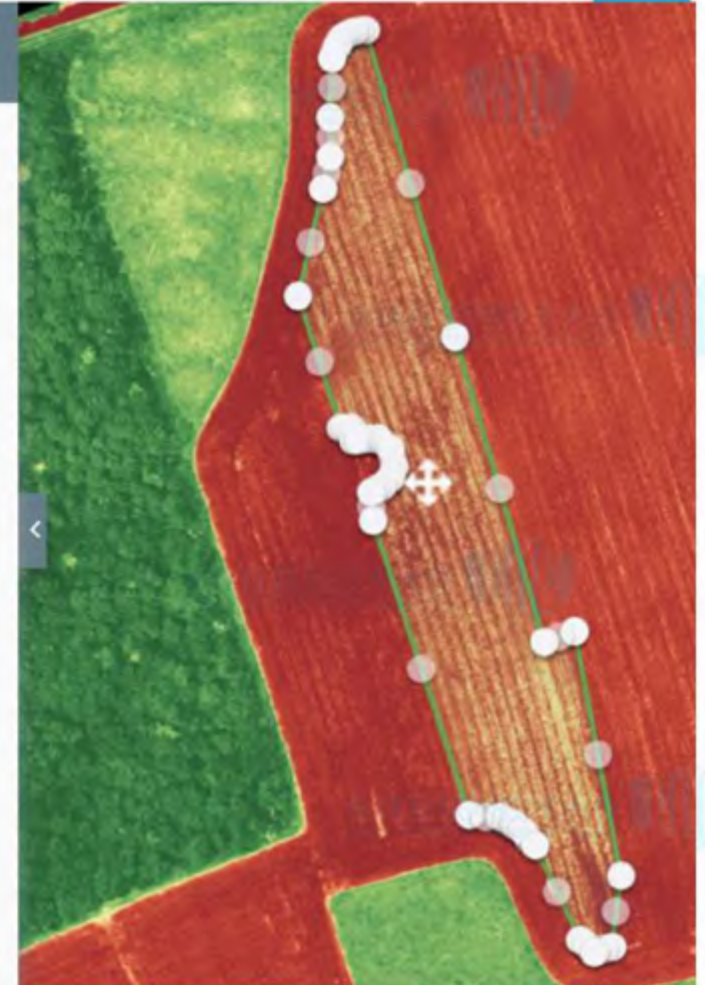
Weeds
jono Sep 14th, 15

Add a comment

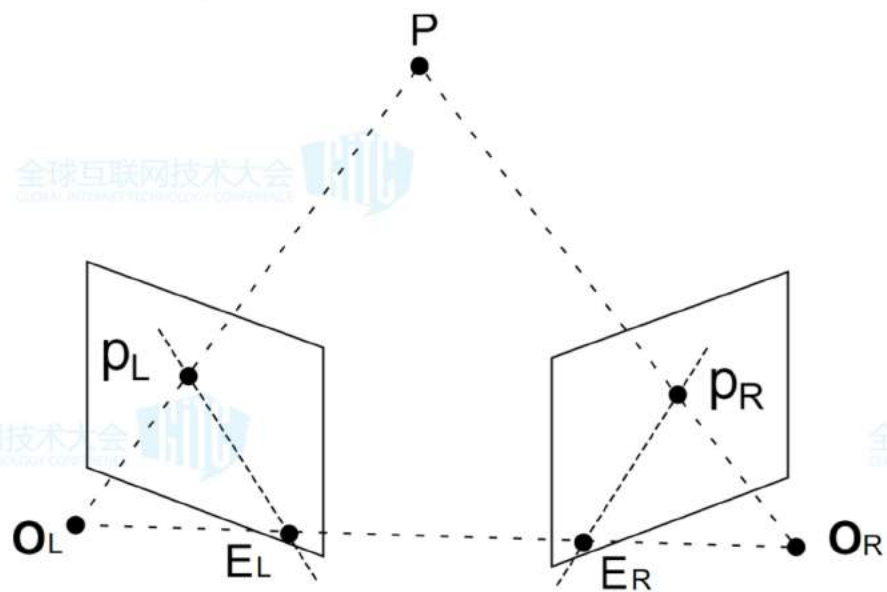
Title

Length 4560.8 ft

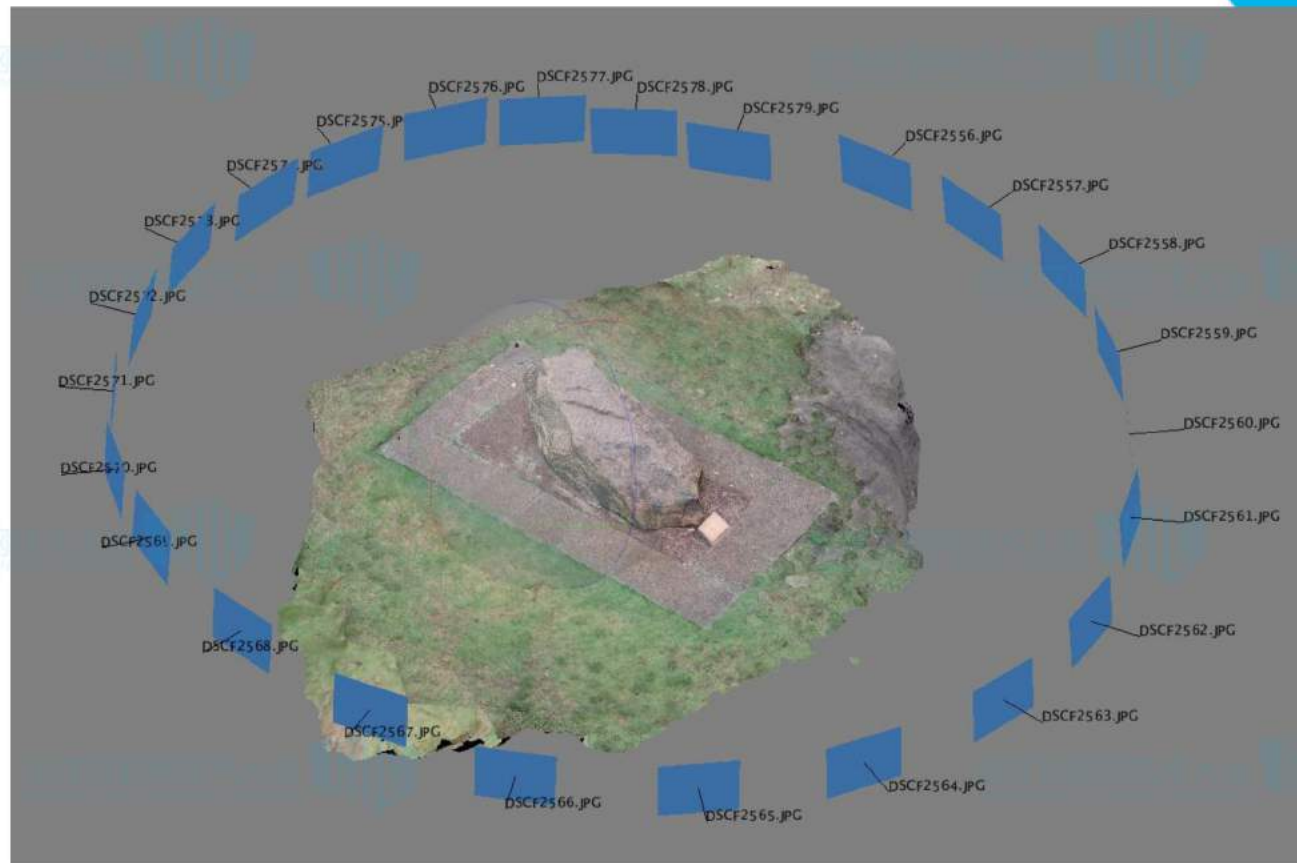
Field Length
jono Sep 14th, 15



3D Reconstruction



https://en.wikipedia.org/wiki/3D_reconstruction_from_multiple_images



Paul Bourke

3D Models and Measurements

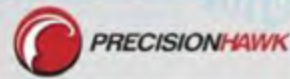


Altizure

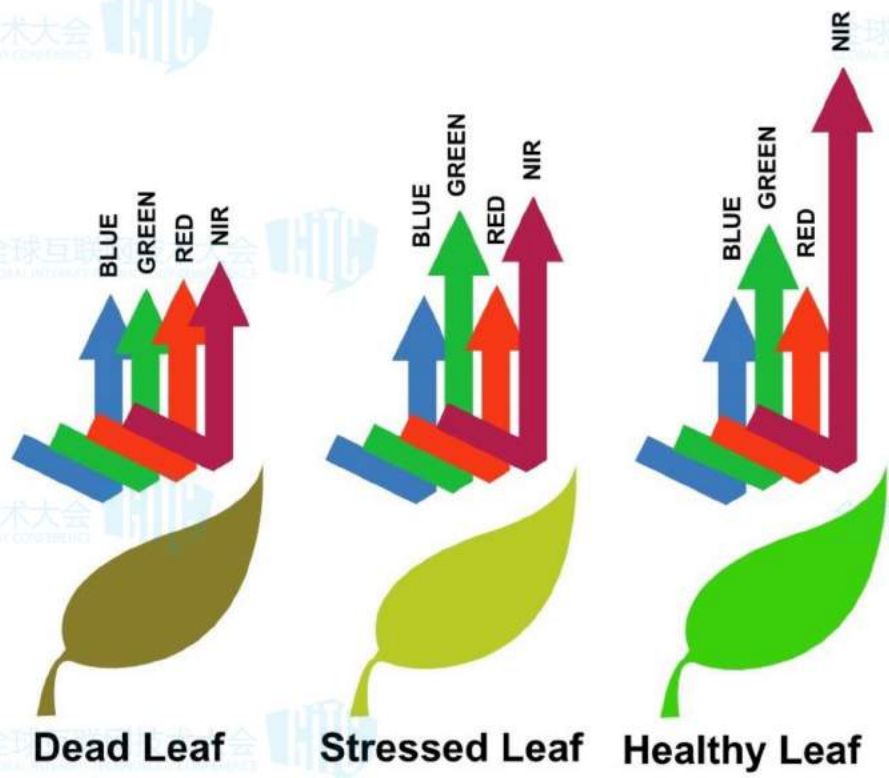
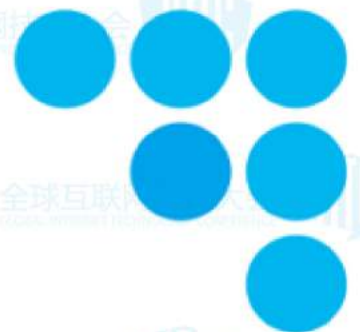


Stockpile Volume Estimation

Precision Hawk



Multispectral Analysis

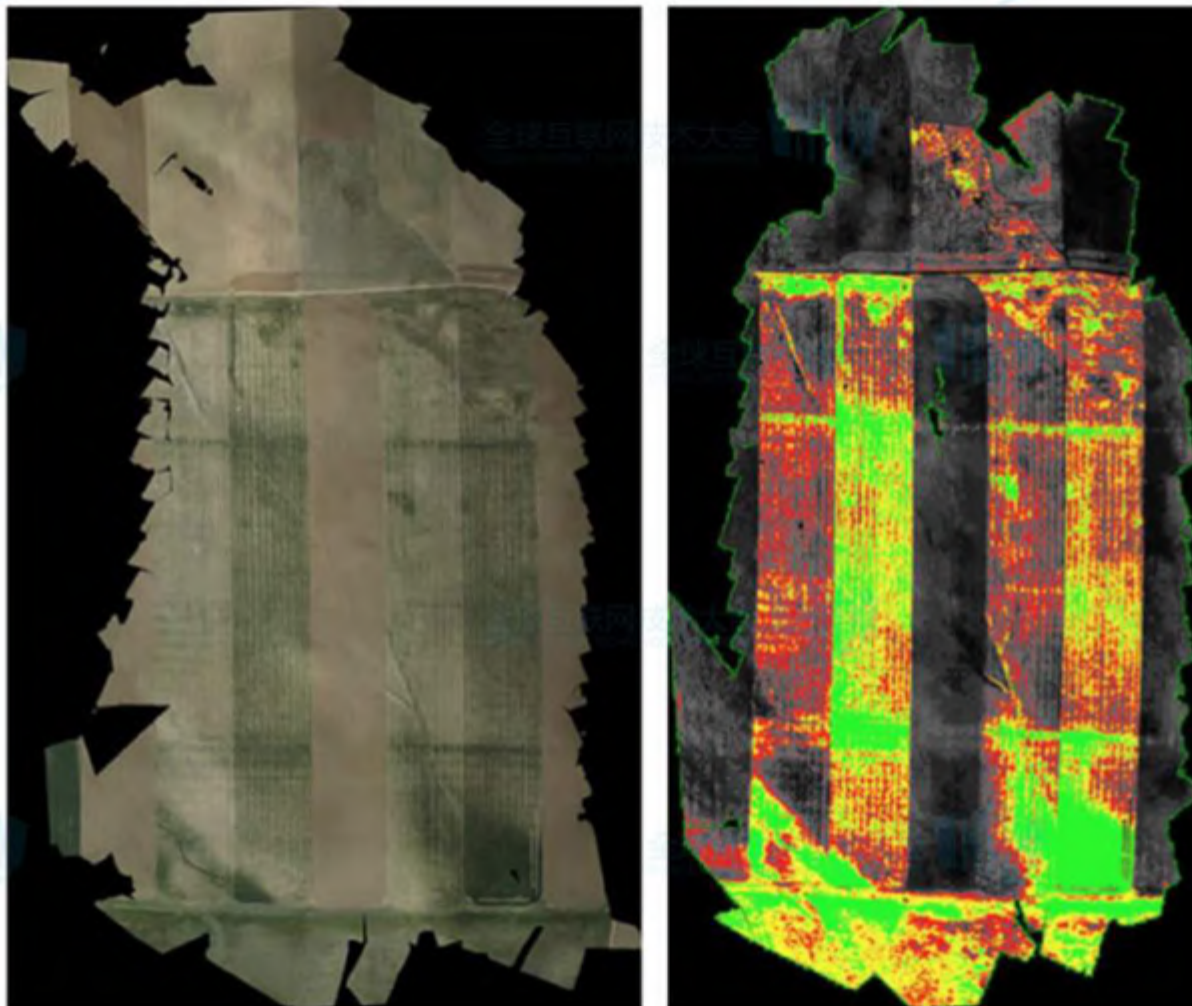


Agribotix



Micasense Sequoia

NDVI



Agribotix

Object Detection – Deep Learning



NVIDIA TX2



NVIDIA DGX-1



Kespry

Drone+Cloud Industry Landscape



Drone+Cloud landscape

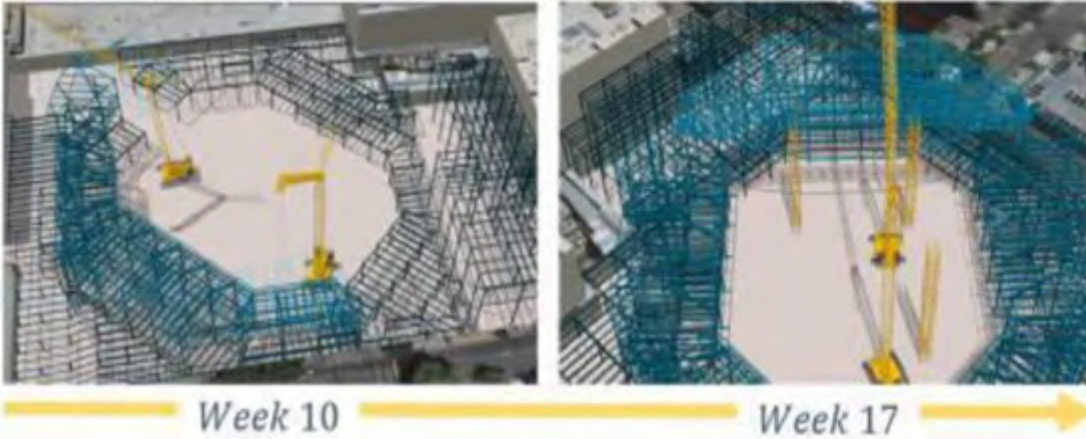


	Founded	Rev	Total Funding	Focus Area
Skycatch	2013	\$1.8M	\$47.8M	Construction
Pix4D	2011	\$1.6M	\$2.4M	Surveying, Agriculture, Construction
DroneDeploy	2013	\$2.3M	\$31M	Agriculture, Construction, Mining
Kespry	2013	\$5M	\$28.4M	Construction
Precisionhawk	2011	\$3.9M	\$30M	Agriculture
Airware	2011	\$5M	\$68.7M	Drone OS
3DR	2009	\$32M	\$126M	Construction, mining, surveying
TraceAir	2015	<\$1M	Seed	Construction
Redbird	2012			Construction / acquired by Airware
Agribotix	2015	N/A	\$250K	Agriculture

* All funding data from owler.com, except for Matternet which is from crunchbase.com

Construction

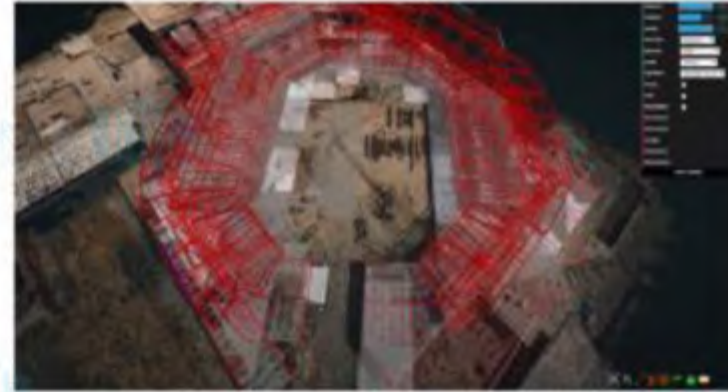
Expected progress: 4D BIM with Weekly Work Planning details



Actual construction progress: 4D Reality Models



Jointly registered
4D BIM and 4D Reality Models



- As-built Documentation
- Progress Monitoring
- Quality Control
- Safety Monitoring
- Contractor Hand-Over

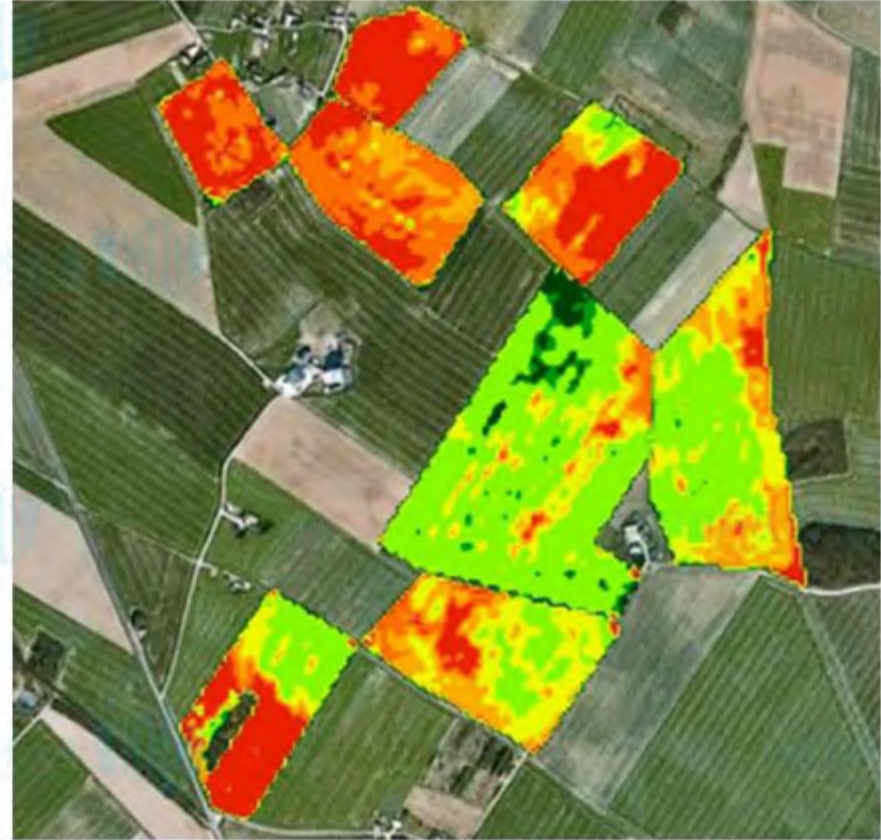
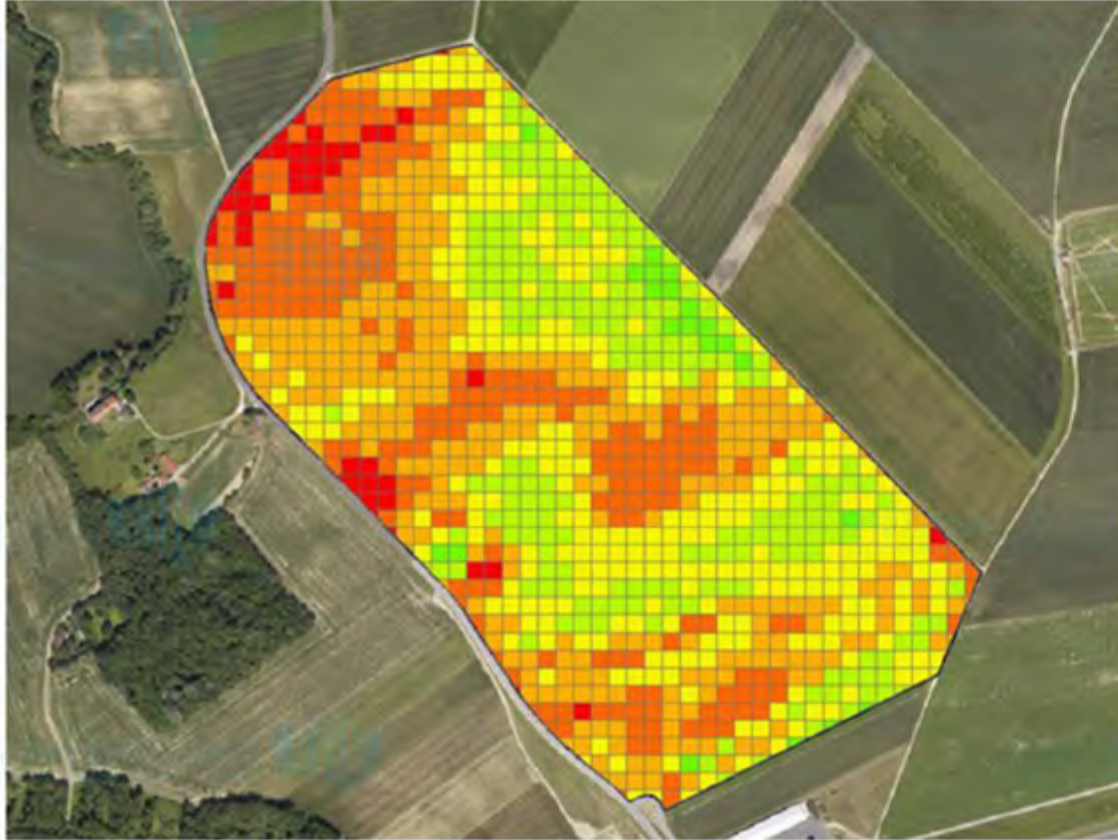


Reconstruct

Windfarm



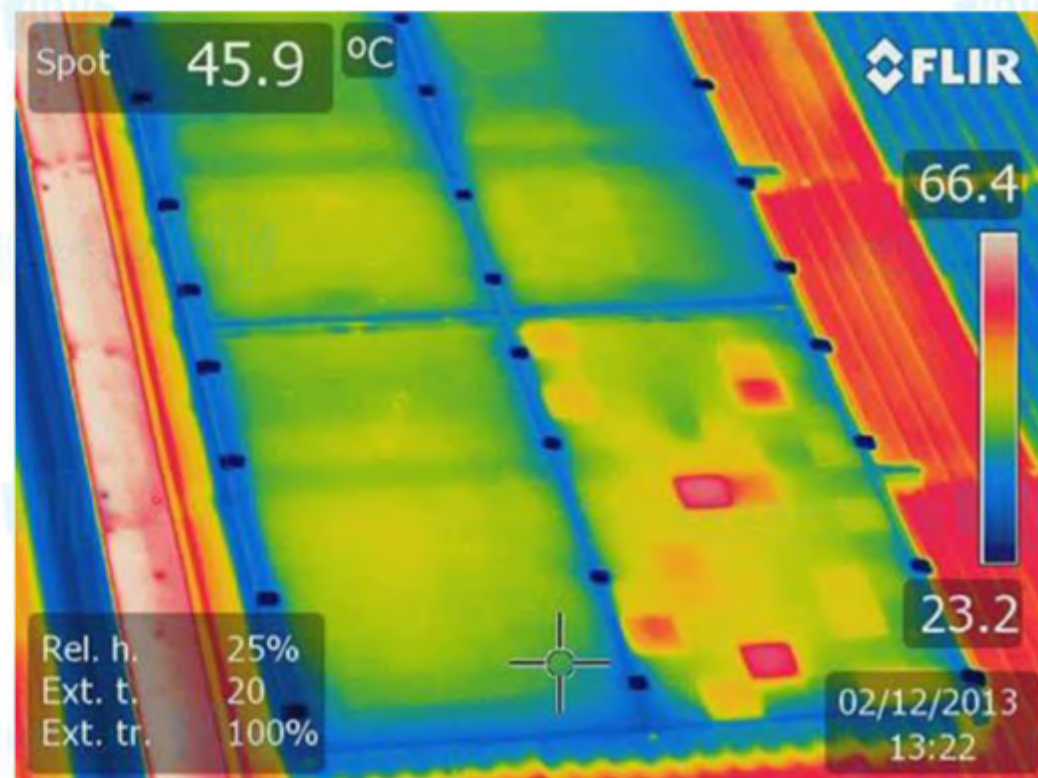
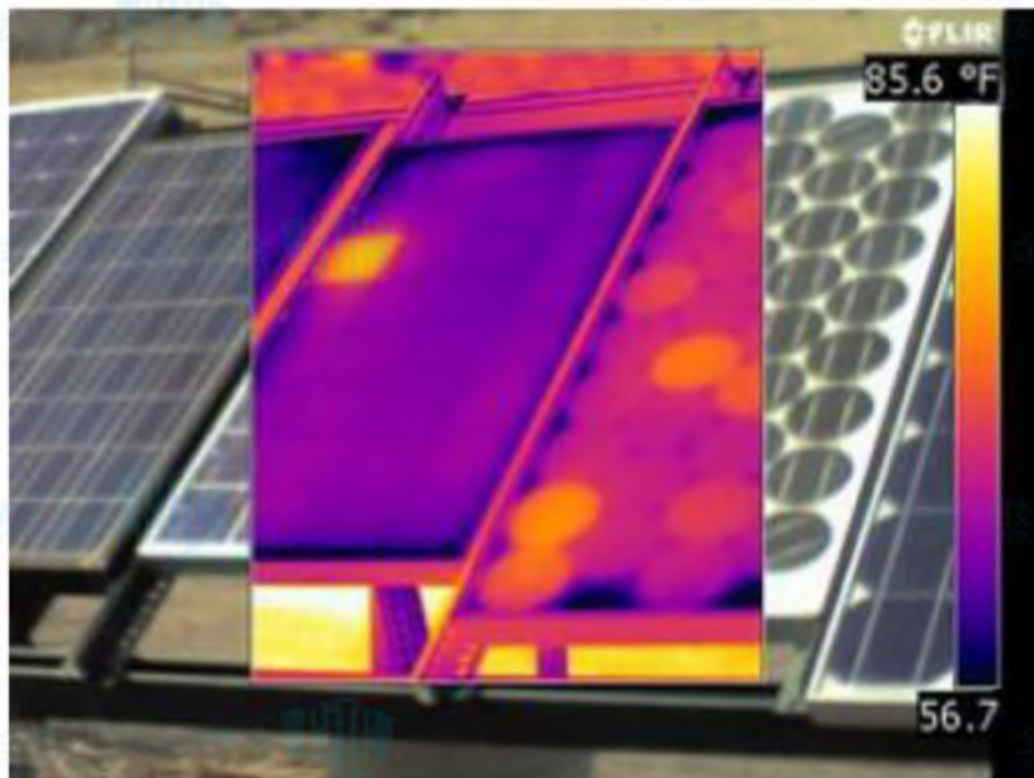
Precision Farming



Roof Inspection



Solar Panel Inspection



FLIR

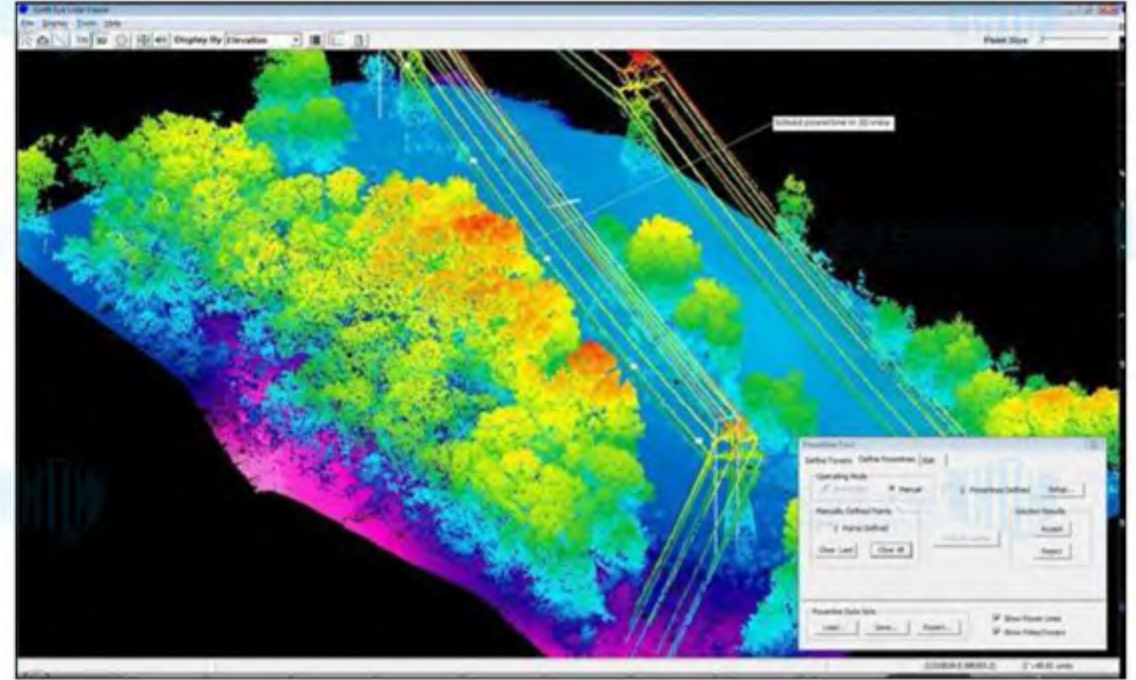
Animal Conservation



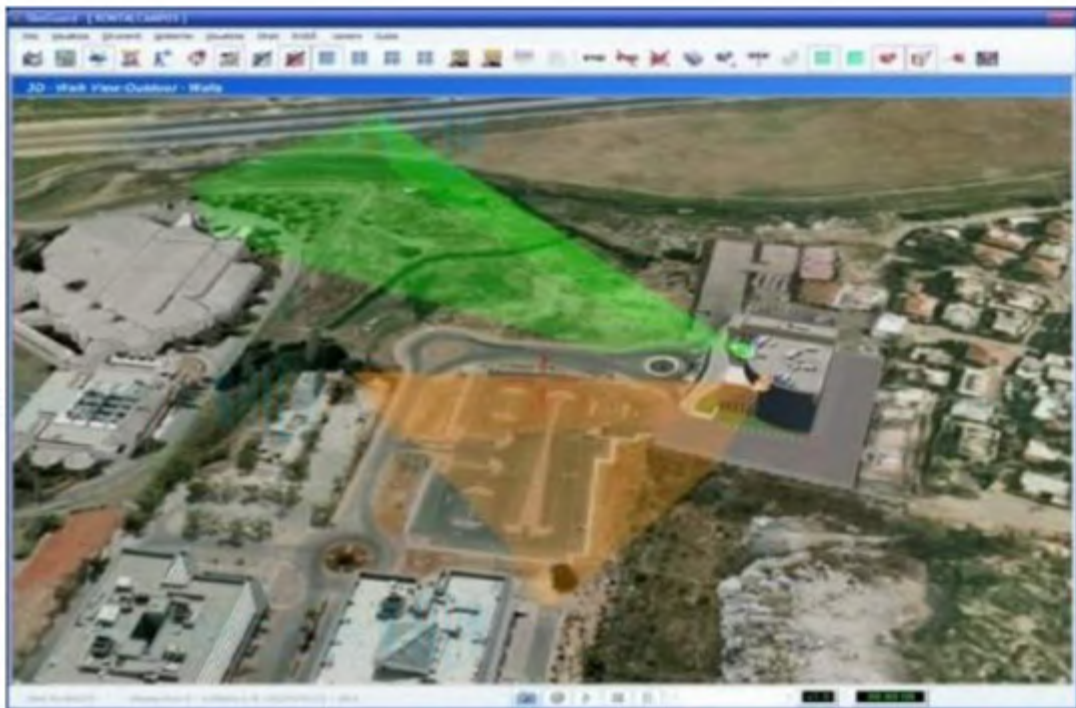
Counting animals

<https://www.newscientist.com/article/mg22530023-000-flying-high-drones-keep-tabs-on-wildlife-from-above/>

Power Lines Inspection



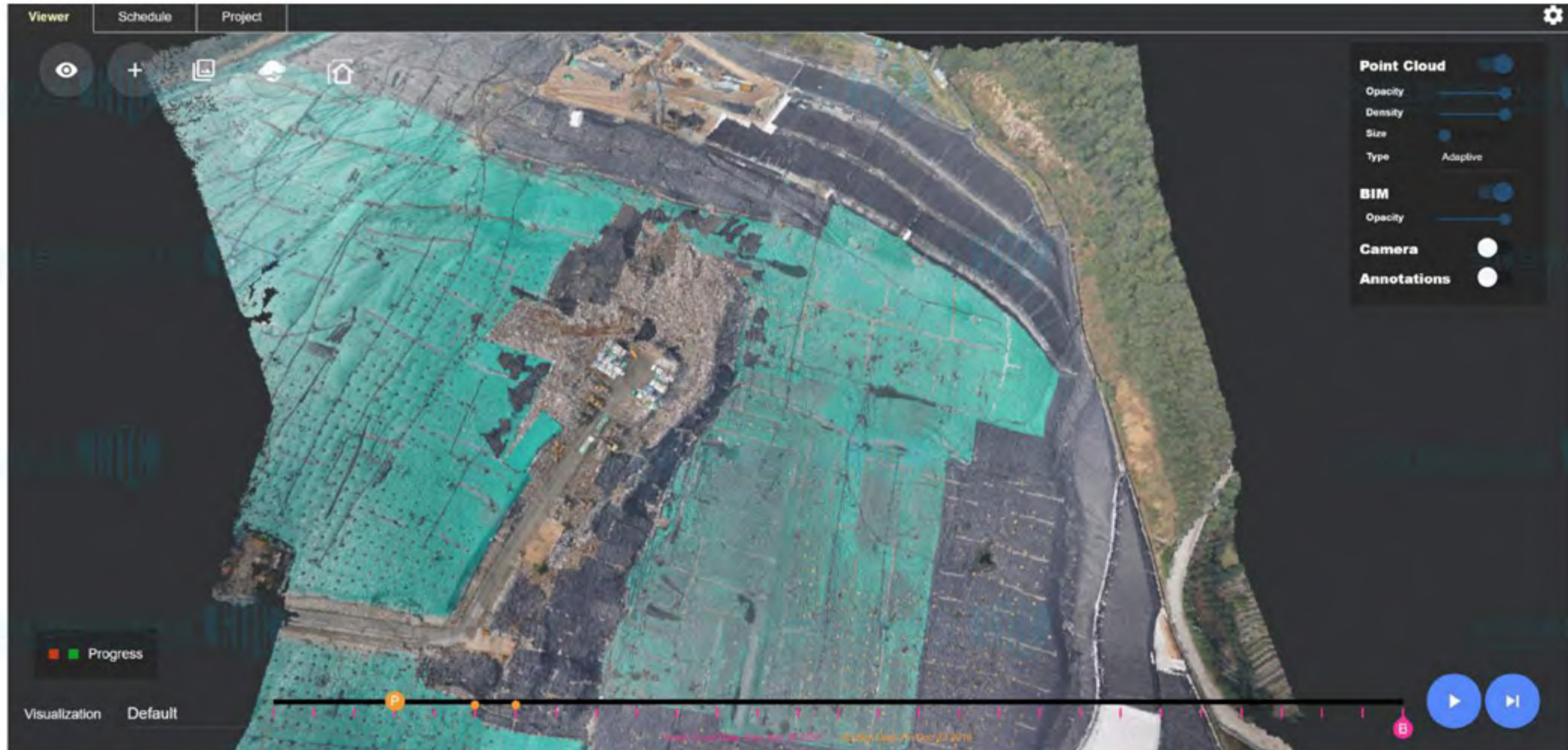
Telecom Industry

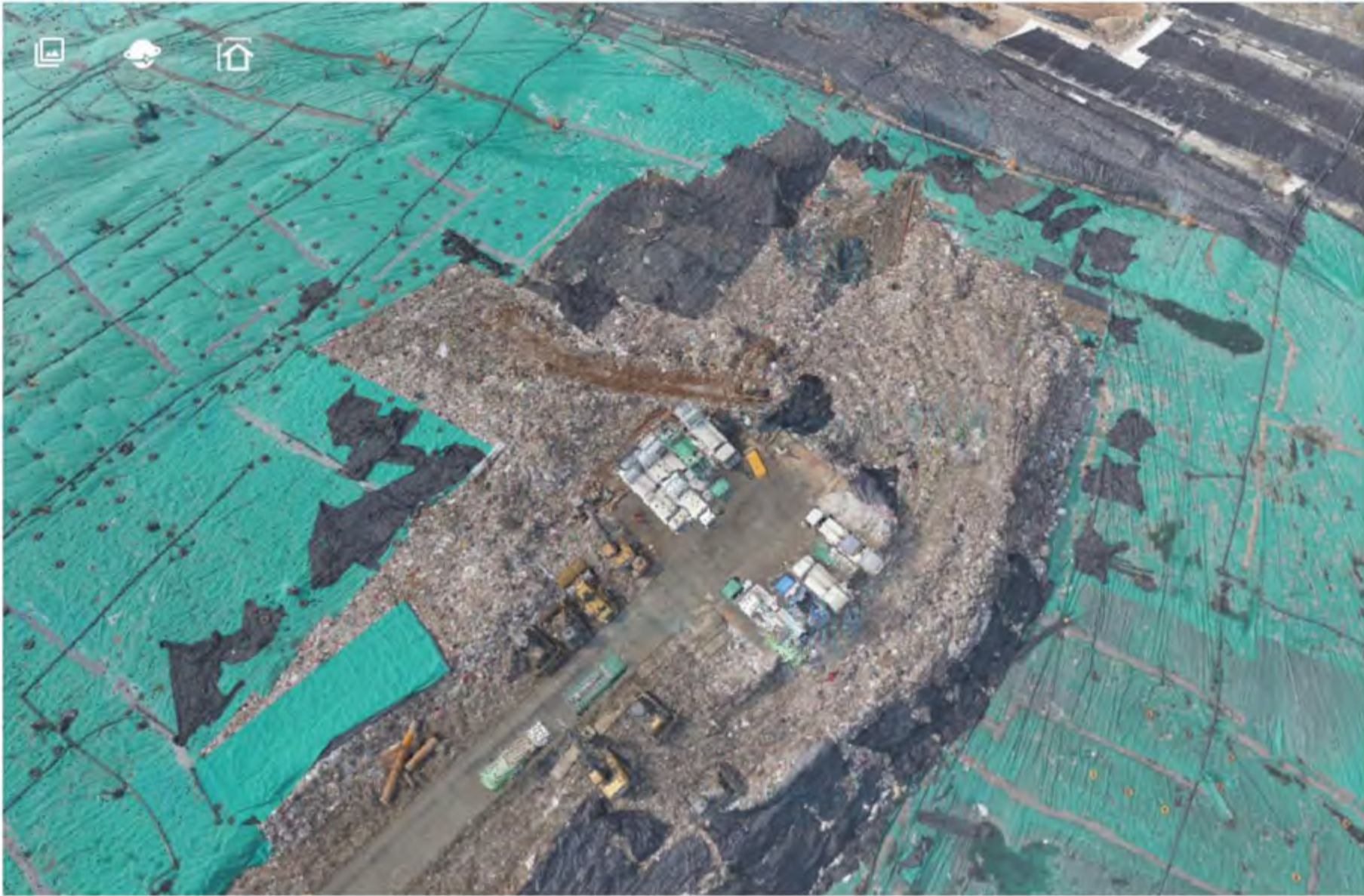


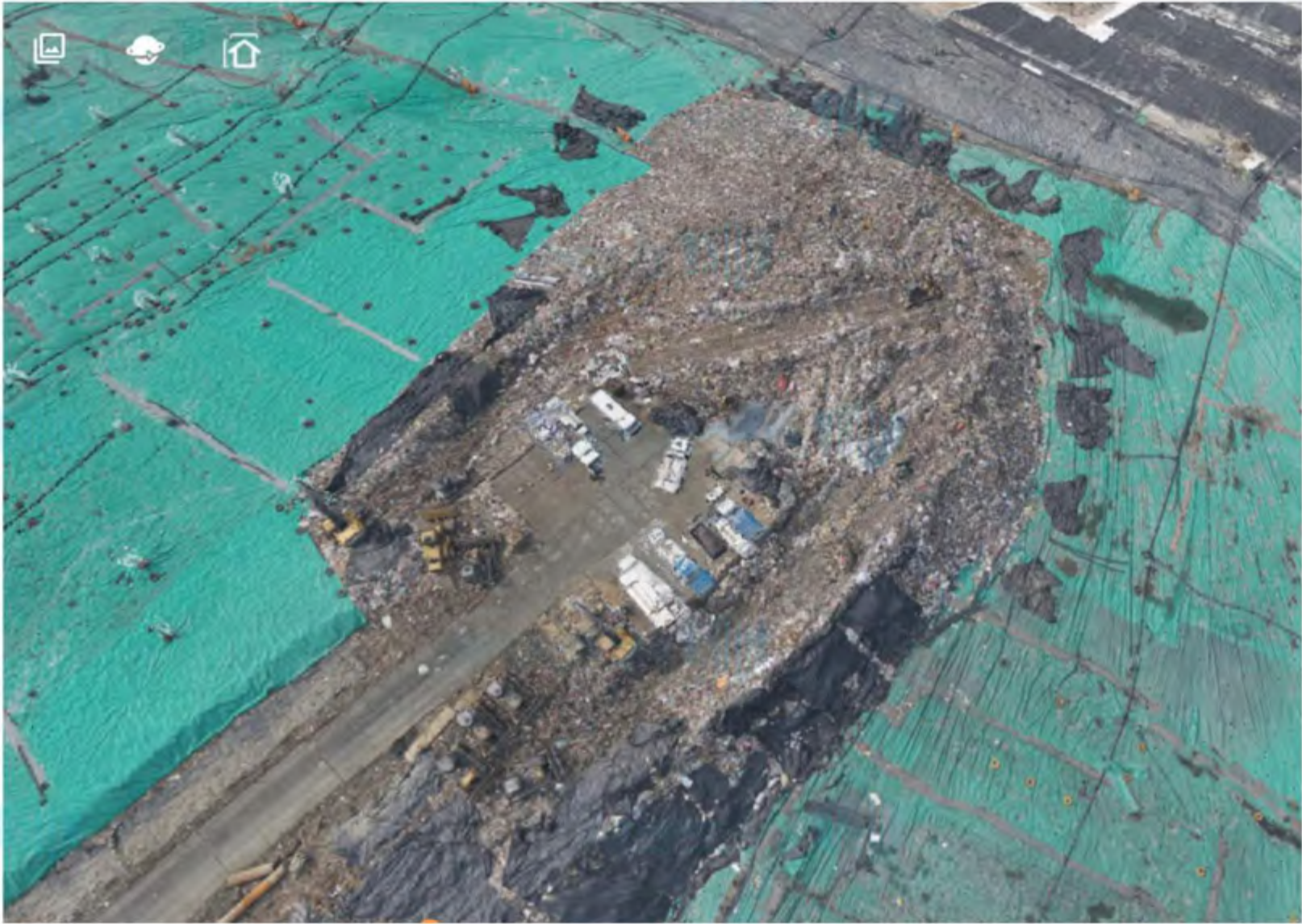
Finding Interference

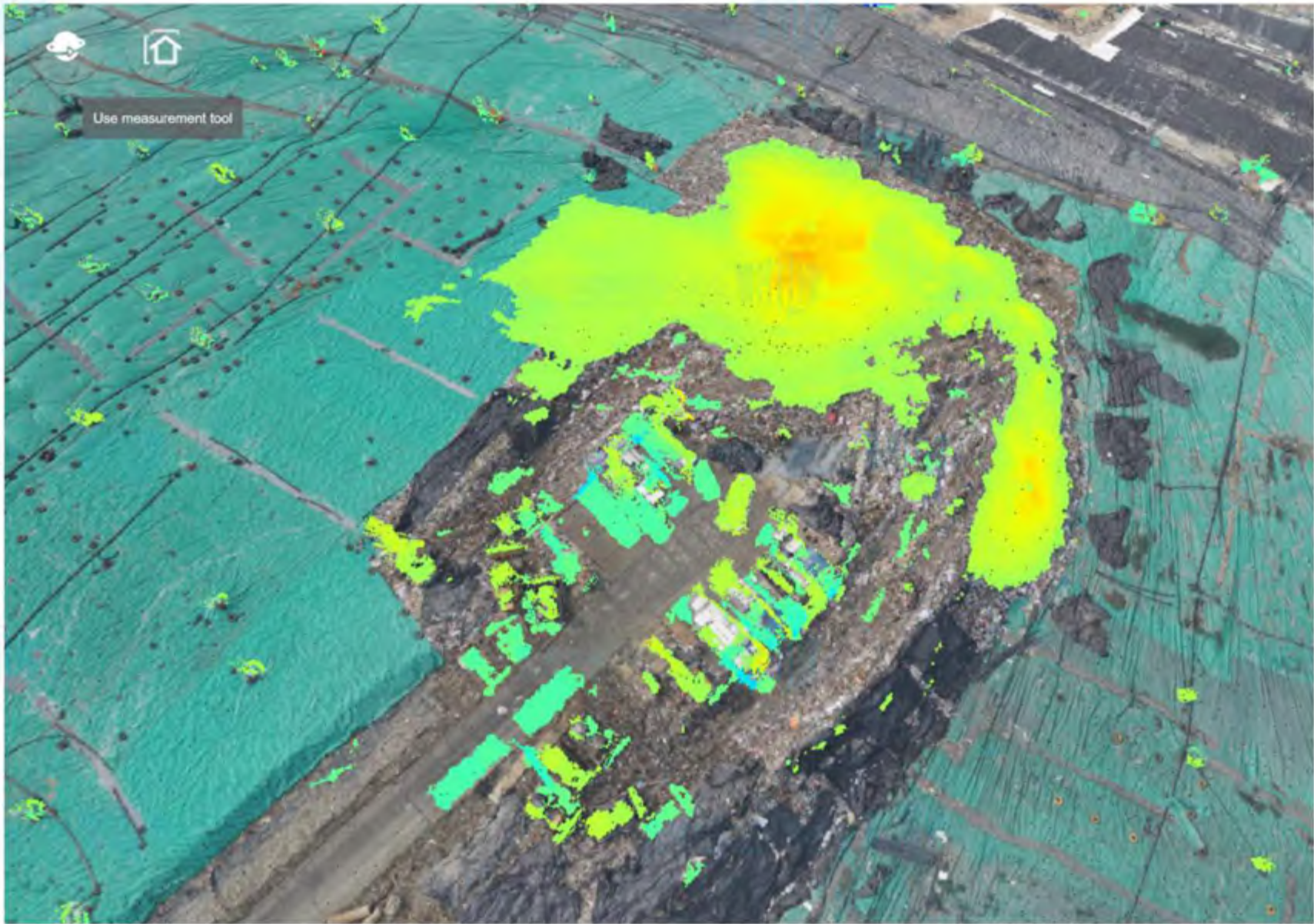


Landfill Fill Rate Estimation











Clobotics

Cloud. Drones. For Your Enterprise.





The problem we are solving

Enterprises are innovating with drones to increase productivity. However, new problems are introduced:



Purchase drones



Find drone operators



Train existing staff

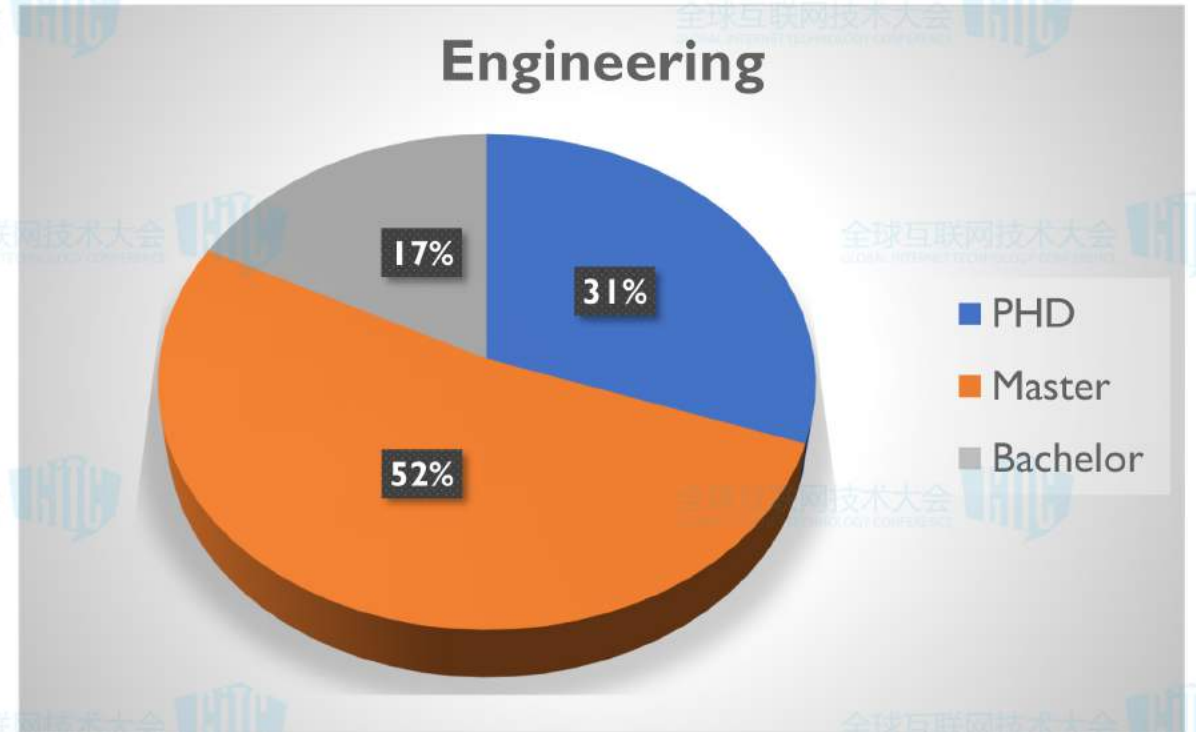


Find data scientists

Clobotics help customers **collect, process, analyze** data using enterprise-ready drones.

Very Experienced Team

- Founder team, and half of company have 10+ years of working experience.
- 1/3 of engineering org are PhDs.



Core Vision IP

Object Recognition

- Neural nets trained with deep learning
- Multi-class object recognition
- Image classification
- Labeling tool and vendor team

3D Reconstruction

- Build 3D models from 2D photos
- Estimate camera poses
- Overlay detailed pictures onto 3D model
- Measure location, lengths, areas, volumes, to cm level accuracy

Questions?

Email: info@clobotics.com

Website: www.clobotics.com



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