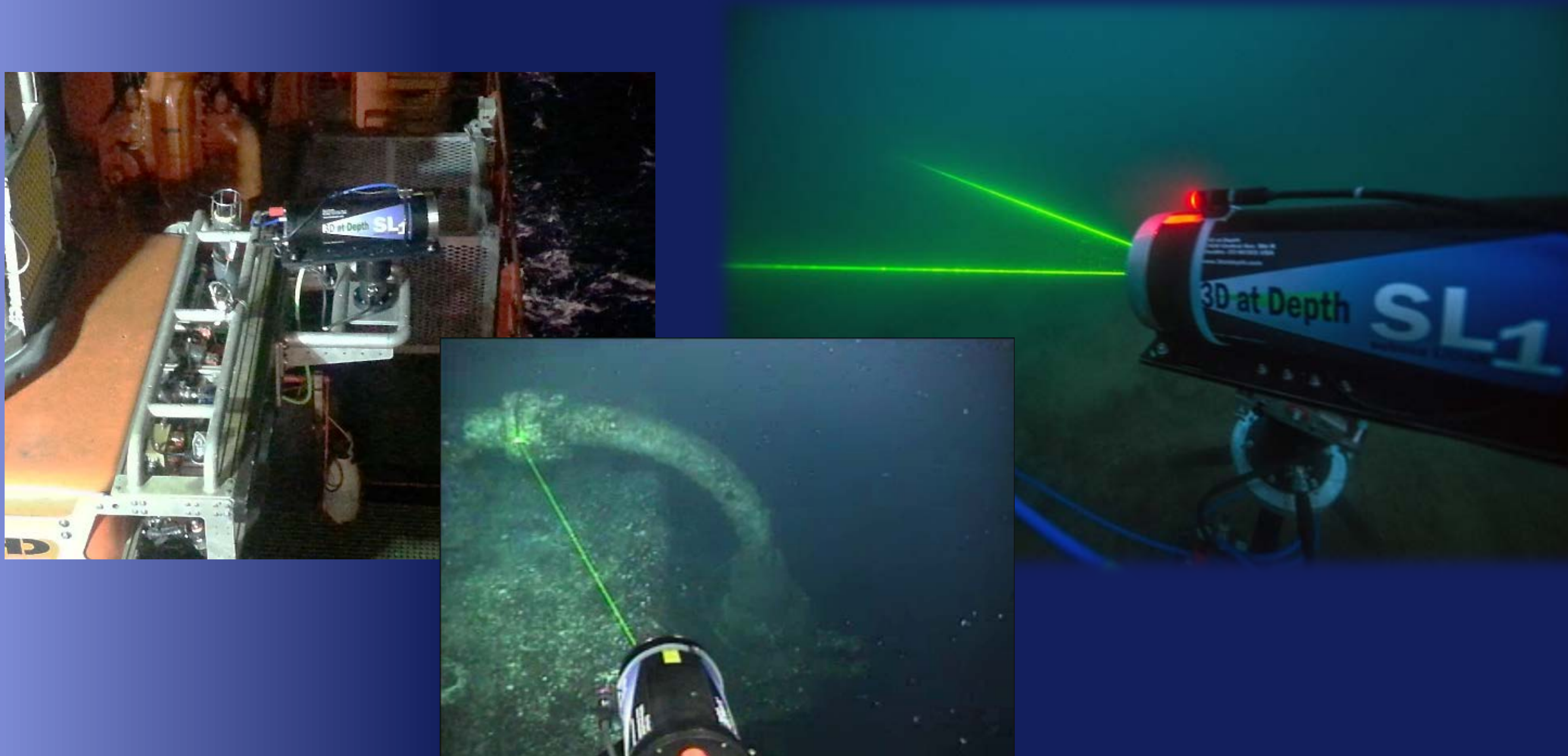


Subsea LiDAR Metrology

Mark Hardy
Co-Founder
3D at Depth
mark.hardy@3datdepth.com

3D at Depth
SUBSEA LiDAR

Company Overview

Based in the technology hub of Boulder, Colorado, 3D at Depth is **dedicated to the development of underwater laser measurement sensors and software**

- Patented subsea LiDAR technology
- SL1 subsea LiDAR system launched in March 2013
- Recently launched second generation subsea LiDAR system; SL2
- 3 core application areas; Metrology, Field Survey, Component As-Builts
- Over 40 metrologies completed in 2014

Topics

Metrology workflows using Subsea LiDAR

- Instrument
- Collection Planning
- Operations
- **Post Processing**

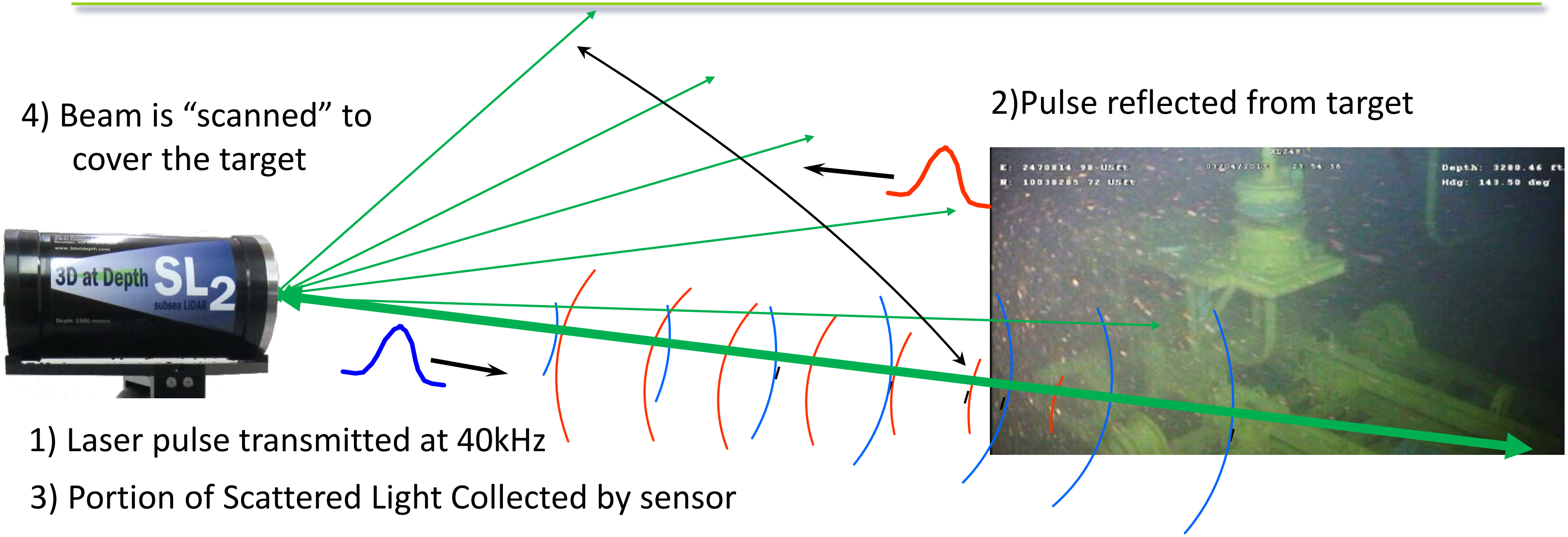
Subsea LiDAR Metrology

INSTRUMENT OVERVIEW

Laser Scanning Basics

4) Beam is "scanned" to cover the target

2)Pulse reflected from target



1) Laser pulse transmitted at 40kHz

3) Portion of Scattered Light Collected by sensor

<u>Phased Array Sonar</u>

Beam divergence angle: 0.5°

Beam diameter at 10m: 8.7cm

Beam diameter at 20m: 17.5cm

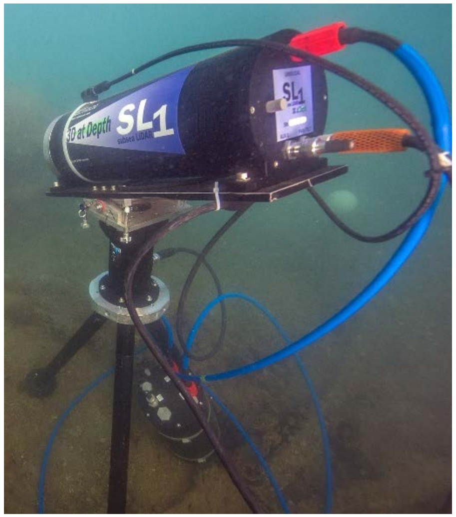
<u>*3D at Depth* Optical Design</u>

Beam divergence angle: 364μrad

Beam diameter at 10m: 3.6mm

Beam diameter at 20m: 7.3mm

SL1 and SL2 Subsea LiDAR Scanners



Time of flight (ToF) 532nm (green) LiDAR system built to offshore Oil and Gas requirements

Performance and accuracy are comparable to topside scanners

- 6mm single shot and 4mm positional accuracy in a single scene

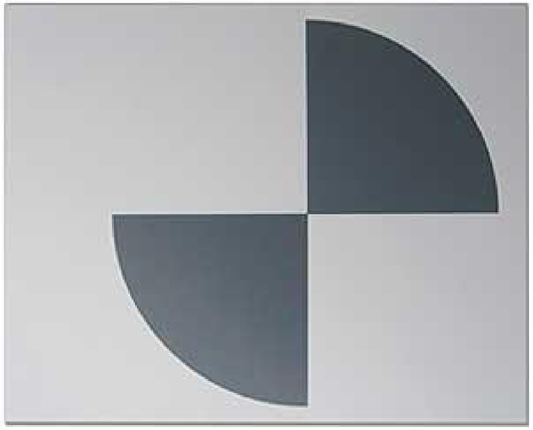
SL1 Single canister, 3000m depth rating integrated pan*

SL2 Dual canister, 1500m depth rating integrated pan and tilt

* SL1 with Pan/Tilt scheduled for June 2015

Registration Targets

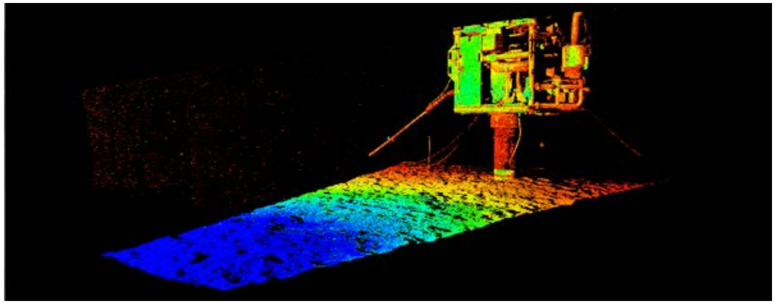
Spheres



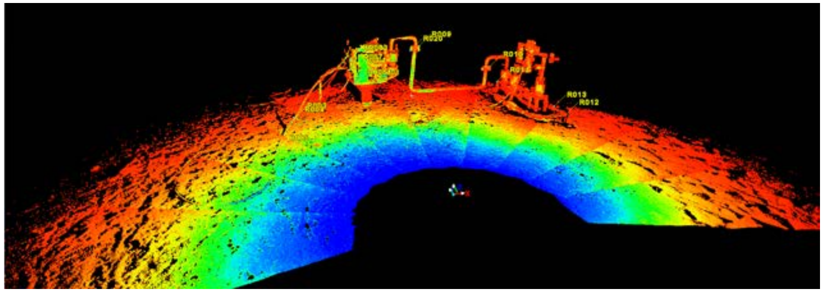
B/W Survey

Reflective

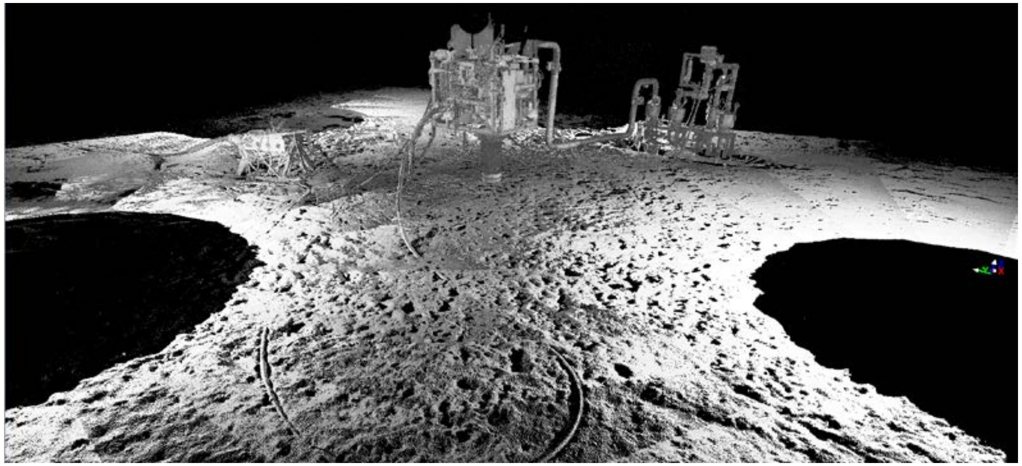
Field of View – “Scans”



Single 30 x 30 scan

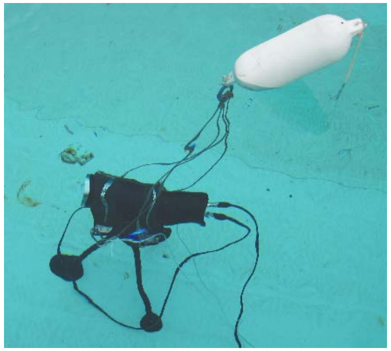


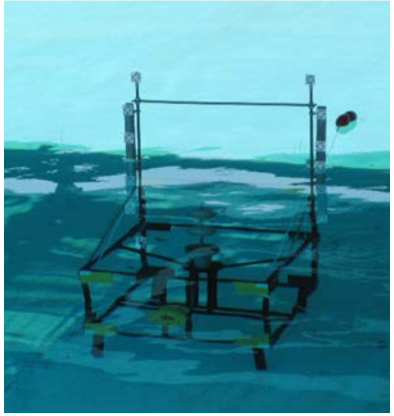
Full scan position – 9 scans



Multiple registered scan positions

Accuracy Verification

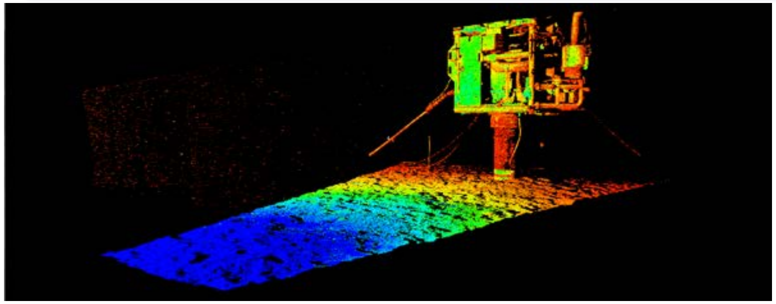





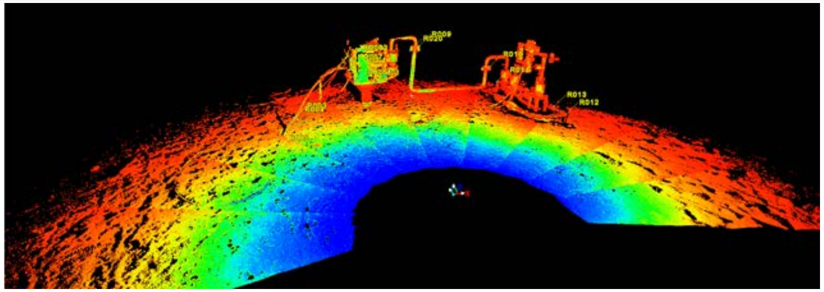
The accuracy of the SL1 was tested at the Ohmsett Facility in April 2013.

- Two cages were constructed and dimensionally controlled.
- The cages were placed in the tank to simulate subsea metrology configurations and surveyed using a total station.
- A laser metrology was performed for each configuration and the results were compared.

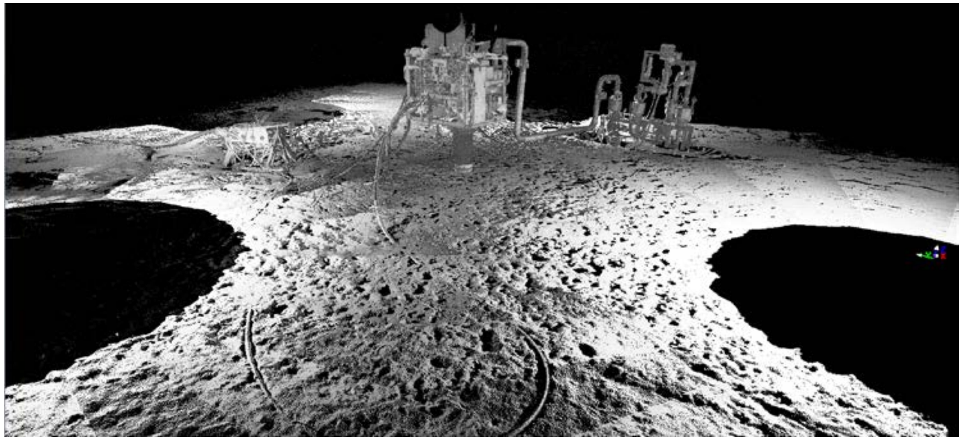
Scanning Tolerances



Single 30 x 30 scan
4mm factory tolerance



Full scan position – 9 scans
7mm to 18 mm variance to total station

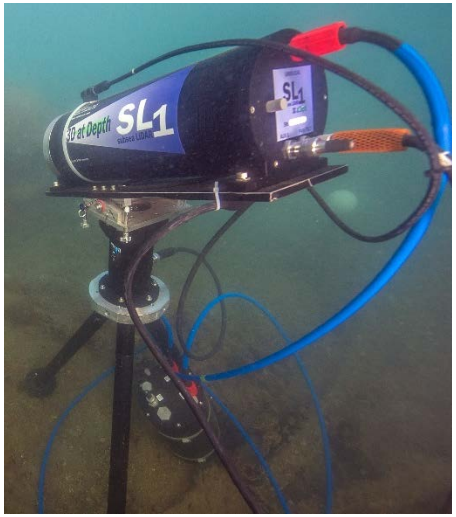


Multiple registered scan positions
Registration adds 8-10 mm error

Subsea LiDAR Metrology

INSTRUMENT OVERVIEW

SL1 and SL2 Subsea LiDAR Scanners



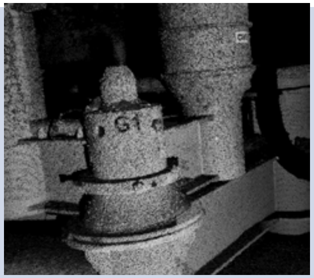
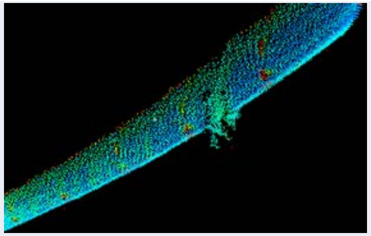
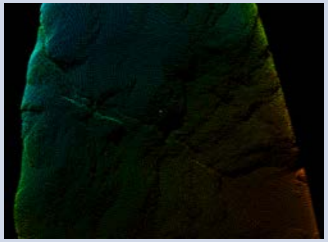
- Time of flight (ToF) 532nm (green) LiDAR system built to offshore Oil and Gas requirements
- Performance and accuracy are comparable to topside scanners
  - 6mm single shot and 4mm positional accuracy in a single scene

SL1 Single canister, 3000m depth rating integrated pan*

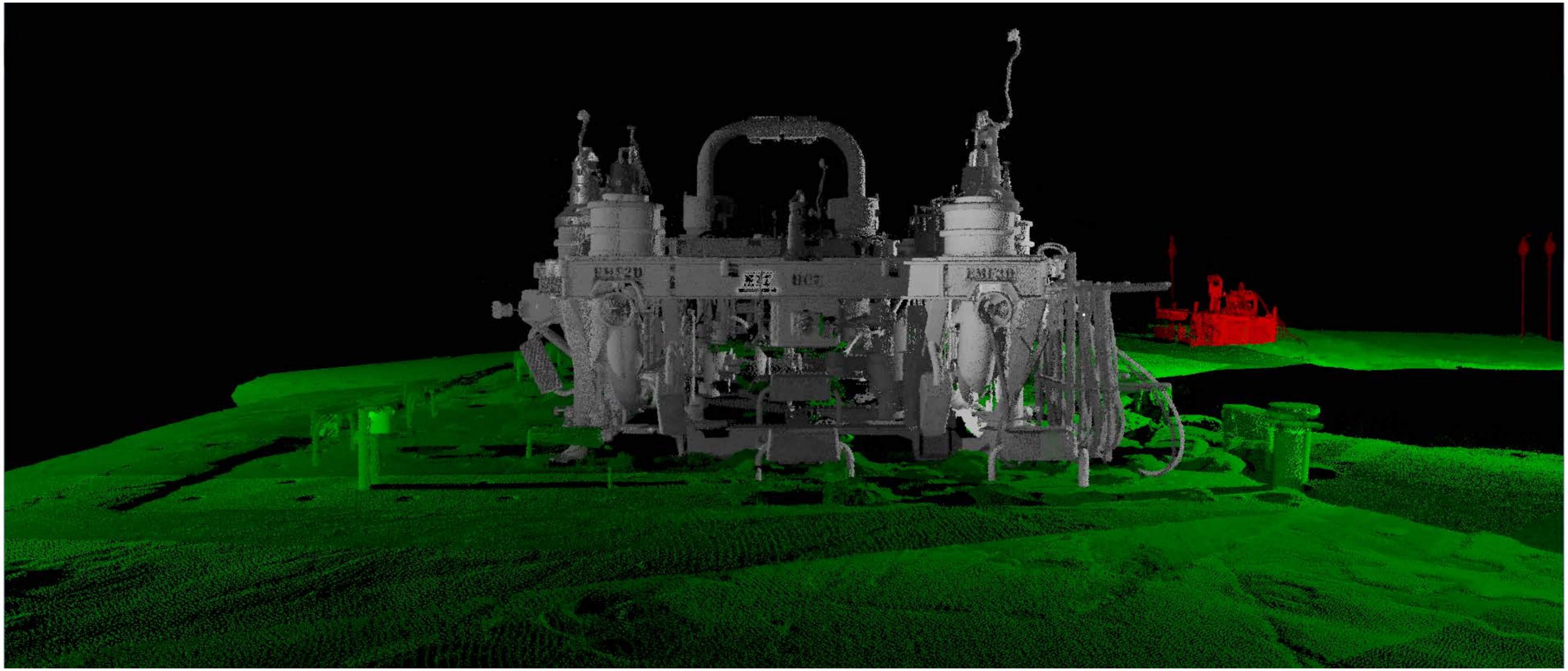
SL2 Dual canister, 1500m depth rating integrated pan and tilt

* SL1 with Pan/Tilt scheduled for June 2015

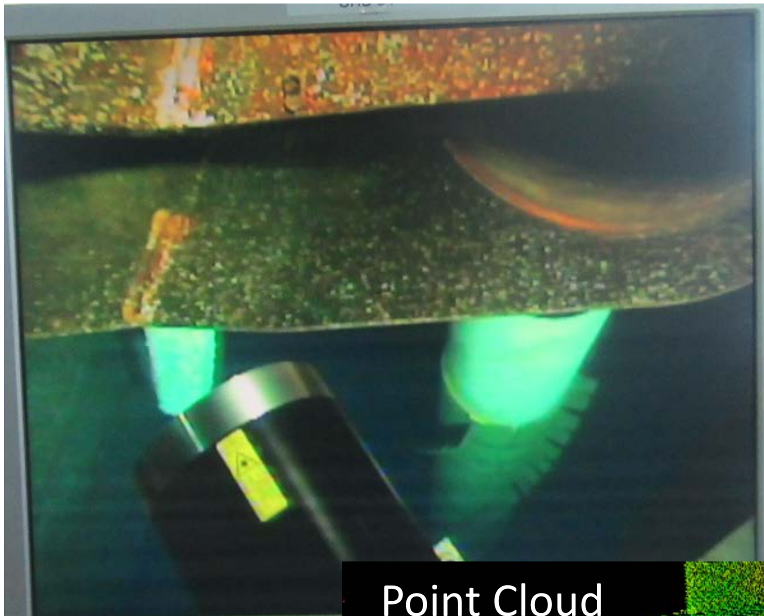
Scanning Modes

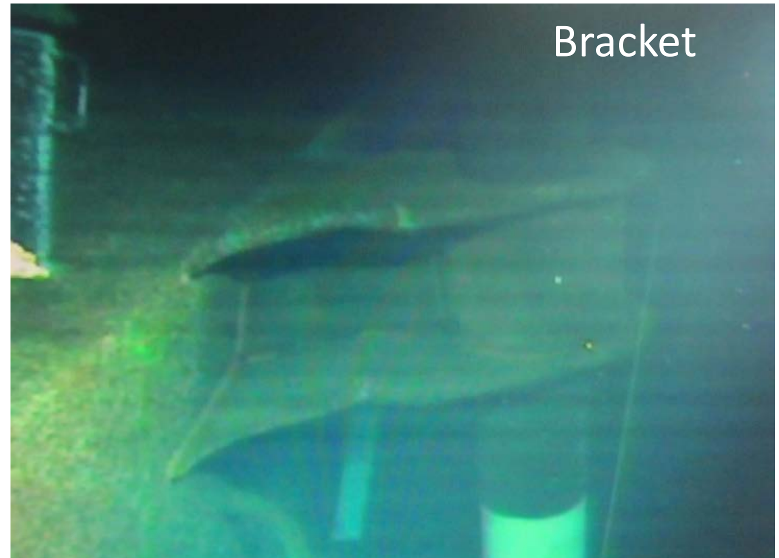
Mode	Description	Parameters	
Survey	Sensor is placed in a stationary location and moved into several scan positions for large areas.	• High resolution • 3-5 minutes per scan • Registration of multiple scan through targets	
Fast	Steady platform but not stationary; mid water ROV	• Lower resolution • 1-2 seconds per scan • Snapshots	
Mobile	Sensor integrated with a moving ROV, AUV or boat and integrated with an INS for motion compensation	• Single axis scanning • Line scan or bowtie pattern • Time stamped to INS feed	

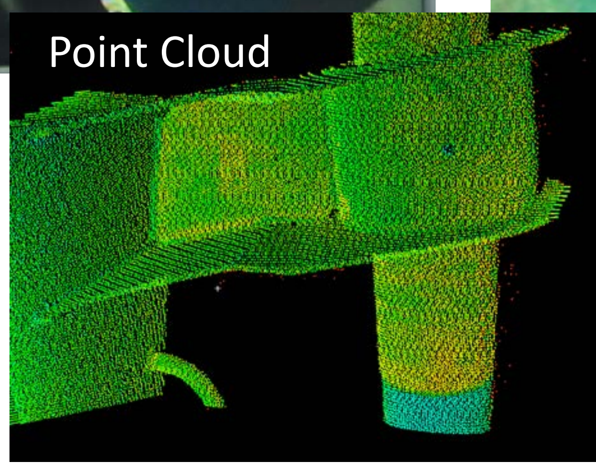
Survey Mode

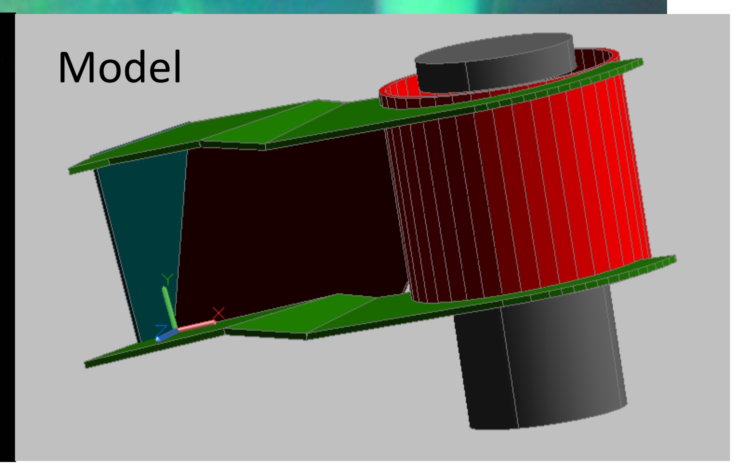


Fast Scan

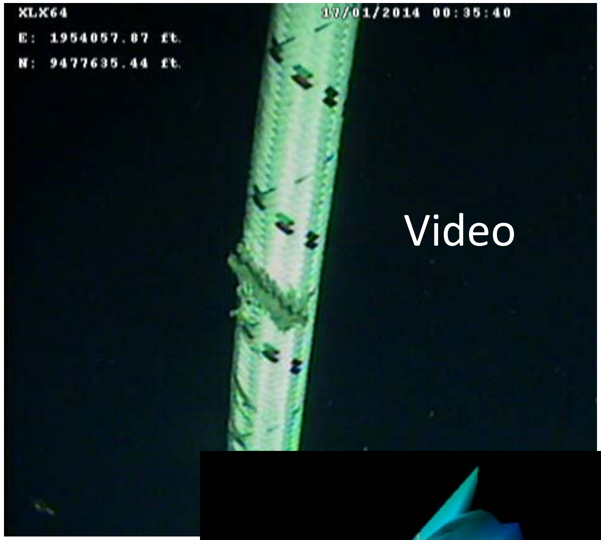


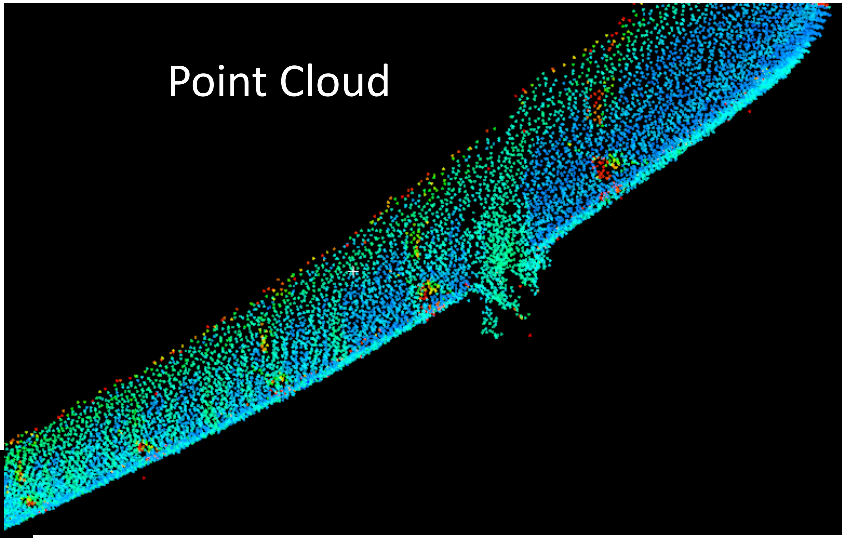


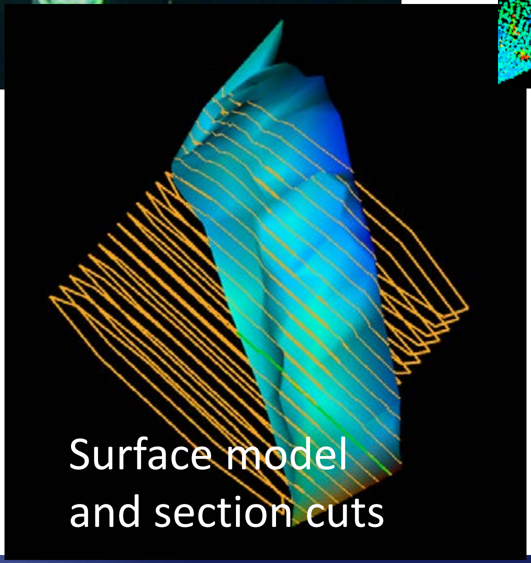


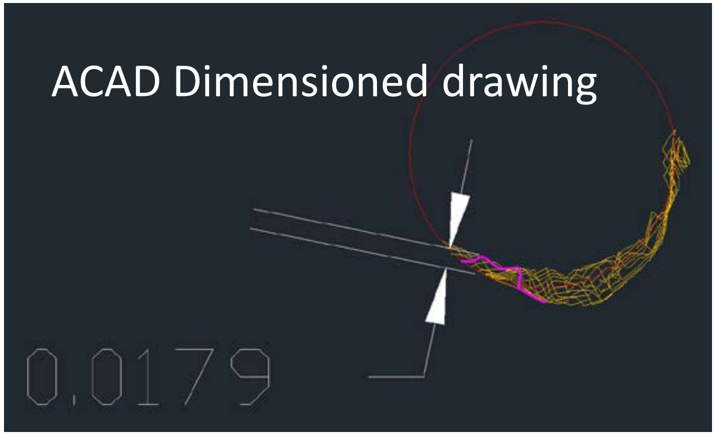


Fast Scan

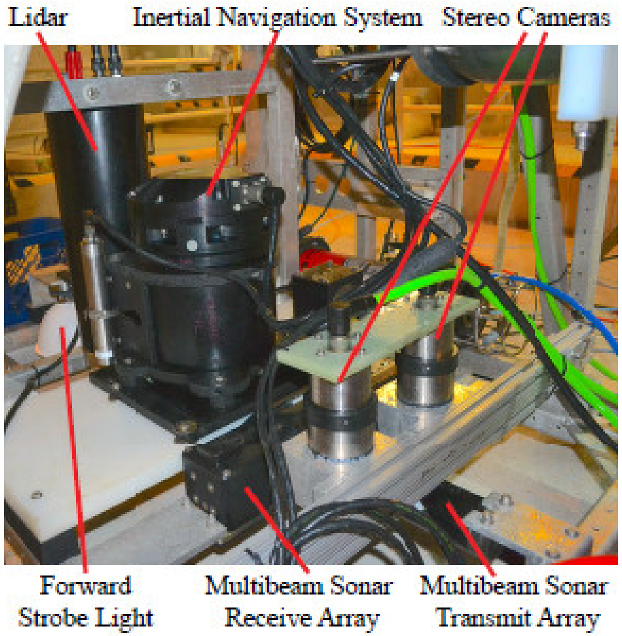

XLX64
17/01/2014 00:35:40
E: 1954057.87 ft.
N: 9477635.44 ft.
Video

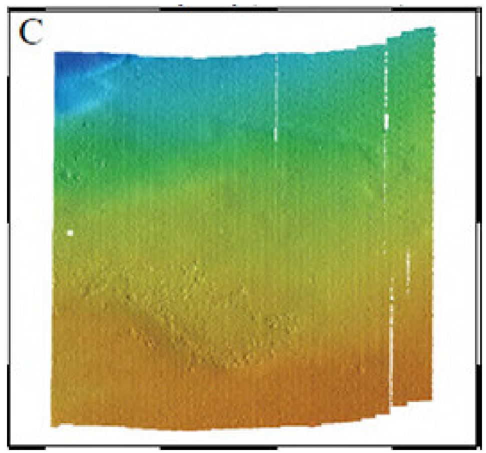

Point Cloud

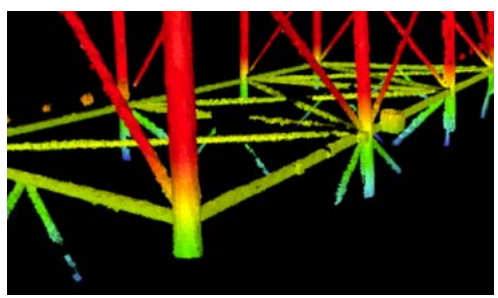

Surface model
and section cuts


ACAD Dimensioned drawing
0.0179

Mobile LiDAR





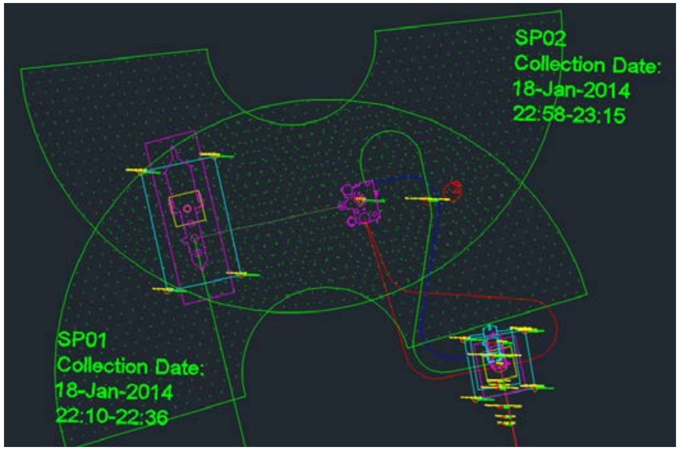


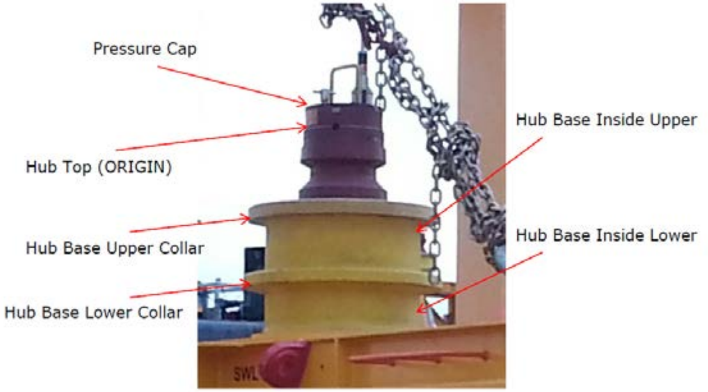
Subsea LiDAR Metrology

COLLECTION PLANNING/DESIGN

Planning Parameters

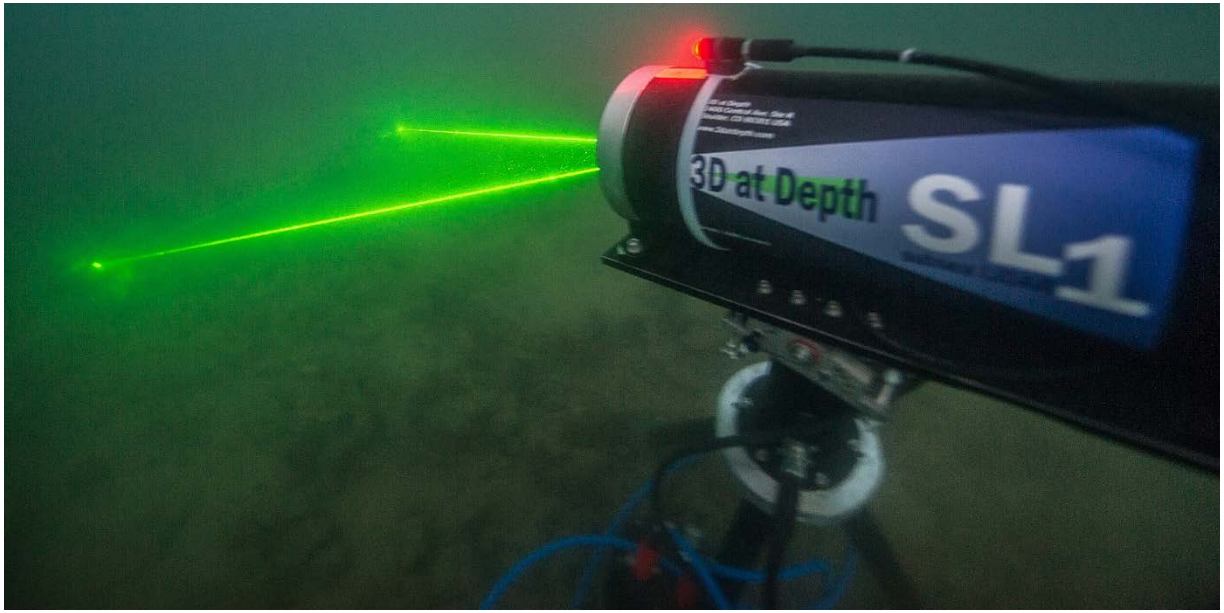
- Accuracy/tolerances
- DC and field drawings
- Range
- Line of sight
- Height of platform
- Scan locations
- Currents
- Seabed

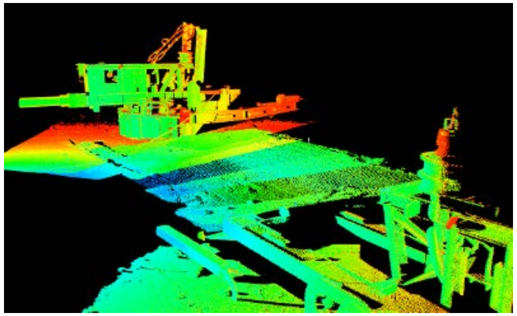




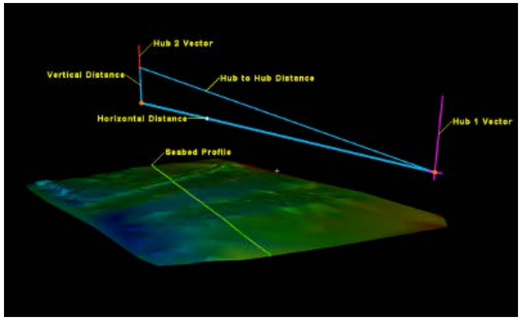
Subsea LiDAR Metrology Workflow

1. Place targets if needed
2. Sensor placed into position
   ROV or Tripod
3. Run test scans
   Range
   Gain
   Line of sight
4. Scan scene
5. QC data
6. Move to next position
7. Repeat workflow

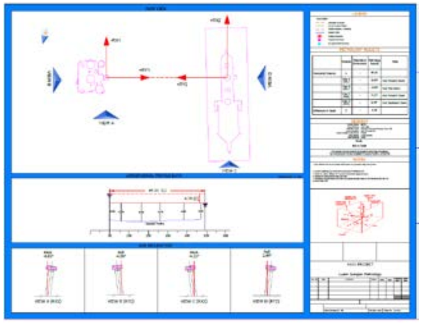




7. Data preprocessed into point clouds

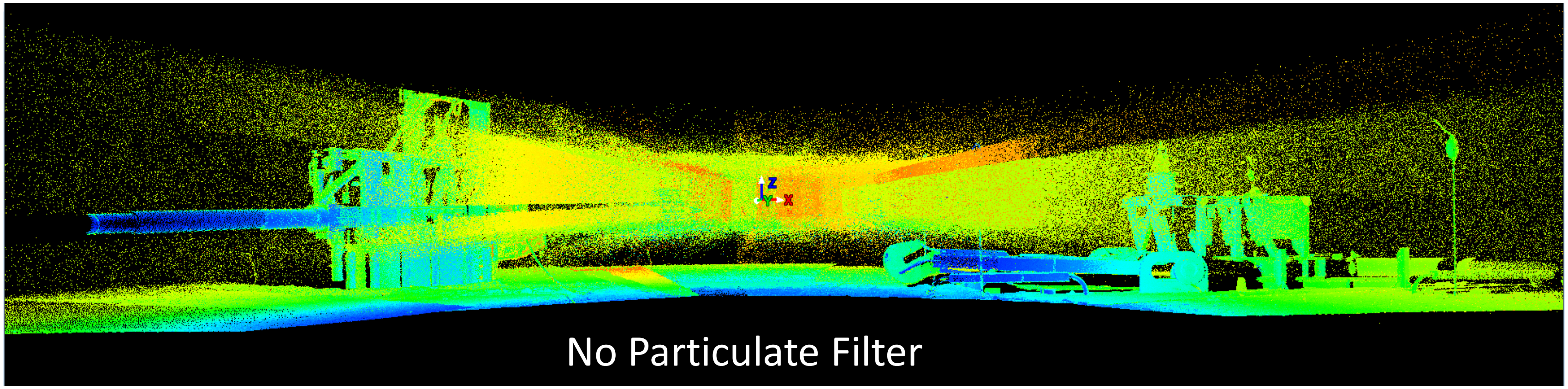


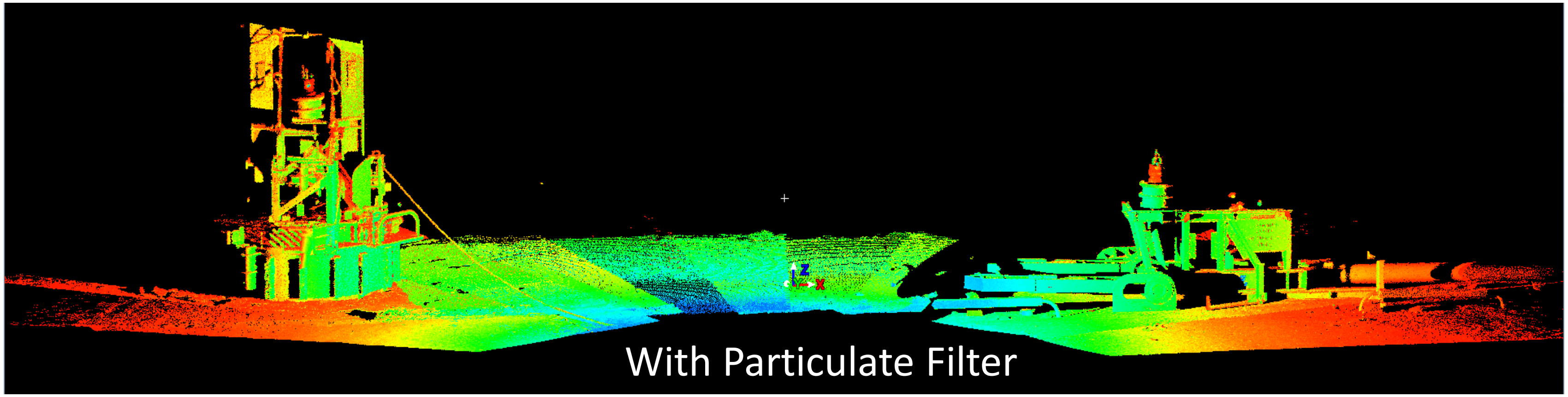
8. CAD elements extracted from point cloud (modeling)



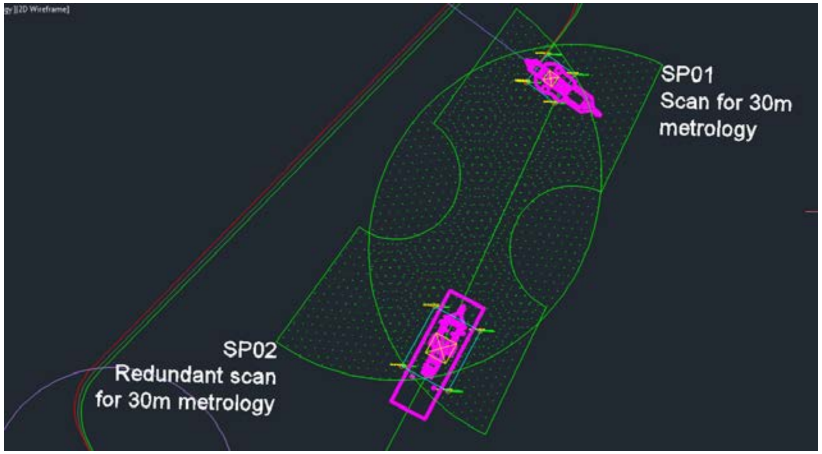
9. Data QC'd and the deliverable is developed

Mitigating Turbidity: Particulate Filter

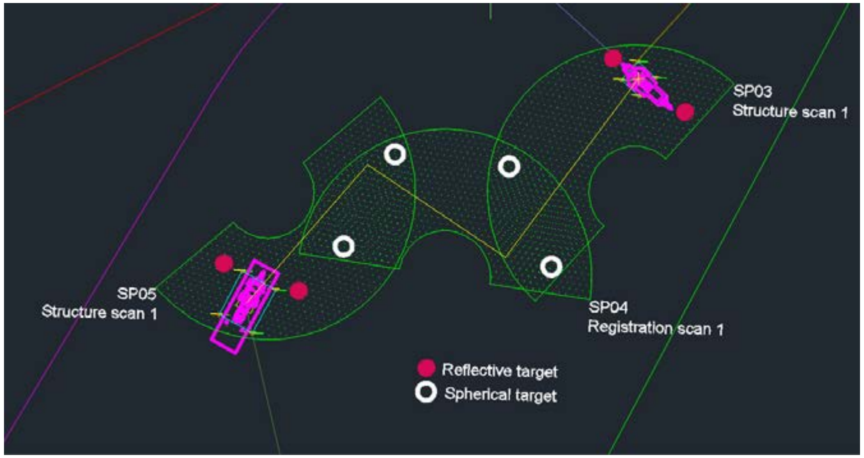




Range Determines # SP's



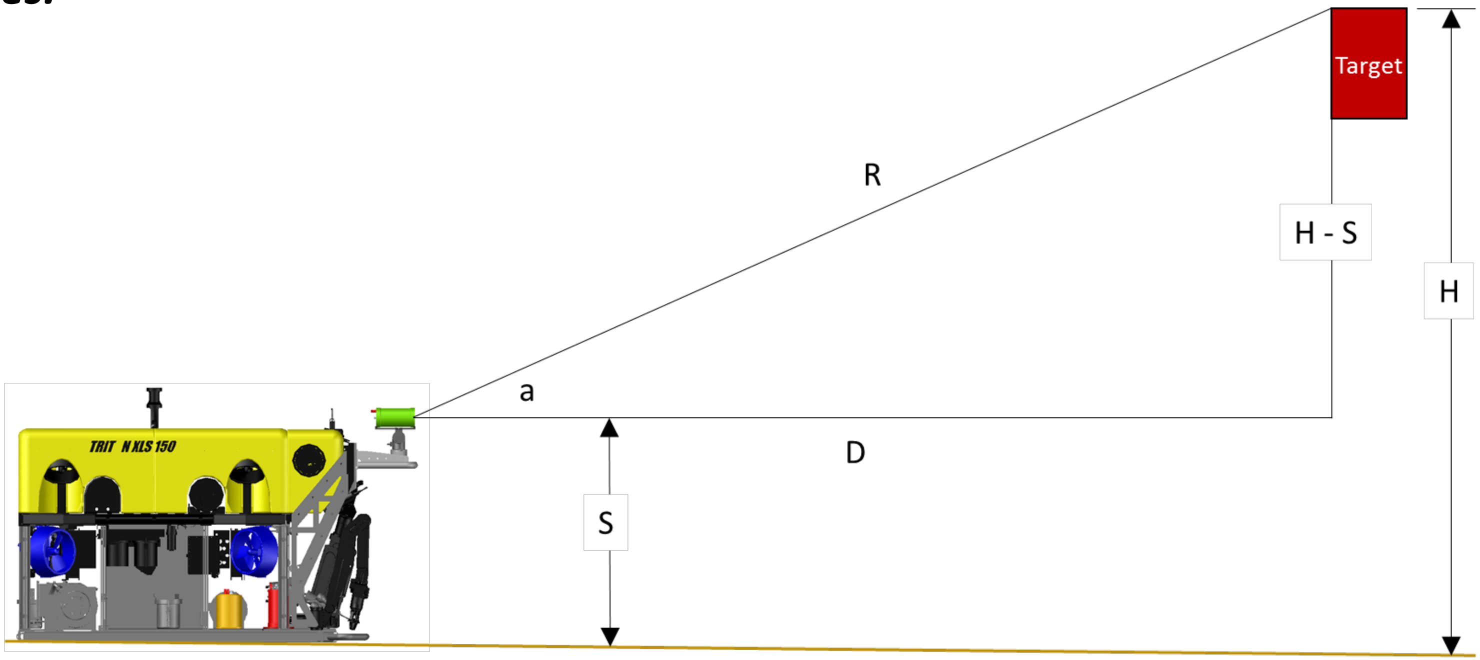
Range > Target Distance



Range < Target Distance

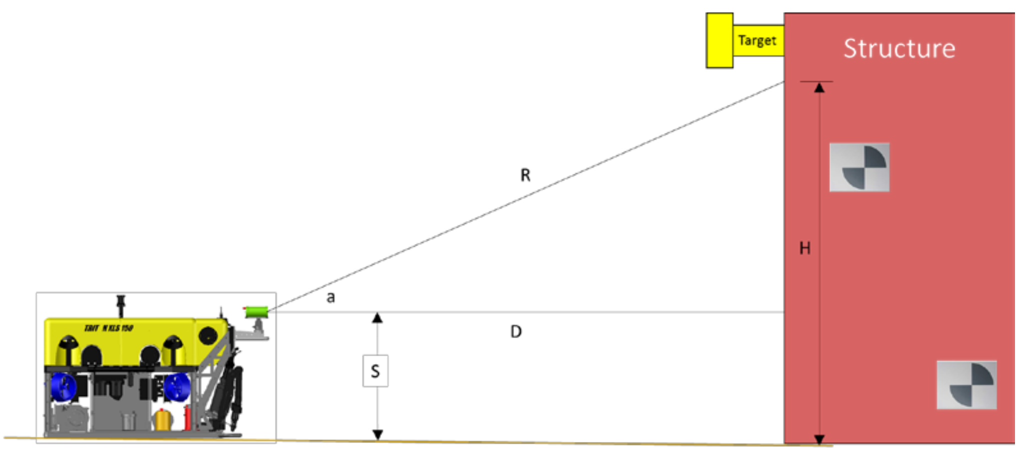
Line of Sight

Direct feature scanning is confined to the range, and height of specific features.



Line of Sight

Subsea Scanning used in conjunction with topside DC or topside scanning provides a fast method for metrologies and mitigates line of sight issues



By scanning the structures topside, the point clouds can be used as part of the data solution – snapped into the subsea scanned scene which mitigates the line of sight issue thus further reducing the collection time and complexity

Subsea LiDAR Metrology

OPERATIONAL CONSIDERATIONS

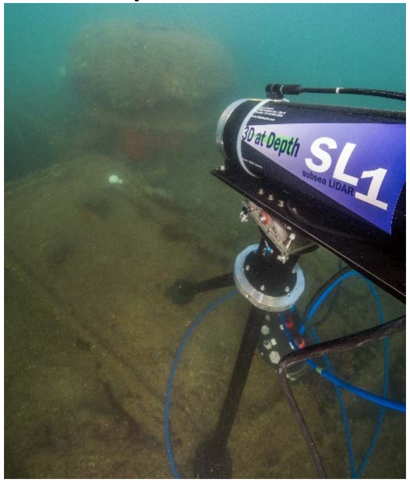
Deployment Options

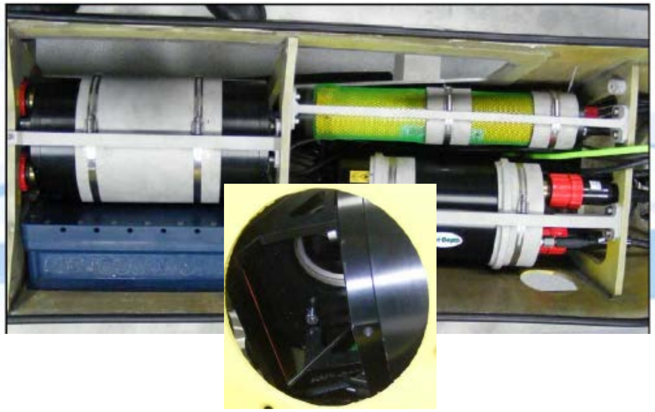
SL1 TOP ROV Mounted

SL1 Tripod Mounted

SL2 AUV Mounted

SL1 DECK ROV Mounted





Underwater LiDAR Best Practices

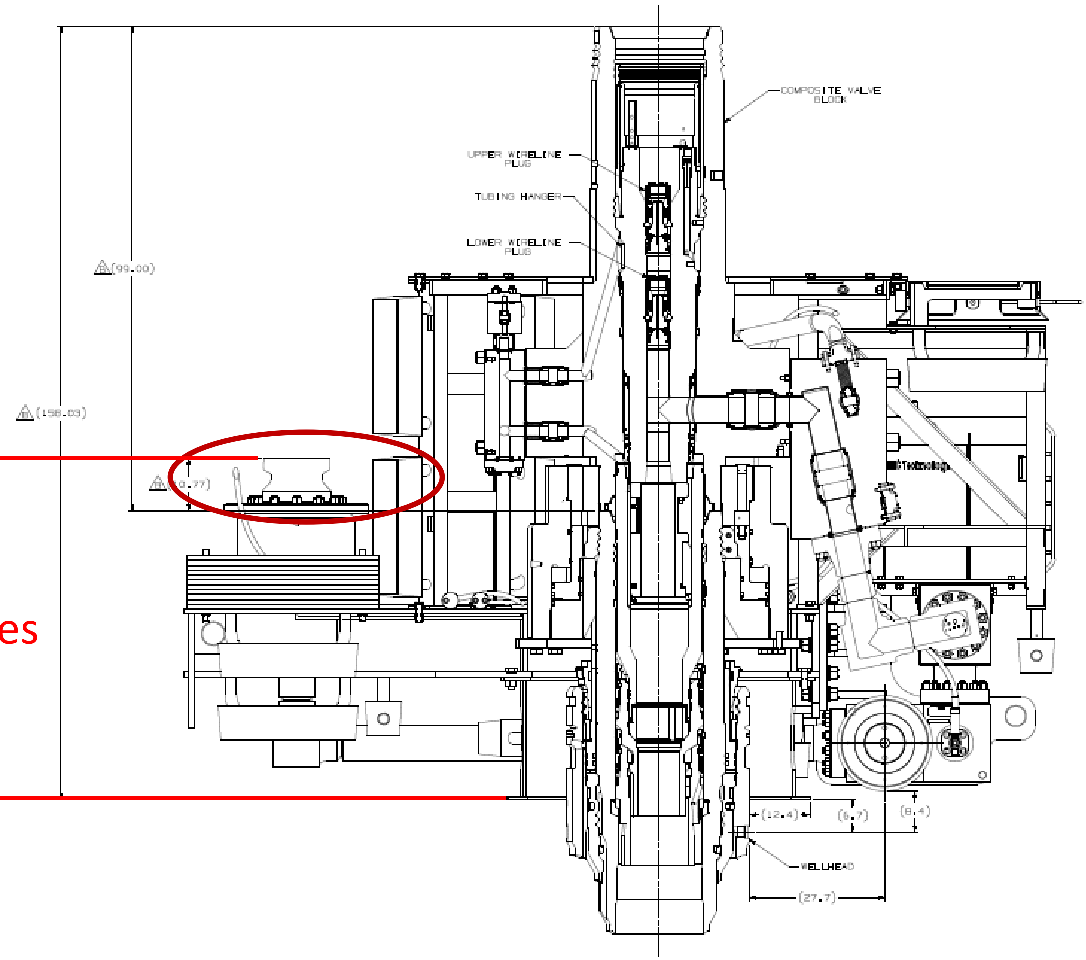
POST PROCESSING

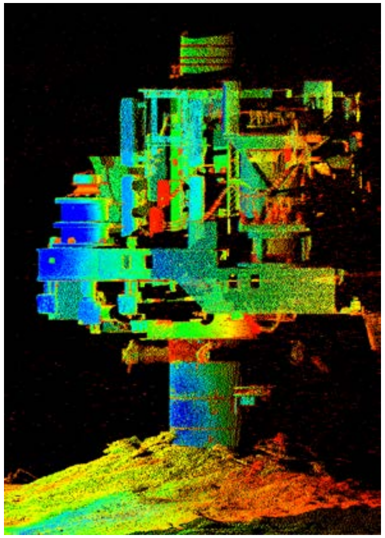
Metrology Process

1. Validate DC or GA drawings for the metrology
2. Import LAS files into Cyclone
3. Model the hubs; offset the hub centers
4. Level the sensor using pitch and roll offsets
5. Define the reference frame
6. Create the seabed profile
7. Export to DXF

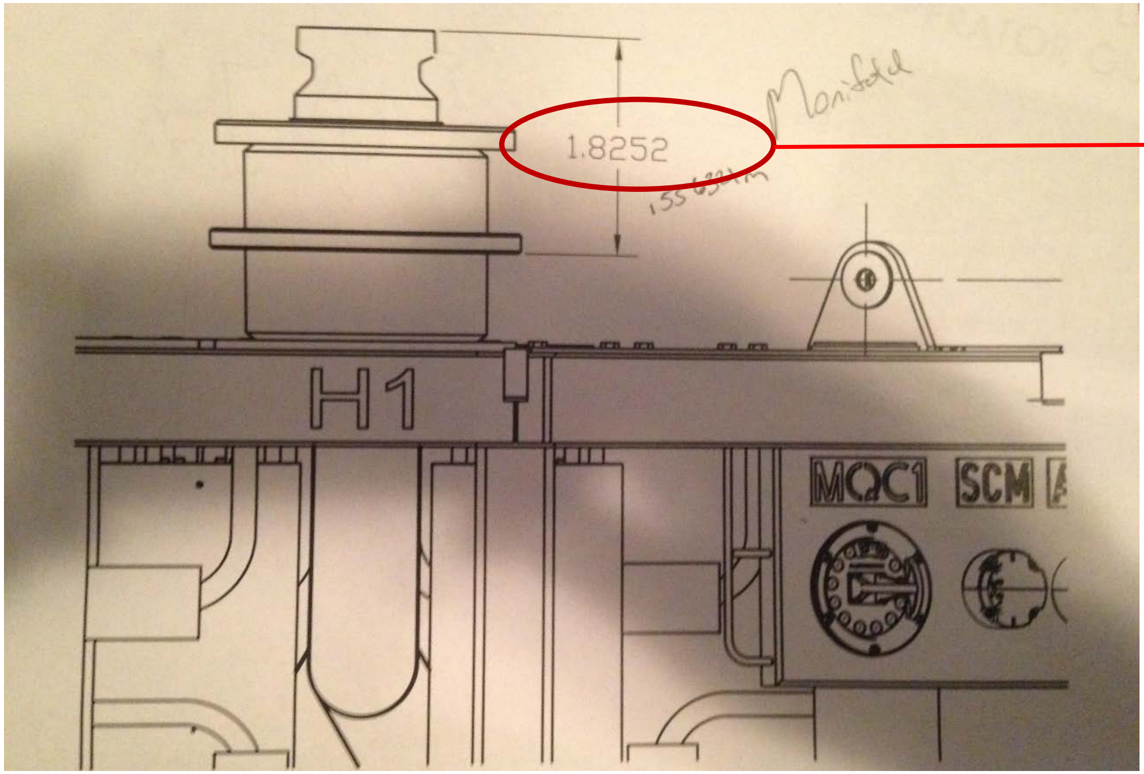
Define the positions from GA data - Well

69.8 inches

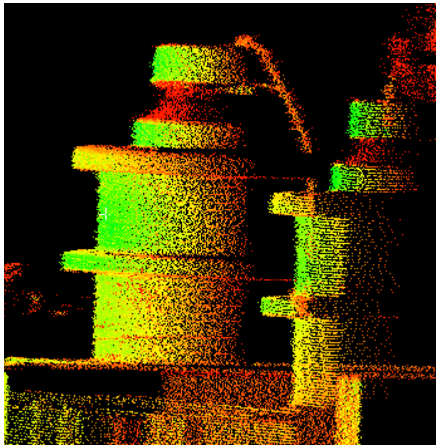




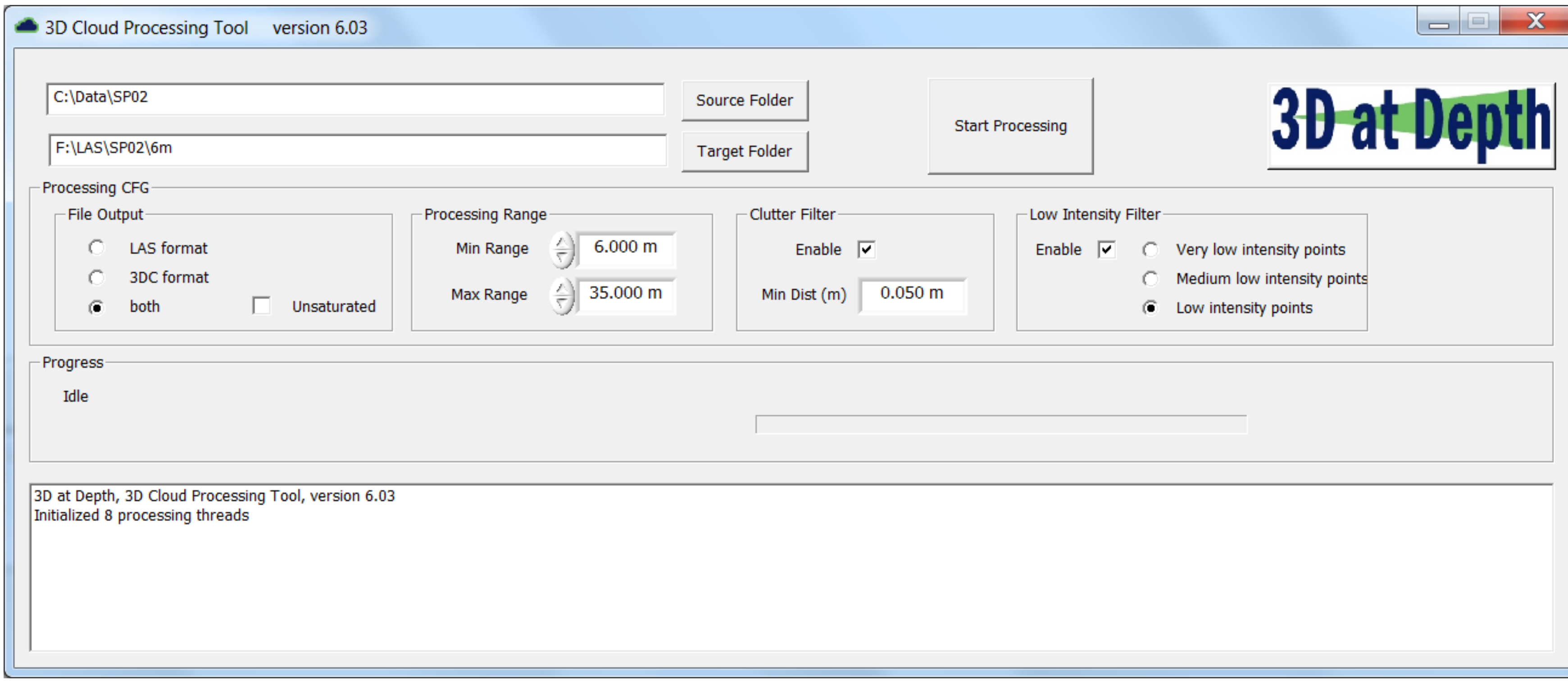
Define the positions from GA data - Manifold



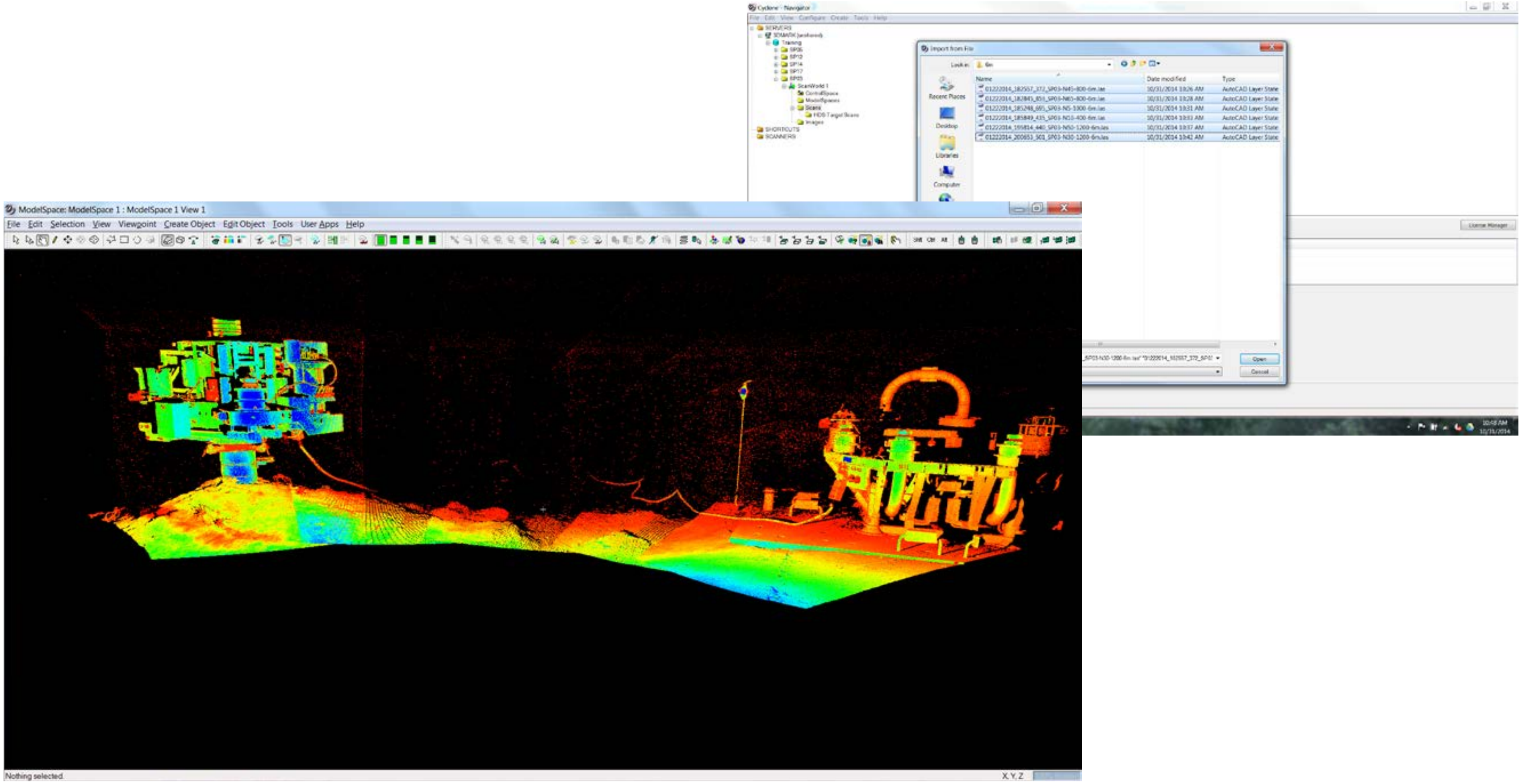
1.8252 ft.



Process from RAW to LAS – 3D Cloud

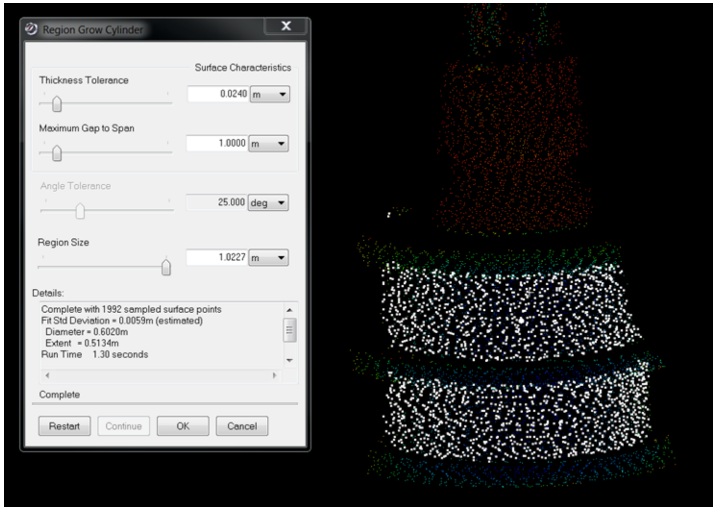


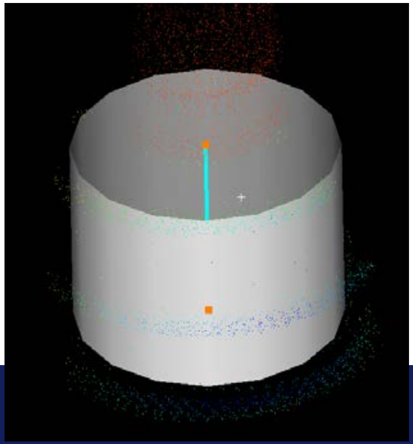
Import Scans into Cyclone



Model the Hub Bases

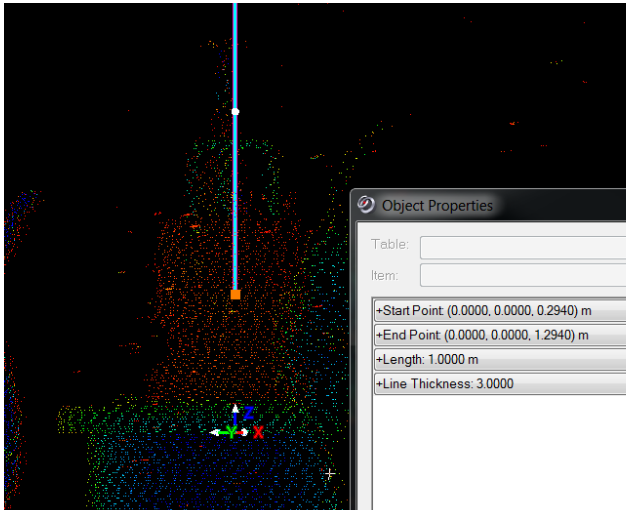
- Isolate the feature to model
- Remove any outside points
- Fit to Cylinder
- Draw a centerline of the cylinder





Model the Hub Bases along the vector

- Set the vector as the Z axis for a temporary coordinate system
- Move the endpoint to one of the hub collar locations from the DC
- Set the origin of the temp CS to the top point of the vector
- Edit the properties of the line to start at the hub center offset and extend up 1 meter (for the vector)
- Place a vertex on the hub center



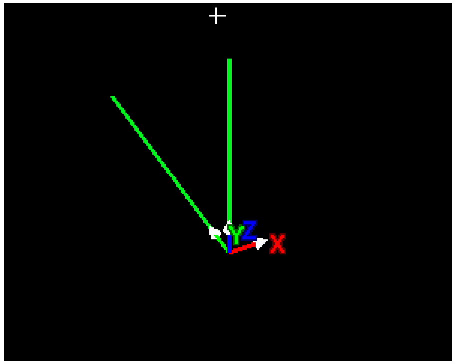
Create a reference frame – level the scanner

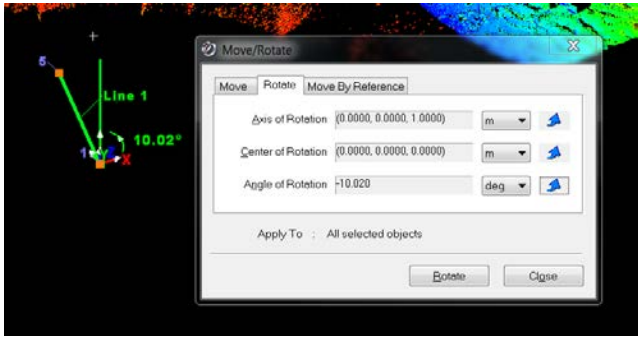
- Open the log file for the scan position
- Locate the zero PAN angle scans (reference frame scans)
- Average the pitch and roll values at 0° PAN angle
- Determine the pitch and roll offsets to level the scanner

Pan (deg)	Pitch (deg	Roll (deg)
-44.912	0.244	2.409
-59.941	0.819	2.213
20.039	-2.071	1.349
15.029	-1.955	1.497
0	-1.515	1.926
0	-1.496	1.929
15.029	-1.947	1.501
15.029	-1.958	1.498
15.029	-1.949	1.518
0	-1.509	1.91
-19.951	-0.787	2.287
-39.902	0.019	2.398
-59.941	0.782	2.169
-59.941	0.781	2.197
0	-1.495	1.921
Offsets		
Roll	**Pitch**	
-1.9215	1.50375	

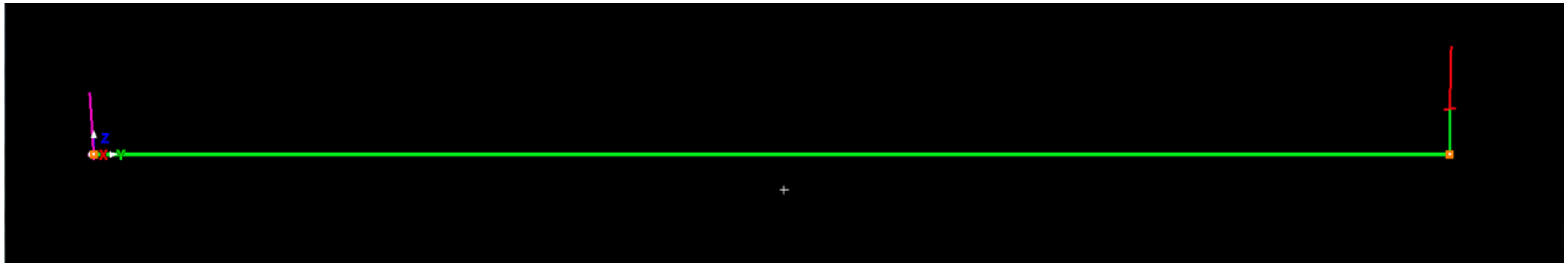
Leveling the Scanner

- Create a Z vector – draw a line and then edit its properties to start at 0,0,0 and end at 0,0,3
- Rotate the Y axis line by the pan angle in the log file if not zero
- Create a new CS with the Y axis along the rotated line
- Rotate the Z vector along X (pitch) and Y (roll)
- Create a new CS with the Z axis along the rotated Z vector – save this CS

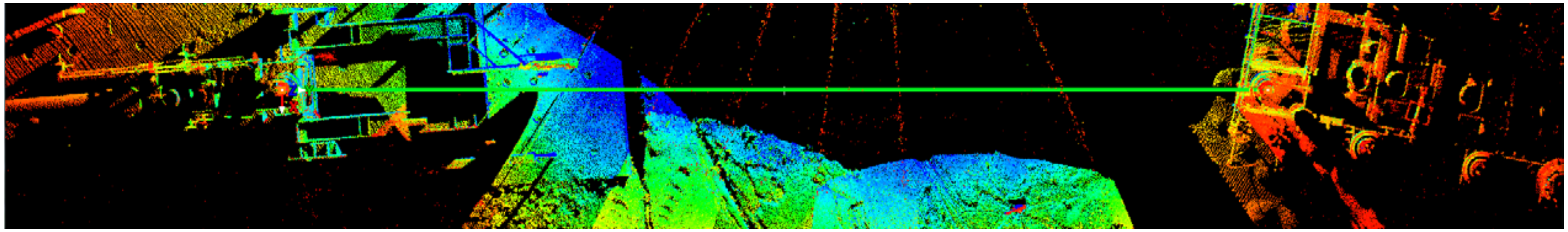




Reference Frame



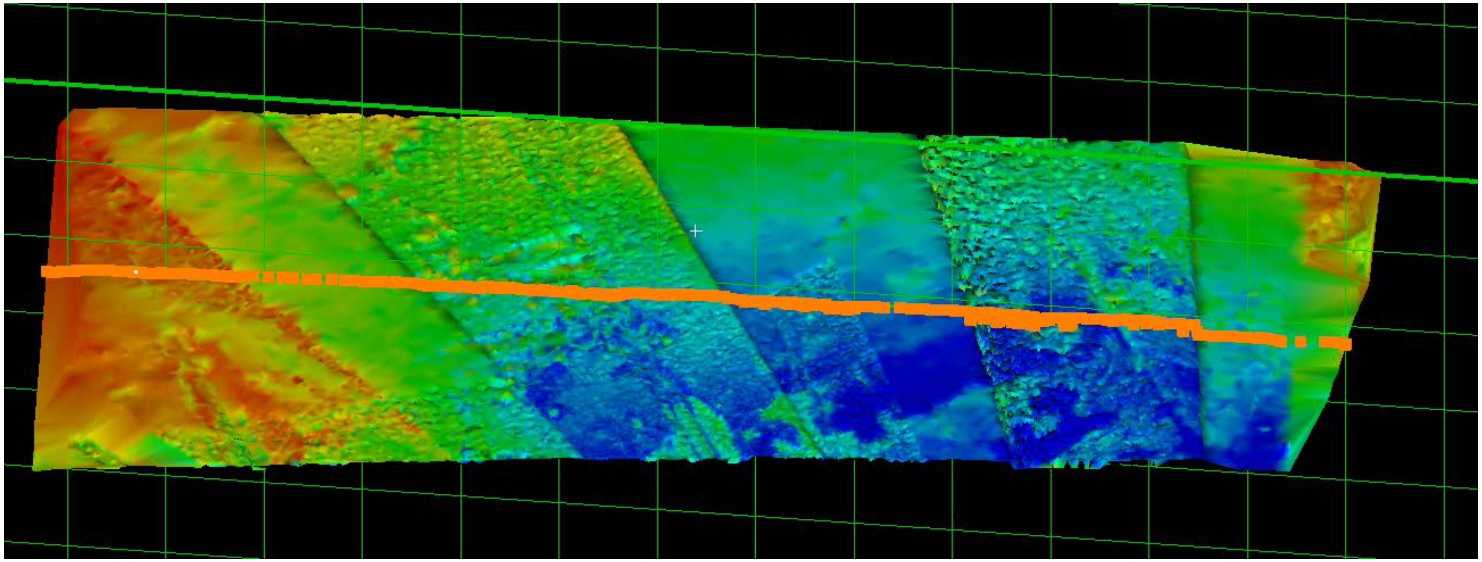
Right View



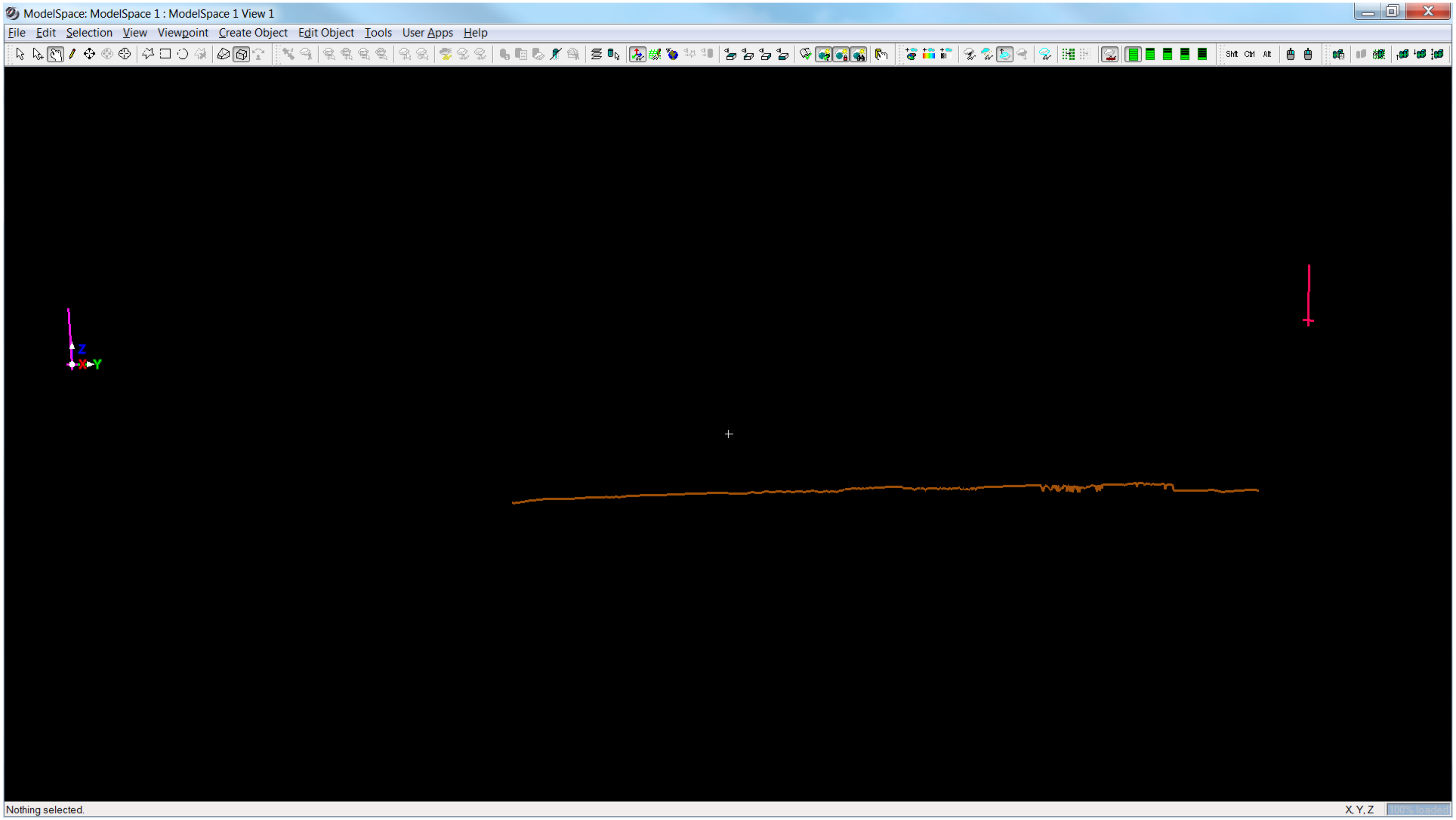
Top View with Point Clouds

Create a seabed profile

- Set a cutplane from the active reference plane
- Create lines from cuts



Completed Metrology Model



Reporting

- Change the units to feet (if necessary)
- Export the two vectors and the seabed profile into DXF using the corrected reference frame
- Open the file in AutoCAD
- Perform the measurements as required in the metrology report
  - Delta Y
  - Delta Z
  - Pitch and roll of each hub
- Create a table with the values
- Hand off the vectors and table for drafting and document completion

ACAD Results