MARINE SURVEY SOLUTIONS

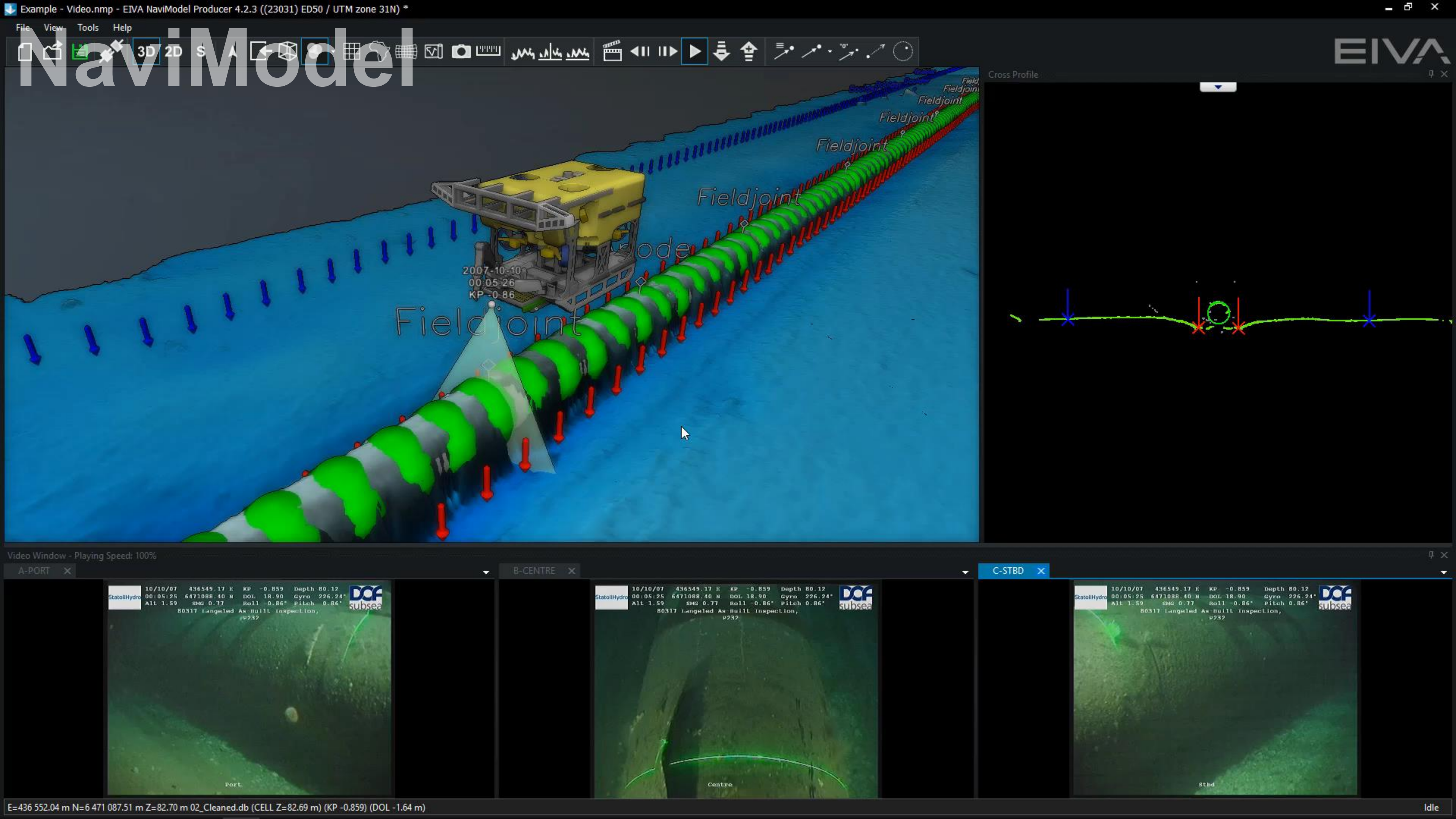
Machine Learning

November 2018

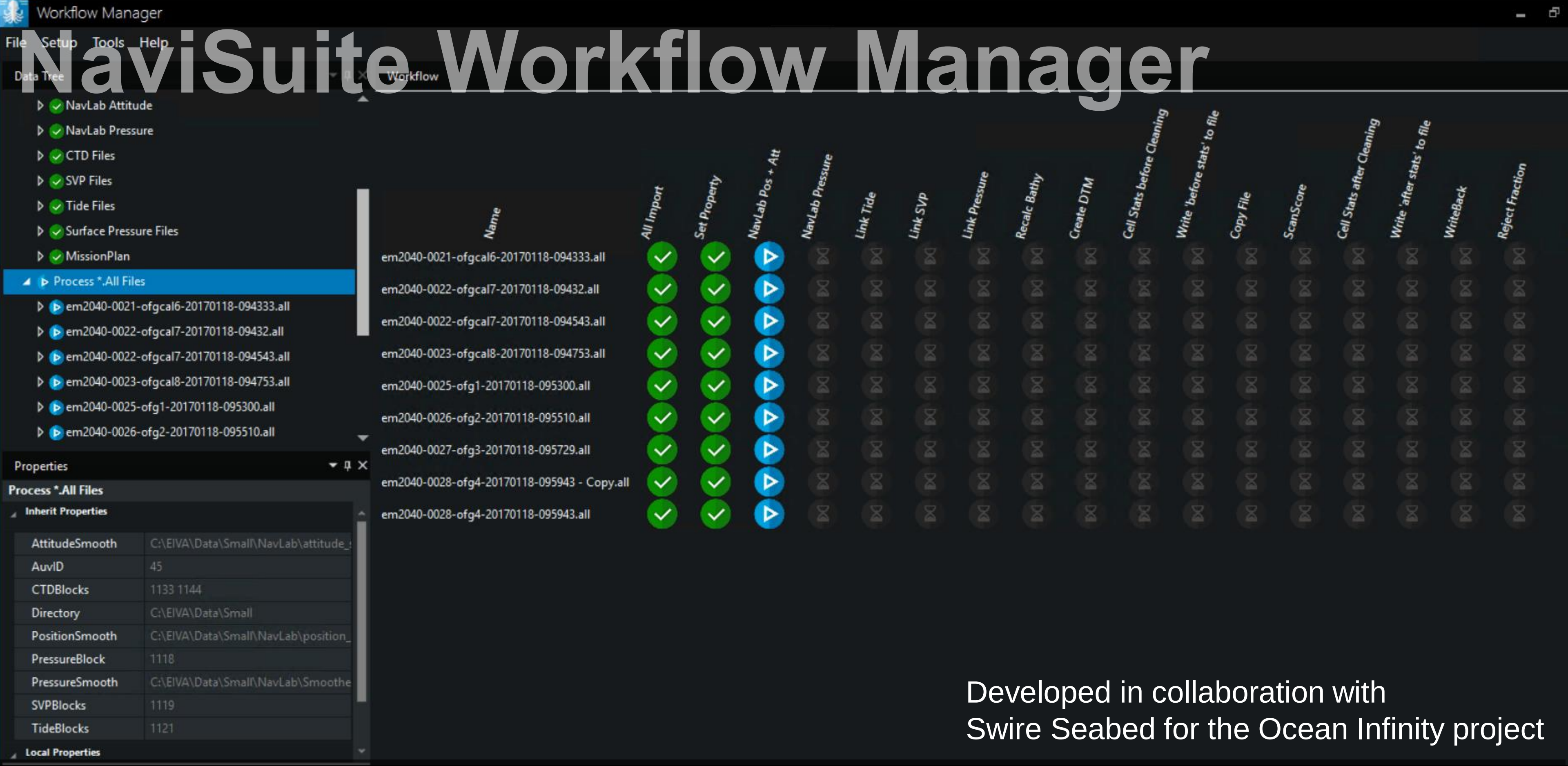
Founded in 1978 • Privately owned • ISO 9001 certified • Headquarters in Denmark
40 years experience in construction and survey • Specialise in software and hardware
Worldwide customer base and workplace • Internal research and development teams

NaviPac

Comprehensive navigation overview in real time


Example - Video.nmp - EIVA NaviModel Producer 4.2.3 ((23031) ED50 / UTM zone 31N) *
File
View
Tools
Help
NaviModel
EIVA
Cross Profile
Fieldjoint
2007-10-10
00:05:26
KP -0.86
Video Window - Playing Speed: 100%
A-PORT
B-CENTRE
C-STBD
Port
Centre
Stbd
E=436 552.04 m N=6 471 087.51 m Z=82.70 m 02_Cleaned.db (CELL Z=82.69 m) (KP -0.859) (DOL -1.64 m)
Idle

NaviSuite Workflow Manager



Developed in collaboration with
Swire Seabed for the Ocean Infinity project

Automatic processing of massive amounts of sensor data

EIVA
MARINE SURVEY SOLUTIONS

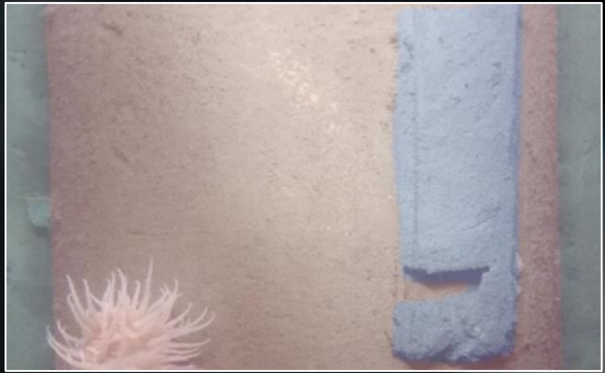
Machine Learning

- EIVA established an extra, dedicated software development team early 2017 to work solely on applying machine learning and computer vision techniques into the subsea & offshore space.

- This team works on several topics:
  - Deep Learning, being able to recognize objects
  - VSLAM, being able to track objects with a camera
  - VSLAM, being able to scan objects with a camera
  - Mesh, being able to generate 3D models
  - Mosaic, generating perfect image stitching

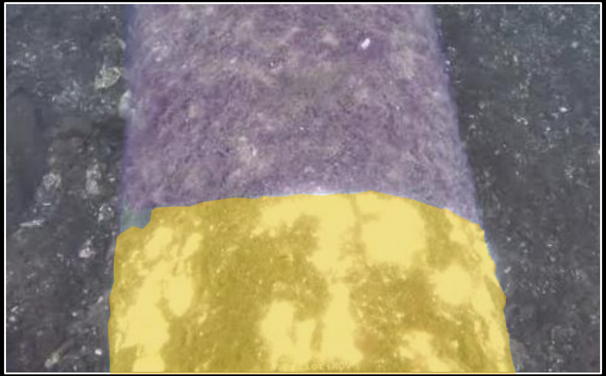
NaviSuite Deep Learning

Pipe Anode



Damage

Marine growth



Real-life examples of how the deep learning algorithm has found marked objects

Deep Learning is used for automatic detection of objects

NaviSuite Deep Learning

Automatic object detection from video

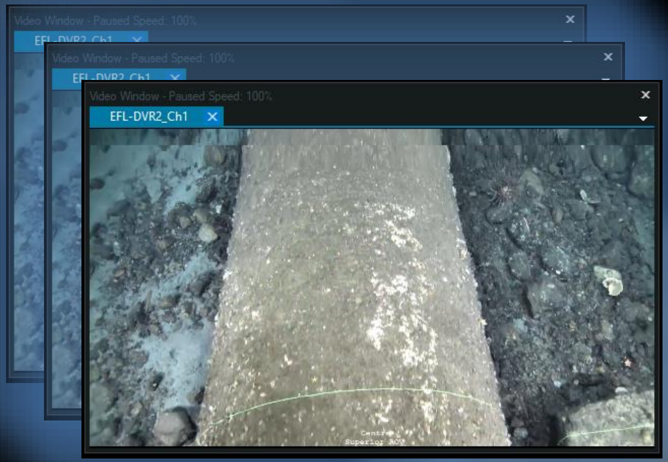
Deep Learning Options

Rack Server
Limited internet connection
(suited for Vessel)

Cloud Service
Internet connection to EIVA HQ
(suited for Office)

Onboard Computer
No internet connection
(suited for AUV / USV)

Deep Learning



Images analysed and classified one-by-one

Objects Identified:

Seabed	100%
Pipeline	97%
Anode	0%
Fieldjoint	0%
Flange	0%

Deep Learning is faster than real-time:

15 minutes of video = 1 minute processing time (Cloud Server)

Deep Learning ‘Classes’

Deep Learning is ‘trained’ to find specific objects using 10,000’s of annotated images.

Our pipeline survey model is focused on pipe inspection surveys.

More than 20 event classes available:

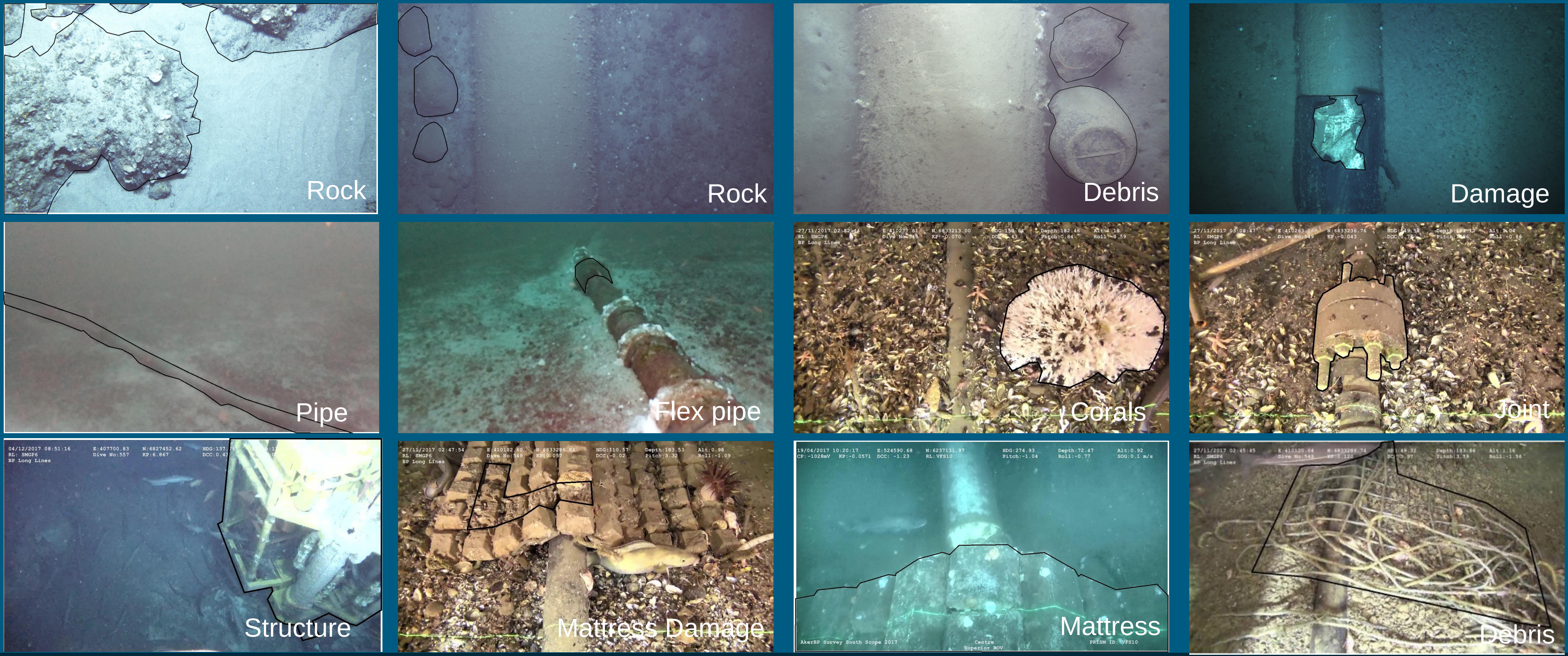
- Seabed
- Pipeline, flex pipe etc.
- Anodes
- Field joints
- Debris
- Damage
- Certain biology (corals)
- Oil seeps in water
- Structures, valves, sand bags, mattresses etc.

Mapped to end-client event types

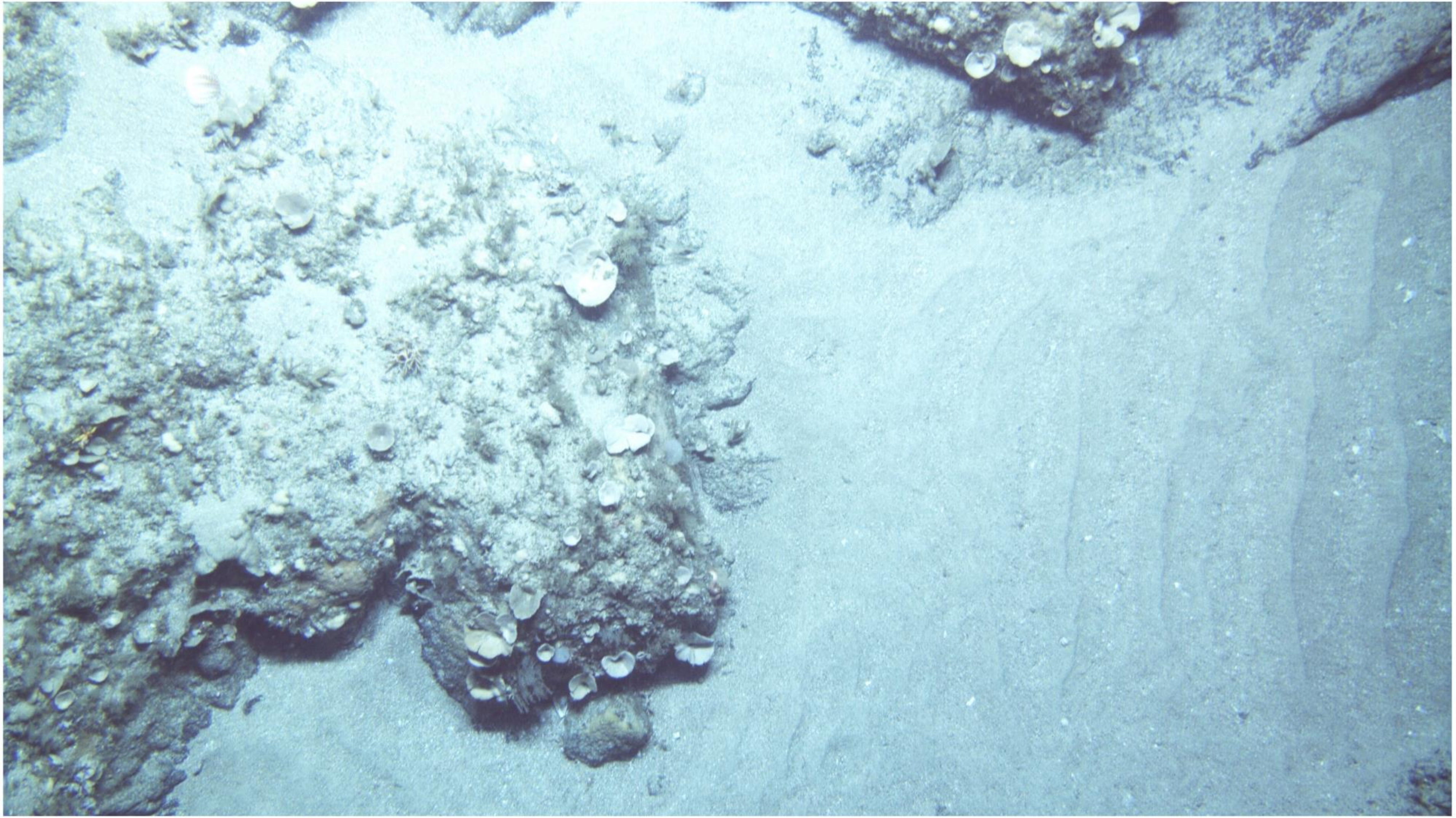
EIVA NaviModel

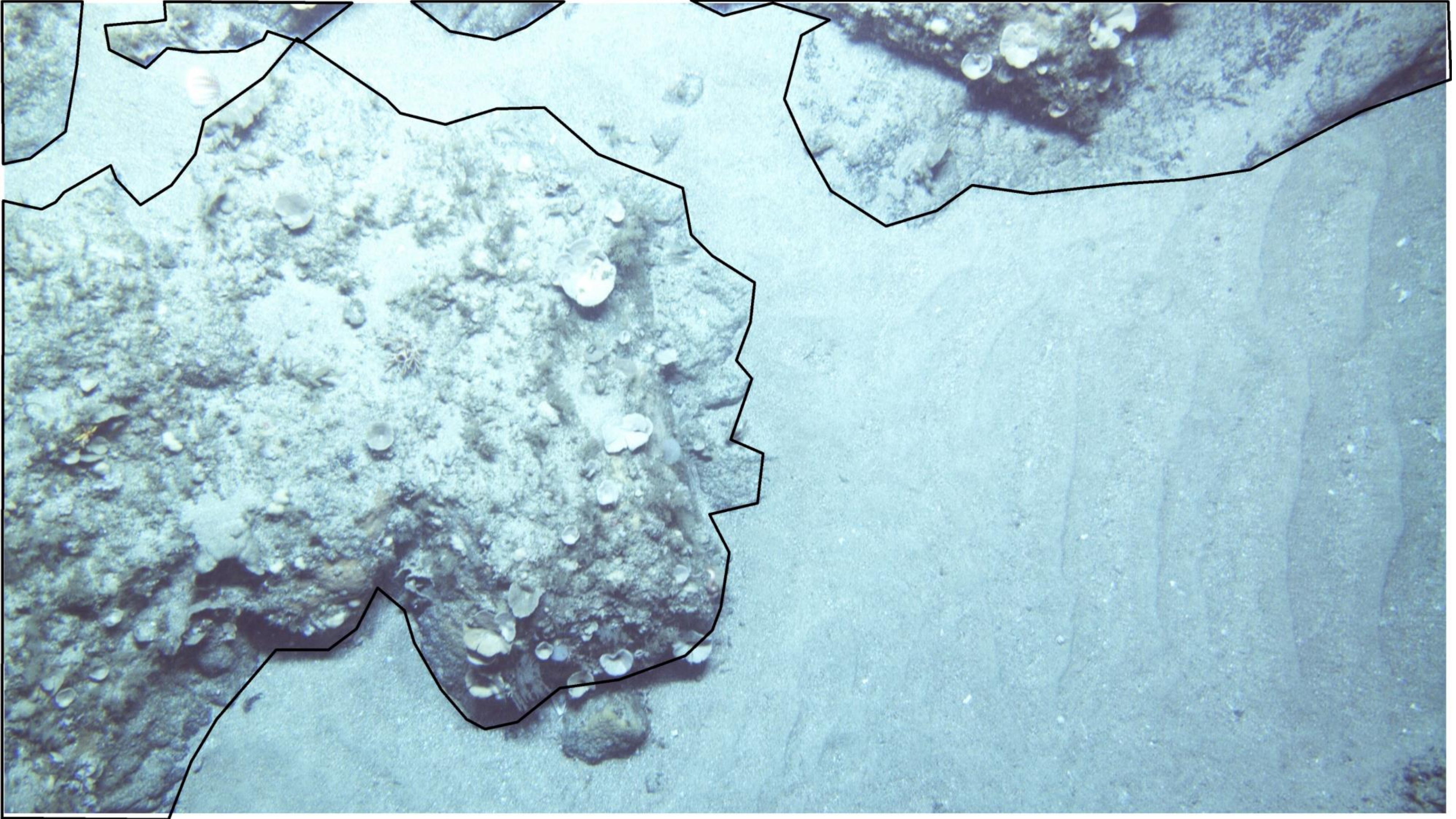
NaviSuite Deep Learning

EIVA



Deep Learning is trained on diverse data sets…






27/11/2017 02:50:44
E:410252.77
N:6833254.66
HDG:149.47
Depth:182.70
Alt:1.74
RL: SMGP6
Dive No:549
KP:-0.022
DCC:0.89
Pitch:2.90
Roll:-0.52
BP Long Lines


27/11/2017 02:50:44
RL: SMGP6
BP Long Lines
E:410252.77
Dive No:549
N:6833254.66
HDG:149.47
Depth:182.70
Pitch:2.90
Alt:1.74
Roll:-0.52


27/11/2017 02:52:44
E:410277.61
N:6833213.00
HDG:150.64
Depth:182.46
Alt:1.18
RL: SMGP6
Dive No:549
KP:-0.070
Pitch:0.84
Roll:-0.59
BP Long Lines


27/11/2017 02:52:44
RL: SMGP6
BP Long Lines
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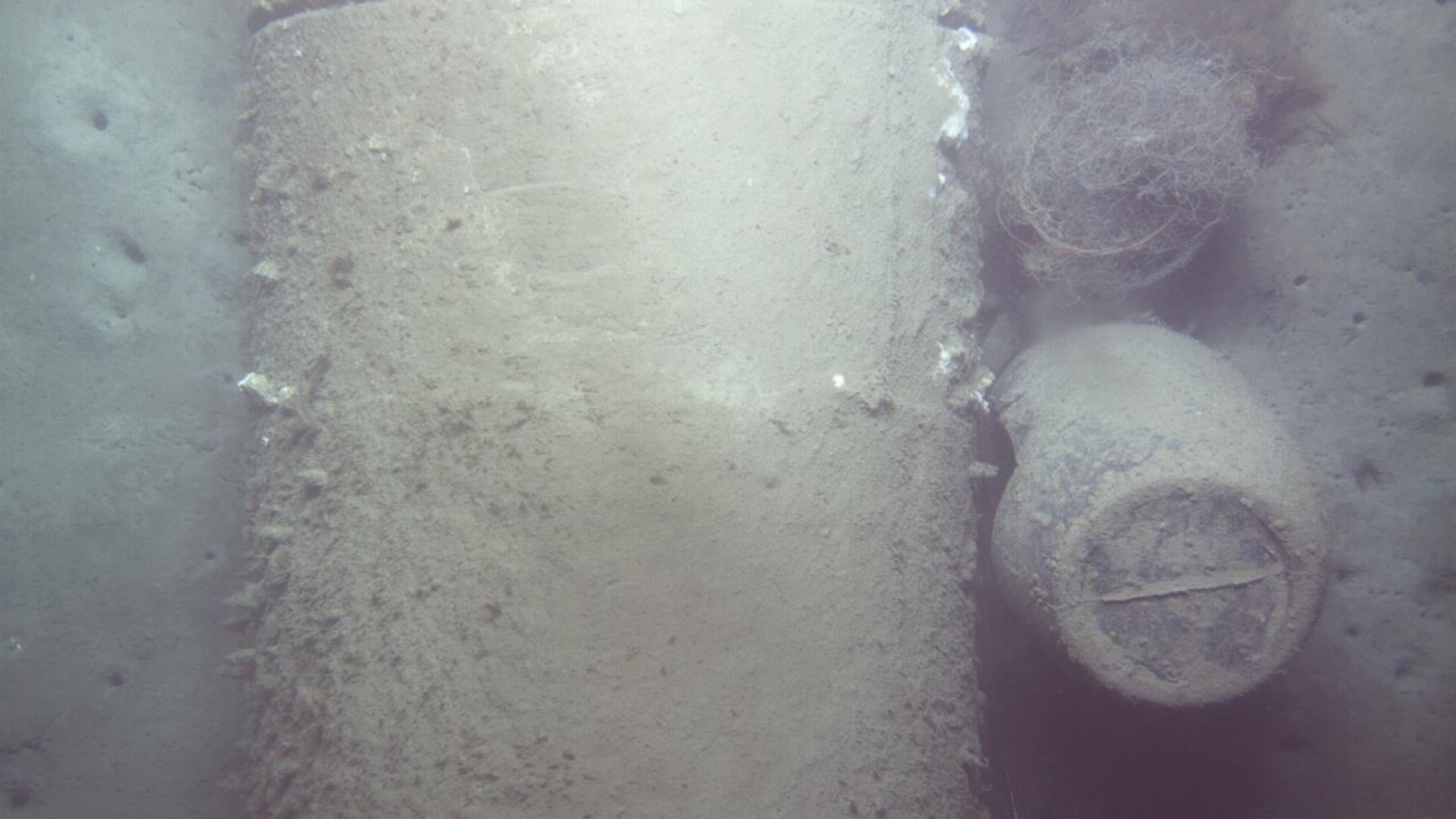


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Depth:183.86
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RL: SMGP6
Dive No:549
KP:0.120
DCC:3.97
Pitch:3.59
Roll:-1.56
BP Long Lines


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HDG:49.32
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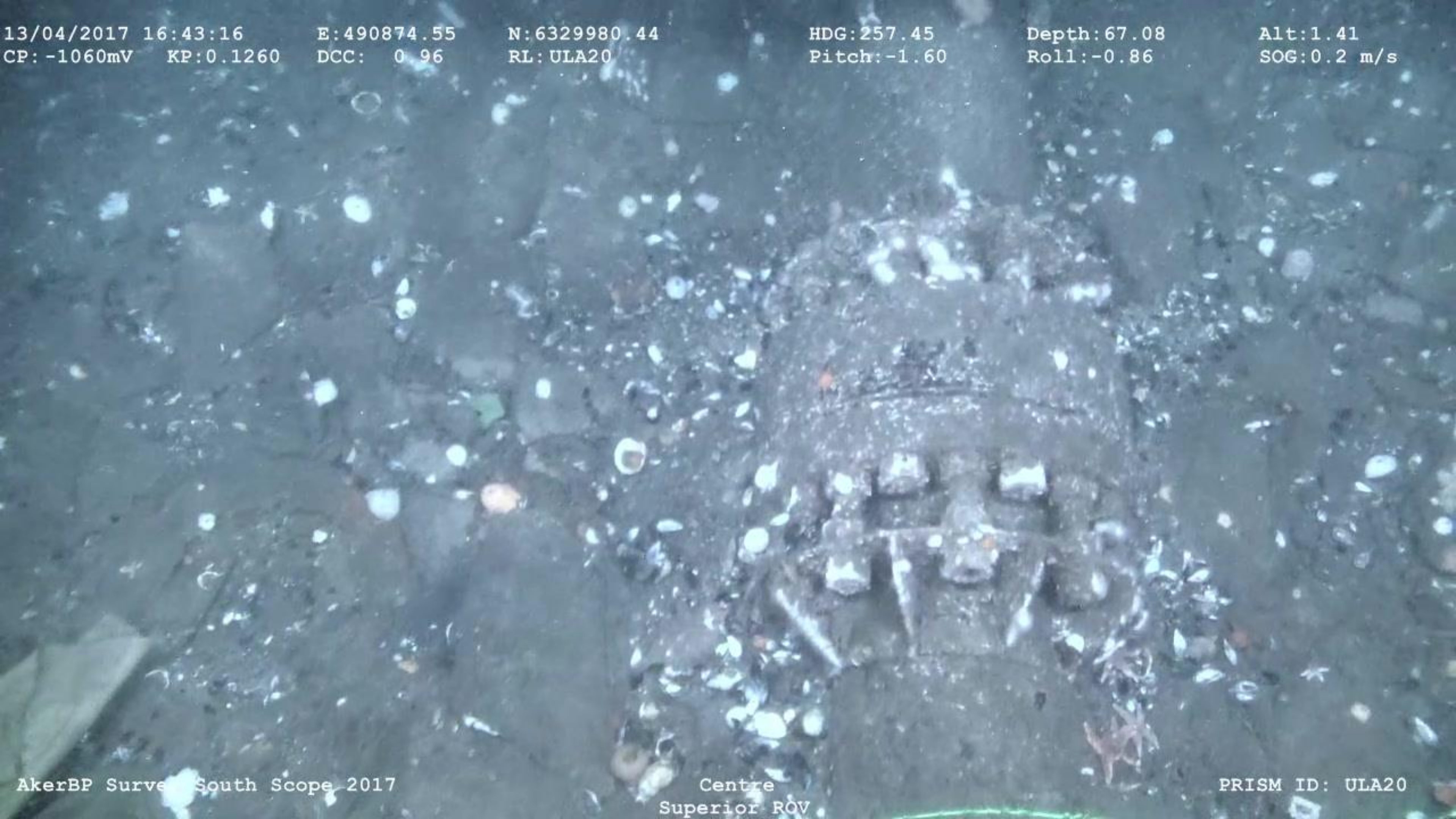
BP Long Lines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E:490874.55
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HDG:257.45
Depth:67.08
Alt:1.41
CP:-1060mV
KP:0.1260
DCC: 0 96
RL:ULA20
Pitch:-1.60
Roll:-0.86
SOG:0.2 m/s
AkerBP Surve South Scope 2017
Centre
Superior ROV
PRISM ID: ULA20


13/04/2017 16:43:16
E:490874.55
N:6329980.44
HDG:257.45
Depth:67.08
Alt:1.41
CP:-1060mV
KP:0.1260
DCC: 0.96
RL:ULA20
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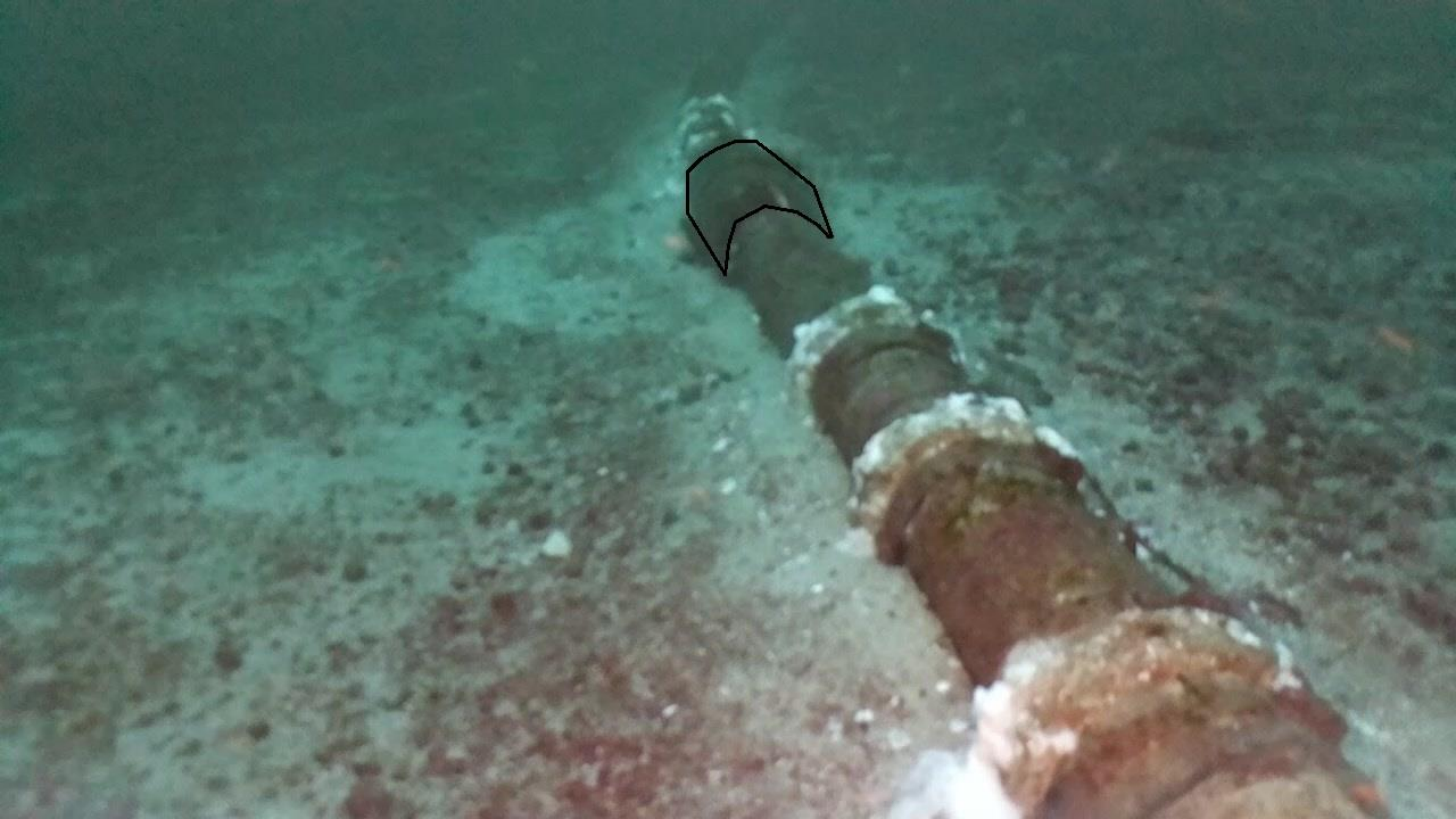
Roll:-0.86
SOG:0.2 m/s
AkerBP Survey South Scope 2017
Centre
Superior ROV
PRISM ID: ULA20

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Dive No:549
KP:-0.043
DCC:0.76
Pitch:1.86
Roll:-0.86
BP Long Lines


27/11/2017 03:08:47
E:410263.06
N:6833236.76
HDG:149.58
Depth:183.17
Alt:1.04
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Dive No:549
KP:-0.043
DCC:0.76
Roll:-0.86
BP Long Lines


13/04/2017 16:40:43
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Alt:1.34
CP:-1057mV
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Roll:-1.13
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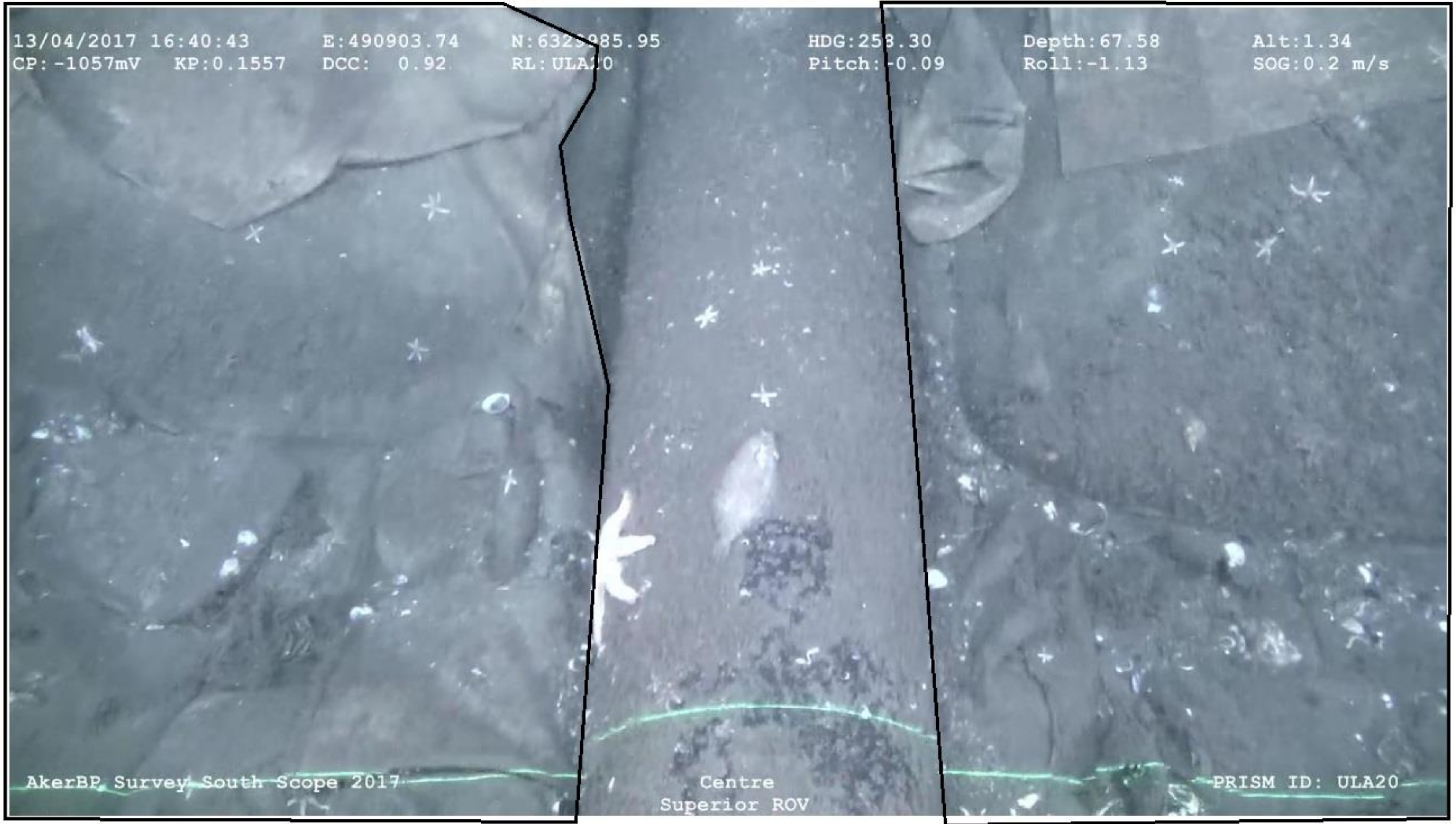
AkerBP Survey South Scope 2017
Centre
Superior ROV
PRISM ID: ULA20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KP:0.1557
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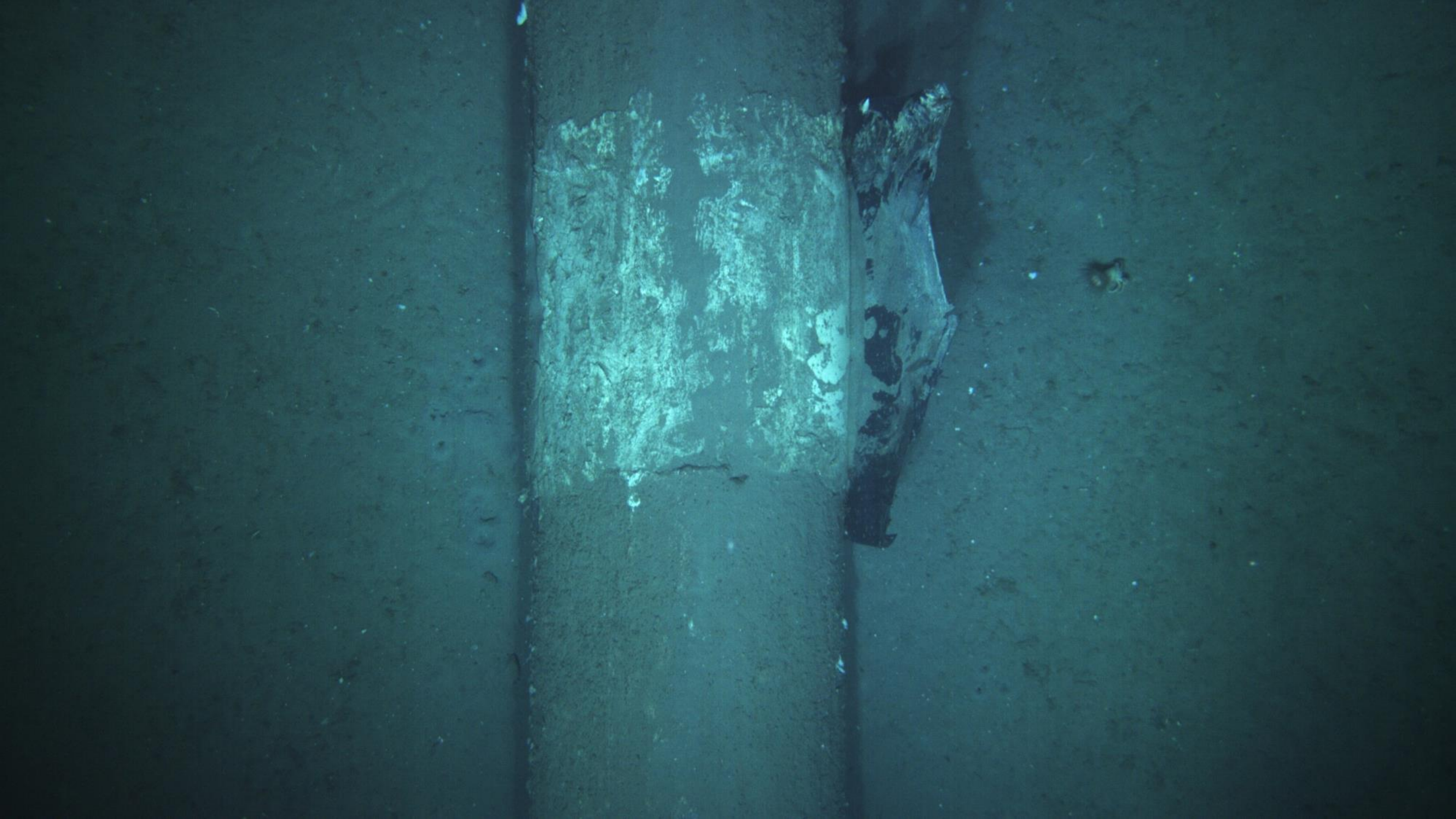
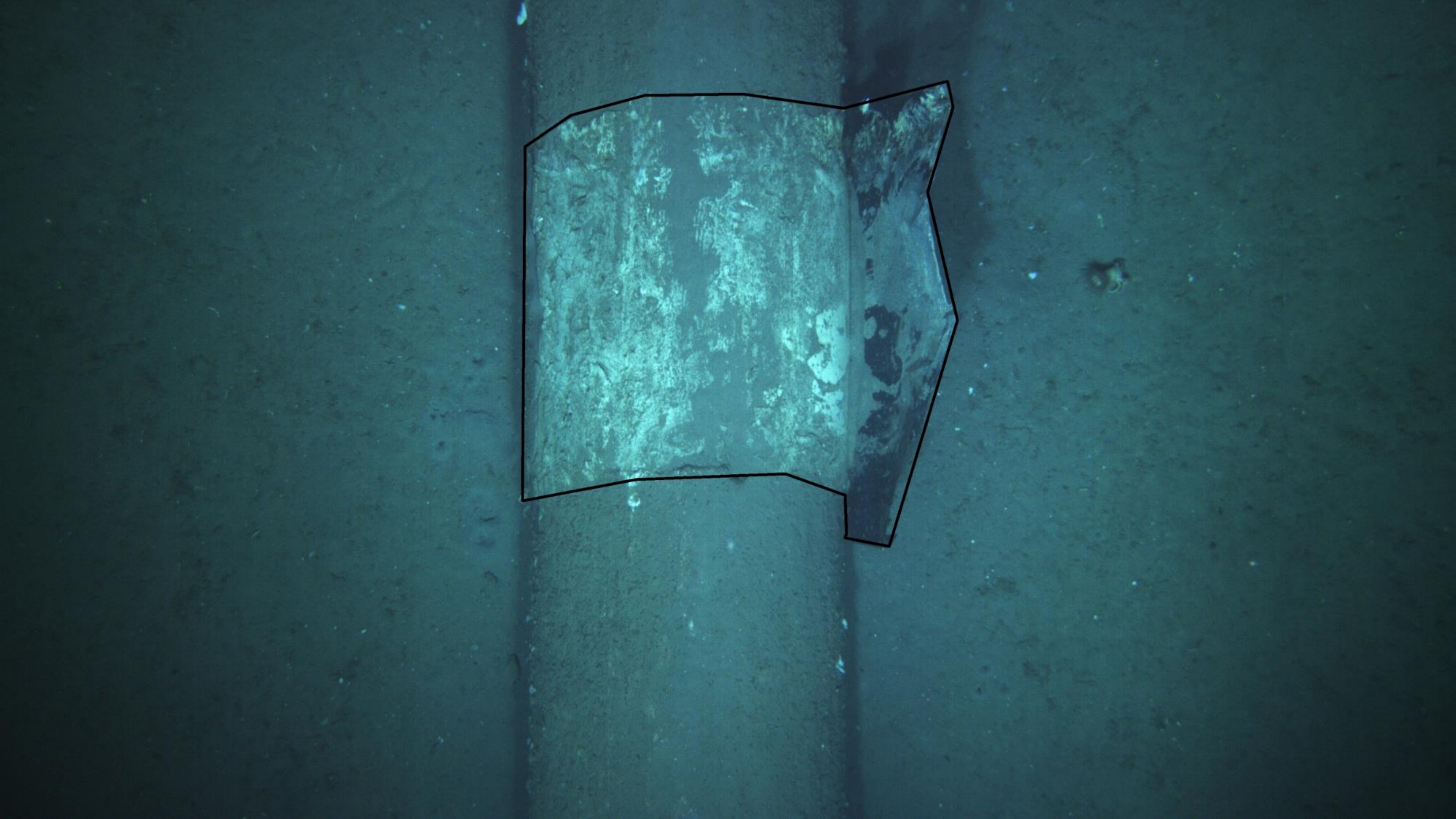
Centre
Superior ROV
PRISM ID: ULA20



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Roll:-1.43
SOG:0.1 m/s
AkerBP Survey South Scope 2017
Centre
Superior ROV
PRISM ID: ULA20


13/04/2017 16:36:28
E:490930.01
N:6329986.62
HDG:350.45
Depth:67.89
Alt:1.38
CP:-1063mV
KP:0.1855
DCC: -0.75
RL:ULA20
Pitch:0.39
Roll:-1.43
SOG:0.1 m/s
AkerBP Survey South Scope 2017
Centre
Superior ROV
PRISM ID: ULA20


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Dive No:549
KP:-0.074
Pitch:-0.53
Roll:-1.27
BP Long Lines


27/11/2017 02:52:56
E:410279.48
N:6833209.86
Depth:182.34
RL: SMGP6
Dive No:549
KP:-0.074
Pitch:-0.53
Roll:-1.27
BP Long Lines

04/12/2017 08:52:04
E:407702.23
N:6827449.71
HDG:202.29
Depth:174.01
Alt:6.92
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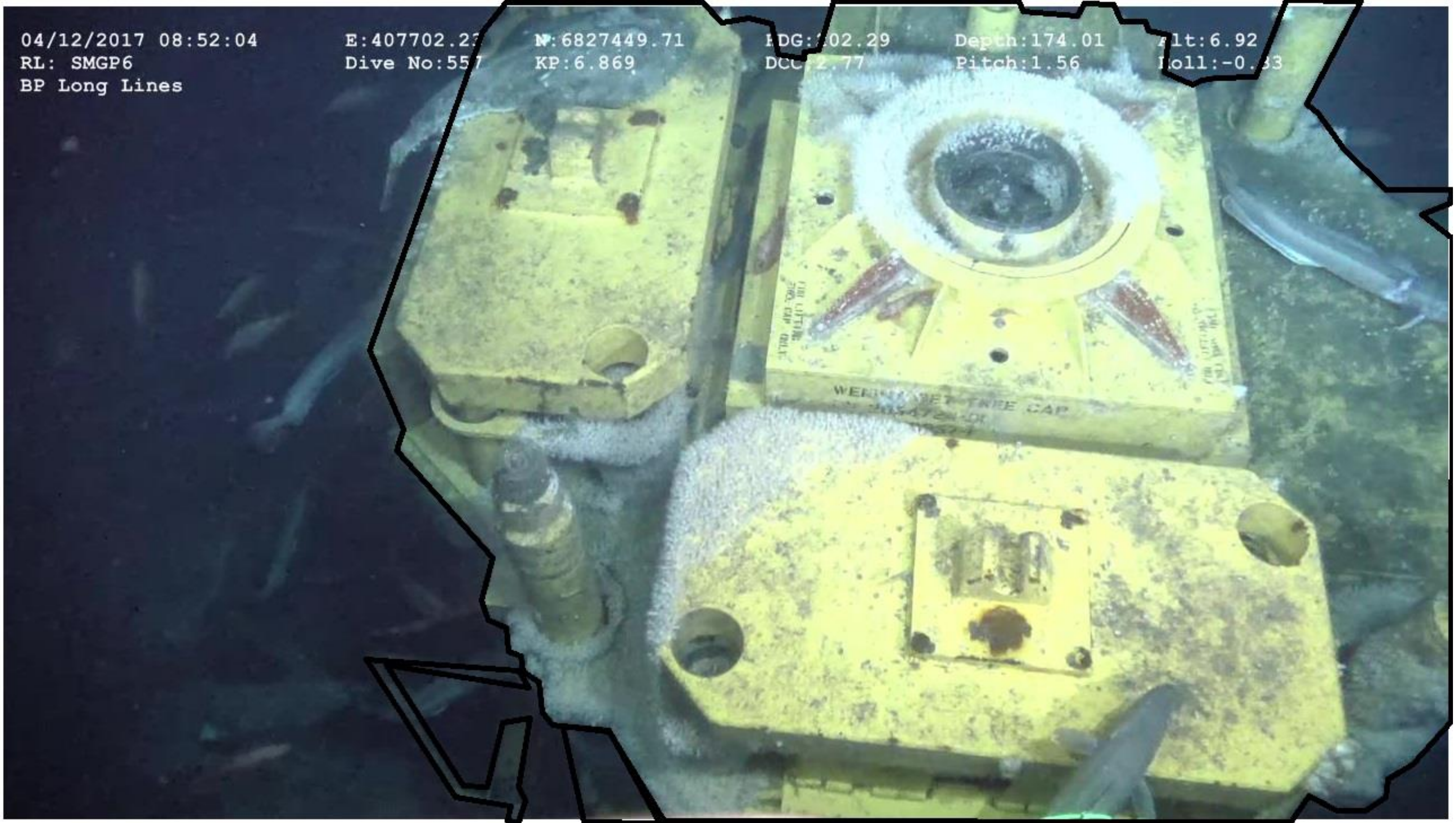
Dive No:557
KP:6.869
DCC:2.77
Pitch:1.56
Roll:-0.33
BP Long Lines
TREE CAP


04/12/2017 08:52:04
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BP Long Lines
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Dive No:557
N:6827449.71
KP:6.869
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DCC:2.77
Depth:174.01
Pitch:1.56
Alt:6.92
Roll:-0.33


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DCC:0.47
Pitch:2.61
Roll:-1.57
BP Long Lines


27/11/2017 02:49:55
E:410239.28
N:6833265.50
HDG:105.64
Depth:183.14
Alt:1.01
RL: SMGP6
Dive No:549
KP:-0.004
DCC:0.47
Pitch:2.61
Roll:-1.57
BP Long Lines


04/12/2017 08:51:16
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N:6827452.62
HDG:137.76
RL: SMGP6
Dive No:557
KP:6.867
DCC:0.43
BP Long Lines


04/12/2017 08:51:16
E:407700.83
N:6827452.62
RL: SMGP6
Dive No:557
KP:6.867
BP Long Lines


19/04/2017 10:20:17
E:524590.68
N:6237131.97
HDG:274.93
Depth:72.47
Alt:0.92
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DCC: -1.23
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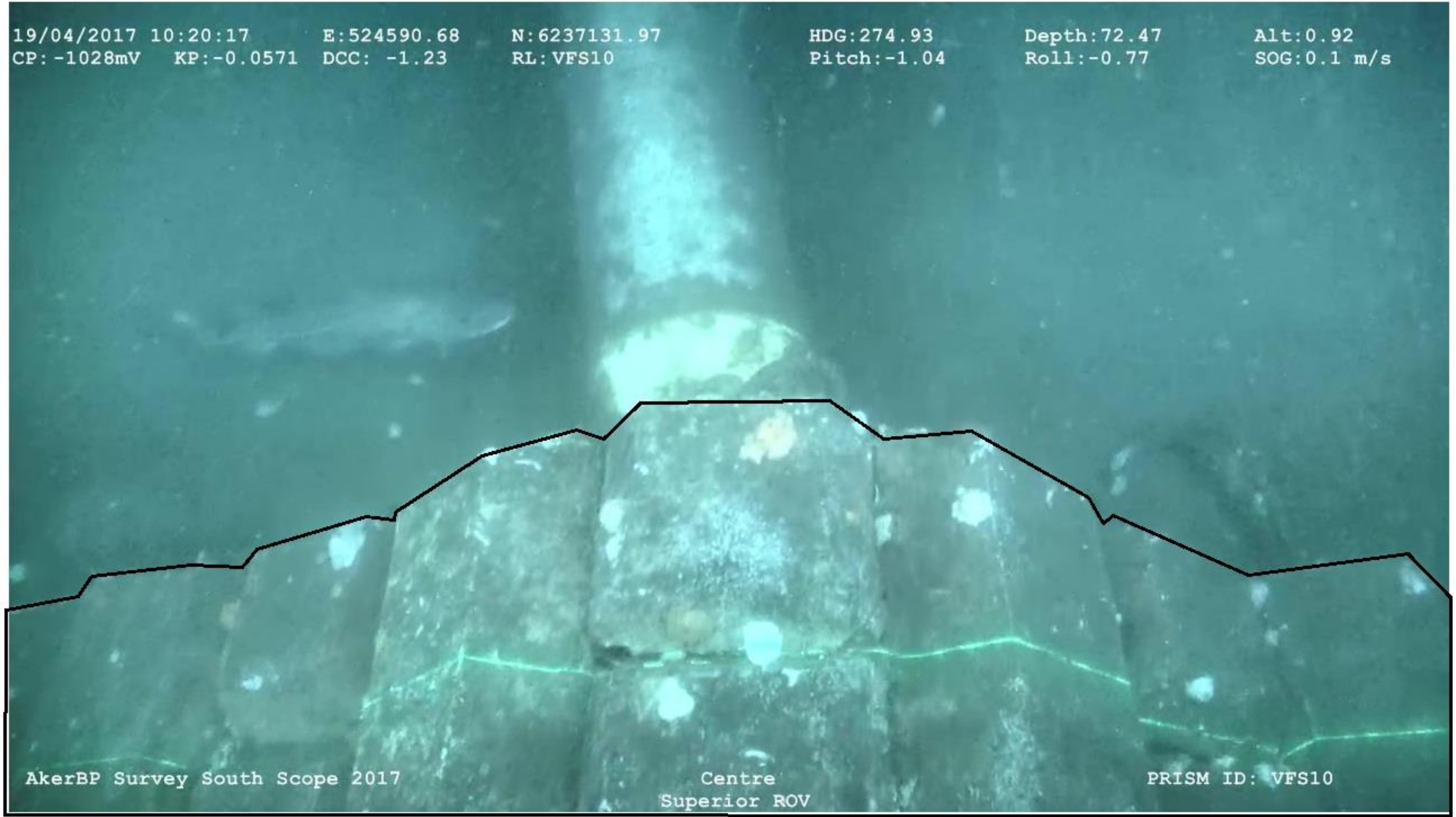
Roll:-0.77
SOG:0.1 m/s
AkerBP Survey South Scope 2017
Centre
Superior ROV
PRISM ID: VFS10


19/04/2017 10:20:17
E:524590.68
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Depth:72.47
Alt:0.92
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KP:-0.0571
DCC: -1.23
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Pitch:-1.04
Roll:-0.77
SOG:0.1 m/s
AkerBP Survey South Scope 2017
Centre
Superior ROV
PRISM ID: VFS10


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DCC:-0.02
Pitch:3.32
Roll:-1.09
BP Long Lines

27/11/2017 02:47:54
RL: SMGP6
BP Long Lines
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Dive No:549
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KP:0.057
HDG:110.57
DCC:-0.02
Depth:183.53
Pitch:3.32
Alt:0.98
Roll:-1.09


E:410214.32
Dive No:549
KP:0.023
Depth 183.23
Pitch:3.71
Alt:0.00
Roll:-0.79
BP Long Lines


E:410214.32
Dive No:549
KP:0.023
DCC:0.21
Depth:183.23
Pitch:3.71
Alt:0.00
Roll:-0.79
BP Long Lines


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HDG:114.96
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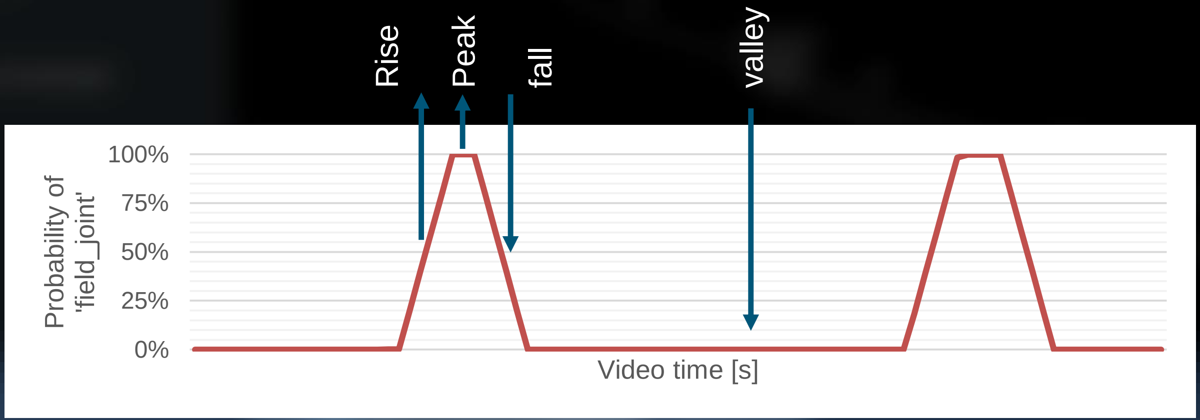
Alt:1.11
RL: SMGP6
Dive No:549
KP:0.037
DCC:0.15
Pitch:3.50
Roll:-1.53
BP Long Lines


27/11/2017 2:48:34
E:410201.16
N:6833279.54
HDG:114.96
Depth:183.13
Alt:1.11
RL: SMGP6
Dive No:549
KP:0.037
DCC:0.15
Pitch:3.50
Roll:-1.53
BP Long Lines

Deep Learning

Images are classified one-by-one (offloaded to remote Deep Learning server)

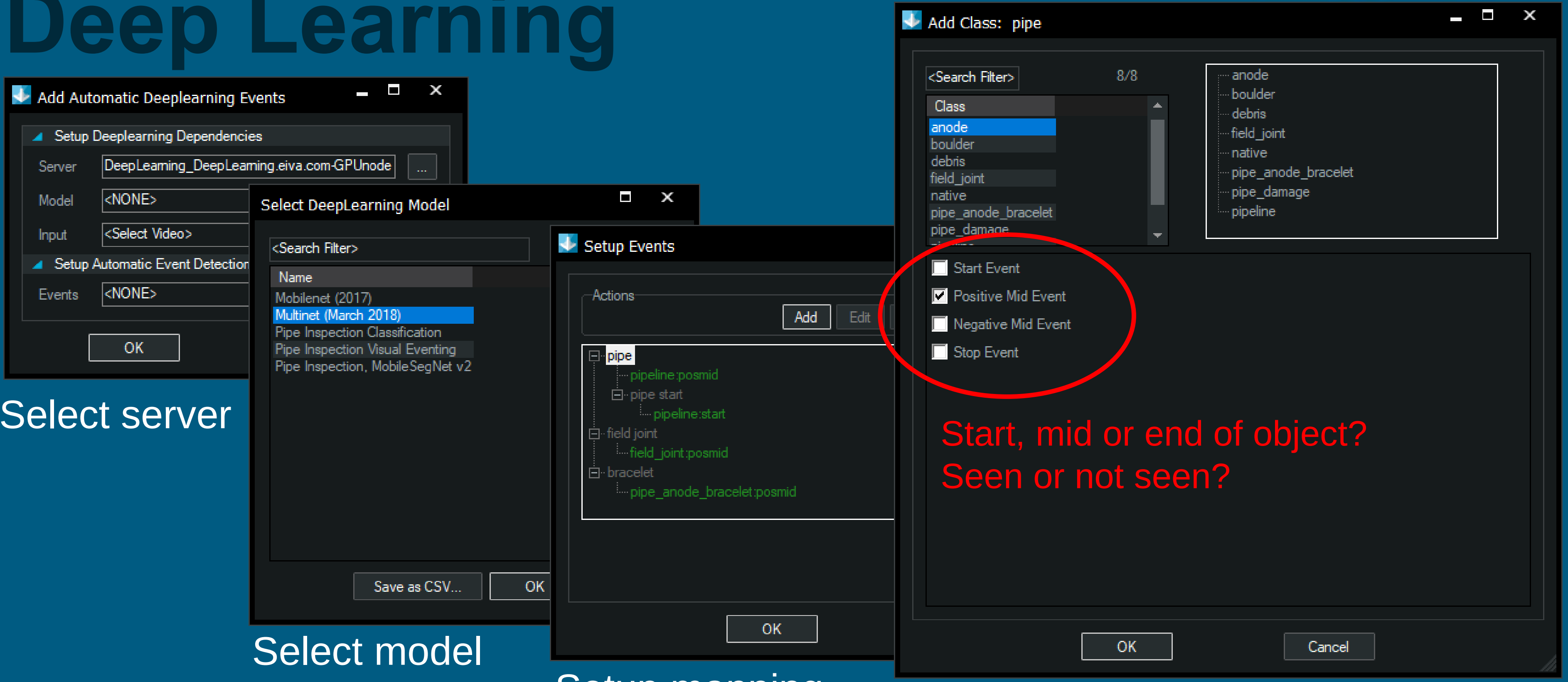
Events are created at any class+state combination wanted



Events at fall and rise of 'pipeline'

Events at peak of 'field joint' and 'debris'

Deep Learning



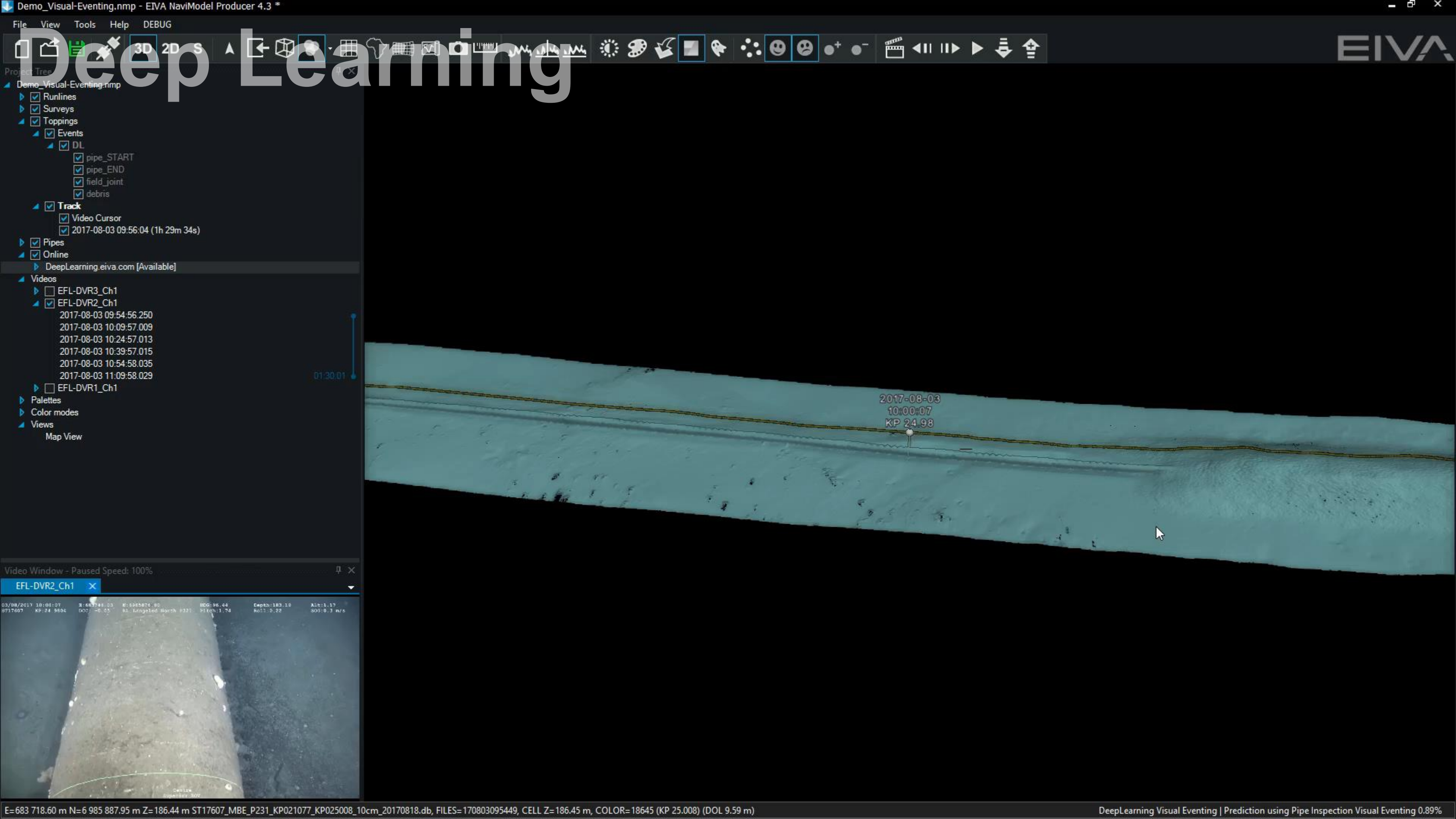
Select server

Select model

Setup mapping

Choose output

Mapping Deep Learning to end-client event hierarchy

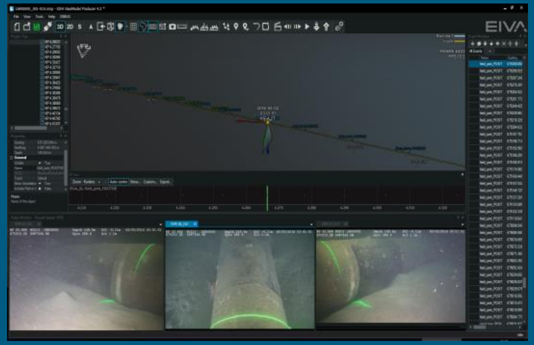


Deep Learning
Demo_Visual-Eventing.nmp - EIVA NaviModel Producer 4.3 *
File View Tools Help DEBUG
3D 2D S
EIVA
Project Tree
Demo_Visual-Eventing.nmp
Runlines
Surveys
Toppings
Events
DL
pipe_START
pipe_END
field_joint
debris
Track
Video Cursor
2017-08-03 09:56:04 (1h 29m 34s)
Pipes
Online
DeepLearning.eiva.com [Available]
Videos
EFL-DVR3_Ch1
EFL-DVR2_Ch1
2017-08-03 09:54:56.250
2017-08-03 10:09:57.009
2017-08-03 10:24:57.013
2017-08-03 10:39:57.015
2017-08-03 10:54:58.035
2017-08-03 11:09:58.029
01:30:01
EFL-DVR1_Ch1
Palettes
Color modes
Views
Map View
2017-08-03
10:00:07
KP 24.98
Video Window - Paused Speed: 100%
EFL-DVR2_Ch1
E=683 718.60 m N=6 985 887.95 m Z=186.44 m ST17607_MBE_P231_KP021077_KP025008_10cm_20170818.db, FILES=170803095449, CELL Z=186.45 m, COLOR=18645 (KP 25.008) (DOL 9.59 m)
DeepLearning Visual Eventing | Prediction using Pipe Inspection Visual Eventing 0.89%

Deep Learning on AUV

EIVA
MARINE SURVEY SOLUTIONS

50 Hour Subsea Mission



We can run Deep Learning on the AUV with a small payload computer connected to the camera:

- Automatic event registration during the mission = reduction of post processing time
- Detect anomalies and adapt the mission to acquire more data
- QC of camera data – huge reduction of resurvey cost

Live now with Swire & Kongsberg

Deep Learning

EIVA's Deep Learning implementation brings AI to the subsea domain:

- It's intuitive, use it together with all the other manual and assisted tools inside NaviModel. Deep Learning eventing will run in the background, while the operator can inspect events as they are found – or do other things.
- It's effective, use it for automatic detection and registration of typical events during inspection.
- It's real-time, use it on recorded data or live during the mission, the embedded version can keep up with at least one HD camera live.
- It's fast, the on-premise server is at least x15 video speed – or monitor many cameras.
- It's software, no special hardware needed.

An integrated part of NaviSuite

Summary

DEEP LEARNING

Let's us recognize objects and automate 'eventing', thus reducing data processing time and cost

EFFECTIVENESS

EIVA's Deep Learning model for pipeline inspection surveys is extensive and built from multiple data sets

EASE OF USE

The automated visual eventing is available within EIVA's subsea inspection software NaviModel – used by most high-end operators

SLAM

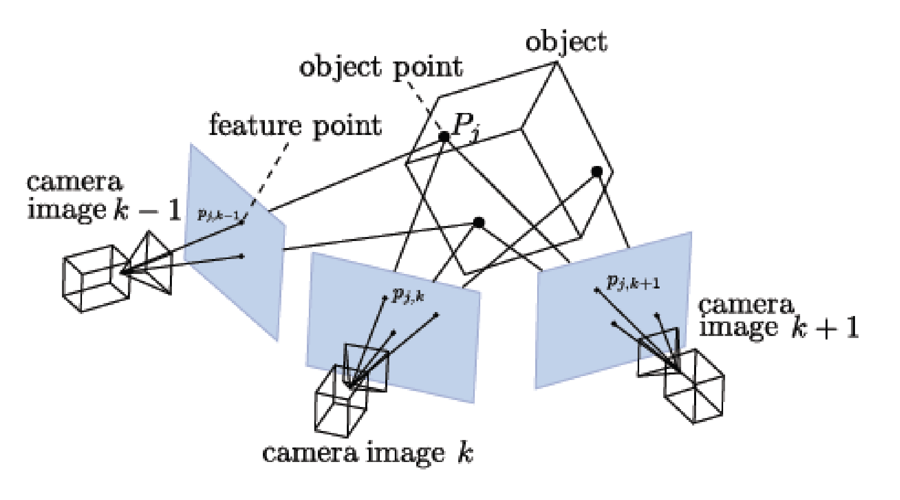
November 2018

SLAM

Simultaneous **L**ocalisation **A**nd **M**apping

'The computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it'

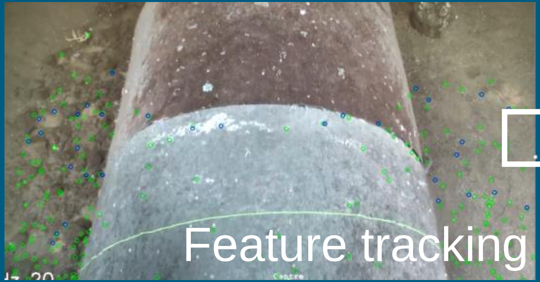
Photogrammetry will just compare features in all images – this is why it is so slow….



If we track recognisable features in moving images, it is possible to calculate the position of the camera and the position of features.

What is SLAM?

NaviSuite SLAM



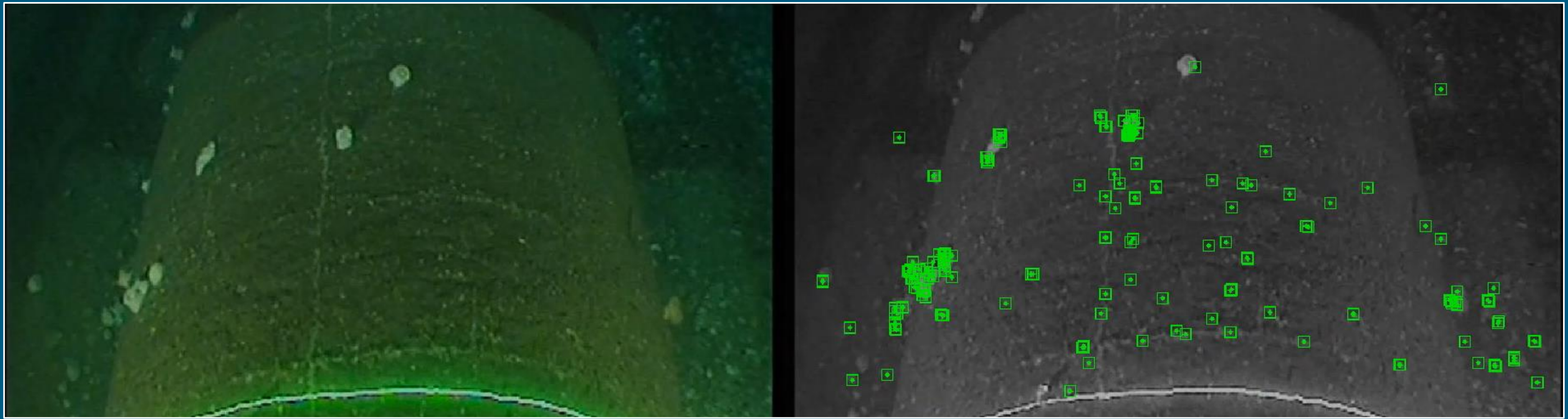
EIVA's VSLAM algorithm creates a real-time sparse point cloud and camera key frame positions. Point cloud has the correct scale, position and orientation.

Calculation of a dense 3D point cloud is optimised for speed by using the key frames found by VSLAM

3D mesh model is generated from the dense point cloud and with coloured textures from all pixels in the original images

Real-time point clouds and 3D Mesh from single camera

Feature Tracking



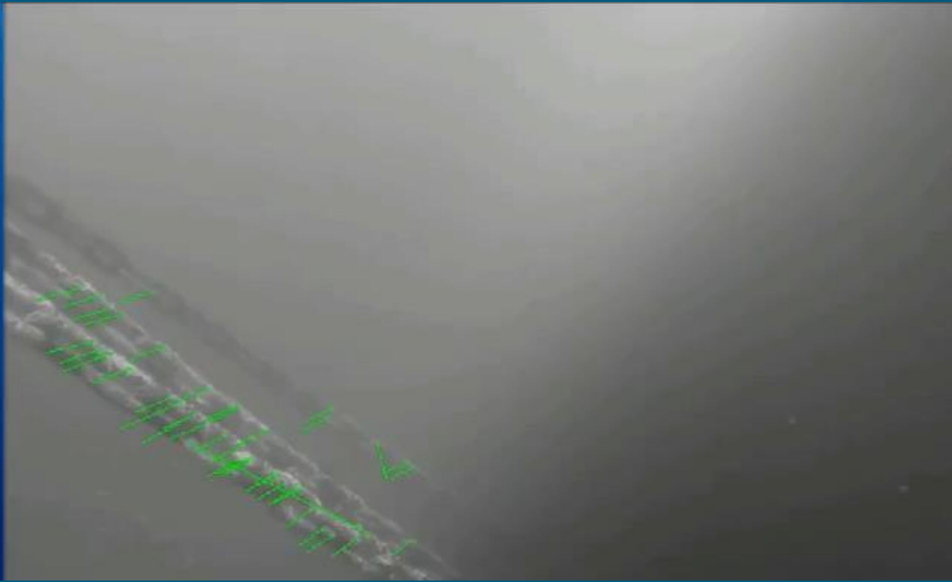
What the human can see...

What SLAM can see...

Green points show SLAM tracking features in REAL-TIME

Vector Tracking

What the human can see...

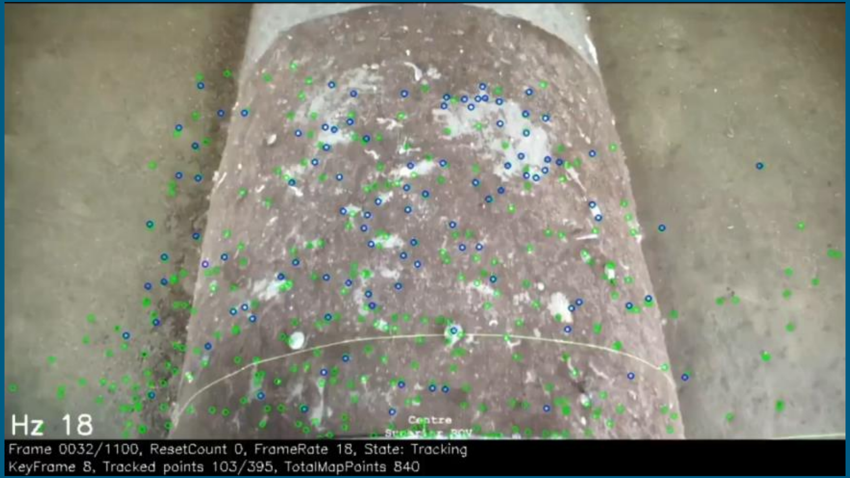


What SLAM can see...

Video is from Youtube (i.e. method works on any video)

Illustration of VSLAM – key frames and tracking feature points

Sparse point clouds



Sparse point cloud is not an end-deliverable.

SLAM tracks around ~200 features in real-time.

Using the tracked 2D points, bundle adjustment runs in real-time to estimate track and 3D point cloud by optimising the reprojection error.

It is used for two things:

- It defines the position of the dense point cloud
- It is meant for autonomous operations, allowing AUVs / UROVs to track structures in real-time using the camera

The sparse point cloud is useful for navigation

SLAM / PHOTOGRAMMETRY

EIVA
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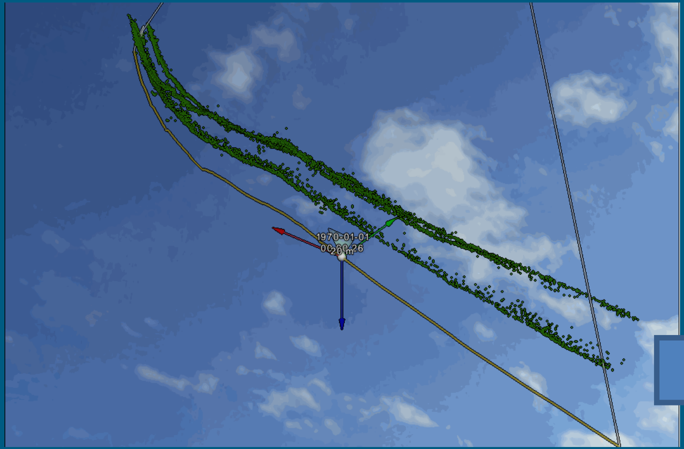
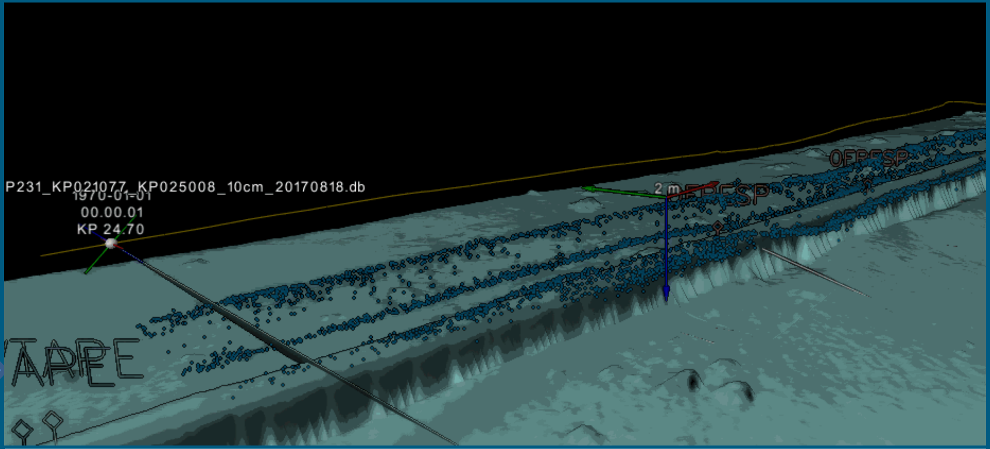
We tried many existing SLAM algorithms, and ended up implementing our own – for the following reasons:

- No loop-closure. Some SLAM algorithms depend on loop-closure, ie when ‘coming back’ to a place visited before, the whole calculation is adjusted. This is not feasible on a long pipeline inspection.
- Tracking at high speeds. The more overlap of features in video, the easier the SLAM tracking is. We needed an algorithm that works with little overlap.
- Bad visibility. The conditions under water are not always good, so an algorithm must be able to handle a lot of noise / particles in the water.
- Performance. We wanted an implementation that could run in real-time on a normal computer.
- Single camera. Some photogrammetry solutions use multiple cameras – finely calibrated. This means a hardware-dependent solution as well as a physically larger solution.

EIVA has implemented its own Visual SLAM algorithm

SLAM challenges





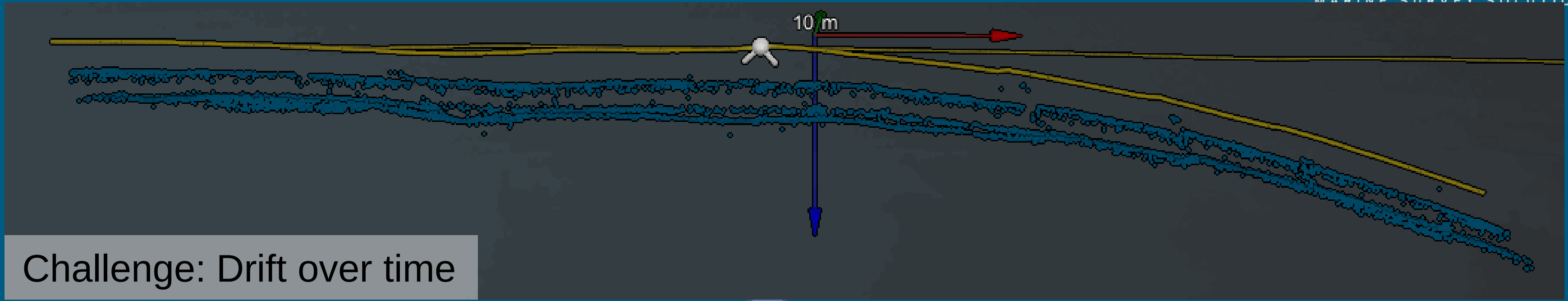
Issue: Track not aligned to world
Wrong scale, position and rotation

Result: Corrected Track

Linear Transformation
(Similarity transformation respecting camera orientation)

SLAM challenge – position and scale

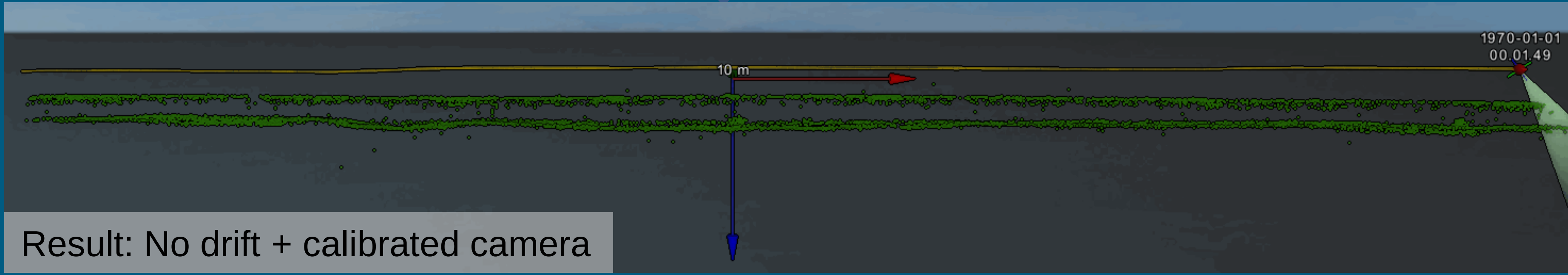
SLAM challenges



Challenge: Drift over time

Bundle Adjustment…

Optimisation includes global positions (eg USBL/track)
and better camera parameters



Result: No drift + calibrated camera

SLAM challenge – drift

Dense point clouds

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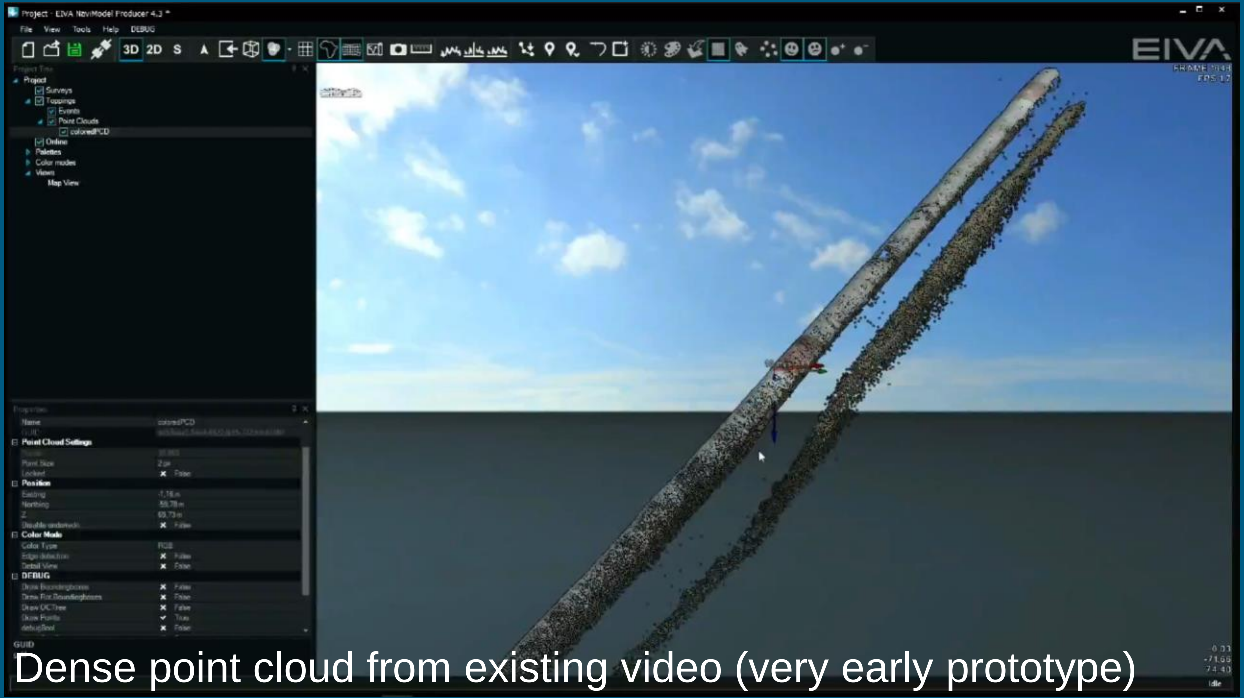


Dense point cloud from existing video (very early prototype)

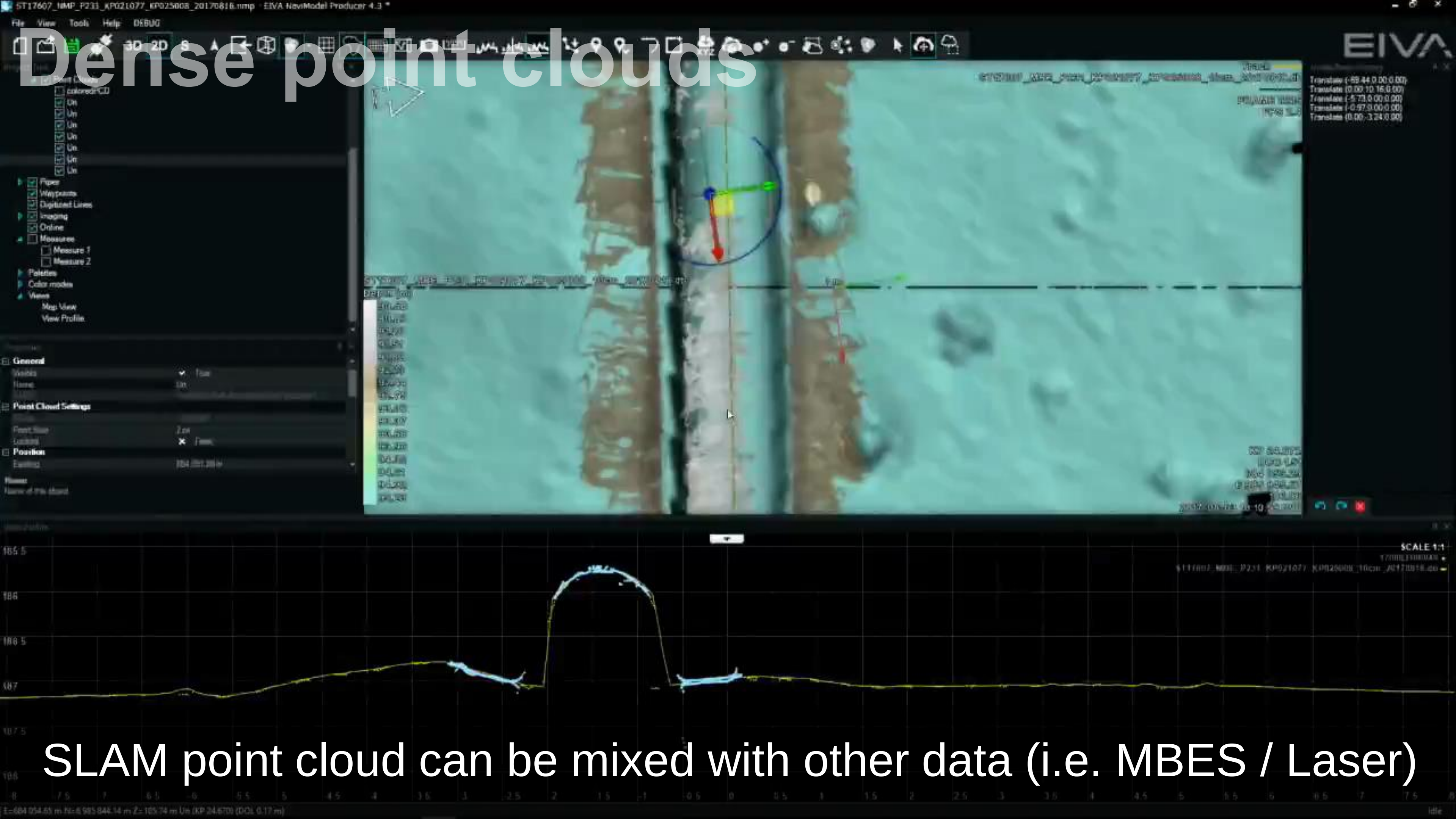
A dense point cloud is produced based on the sparse point cloud and original images.

It is produced with a small delay, so that the SLAM positioning in the sparse point cloud has been completed.

It adds to the point cloud in small sections.

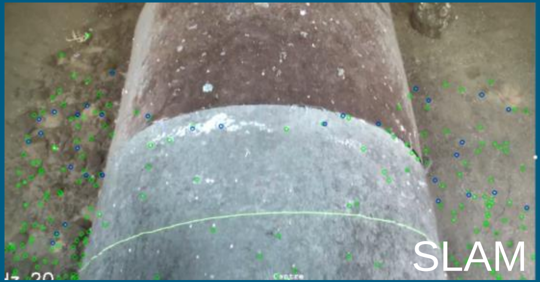
Example of a point cloud generated from SLAM

Dense point clouds



SLAM point cloud can be mixed with other data (i.e. MBES / Laser)

Dense point clouds



Real time on small devices | Heavier process | Slightly better than 1:1

The entire process is 1:1

(i.e. 1 min of video = 1 min of processing

3D Mesh and Dense Point Cloud generated in real-time

SLAM / dense point cloud

- EIVA is a product company, not a survey/service company.
- Our SLAM implementation is available to all the survey companies with NaviSuite
  - Use live, delayed real-time (few seconds delay)
  - Use on existing projects / playback
  - 3D Mesh and colour point clouds can be handled in the NaviModel Free Viewer

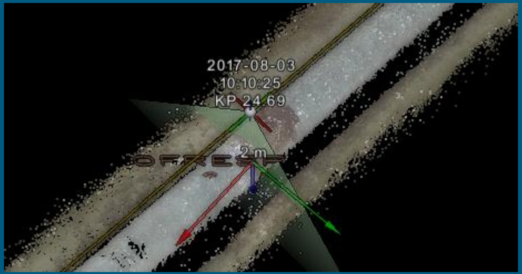
- Use your existing ROV spread
  - Single camera or multiple cameras
  - Also mini and micro-ROVs
  - Any camera
  - Still images or video

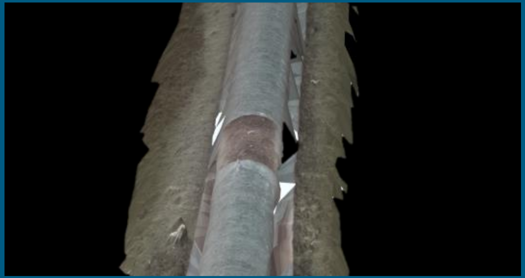
- No special HW for processing, just a fast PC

EIVA's photogrammetry implementation is a bit different

SLAM on AUV

50-hour
Subsea Mission





SLAM on AUV with a small payload computer

- Automatic tracking of structures with camera
- Calculate camera movement for later use in generation of dense point cloud and 3D mesh

Live now with Swire & Kongsberg

Summary

SLAM

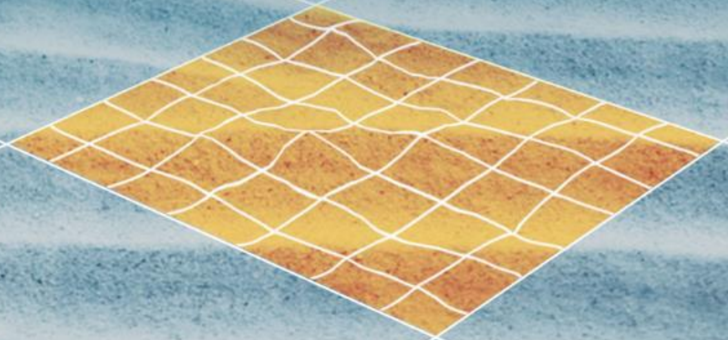
Let’s us track structures, build point clouds and 3D Mesh – and measure movement from camera

REDUCE COST

SLAM requires no special sensors for scanning and can be used on any moving camera device

IT’S FAST

EIVA SLAM is real-time
– no slow post-processing



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MESH

November 2018

Mesh

A digital terrain model (DTM) is a simple 2D mesh surface 'seen from above' (i.e. assumes a single surface).

For 3D scanning, a 3D model is needed if we want to work on volumes, surfaces etc.

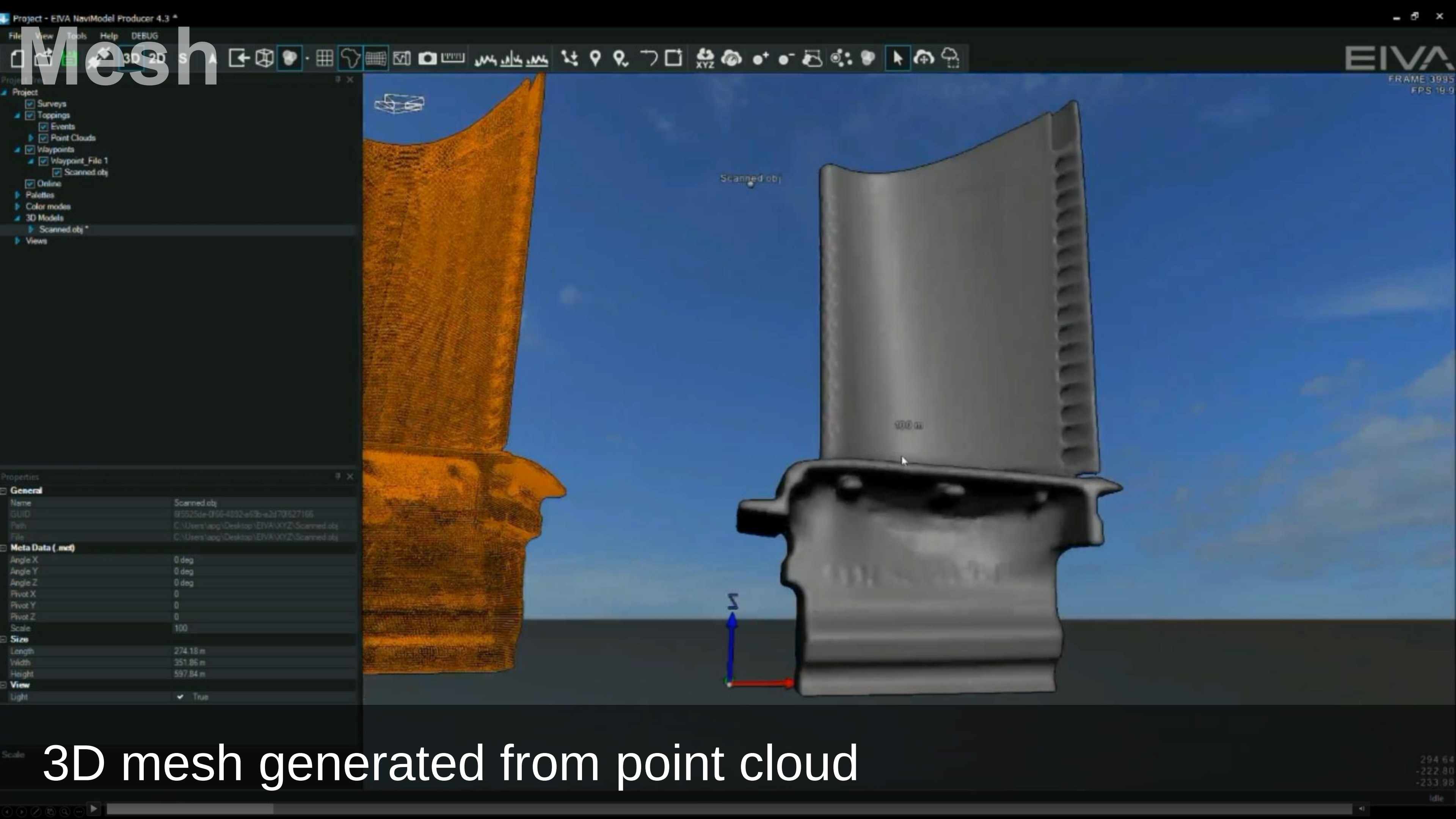
We have implemented support for mesh:

- Import and display of large mesh in .obj, .fbx and other formats
- Generate textured mesh from SLAM
- Generate textured mesh from any point cloud

Mesh with colour textures from SLAM point cloud in NaviModel

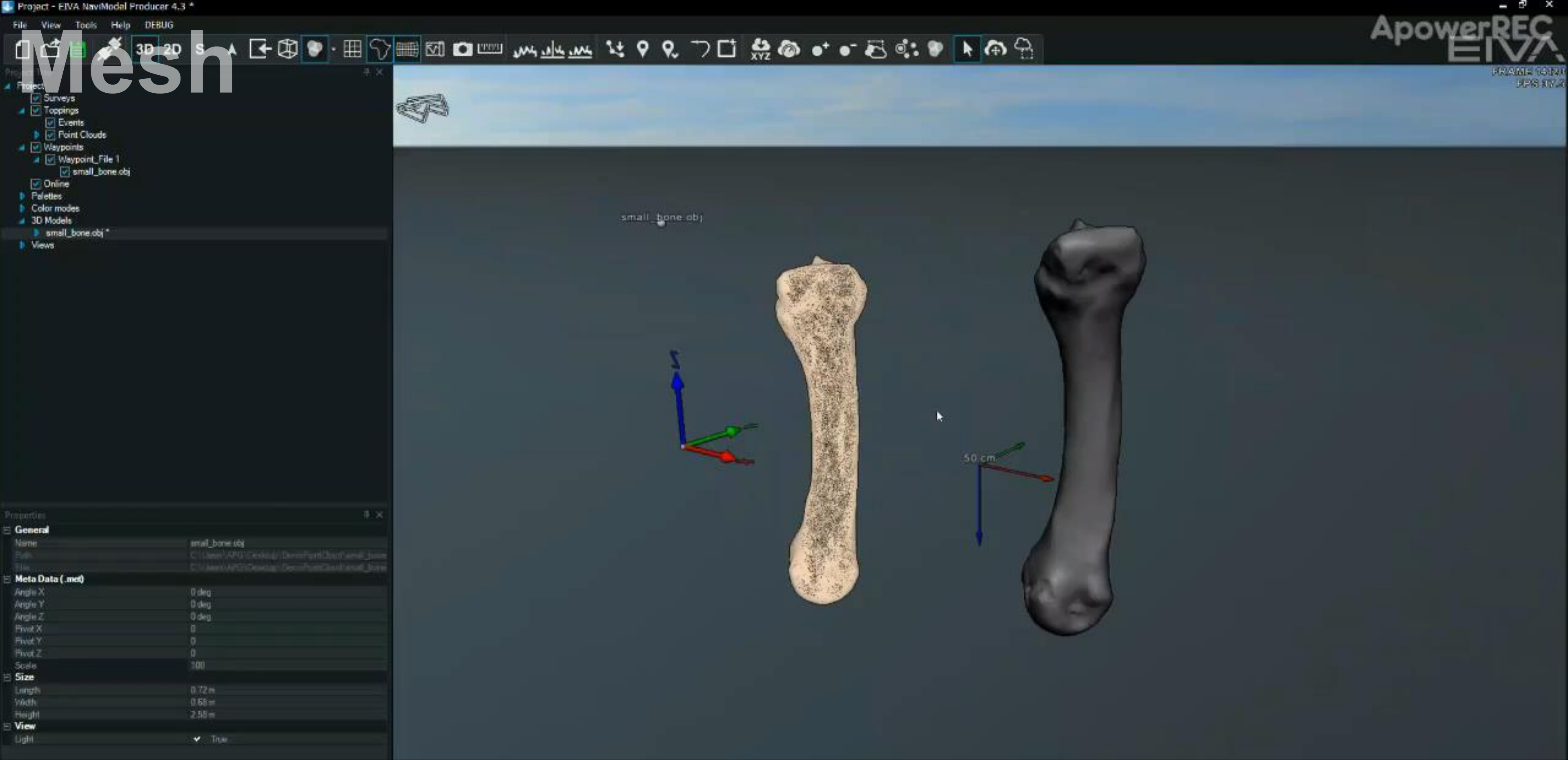
Mesh (3D) is the new deliverable

Mesh



3D mesh generated from point cloud

Mesh



3D mesh generated from point cloud

Summary

MESH

Textured mesh is the way to represent 3D objects with surfaces and textures

MANY SOURCES

Import of 3D models in different formats
Export as DTM, point clouds, lines, catenaries etc.

FROM SLAM

Generate textured mesh from the SLAM derived point clouds or xyz

Machine Learning Roadmap

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2018

Deep Learning

VSLAM release together with mini-ROV control

AUV trials

2019

Live AUV projects

Enhanced AUV autonomy

Visual navigation

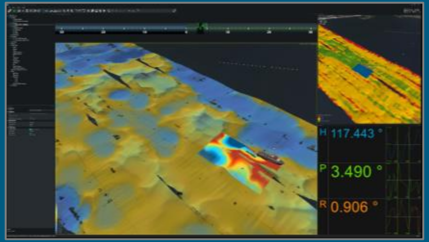
2020

UROV / AUV autonomous inspection and light intervention

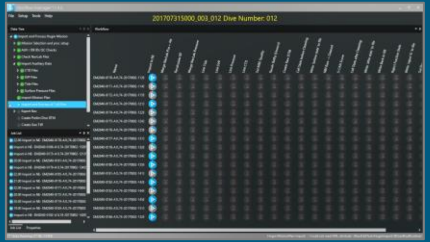
AUV Onboard Processing

NaviSuite Embedded
Payload computer

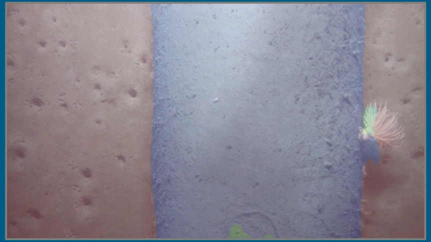
NaviSuite Machine Learning
Payload computer



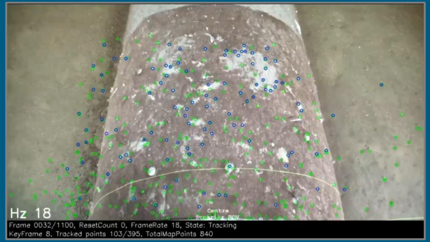
NaviScan
Sonar / Laser acquisition



Workflow Manager
Automated processing



Deep Learning
QC of camera data



VSLAM
Camera tracking

Live now with Swire & Kongsberg

Subsea Navigation

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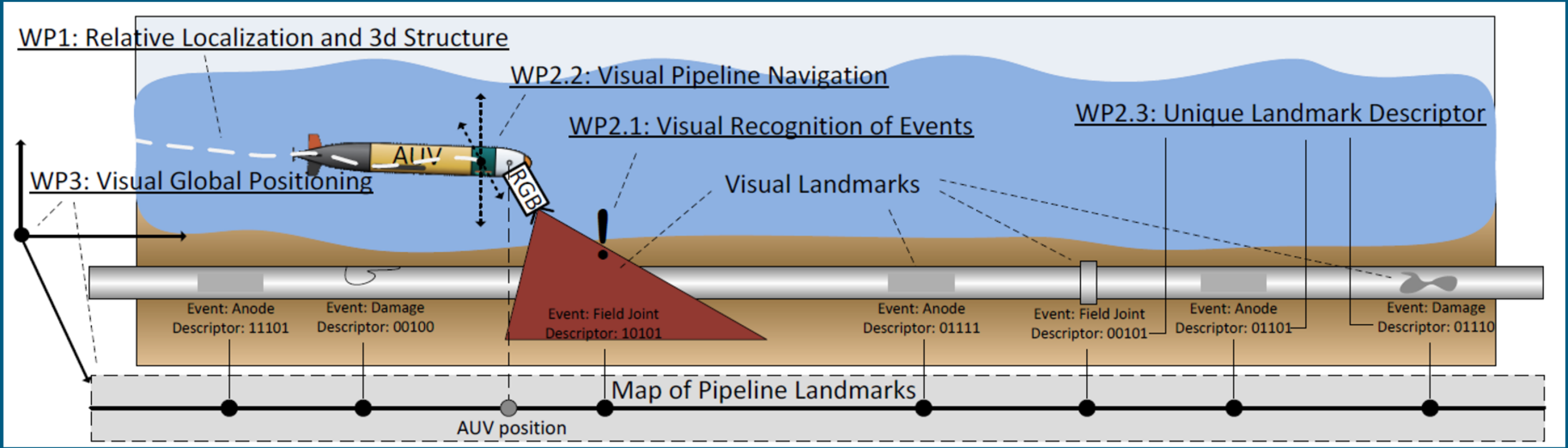

Autonomous underwater navigation based on a landmark world map, and automatic recognition of landmarks using deep learning and automatic tracking of structures using computer vision / SLAM

Where do we go from here?

Contact

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Thank you for your time.

EIVA

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