Unmanned Aerial System LiDAR Survey Of Two Breakwaters In The Hawaiian Islands

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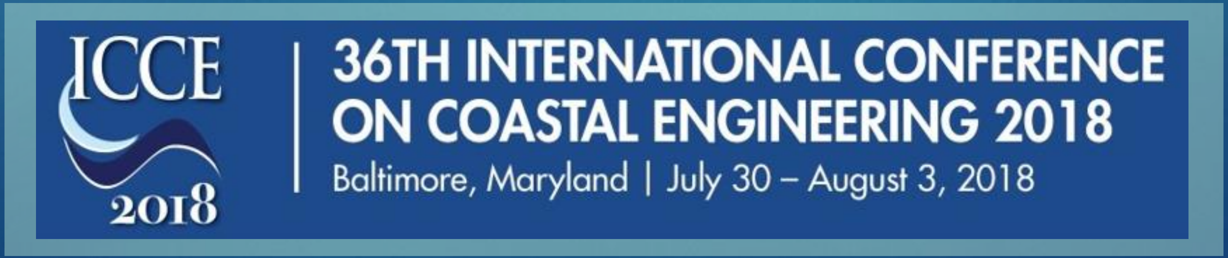

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MOTIVATION FOR THIS WORK

- The US Army Corps of Engineers maintains 926 deep and shallow draft harbors in the U.S. and its territories, supporting the nation's commerce, tourism and recreation
- The Honolulu District is responsible for the operation and maintenance of 26 navigation projects within the State of Hawaii and the U.S. Pacific territories – almost all include breakwaters as navigation features
- The substantial and varied Pacific Ocean wave climate requires Honolulu District to maintain a rigorous inspection program to monitor damage and functionality of its aging navigation infrastructure
- Traditional survey techniques used in the past (topographic survey and aerial imagery) are expensive, time-consuming and not always at the level of detail needed

LIDAR DATA: VARIOUS PLATFORMS FOR VARIOUS PURPOSES

AIRBORNE LIDAR	TERRESTRIAL LIDAR	UAV/DRONE LIDAR
Expensive	Less expensive	Less expensive
Suited for large areas	Suited for small areas	Suited for small to medium areas
Accuracy ~ 15cm Density ~ 20 pts/m^2	Accuracy ~ 1-2 cm Density ~ 5000 pts/m^2	Accuracy ~ 2-3 cm Density ~ 1000 pts/m^2
Requires an aircraft and takes days/weeks	Time for survey dependent on number of setup locations/required density (~ days)	Can cover a large area quickly (< 1 day)
Produces georectified imagery (RGB/hyperspectral)	Ground based imagery only (no aerial view)	Aerial imagery/video (can be georectified)

USACE UNMANNED AERIAL SYSTEM FOR LIDAR

USACE Cold Regions Research and Engineering Lab, Remote Sensing and GIS Center of Expertise

- Riegl RiCOPTER
- Riegl VUX-1UAV laser scanner
- Trimble R10 GNSS system for survey control
- Applanix AP20 IMU
- Sony Alpha 6000 digital camera (x2)
- UAV platform
- flight planning and data acquisition software

- Range ~ 1km
- 2-3 people to operate
- Pulse Repetition Rate = 820 kHz
- Scanner wavelength = 1550 nm
- Air Speed = 8 m/s
- Swath Width = 60m

- Requires coordination with Army Aviation Engineering Directorate (within DoD) and Federal Aviation Administration to assess safety risks and airspace requirements

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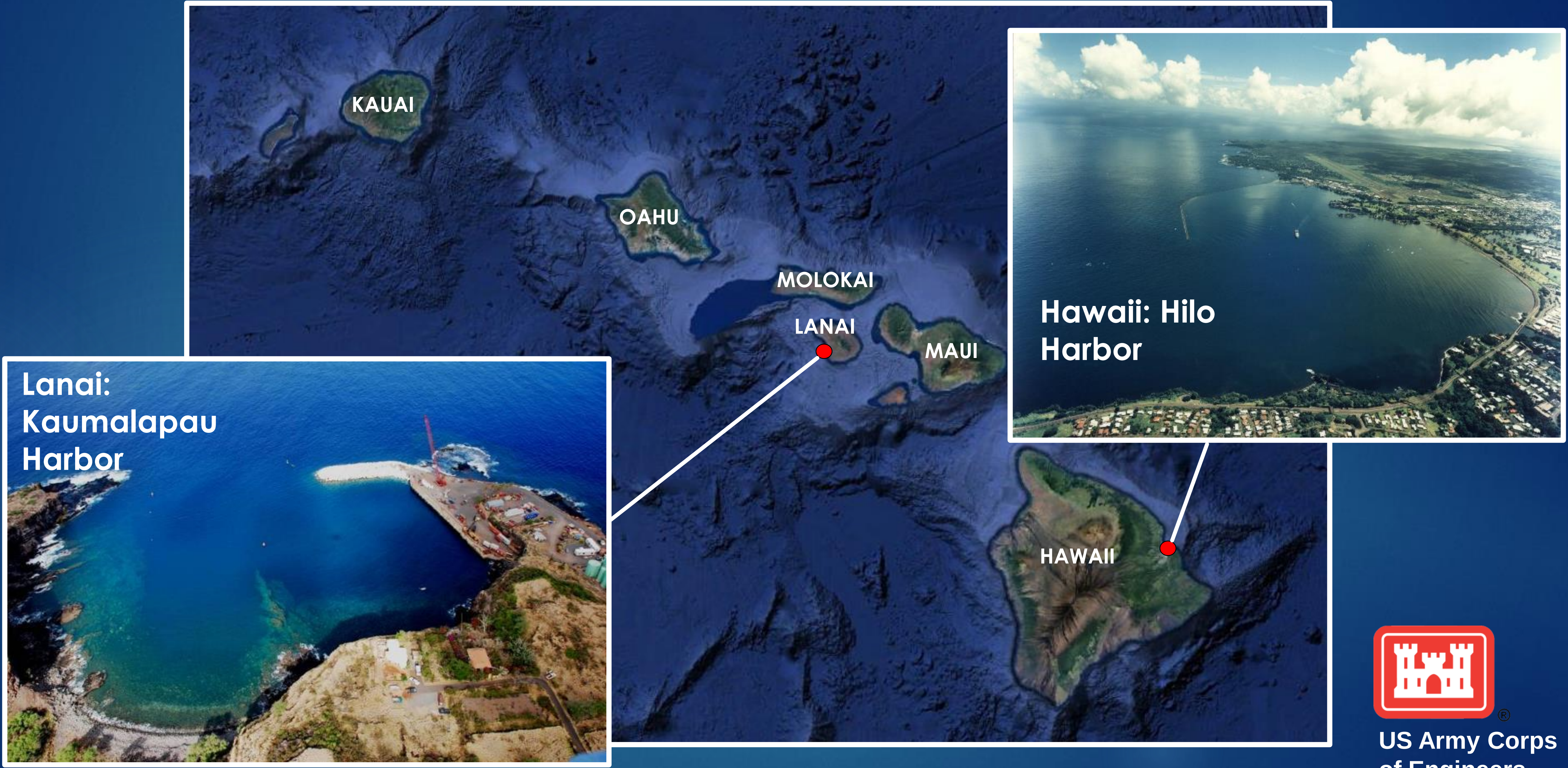
HONOLULU DISTRICT NAVIGATION PROJECTS: HILO HARBOR AND KAUMALAPAU HARBOR



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HONOLULU DISTRICT NAVIGATION PROJECTS: HILO HARBOR AND KAUMALAPAU HARBOR

Hilo Breakwater

Kaumalapau Breakwater

HILO BREAKWATER:

- LONG (3+ kilometers)
- ARMOR LAYER IS PRIMARILY ROCK (up to 7.3 m-ton)
- HIGH TRAFFIC HARBOR
- EXPOSED TO CONSISTENT SWELL AND WIND WAVES
- SHALLOW TOE ON REEF
- EXPERIENCING DAMAGE (originally built 1910-1930)

KAUMALAPAU BREAKWATER:

- SHORT (~ 67m length)
- ARMOR LAYER IS CONCRETE ARMOR UNIT (up to 31.75 m-ton)
- LOW TRAFFIC HARBOR
- PROTECTED DURING TYPICAL CONDITIONS
- DEEP TOE ON SAND/ROCK
- MINIMAL DAMAGE (completed in 2007)

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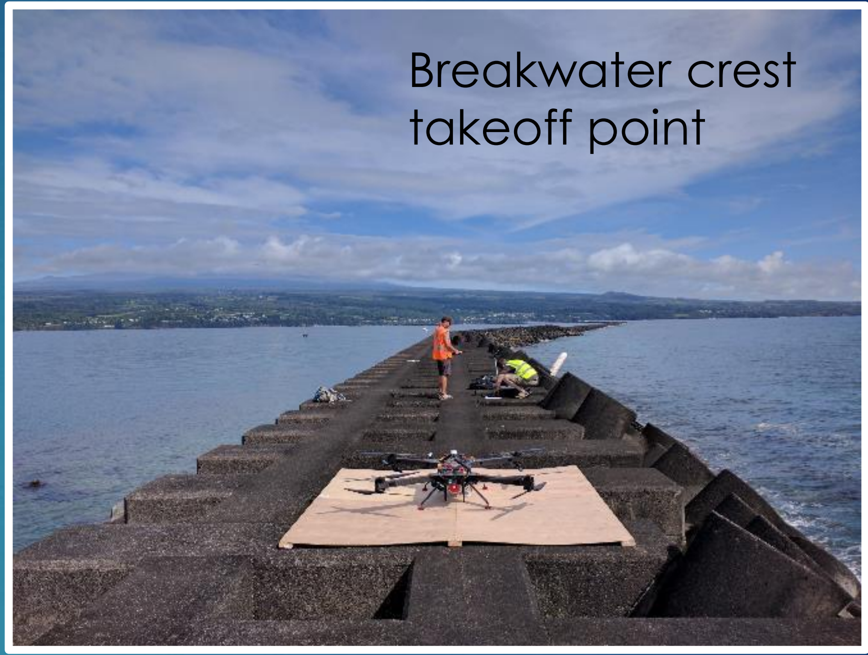
HILO HARBOR LIDAR SURVEY LOGISTICS

- Completed June 7-8, 2018
- Takeoff from Hilo Pier 1 and breakwater crest
- Vessel used to transport UAV to outer crest takeoff point



- 3 flights required to cover breakwater (20-30 min each)
- Maximum range reached 1.2 km from operator
- Some afternoon wind challenges (>8 m/s)

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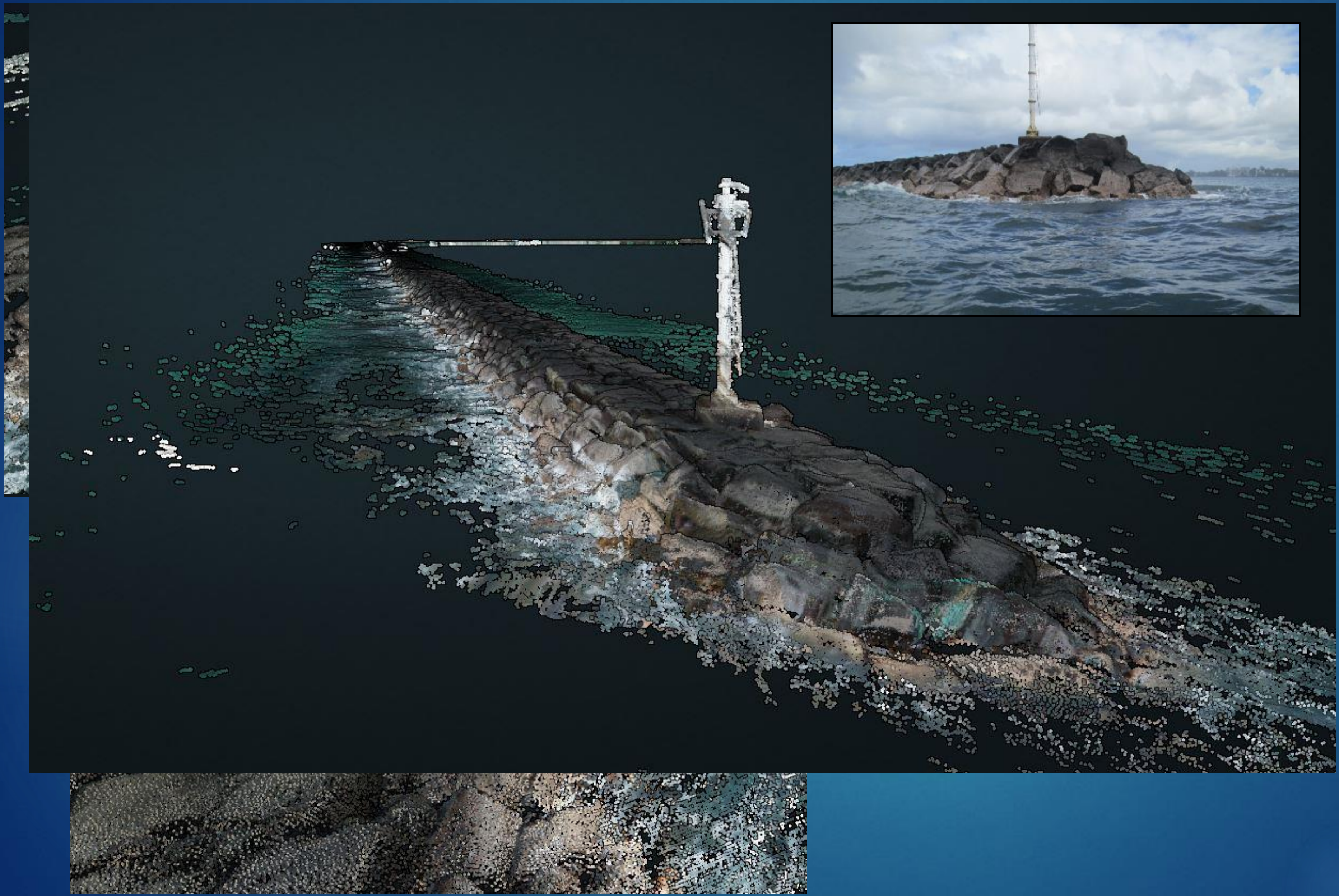
HILO HARBOR LIDAR SURVEY DATA



- 70.9 million data points
- ~600 points/m^2
- 2-3 cm accuracy

- Complete subaerial coverage
- Visible ocean side armor layer separation and possible toe instabilities
- Head damage

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HILO HARBOR LIDAR SURVEY DATA

- Poor armor stone contact with adjacent stones
- Concrete rib cap
- Tribar armor units

Potential uses for this data:

- Verify and identify damage
- Guide divers for underwater inspections
- Use to develop repair construction plans

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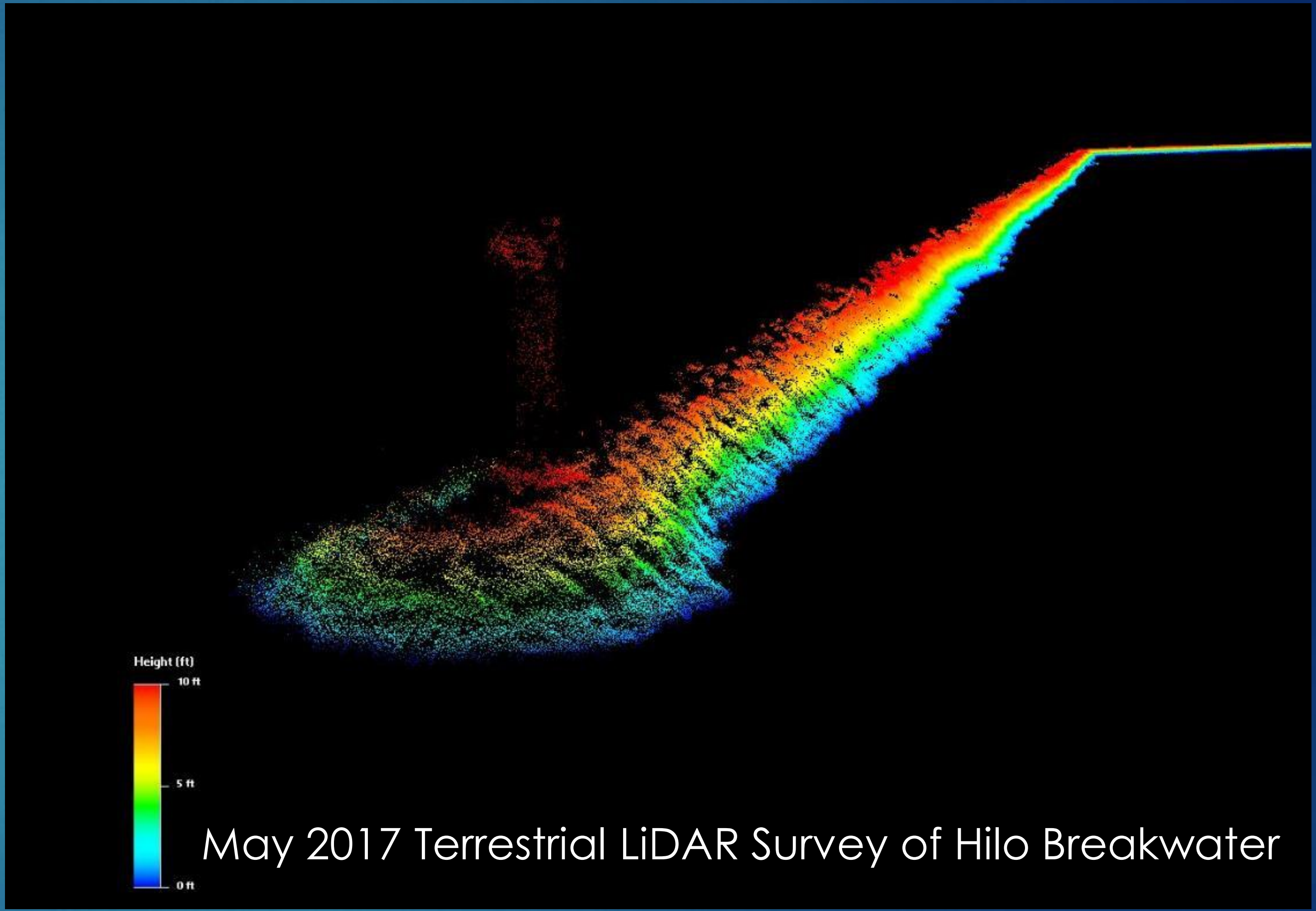
COMPARISON WITH PREVIOUS TLS OF HILO BREAKWATER

- UAV was able to get coverage of oceanside and crest
- Higher density point cloud
- Reduced collection time
- Video and imagery from UAV

- Limited bathymetric data
- Still required a vessel due to breakwater length
- More clearances required for UAV than TLS



May 2017 Terrestrial LiDAR Survey of Hilo Breakwater

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KAUMALAPAU HARBOR LIDAR SURVEY LOGISTICS

- Completed June 9, 2018
- Takeoff from Kaumalapau Barge Pier
- Single flight with multiple passes in a pre-set grid pattern
- 34 minutes total flight time

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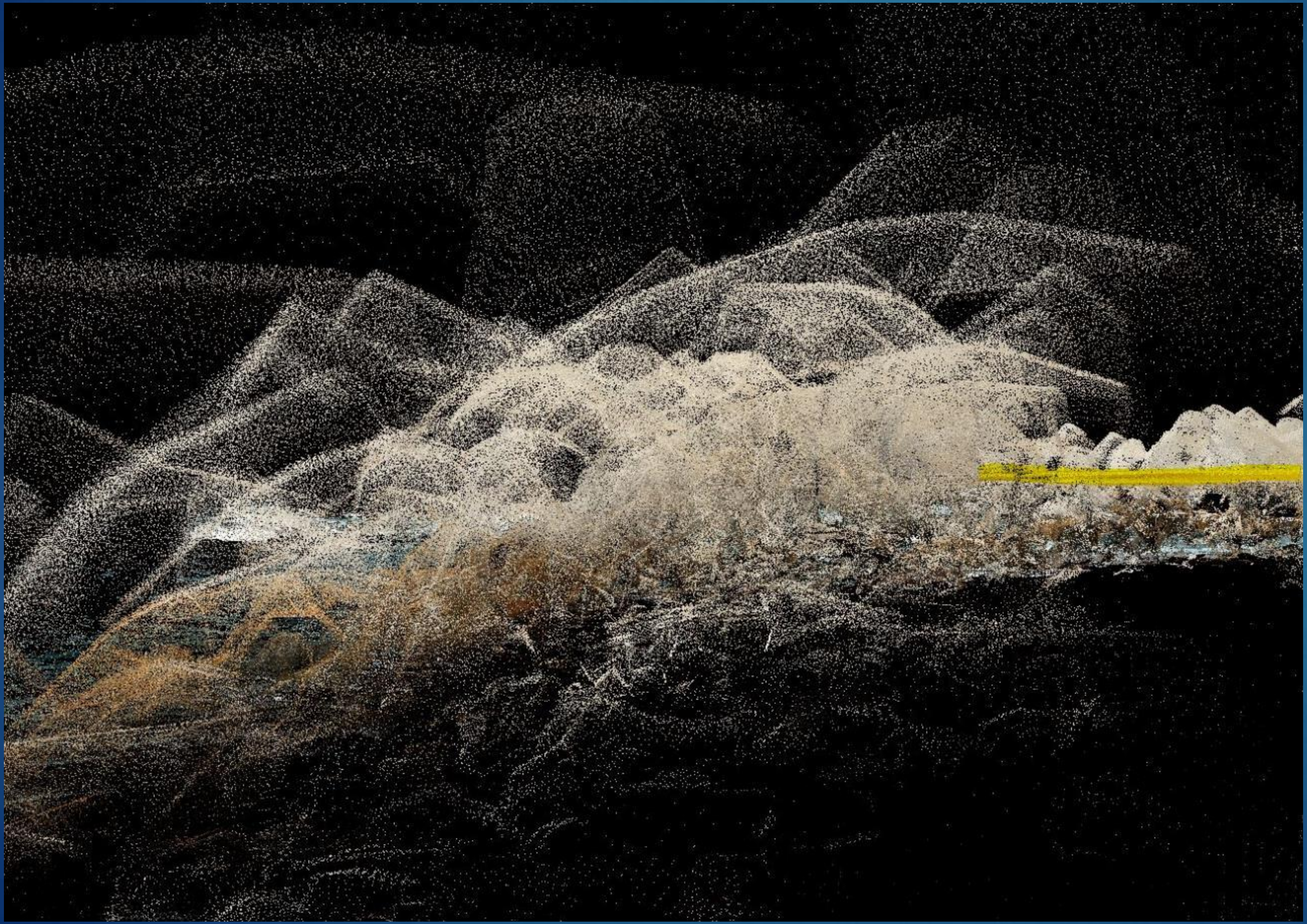
KAUMALAPAU HARBOR LIDAR SURVEY DATA



- 13 million data points
- ~3000 points/m^2
- 2-3 cm accuracy

- Complete subaerial coverage
- Detailed armor unit characterization
- Visible stone underlayer

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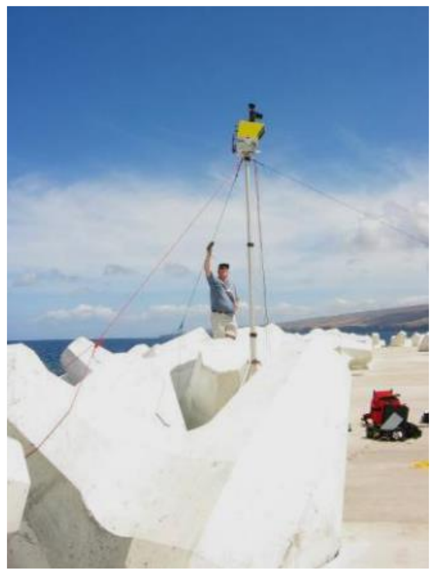
COMPARISON WITH PREVIOUS TLS OF KAUMALAPAU BREAKWATER

- UAV was able to get better coverage of oceanside
  Significantly less collection time
- Less risk to survey team

- No wind effects on accuracy
- No reflected intensity issue

- Density of TLS was much higher (~10,000 points/m^2)



Survey Date	# of setup locations	# of scans	Data points
June 2007	7	115	66 million
July 2008	17	312	128 million

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CONCLUSIONS

- Survey time with UAV is faster with density/accuracy comparable to TLS methods using both vessel and multiple static setups
- UAV acquired better coverage of oceanside of breakwaters (due to access issues during large waves or shadowing of TLS setup)
- UAV LiDAR captured details of both rock and concrete armor unit structures very well
- Very long structures may require vessel access and/or hauling equipment
- Approvals do take time, though hopefully this will become more streamlined in the future
- Overall, application of UAV LiDAR to coastal structures is a good balance of high accuracy and density with ease of deployment, time of survey, and safety

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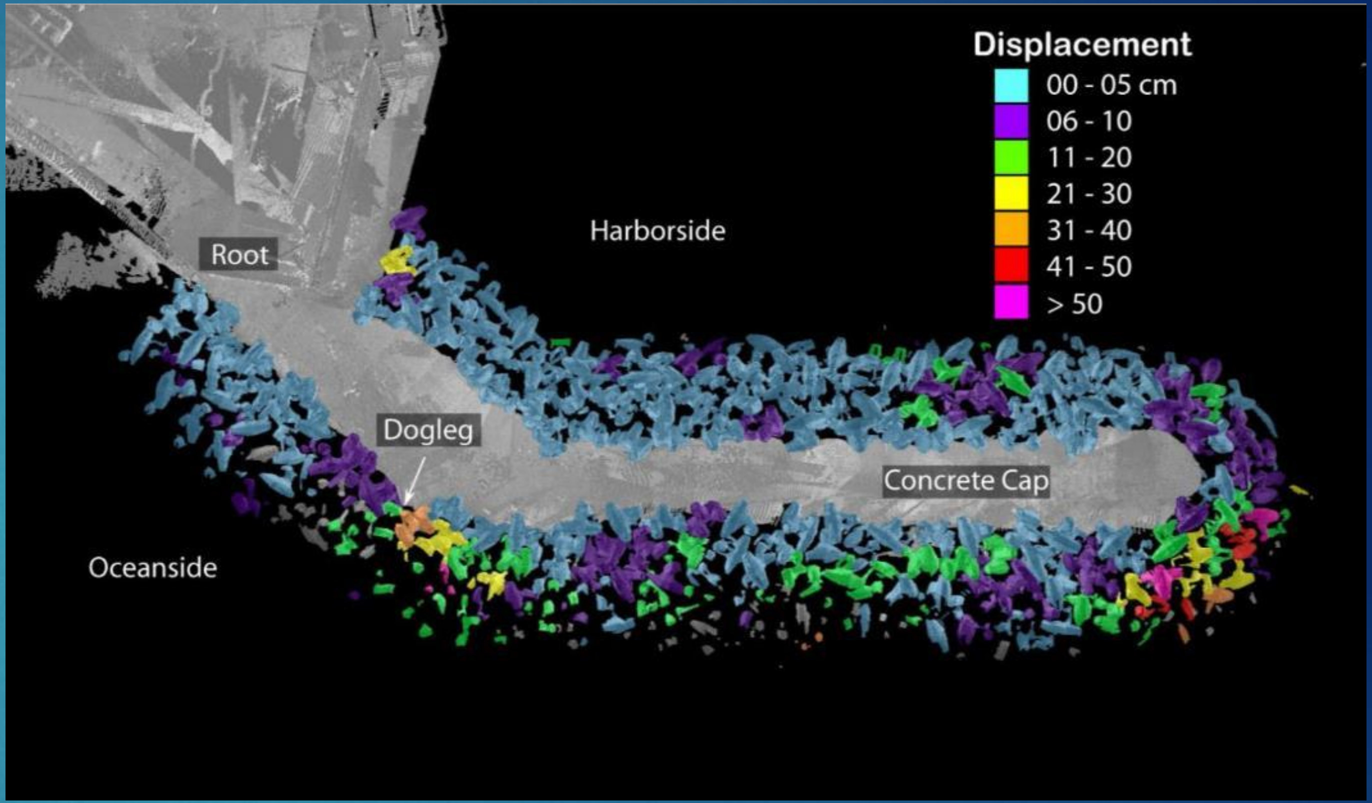
FUTURE WORK

- Continue to test and advance technology on bathymetric LiDAR
- Potentially use UAV to inspect structures that are difficult to access
- Combine LiDAR, bathymetry, imagery, and inspection to improve construction volume estimates and construction drawings
- Utilize for post-storm initial rapid assessment of coastal structures
- Compare armor unit movement at Kaumalapau using 2007, 2008 and 2018 subaerial LiDAR data sets



Podoski, et al., (2010): Post-Construction Monitoring of a Core-Loc Breakwater Using Tripod-Based LiDAR, Coasts, Marine Structures and Breakwaters, Thomas Telford, vol. 2, pp. 448-459.

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ACKNOWLEDGEMENTS

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