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Compact Lightweight Lidar for UAV-based Bathymetric and Topographic Mapping

Areté Associates
Peter Rusello

JALBTCX Workshop

July 20, 2016

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Outline

- Overview
- Program History
- Technology
- Data Collections
- Summary/Future Plans

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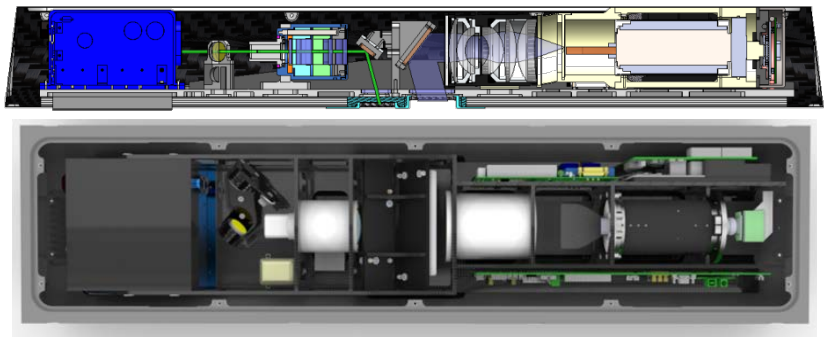
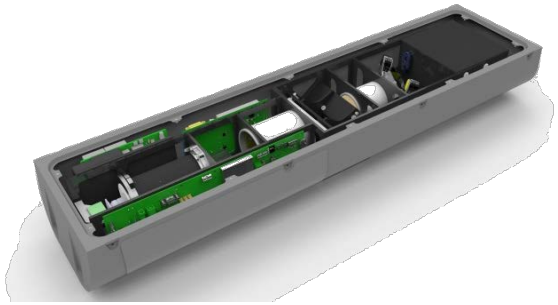
PILLS Overview

- Pushbroom Imaging Lidar for Littoral Surveillance (PILLS)
- SBIR project funded by ONR and NAVAIR
- Goal: Capability of current manned platforms in a configuration compatible for tactical UAV (e.g. RQ-21A Blackjack)
- Several manned data collections in the past 3 years
  - Version 1.0 – 2012 to 2015
  - Version 2.0 – 2015 to present
- Current status: Successful completion of flight tests on SeaHunter UAV in May 2016

28 pounds, 230W



Total Payload 39” x 9” x 4”



Contact: Jeff Mercer, 520-784-1872, jmercer@arete.com

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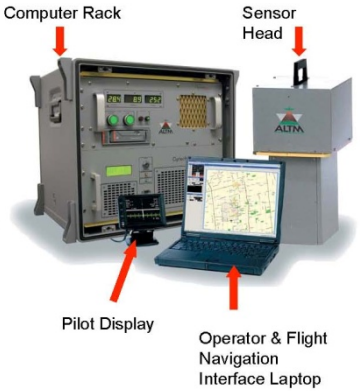
A Compact UAV-based Lidar enables…

- Precision bathymetry, topography, and urban area mapping for a variety of terrestrial and strategic missions

From this…



> 170 lbs
980 W (peak)

To this…

< 30 lbs
< 230 W (peak)

Platform independent, autonomous operation, world-wide access

Navy SBIR 2010.1 - Topic N101-089 - Jan 2010

Objective:

- Design and build an autonomous hydrographic charting, terrain and urban area mapping system that can be accommodated within the payload and operational limitations of a Tier II UAV, with equal or better capabilities to the current manned Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system.

  "data point ground spacing no larger than 4-meters by 4-meters"

Technical Approach:

- Leverage demonstrated pushbroom imaging lidar configuration (no scanner)
- High-efficiency air-cooled solid state laser technology (no chiller)
- Proven real-time processing architectures to fit within UAV SWAP

Key Components to Achieve small SWAP

- Laser: Areté made *Air-cooled* diode-pumped solid-state laser based on existing 1.5μ Target Identification-Designation (TID) laser
  - Replace OPO with doubler (532nm)
  - 20-50Hz (30Hz nominal), 30mJ/pulse, < 3nsec FWHM
- Streak Tube Imaging Lidar (more sensitive than alternative sensors)
  - Beam Diverger
    - 50° divergence (cross-track), 3.5 mrad (along-track)
  - Receiver:
    - Hamamatsu streak tube
    - 1900 x 1200 CMOS imager (PointGrey)
- Geolocation via NovAtel GPS and Systron Donner MMQ
  - Will be upgraded to Applanix APX-15 later this year

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Mine Counter Measure Production Systems

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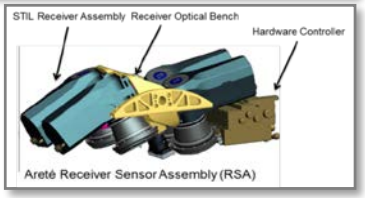
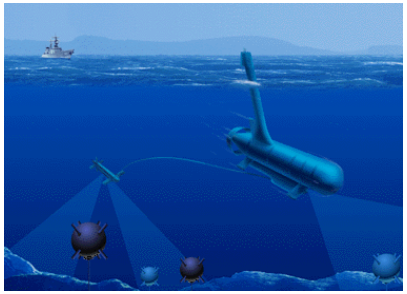
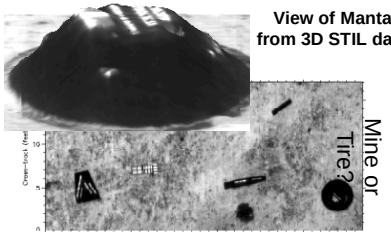
Airborne Laser Mine Detection System
- Detection and classification of surface and near-surface mines
- Status: **17** systems delivered and in use, **8** systems in fabrication



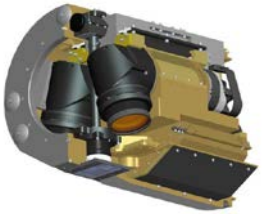
Electro-Optic Identification (EOID) for AQS-20 towed minehunting system
- Identification of bottom mines
- Status: **30** systems delivered and in use, **10** systems in fabrication





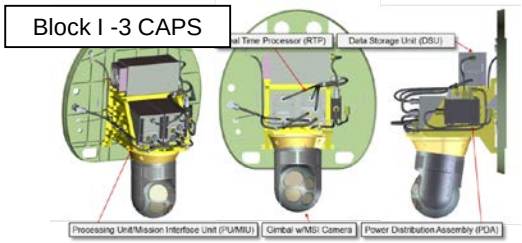
View of Manta from 3D STIL data

STIL Bottom contrast Image (45' depth)



Coastal Battlefield Reconnaissance and Analysis System (COBRA)
- Prime sensor contractor
- Delivered **2** systems, **1** in fabrication

Block I -3 CAPS



Areté has produced and delivered >45 green ocean lidar systems for the US Navy

PILLS Development Timeline

Milestone	TRL	Note	Date	Sponsor
Prelim Design Review	3	Meets requirements	Nov-10	Phase I (ONR)
Critical Design Review V1.0	3	Meets requirements	Jan-12	Phase II (ONR)
Lab Integration and Test	4	Meets radiometric requirements	Dec-12	(ONR)
Manned Flight Test #1	5	Arizona (Topography)	May-13	(ONR)
Manned Flight Test #2	6	Florida (Bathymetry)	Jun-13	(ONR)
PILLS + IRIS Currents Demo	7-M	Colorado River; measured discharge	Jun-14	IR&D (Areté)
Redesign PILLS V2.0	7-M	Update hardware for UAV operations	Aug-15	Phase II.5 (ONR/NAVAIR)
Manned Flight Test #3	7-M	San Diego (Bathymetry)	Sept-15	(ONR/NAVAIR)
UAV Flight Test #1	6-U	Alabama; SeaHunter integration test	Mar-16	(ONR/NAVAIR)
UAV Flight Test #2	7-U	Vandenberg (Bathymetry)	May-16	(ONR/NAVAIR)

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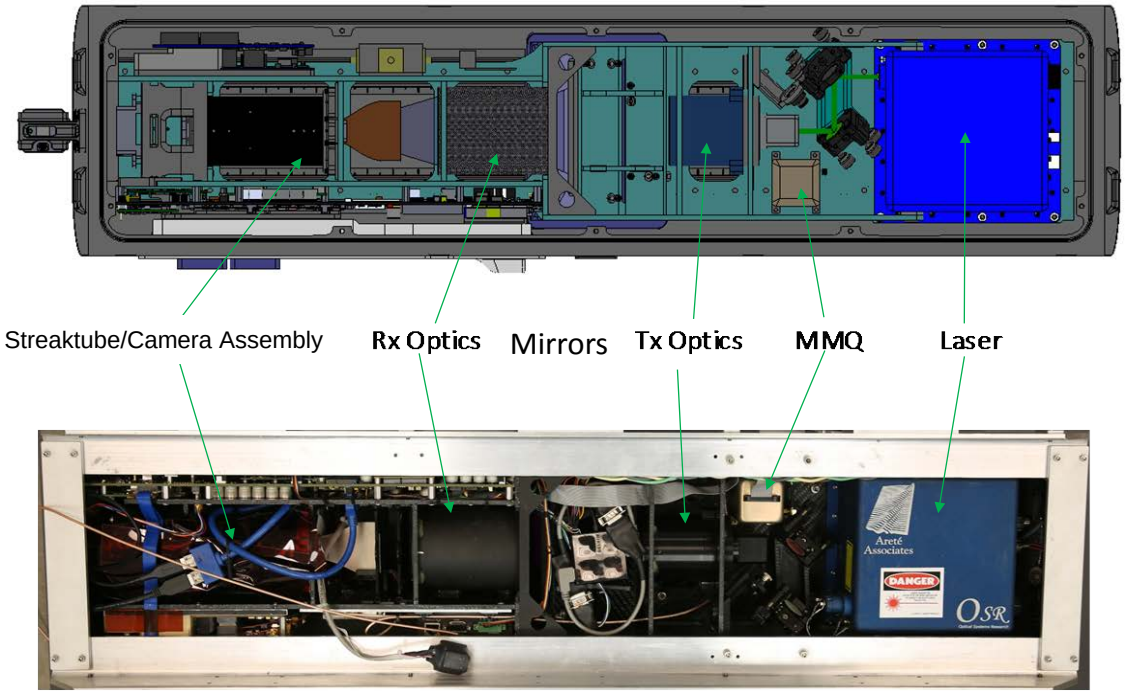
PILLS 2.0 Configuration



PILLS 2.0 has Carbon Fiber and Other Low Weight Components
Radio Comms total weight ~ 28 lbs

PILLS Performance Objectives

Characteristic	Spec	Notes
Platform	RQ-21A Blackjack (UAV)	Roll-on/Roll-off capability for manned aircraft
Nominal Speed	55-90 kts	
Nominal Altitude	1000 ft	
Power	230 W	
Weight	28 pounds	
Size	39” x 9” x 4”	0.8 cubic feet
System Cooling	Ambient Air	
Maximum Depth	3 K_d	30mJ/pulse, 36mm aperture
Horizontal Sampling	1m x 1m	Cross-track fixed, Along-track scales with ground speed
Horizontal Accuracy	<2.0m, 1 sigma	MMQ/NovAtel post-processing
Vertical Accuracy	25 cm, 1 sigma	APX-15 upgrade later this year
Processing	Post-processing	Real-time point cloud implementation later this year

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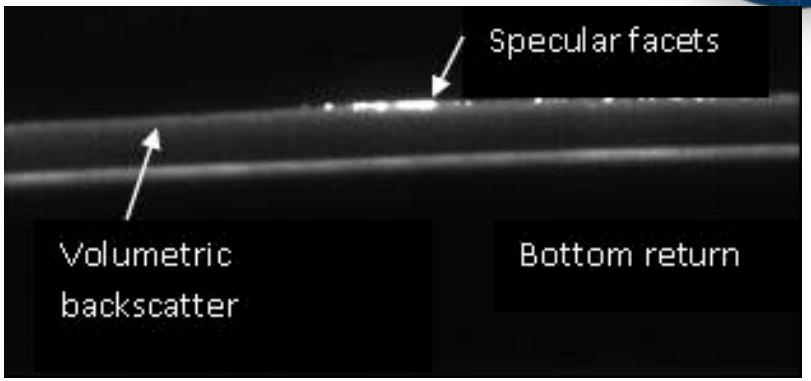
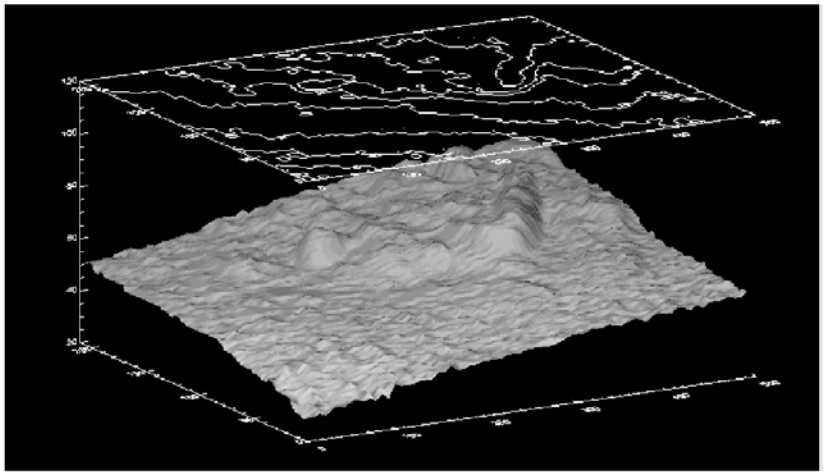
PILLS Design Approach

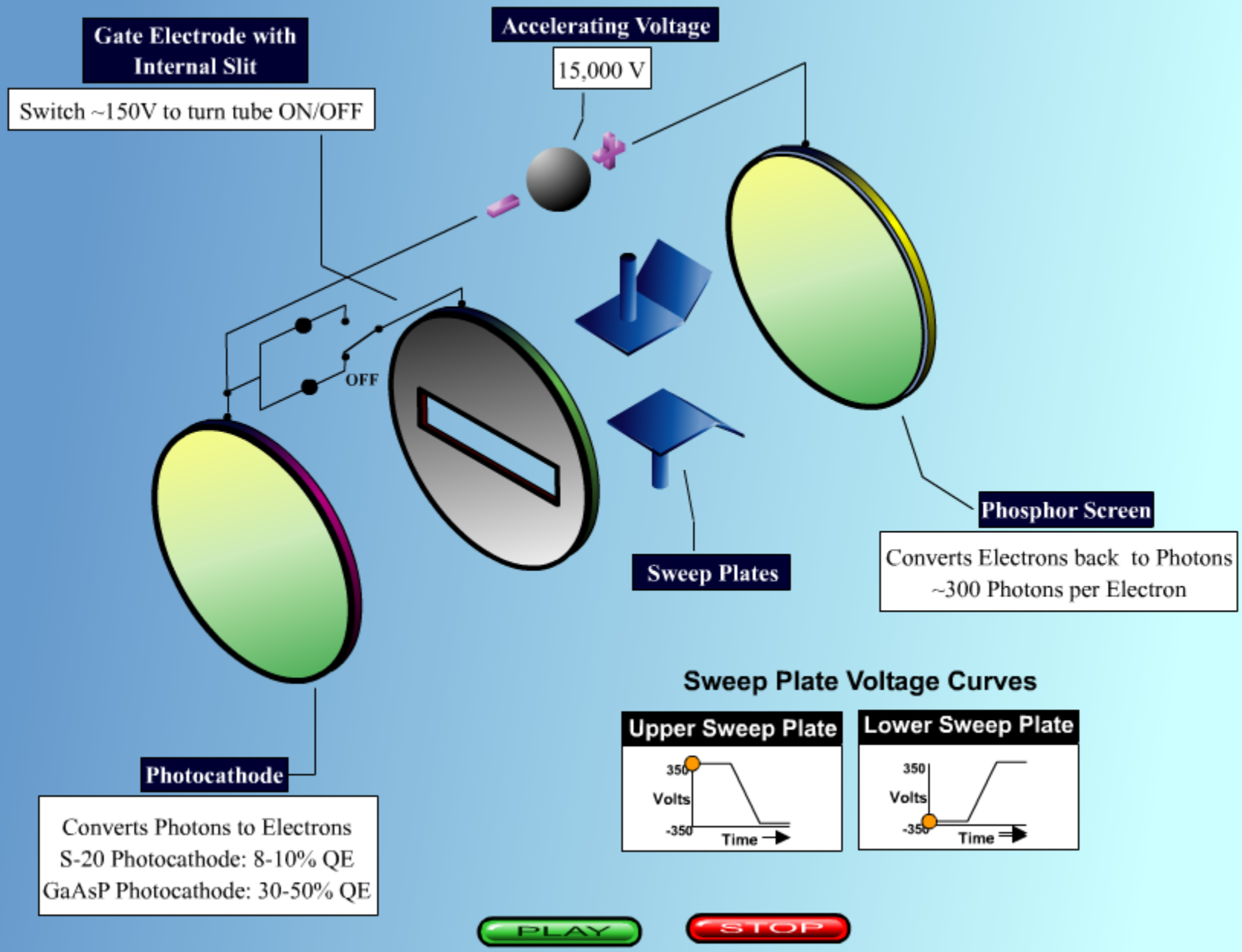


Single Pulse Range-Azimuth Image



3D Map Constructed from Multiple Pulses

Areté Streak Tube Animation



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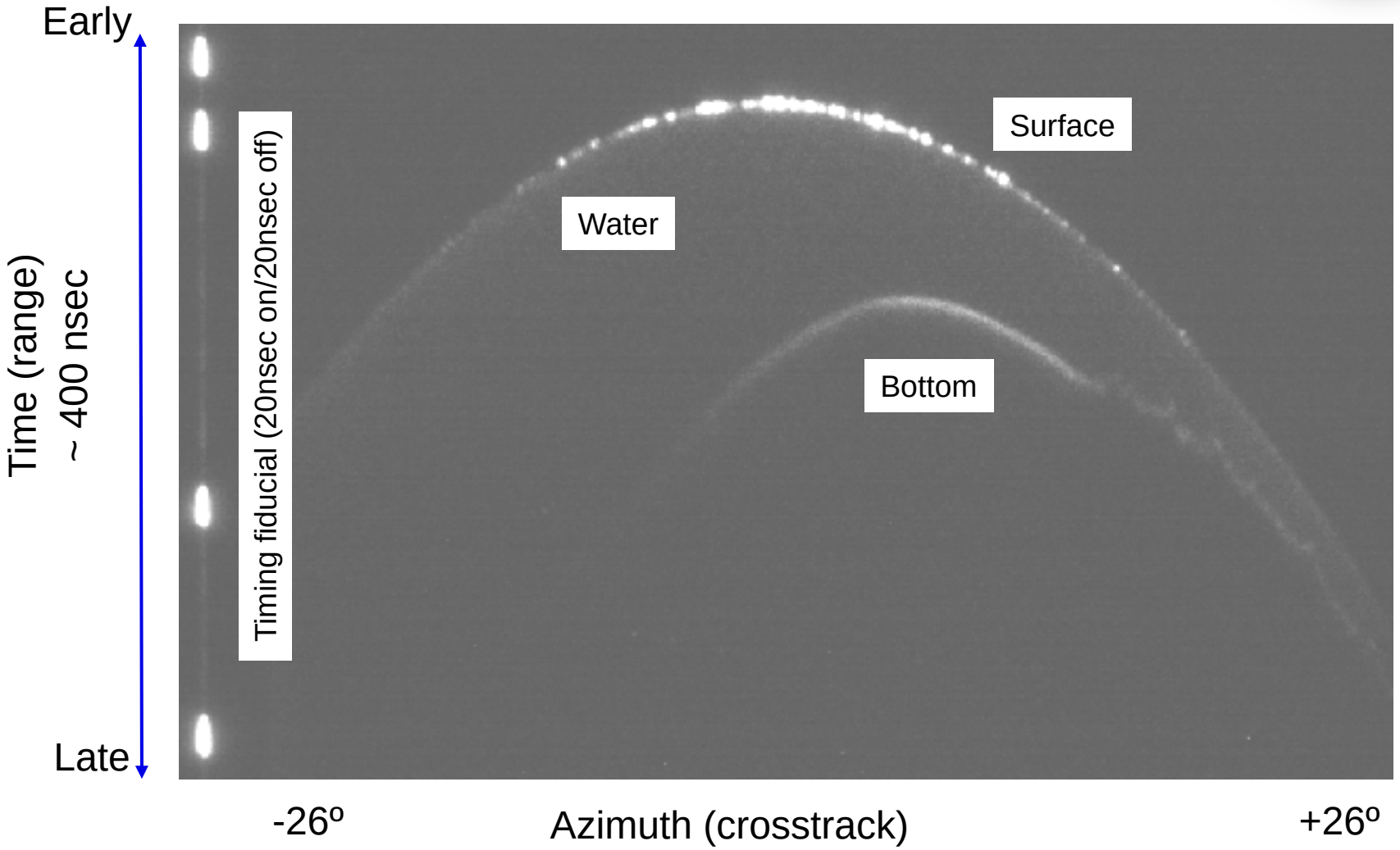
PILLS Raw Waveform



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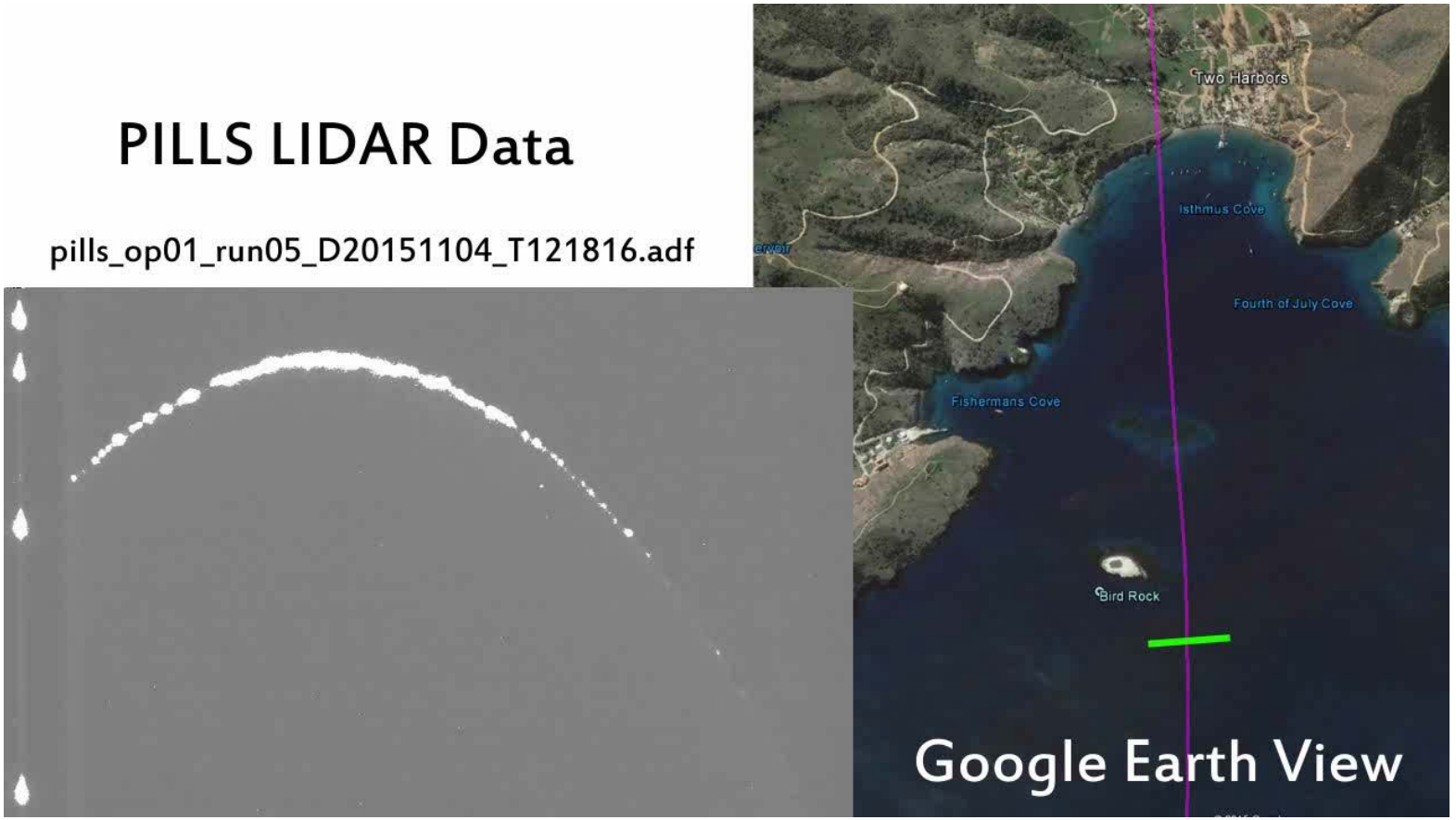
PILLS Nov 2015 Data Collections

- PILLS 2.0 – manned flights over Catalina Island in Nov 2015
  - Movie with raw data example:



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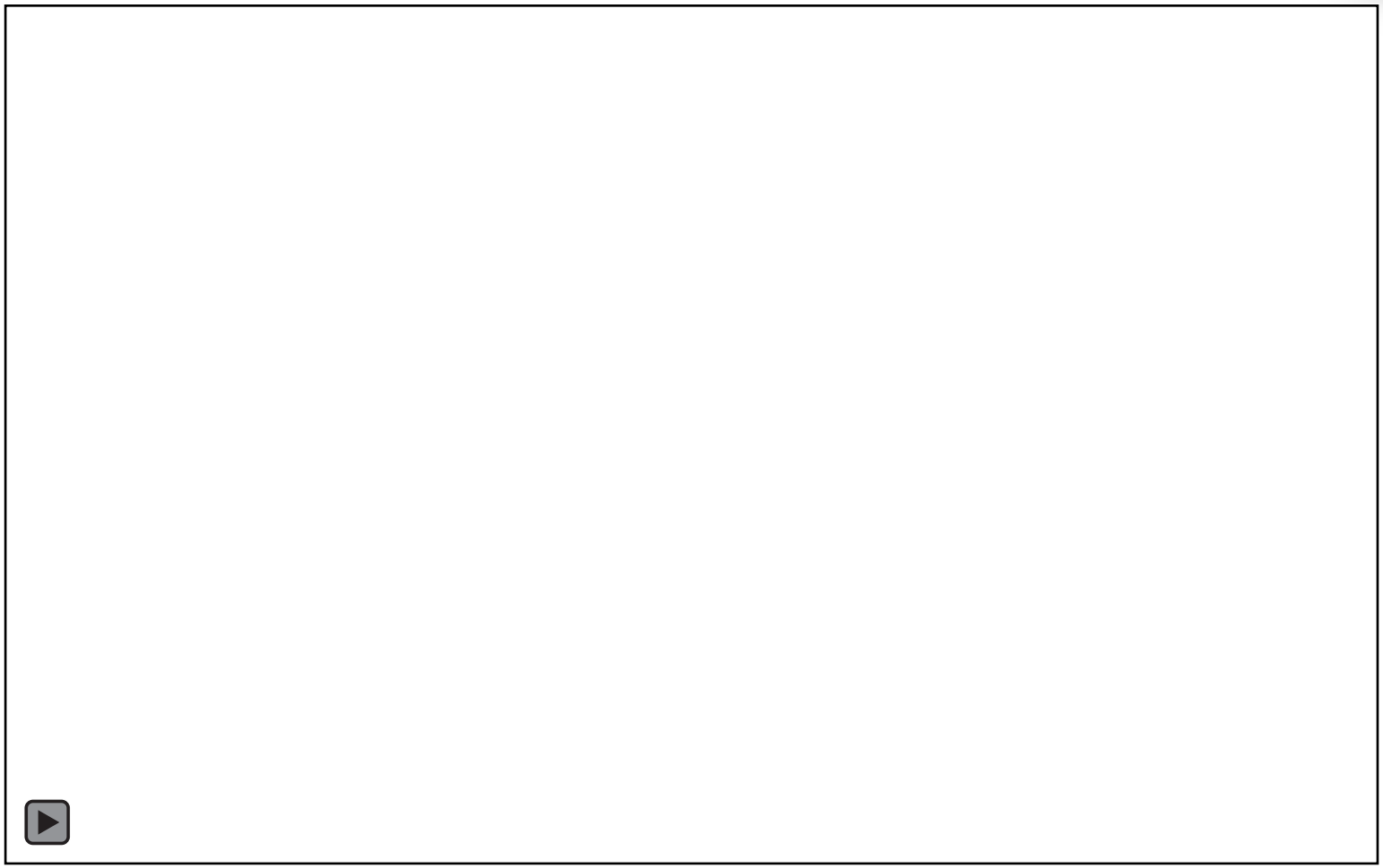
PILLS 2.0 Data Example – November 2015 - Isthmus Cove



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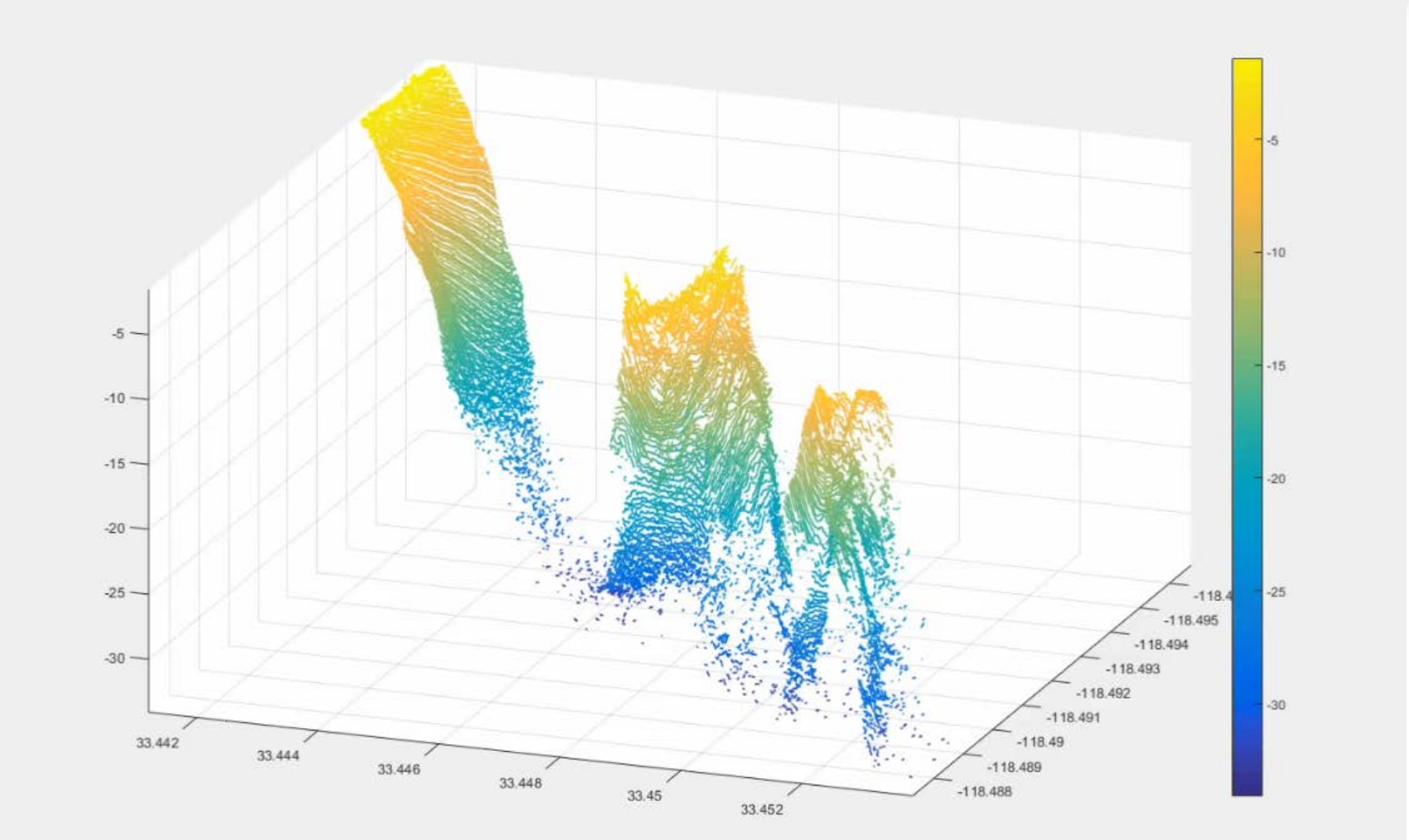
PILLS 2.0 Data Example – November 2015 - Isthmus Cove



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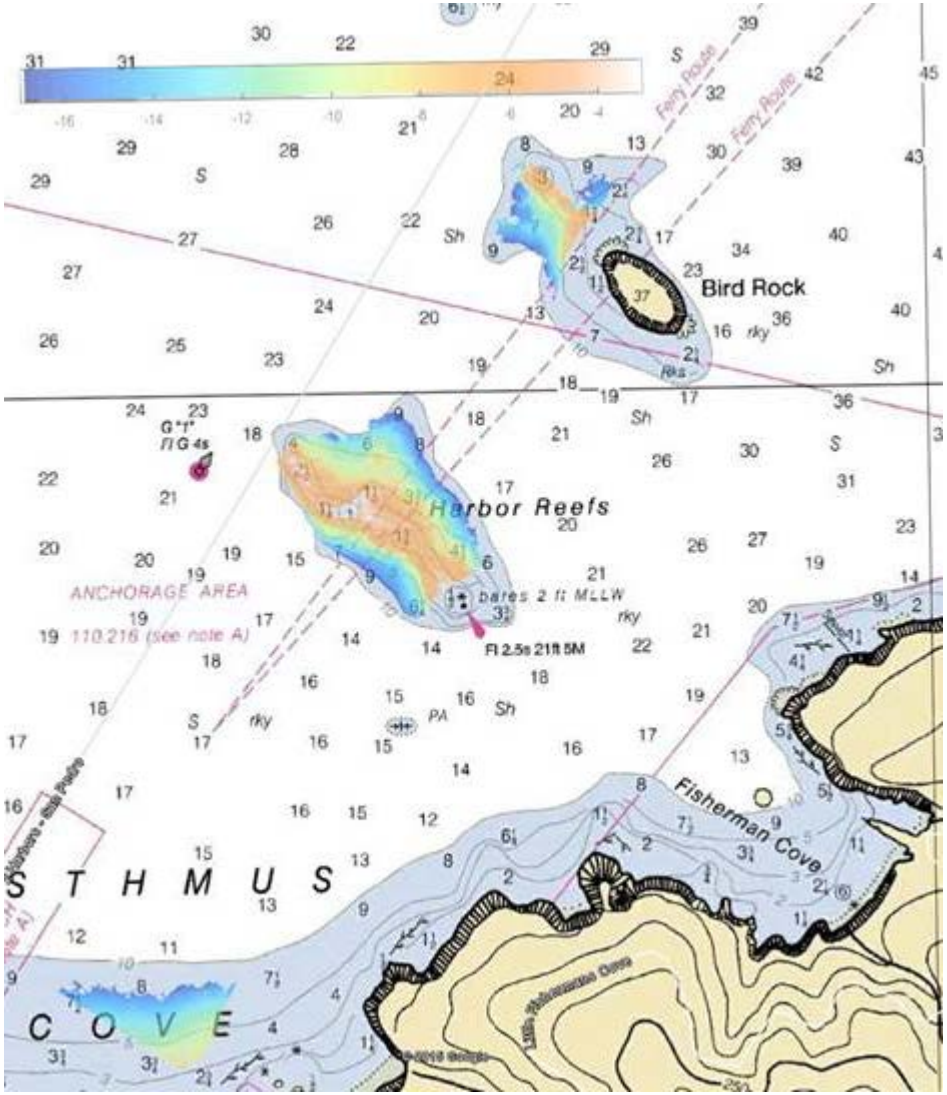
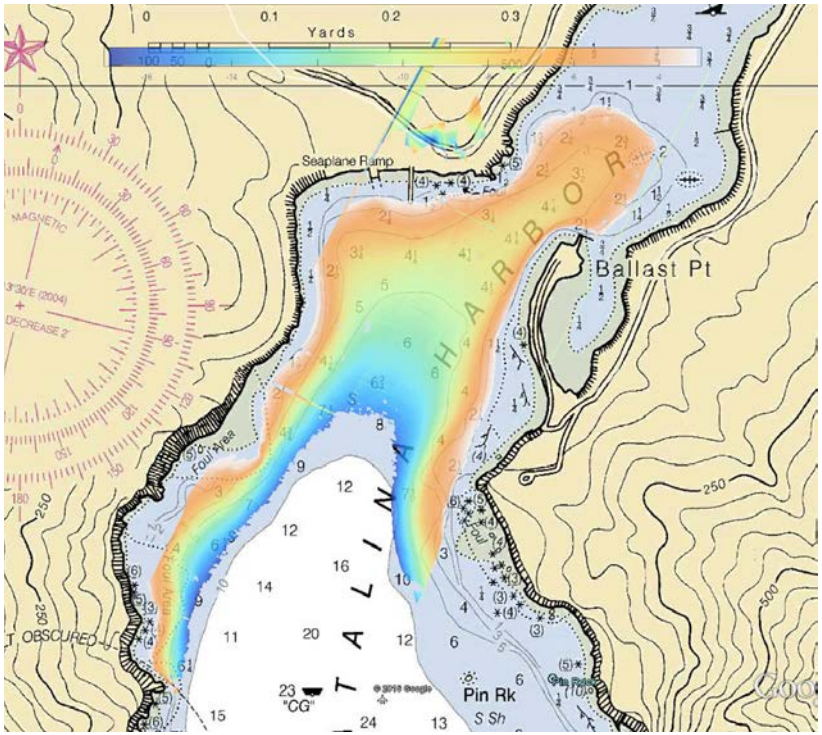
PILLS 2.0 November 2015
Catalina Island





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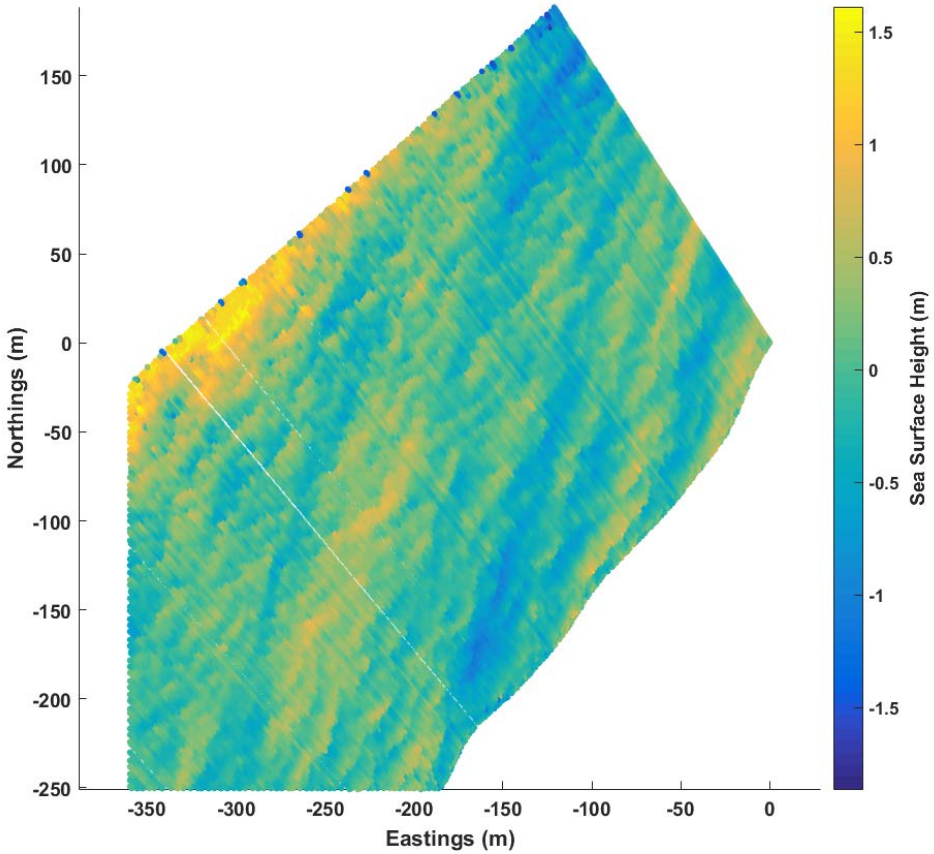
PILLS Surface Waves Example



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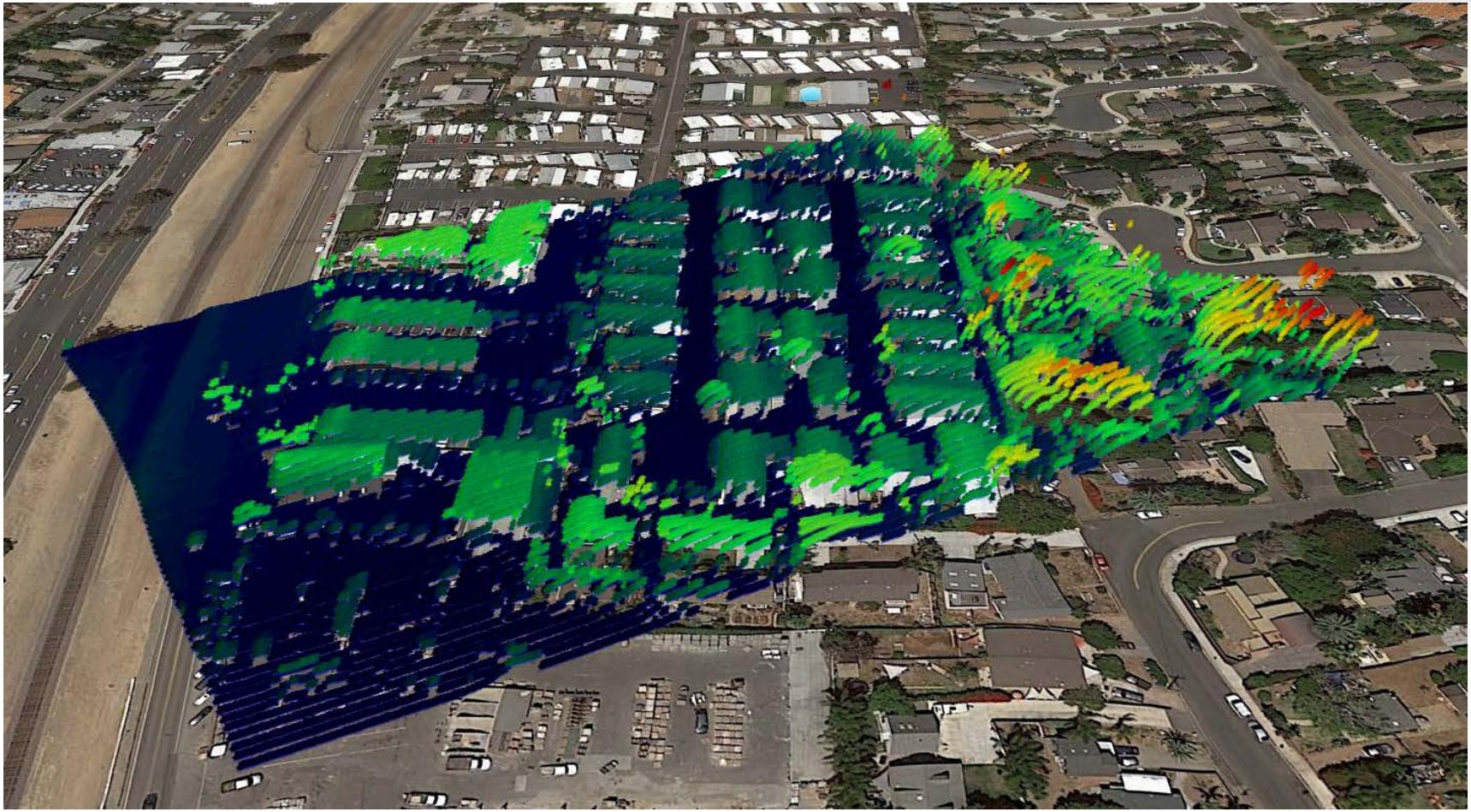
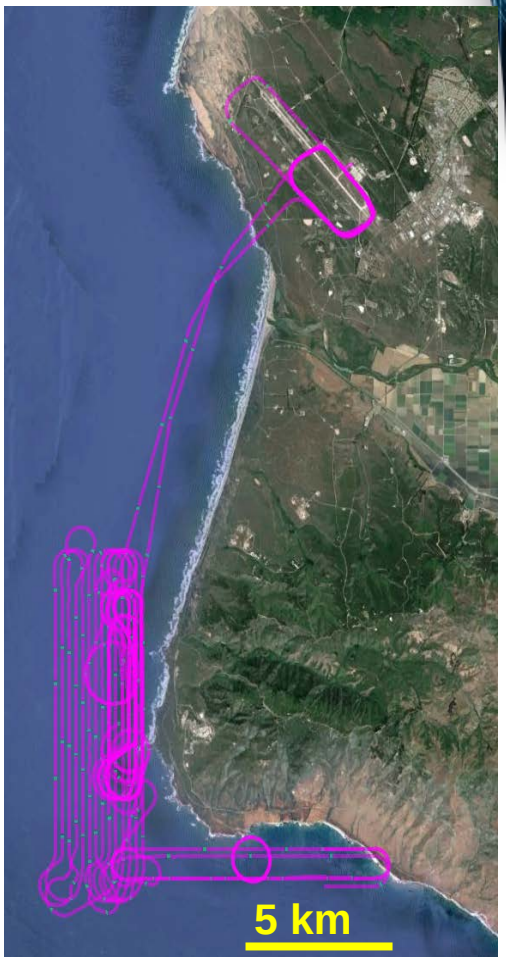
PILLS Topo Example



Vandenberg Data Collections

- Three successful flights on SeaHunter UAV in May 2016
- Strong surface returns
- Very limited bottom returns due to poor environmental conditions
  - Secci depth ~ 3m
- Communication issues – need stronger radio onboard UAV



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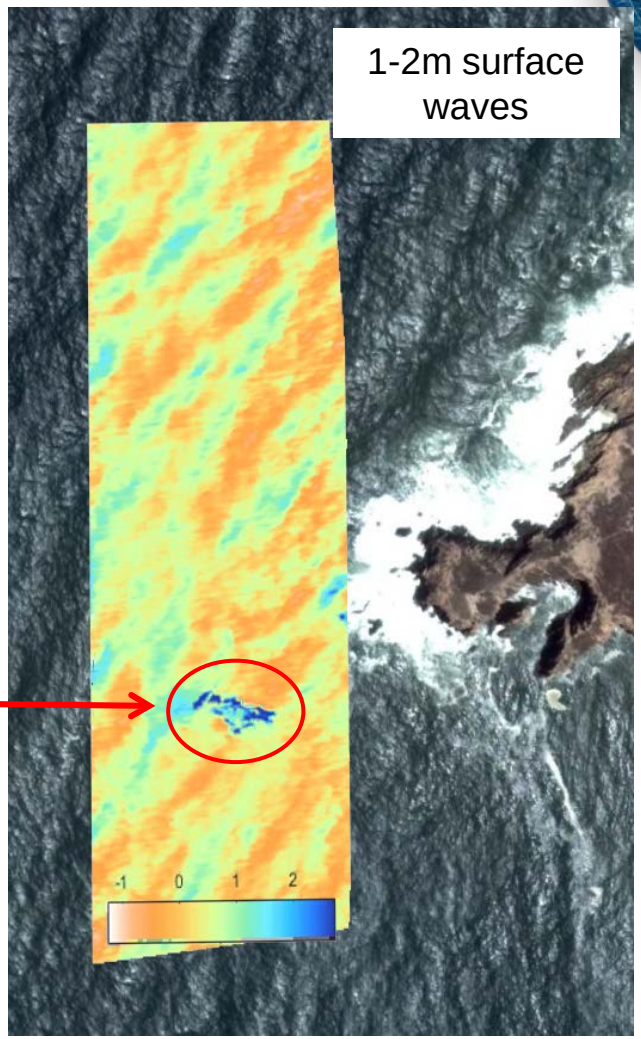
Vandenberg Surface Returns

Google Earth



PILLS Surface Return

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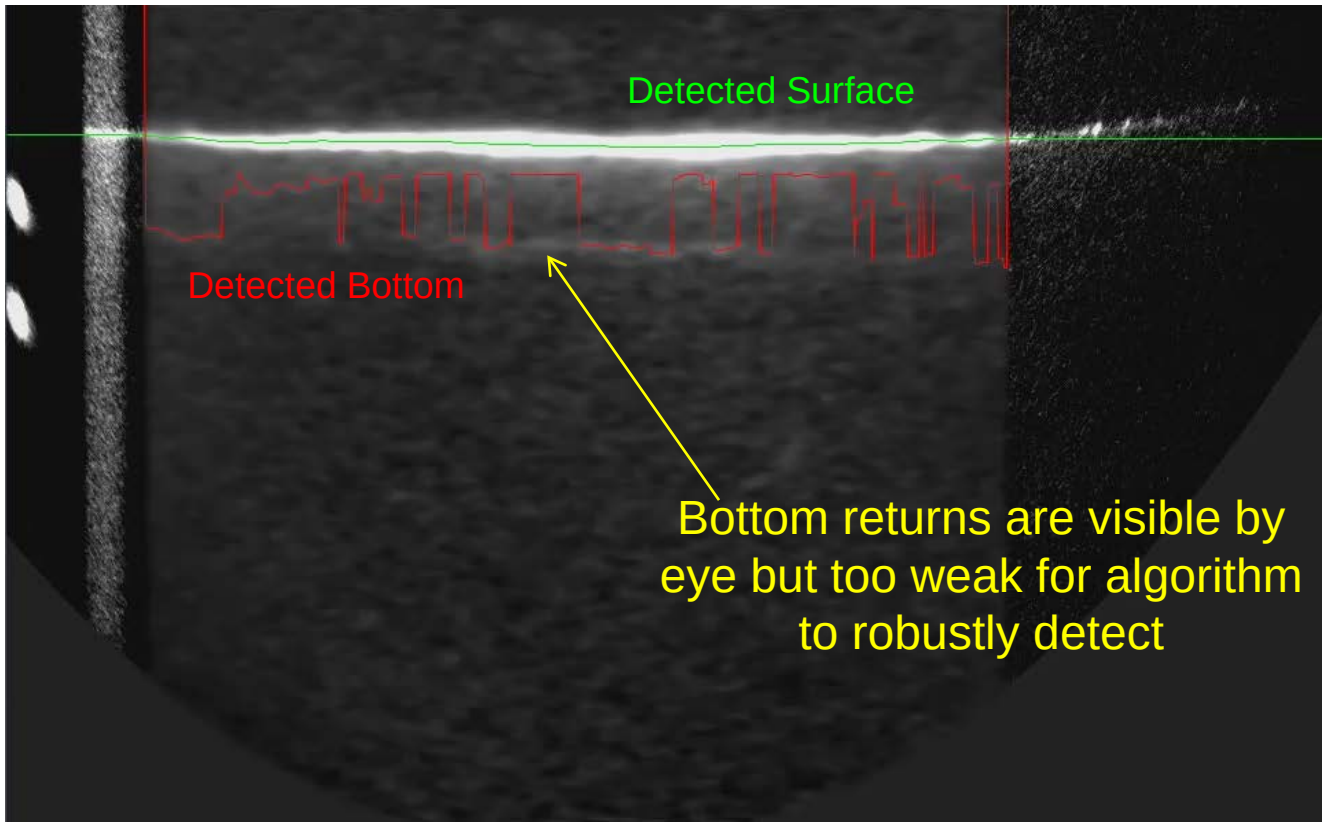
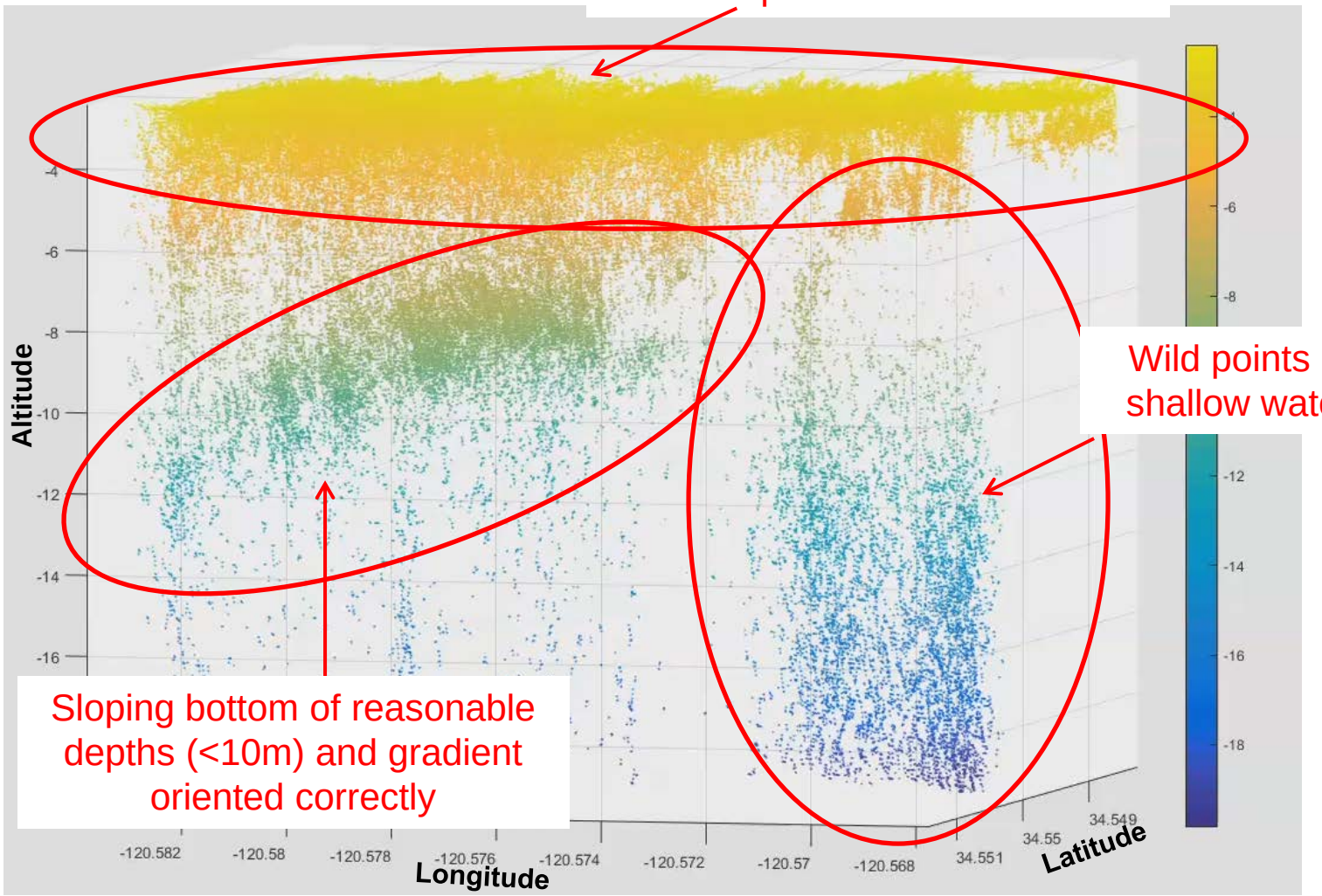
Vandenberg Bottom Returns

- Only bottom returns occurred on May 23 from one pass near shore
  - Slightly sheltered area, less sediment and turbulence
- PILLS image has been shifted into Az/Alt coordinates



Vandenberg Bottom Returns

- 3D Bathymetry point cloud
- Many wild points, but bottom trend is visible
- Algorithm improvements needed for better detection with low SNR



Remaining Technical Challenges

- Remote control – R/F interfaces to PILLS on UAV
- Real-time onboard bathy point clouds
- Ruggedized for RQ-21A Blackjack with catapult launch and wire recovery
- Improved onboard INS (Applanix APX-15)
- Post processing improvement needed for 25 cm accuracy:
  - Boresight calibration and distortion corrections
  - Very shallow water (<2 m)
  - Meaningful error-metrics to remove mid-water points
- Further reduction of ambient light using new bandpass filter technique
- Upgrade to Areté AIRTRAC laser will reduce weight to 22 pounds
  - Use saved weight for ruggedization

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PILLS Version History

	Version 1 (2012-2015)	Version 2 (2015-present)	Version 2.5 (2016-2018)
Size	39” x 9” x 4”	39” x 9” x 4”	39” x 9” x 4”
Weight	49 lbs	28 lbs	22 lbs
Power	240 W	230 W	150 W
Laser Type	Areté TID (9 lbs)	Areté TID (9 lbs)	Areté AIRTRAC (2 lbs)
Laser Specs	30 Hz, 30 mJ, 532 nm	30 Hz, 30 mJ, 532 nm	30 Hz, 30 mJ, 532 nm
Receiver	LUPA-1300-1 (ALMDS custom sensor)	IMX174 (PointGrey Grasshopper3)	IMX174 (PointGrey Grasshopper3)
Intensifier	Yes	No	No
Navigation	MMQ & NovAtel	MMQ & NovAtel	APX-15
Platform	Manned Aircraft	Griffon SeaHunter UAV	RQ-21A Blackjack UAV

Summary

- PILLS is a compact lightweight green lidar system
  - Design compatible with RQ-21A Blackjack
  - Bathymetry, terrain, and urban area mapping
  - Low SWAP allows simultaneous operation with EO/IR sensors
  - Real-time generation of bathymetric and topographic maps
  - Full waveform processing
  - Compact, lightweight, and modular architecture
- Program status:
  - Manned demonstrations completed November 2015 (TRL 7)
  - UAV demonstration completed May 2016 (TRL 7)
  - Additional manned data collections Sept 2016 as part of Unmanned Warrior in Scotland (ONR)
  - Next Step: PILLS version 2.5 upgrades to hardware and software