DEEPOCEAN

AUV Seabed Mapping and Pipeline Inspection using Synthetic Aperture Sonar

Aberdeen, 20th April 2016

Trond Hagland, DeepOcean

- Making a difference

Company snapshot

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Vessels

Owned: 7
Long Term Charter: 10
+2 Charters starting in 2016

ROVs

40 ROVs
1 ROTV
2 AUVs
ROV tooling

Trenchers & Ploughs

5 Ploughs
7 Jet Trenchers
4 Mechanical Cutters

Talent

1000 employees
11 offices in 7 countries

2014 financials

$635 million revenue
$86 million EBITDA
10% ROCE
$22m net debt

Other assets

Module Handling System
Geotechnical Rig
Excavators / dredgers

Presentation outline

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- **Introduction**
- **SAS systems – capabilities and features**
- **AUV pipeline inspection**
  - Line planning
  - Pipeline tracking, Data gaps
  - Spot processing
  - Data examples
- **AUV – SAS seabed mapping**
  - Coverage – speed versus range
  - Types of data available
  - Real-Aperture Bathymetry

SAS - Basics

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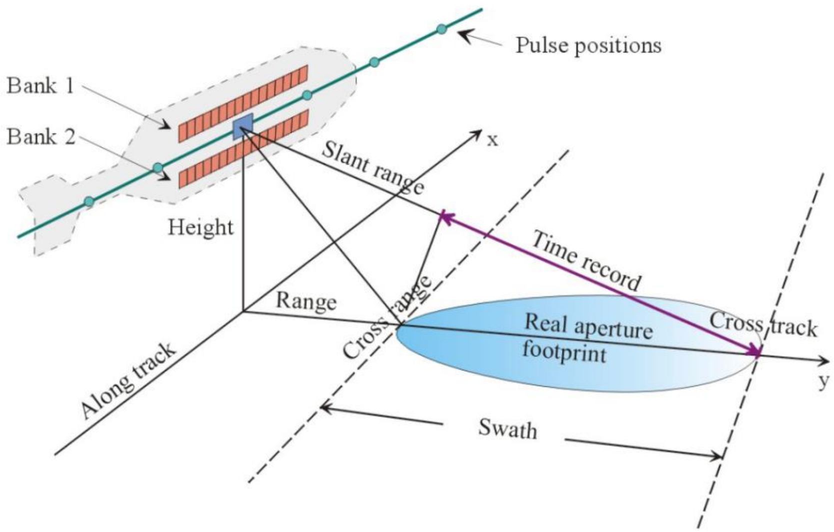
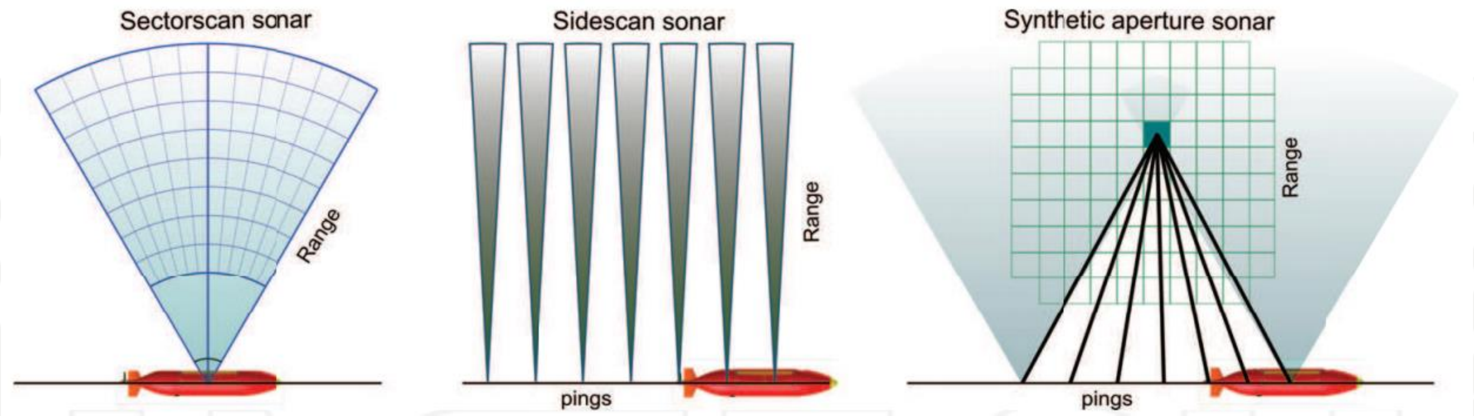
Synthetic aperture sonar uses multiple pulses to create a large synthetic array (or aperture).

In other words, the technique combines successive pings coherently along a known track in order to increase the azimuth (along-track) resolution





SAS – Resolution

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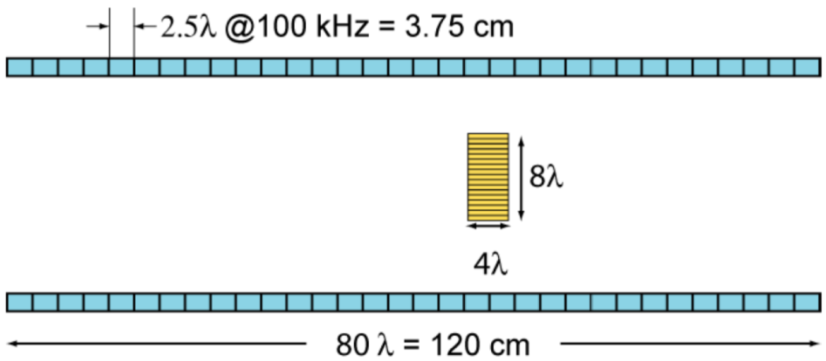
Range and frequency independent along-track resolution



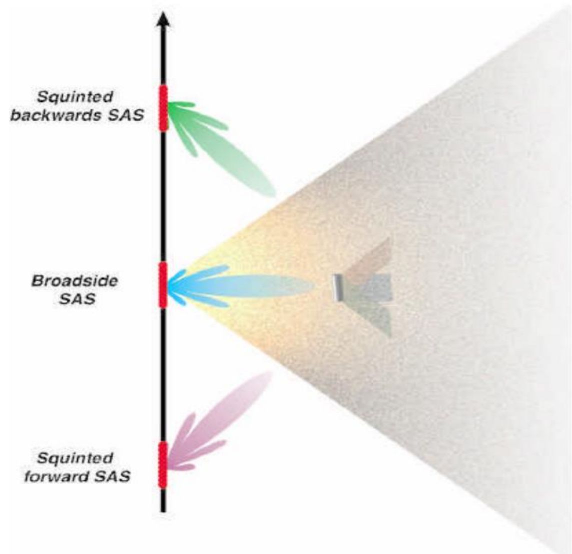


Figure 5. Multi-look SAS.

Quantity	Value
Receiver length	120 cm
Number of receive elements on each side	2x32
Vertical baseline	30 cm
Transmitter size	7.5x15 cm
Number of transmitter elements	8x16
Typical mounting roll angle	20 degrees
Frequencies	50-120 kHz
Typical operational bandwidth	30 kHz
Typical pulse type	LFM
Typical pulse length	6 ms
Typical operational range	200 m
Theoretical resolution	1.9x2.5 cm
Practical resolution	5x5 cm
Theoretical area coverage rate	3.25 km^2/h
Practical area coverage rate	2.3 km^2/h

DeepOcean/AXA AUV operations - Brazil

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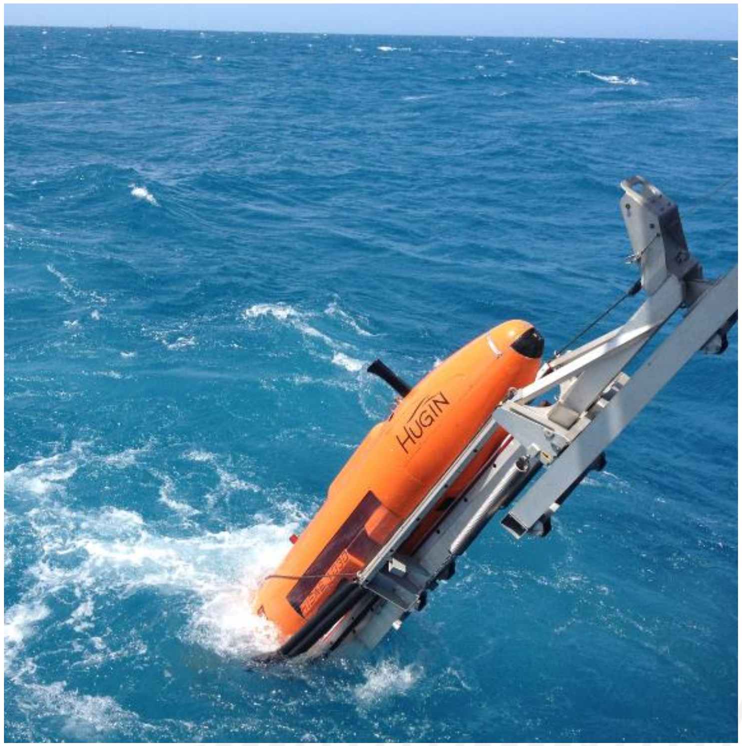
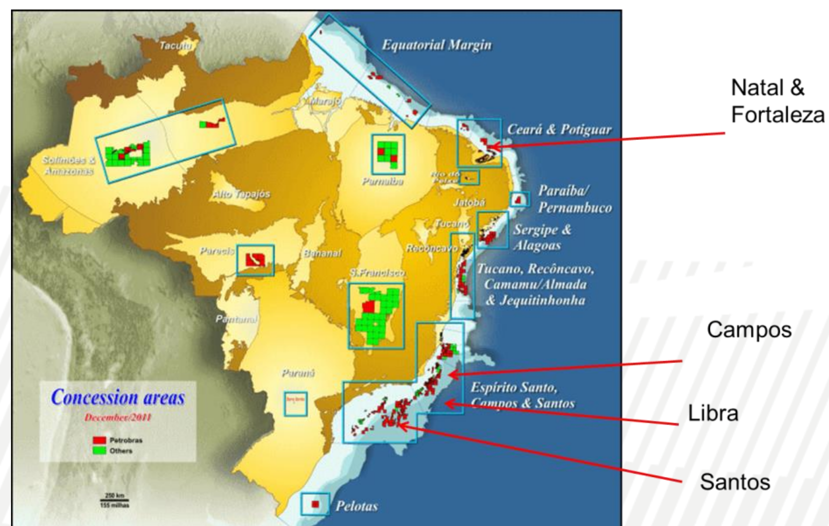
Pipeline inspection contract – Nov 14 – Nov 15



- **MV Tau with Hugin 1000 AUV – 1000 m rated**
- **Deliverables:**
  - HiSAS 1030 – SAS Data
  - EM2040 – Bathymetry
  - TileCAM - pictures



AUV Pipeline Inspection

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Brief methodology

First pass 50-100 m laterally offset from pipeline

- HISAS tracking and data collection
- Wide-swath high-resolution sonar image (and bathymetry)
- Create “pipeline map” for use during second pass

Second pass at low altitude (4-10 m) directly above pipe

- Use position info from first pass or previous position information if tracking is not possible (e.g. due to burial)
- MBE tracking and data collection
- Camera data collection (if visibility allows)

Line planning

SAS processing is done by analysing the AUV trajectory and splitting the data into straight line segments, or blocks. The processing "straightens out" the trajectory within each block, resulting in an apparently perfectly linear motion through the block (constant heading, constant pitch, zero roll; with lat, long and depth changing linearly through the block). This is called motion compensation and is a central part of the SAS processing.

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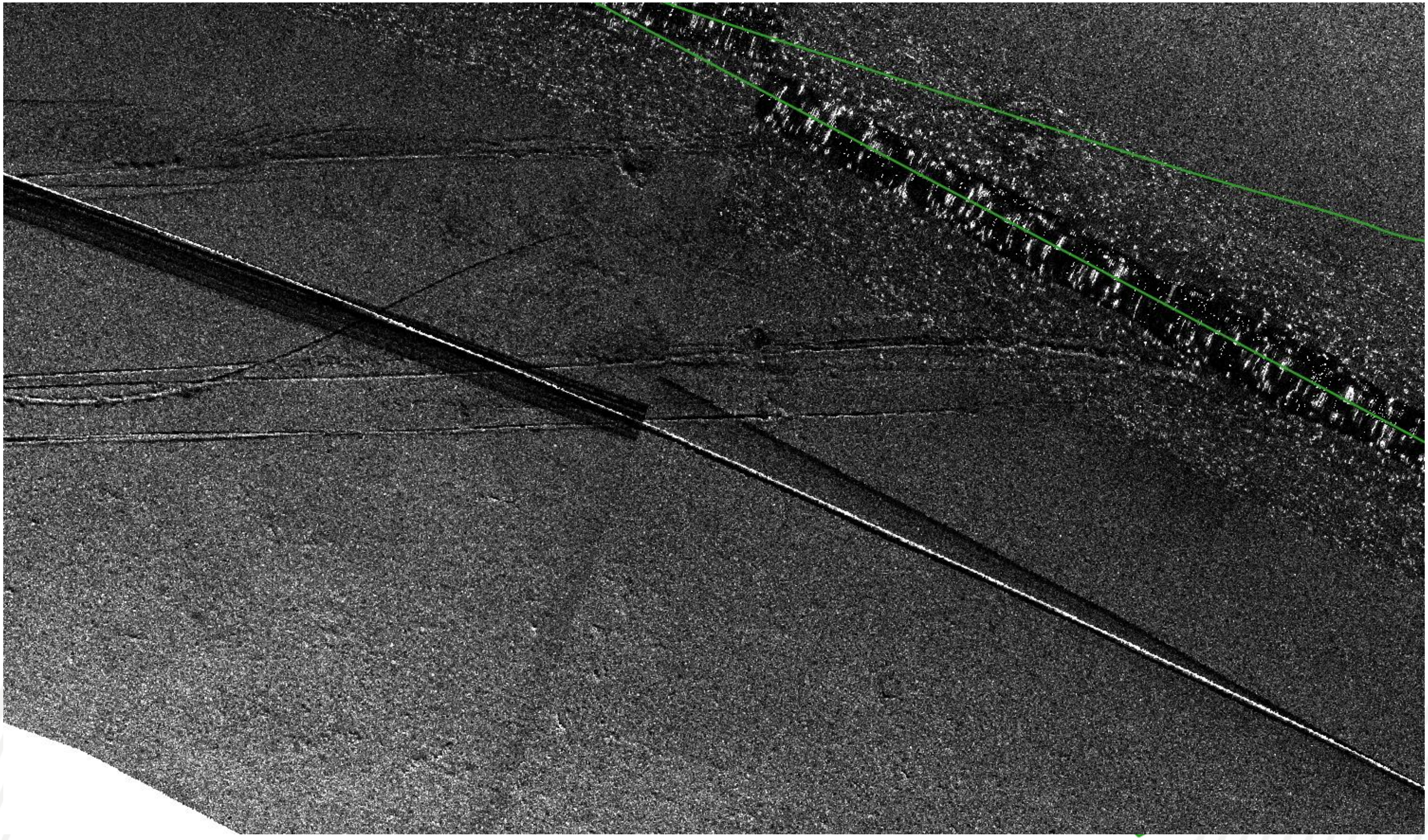
Line planning



Good positional correlation before and after turn. The turn actually improves the navigation accuracy obtained from the INS.

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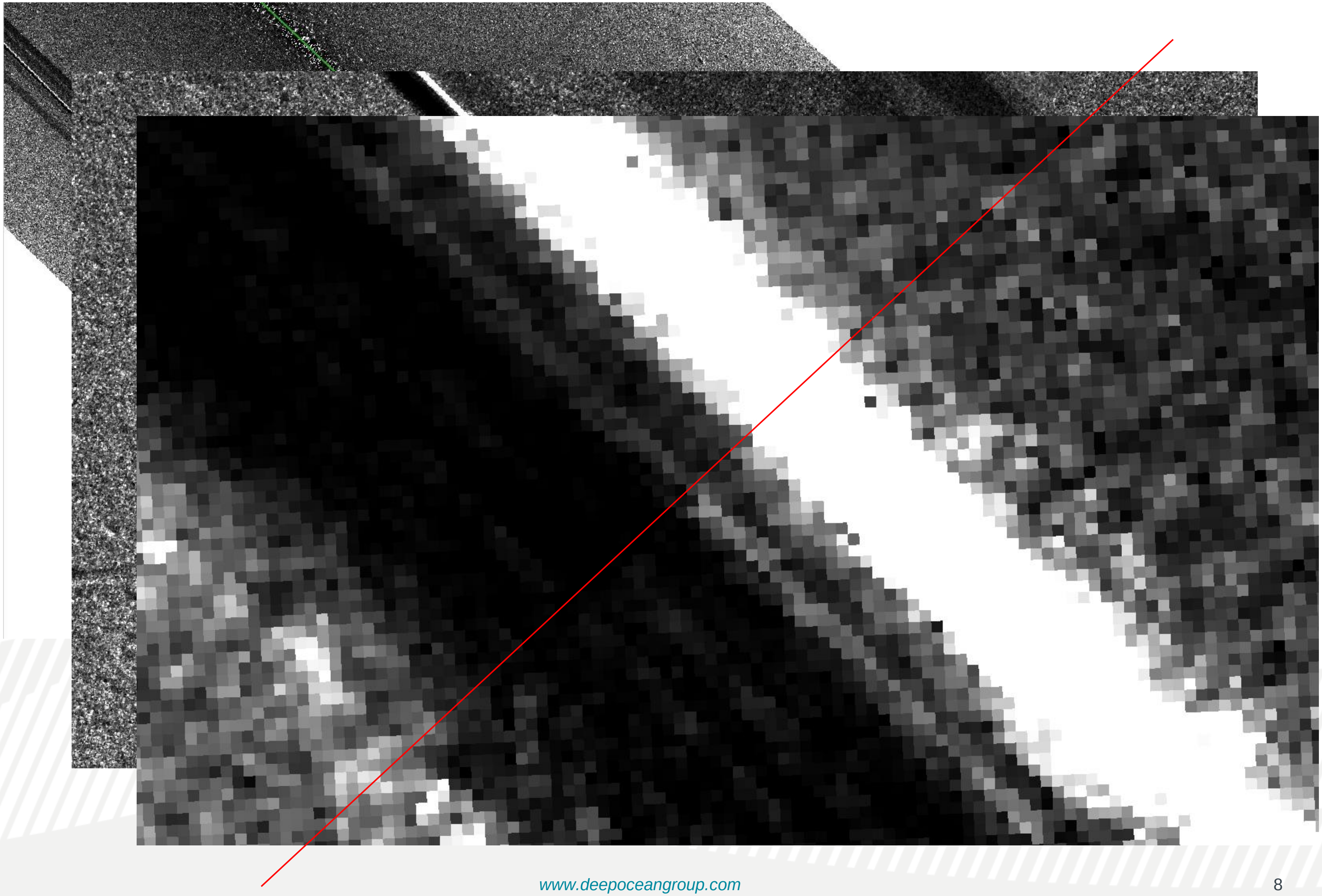
Data gaps and overlap



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Line planning issues

Some recommendations:

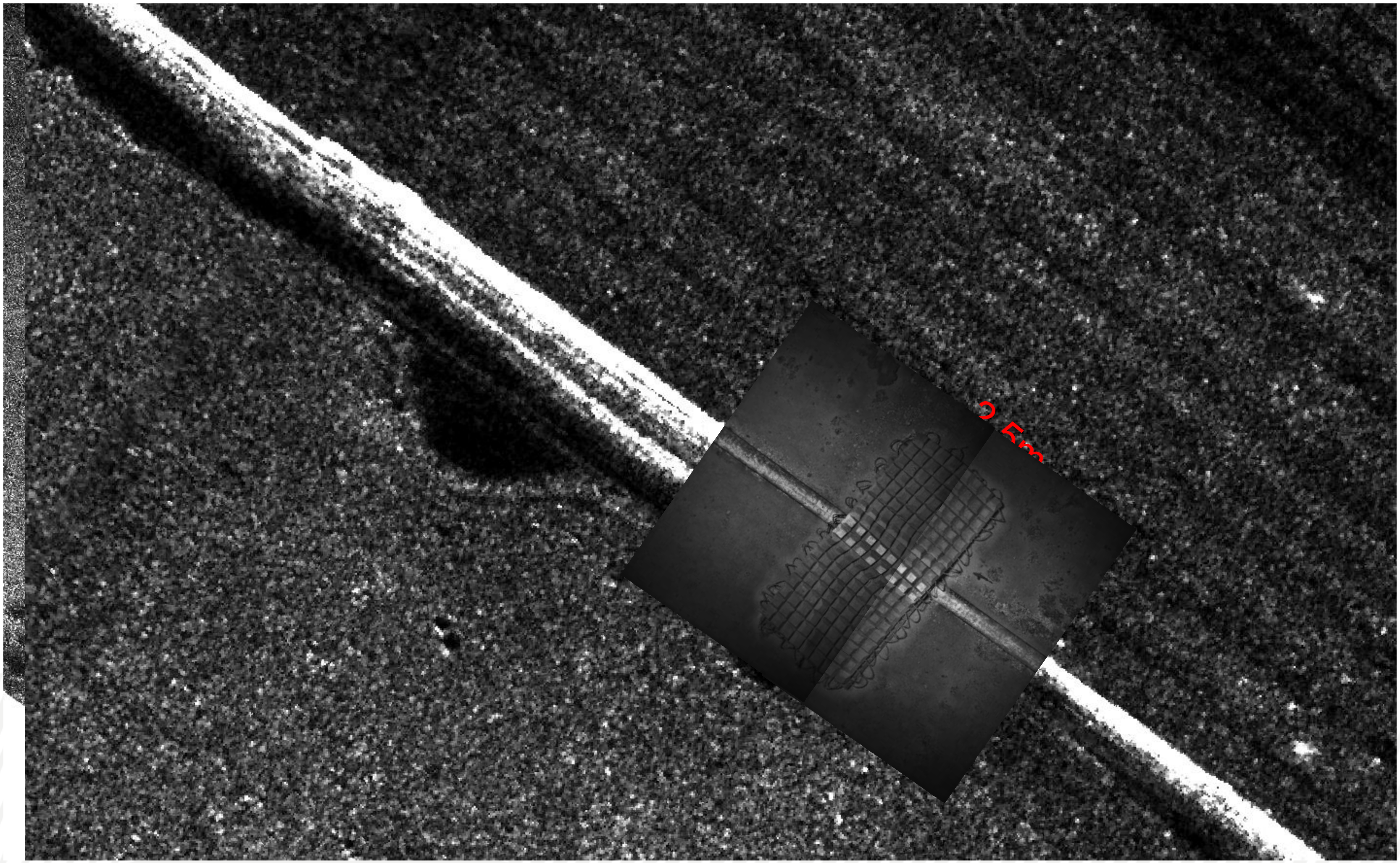
- When doing pipeline tracking, if continuous coverage is required, try to split into survey lines where the trajectory curves **towards** the pipe (rather than on a straight segment, or when turning away from the pipe). When the trajectory curves towards the pipe, there will be overlapping coverage between the two segments

- For area surveys, do not split up each survey line with multiple survey tags. It is generally preferable to limit the length of each survey leg to a few kilometres.

- Use “Hi-Fi Spot processing” to generate imagery (and bathymetry, if desired) from any gaps that remain.

AUV Pipeline Inspection

Inline features – comparison with Tilecam picture



AUV Pipeline In

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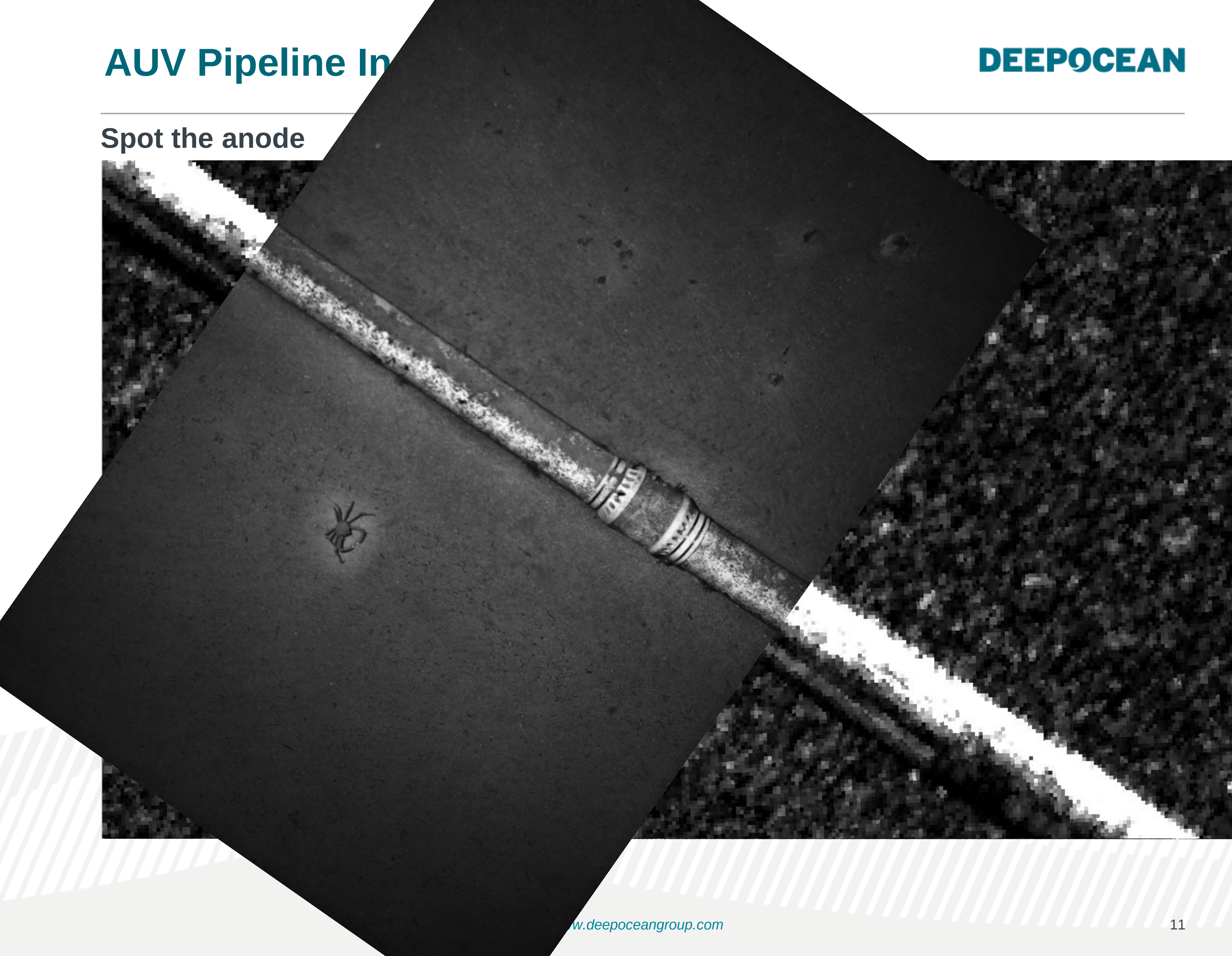
Spot the anode



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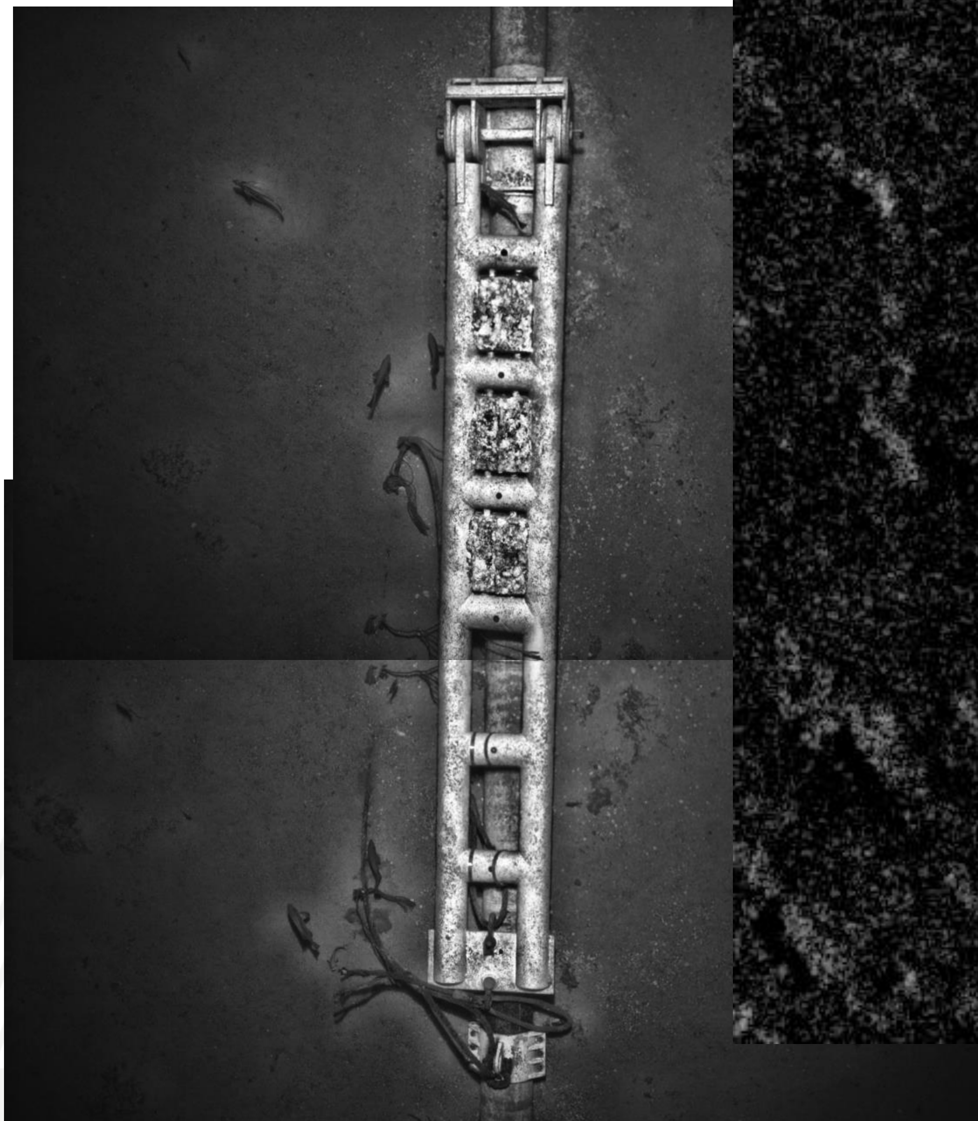
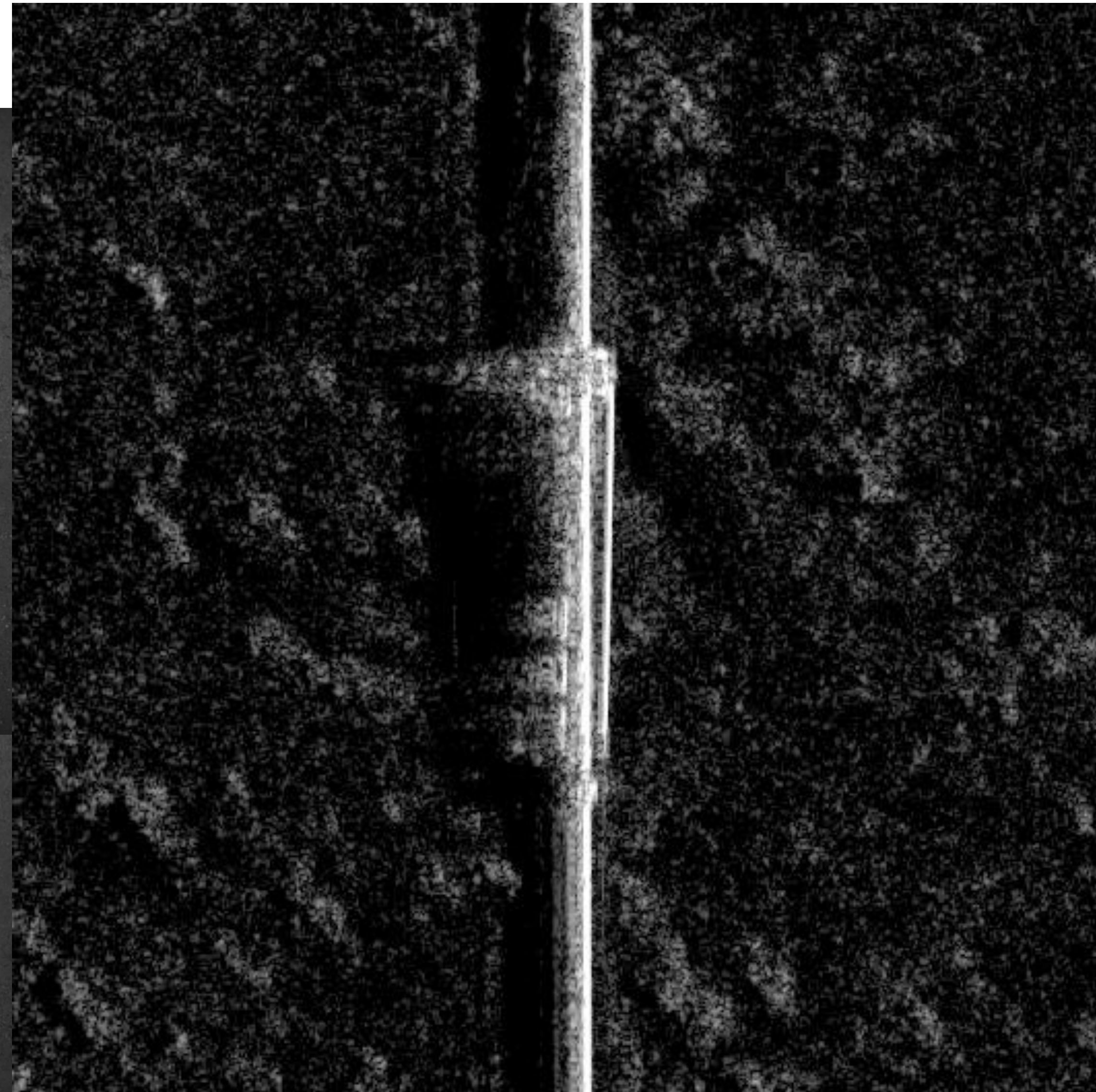
Spot processing

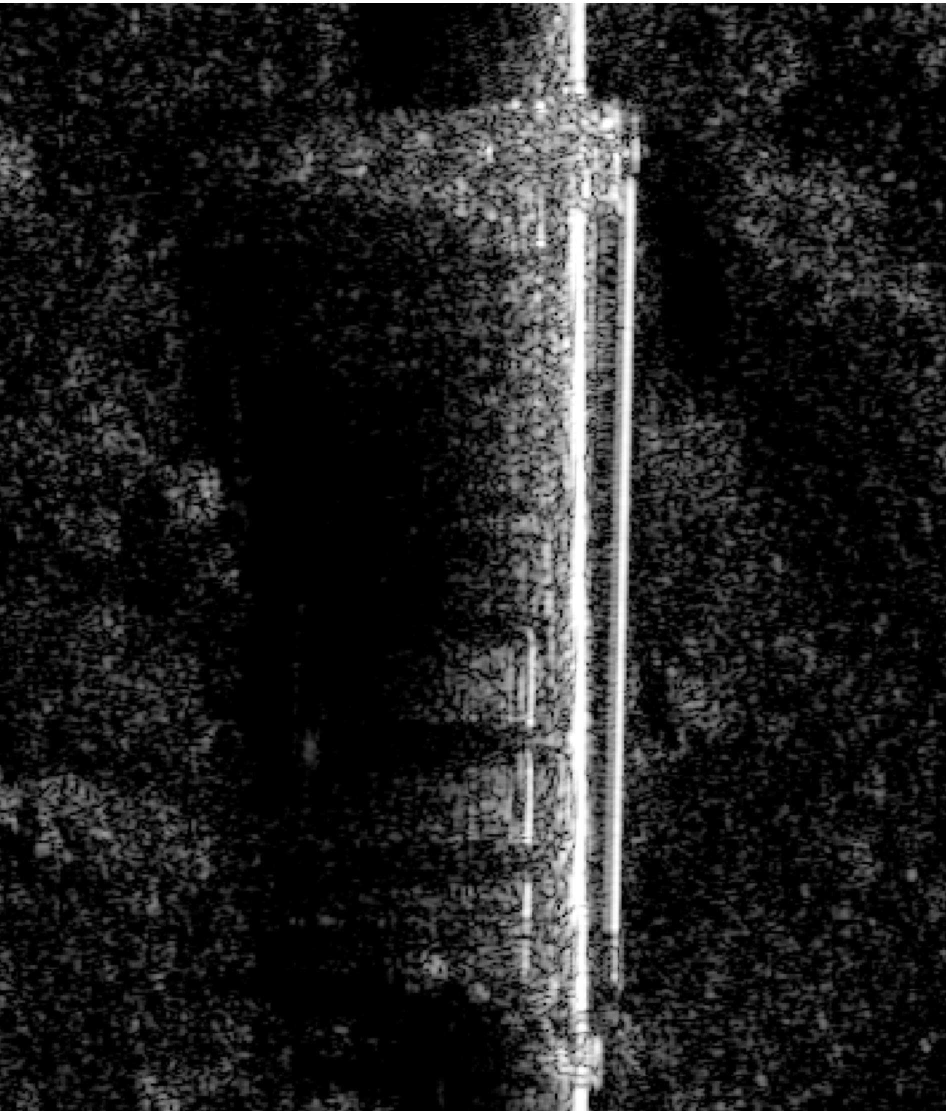




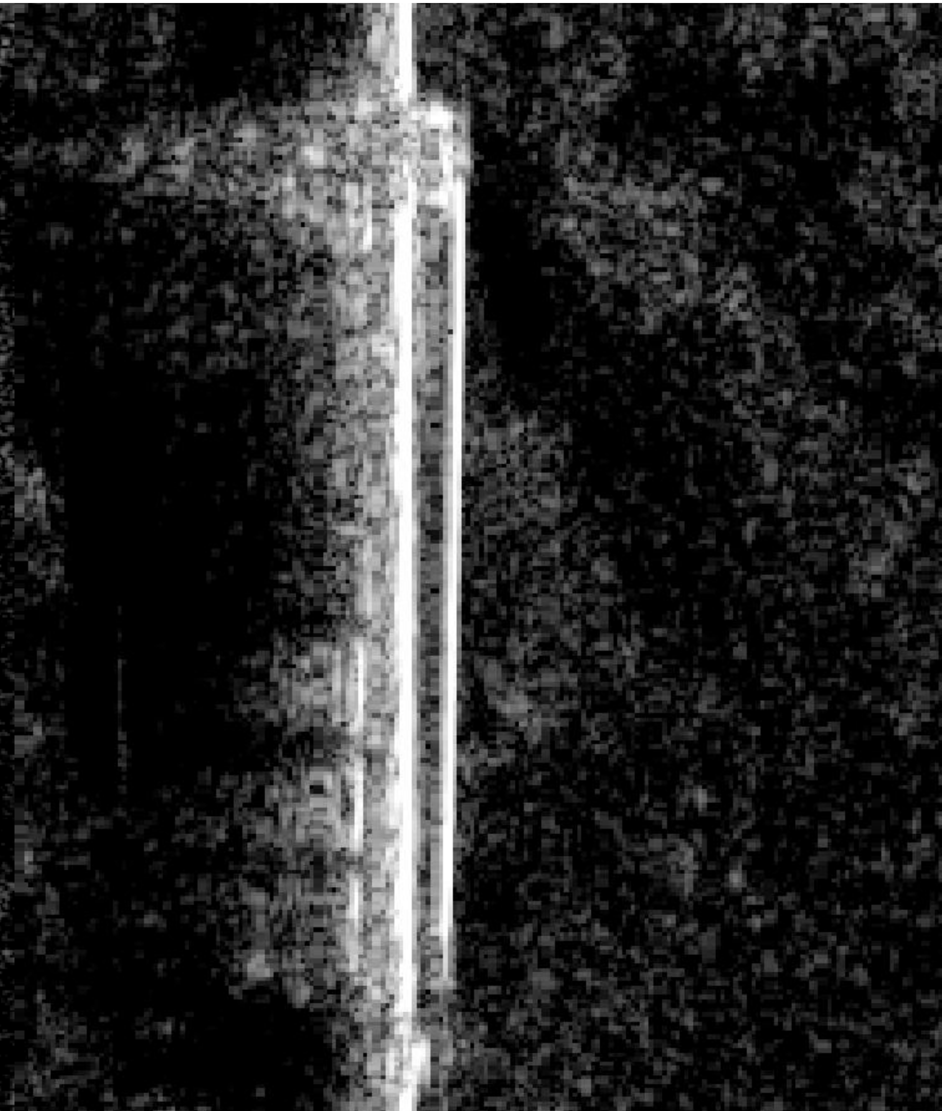
Standard resolution 4 x 4 cm – 20 x 20m area

AUV Pipeline Inspection

Spot processing



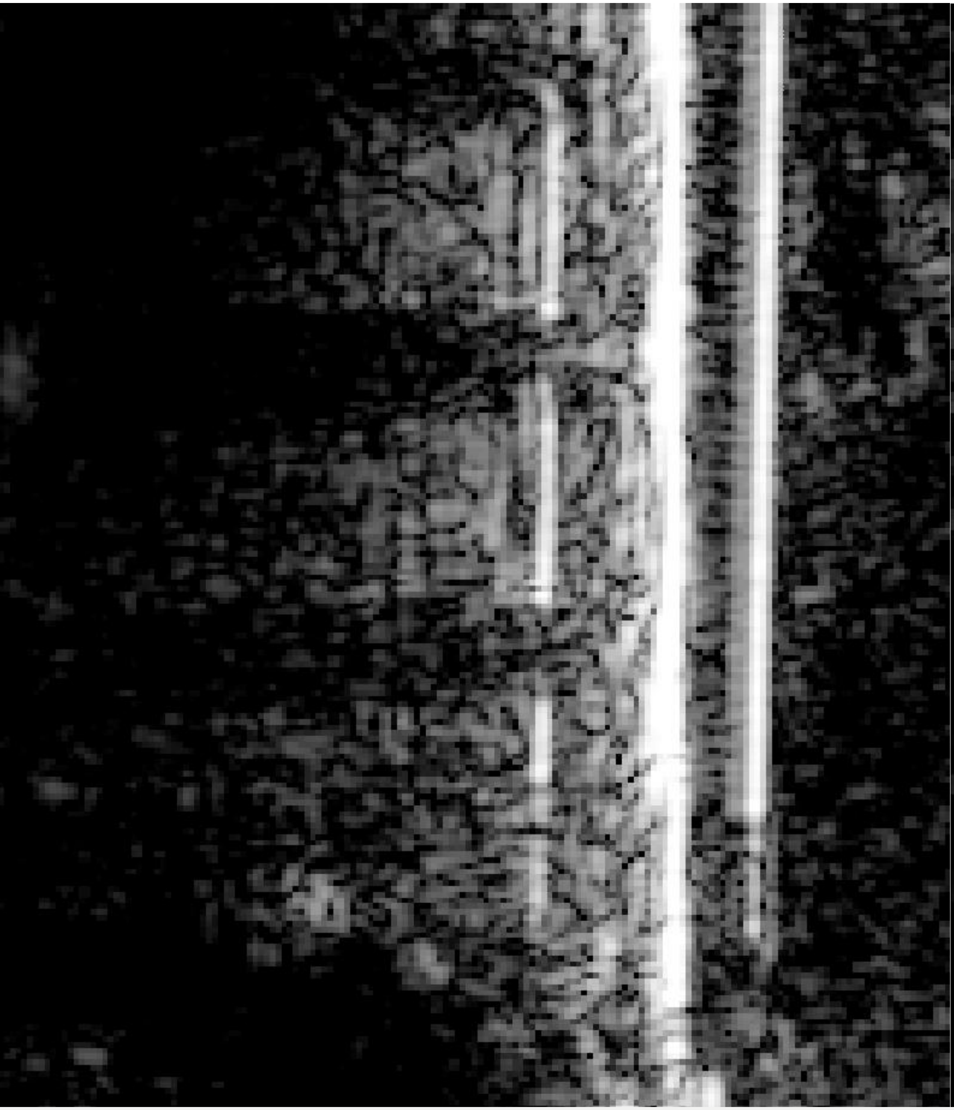
2 x 2 cm spot processing – 20x 20 m area



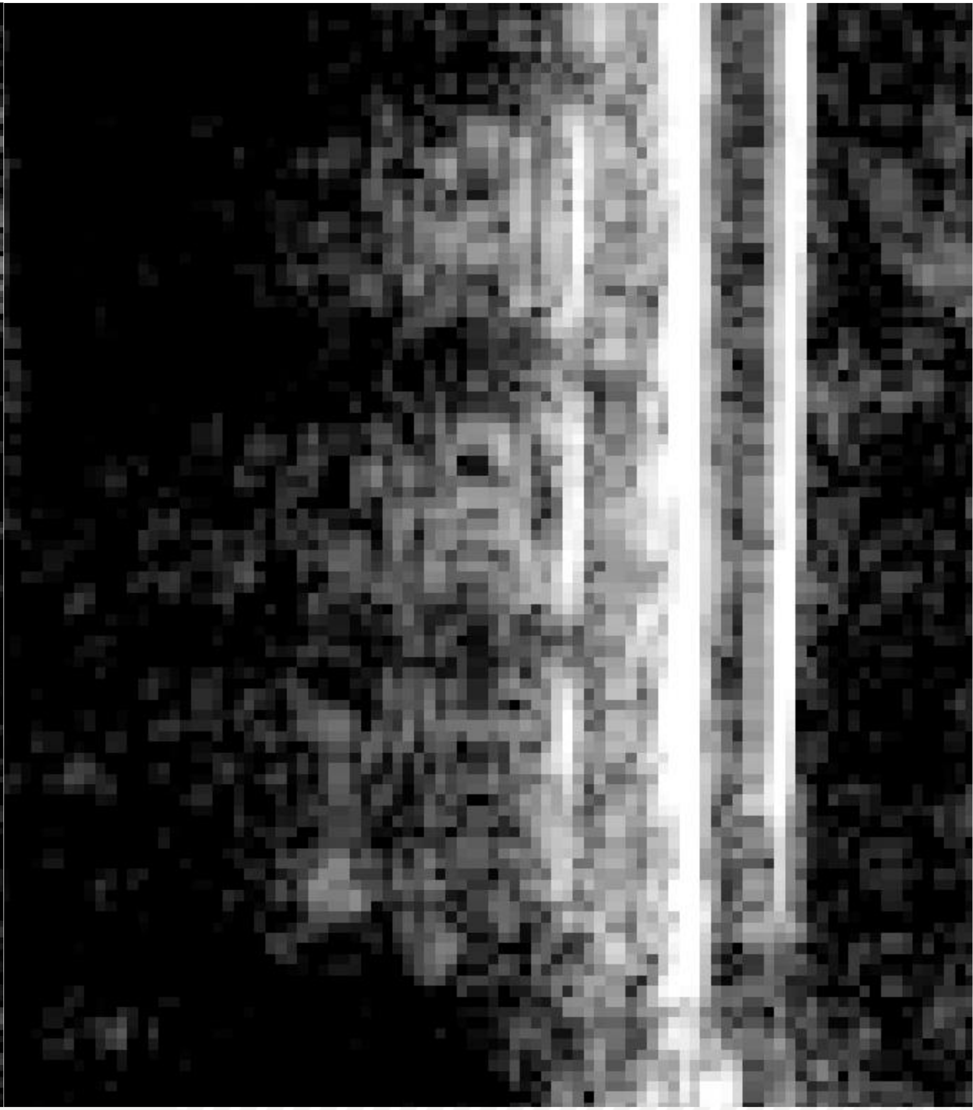
4 x 4 cm std processing – 20 x 20m area

AUV Pipeline Inspection

Spot processing



2 x 2 cm spot processing – 20x 20 m area



4 x 4 cm std processing – 20 x 20m area

AUV Pipeline Inspection

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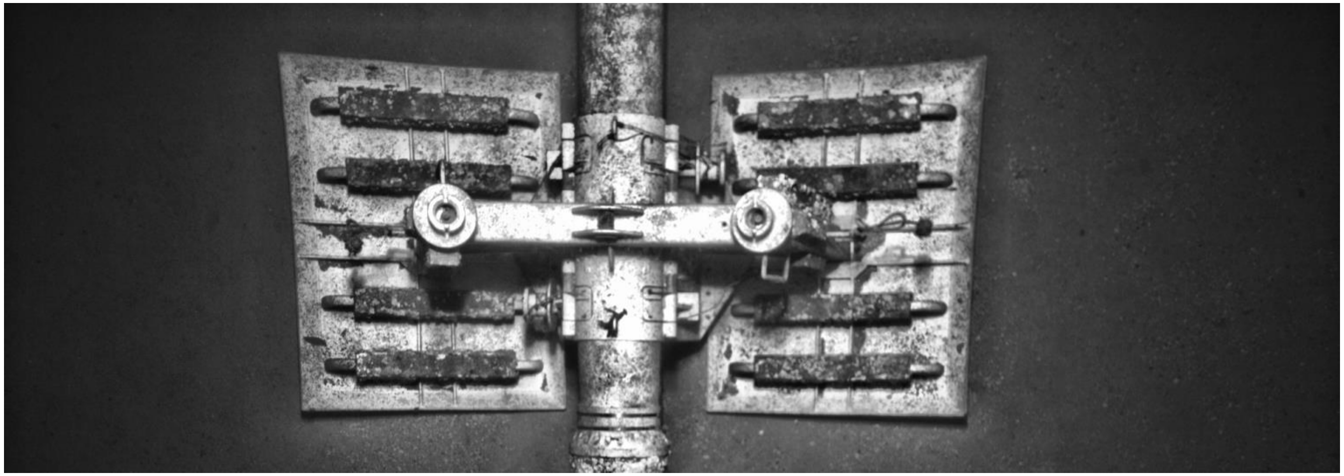
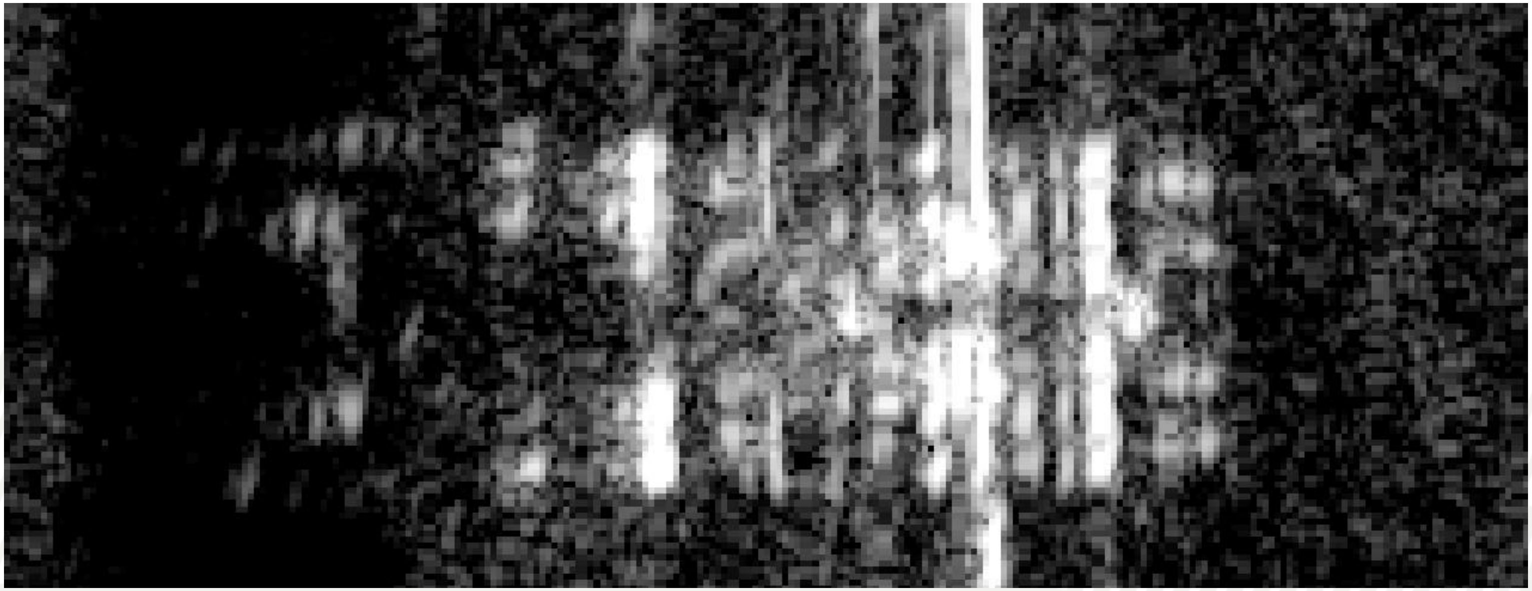
Spot processing





AUV Pipeline Inspection

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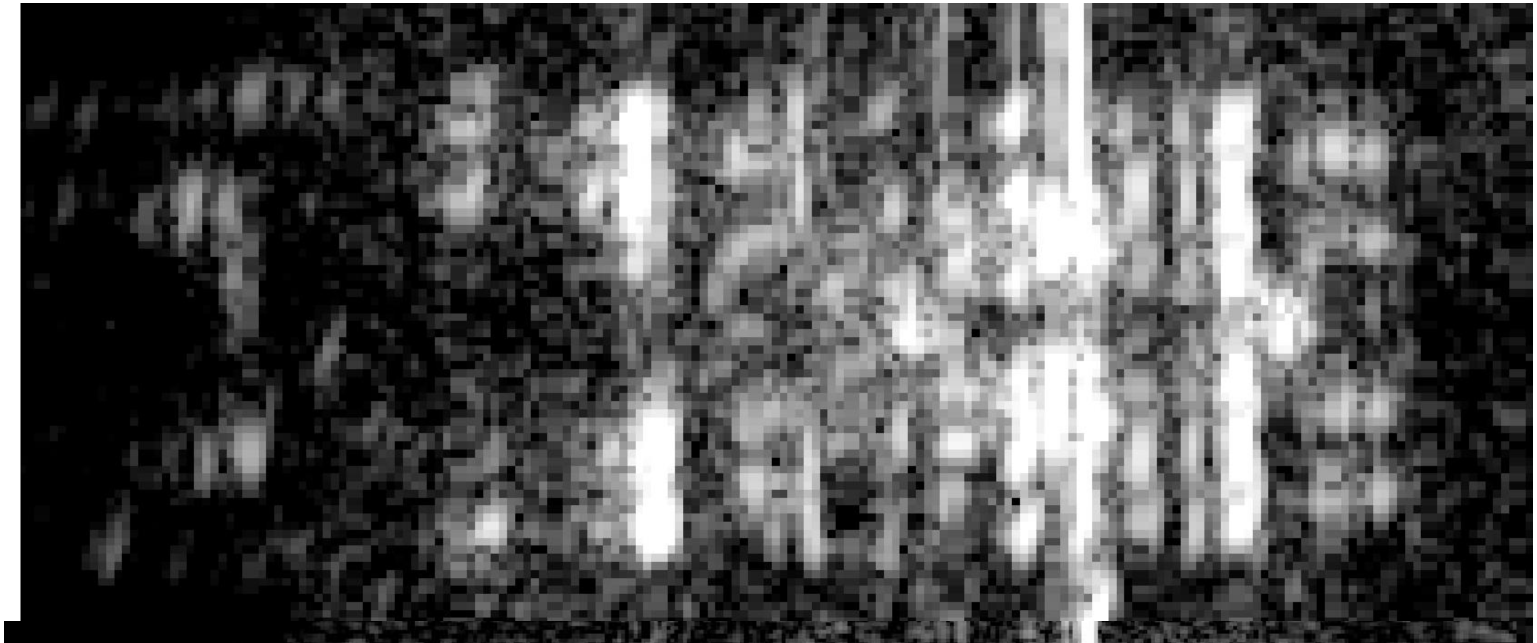
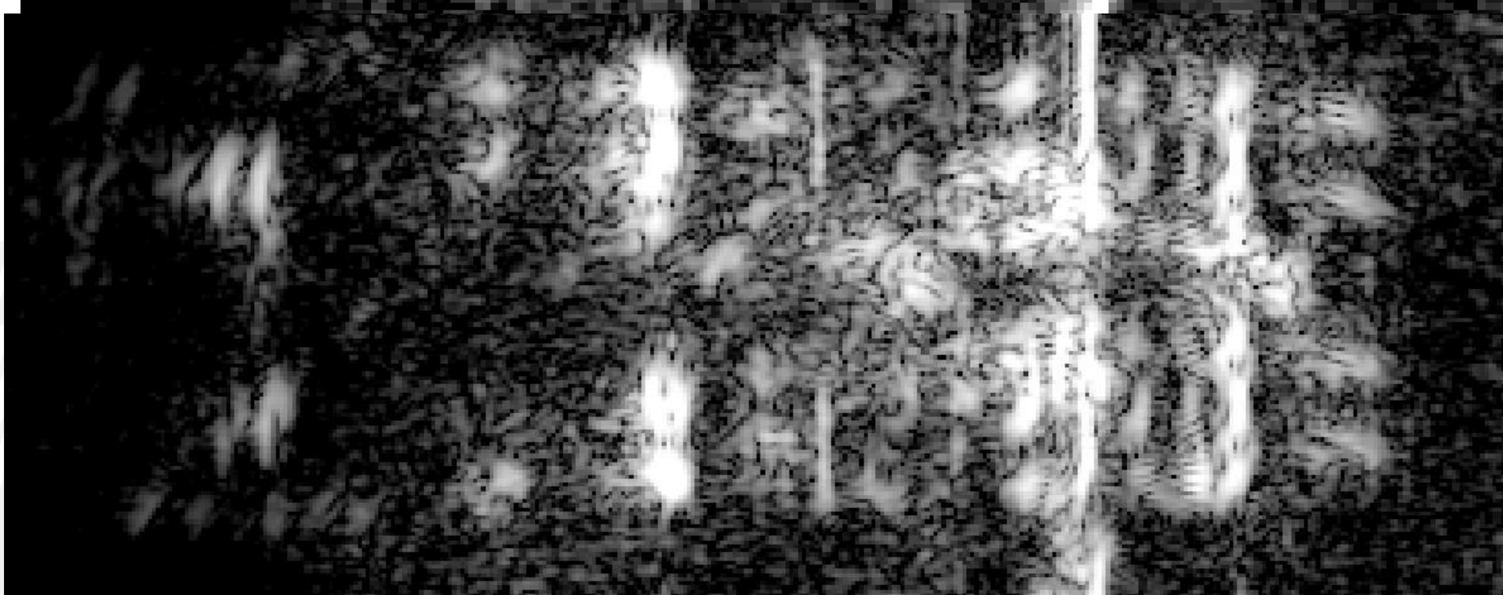
Spot processing



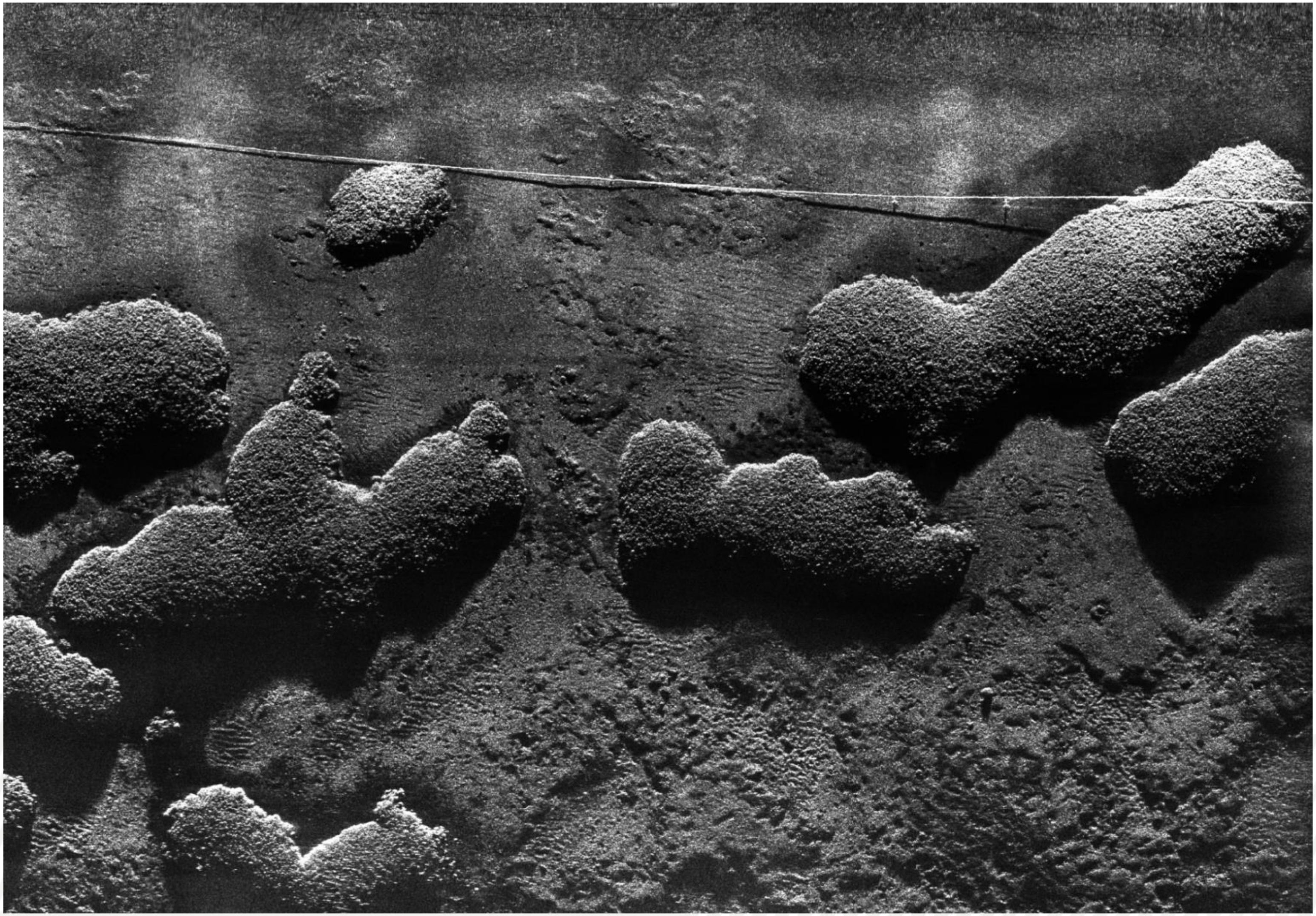
4 x 4 cm std processing



2 x 2 cm spot processing

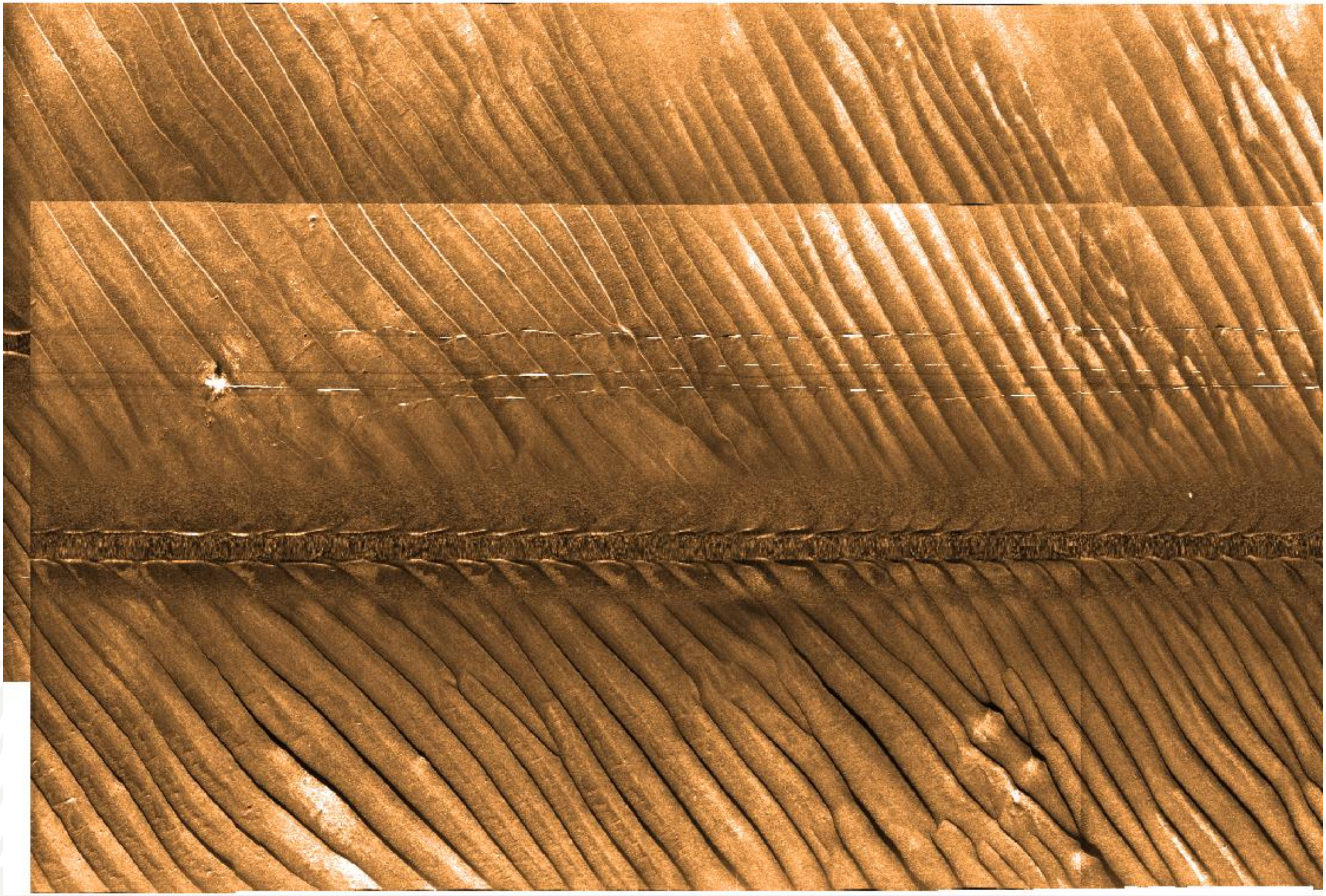
AUV Pipeline Inspection

Pipeline over Carbonatic Formation



Pipeline Inspection Data examples

Pipelines in area of sandwaves



Pipeline Inspection Data examples

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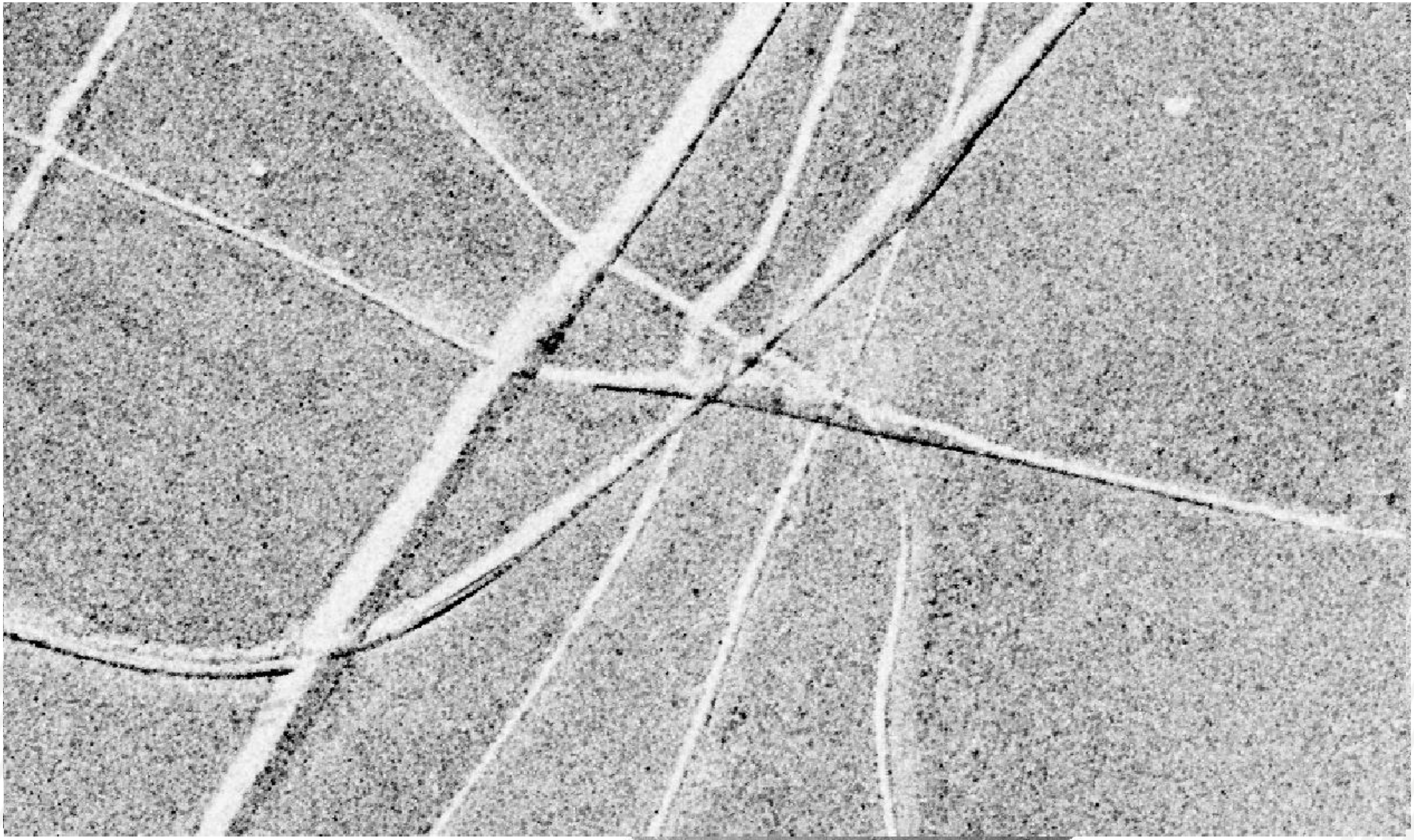
Multiple pipelines and umbilicals



Pipeline Inspection Data examples

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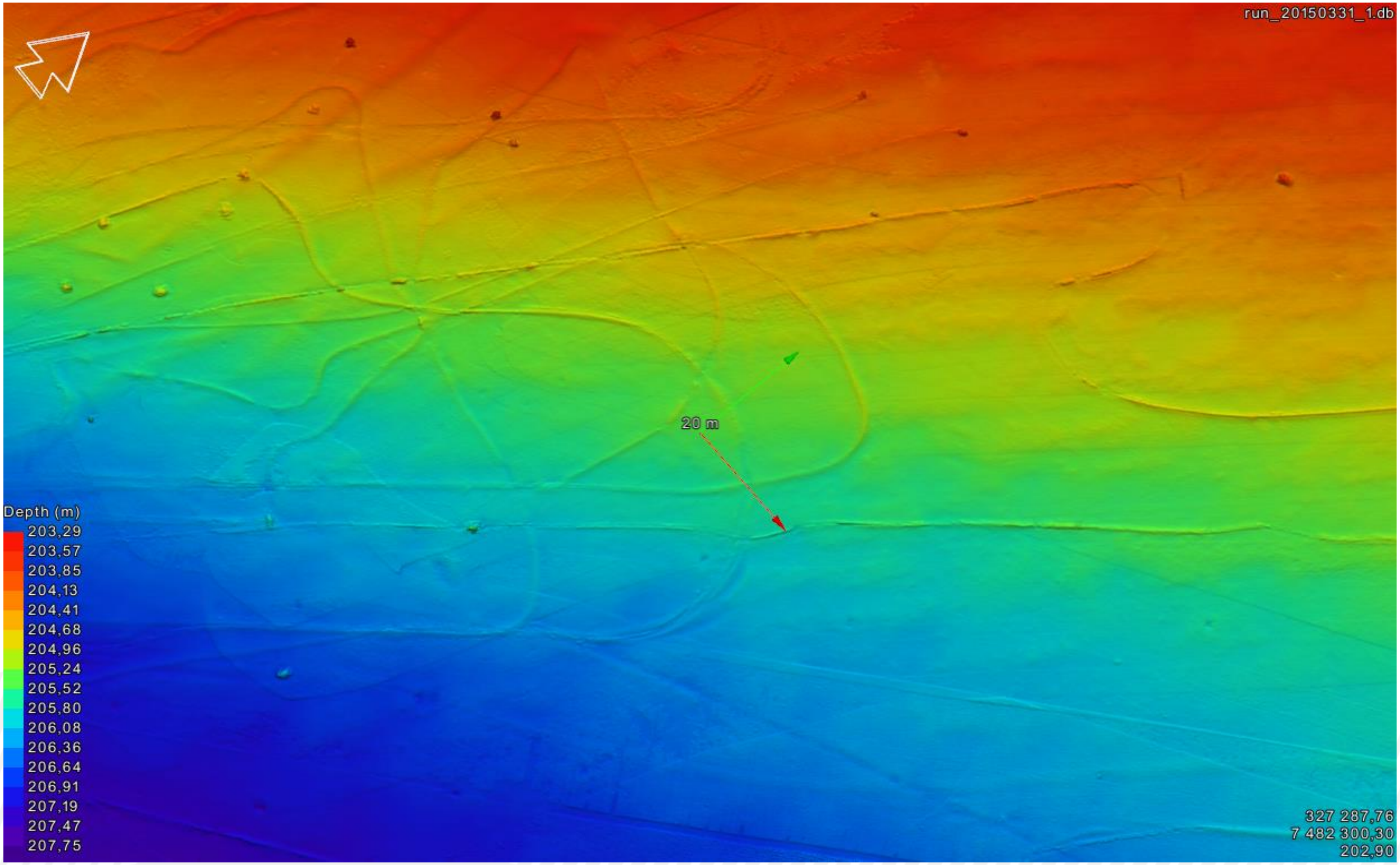
MBE data – Multiple Pipelines/umbilicals



DeepOcean/AXA AUV operations - Brazil

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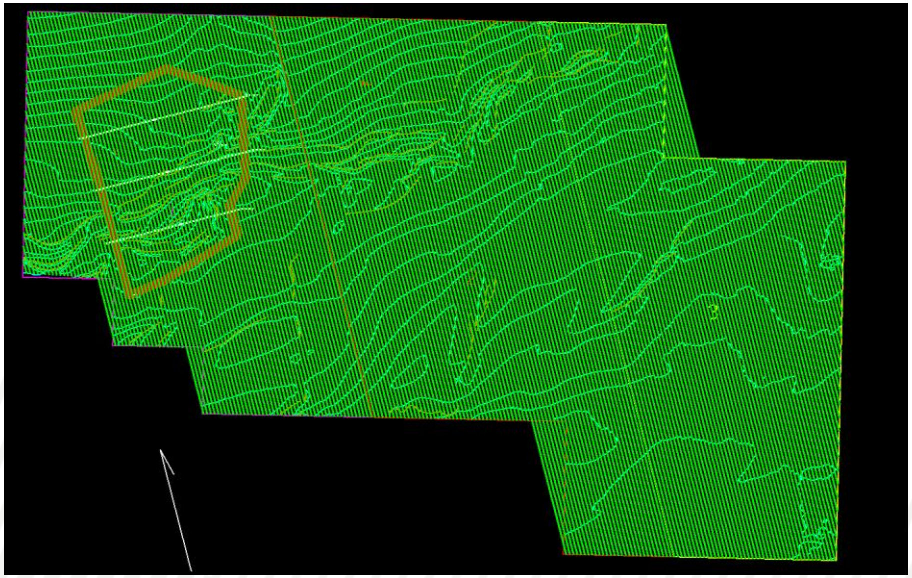
Seabed mapping contract – Libra Field

CBO Campos with Hugin 1000 AUV – 3000 m rated incl.:

HiSAS 1032 – Upgraded HISAS w/ Real-time sidescan bathymetry (SSB) and quality estimation

EM2040 - Edgetech 2200 SBP – Mets methane sniffer – DVL, Upward looking ADCP, etc.



- Libra field: 1642 km2

Area coverage rate

- **HISAS 1030 range is given by the formula:**

SR = 14 * dx/v - 26 m

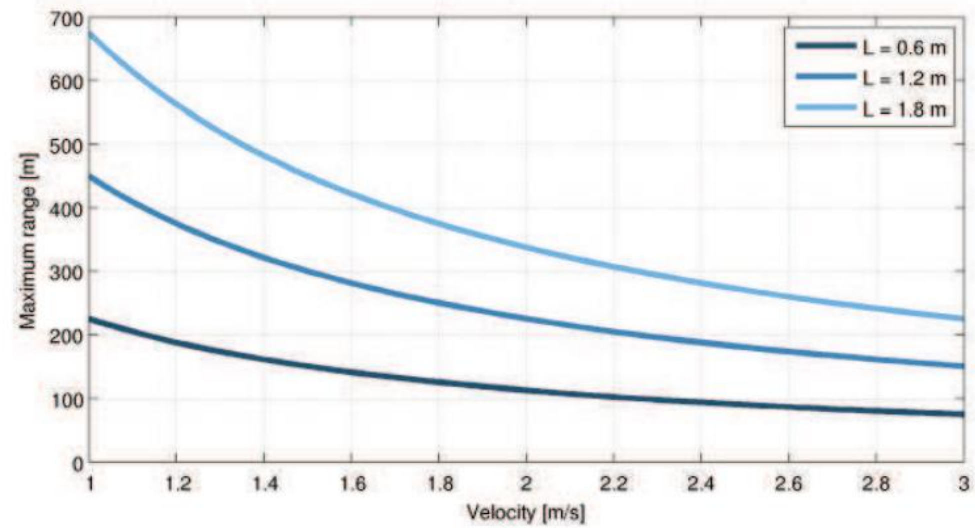
Where dx is distance between pings in phase centres and v is speed in m/s. For nominal overlap of 4 (dx = 28) this becomes

SR = 392/v - 26 m <=> v = 392/(SR + 26 m)

Some typical examples:

v = 1.5 m/s SR = 235 m, v = 2 m/s SR = 170 m, v = 2.5 m/s SR = 130 m

- **Hence Area coverage rate is more or less constant, and proportional to size of physical transducer.**
- **Minimum range is typically equal to flying height (45 degrees angle)**



Line spacing

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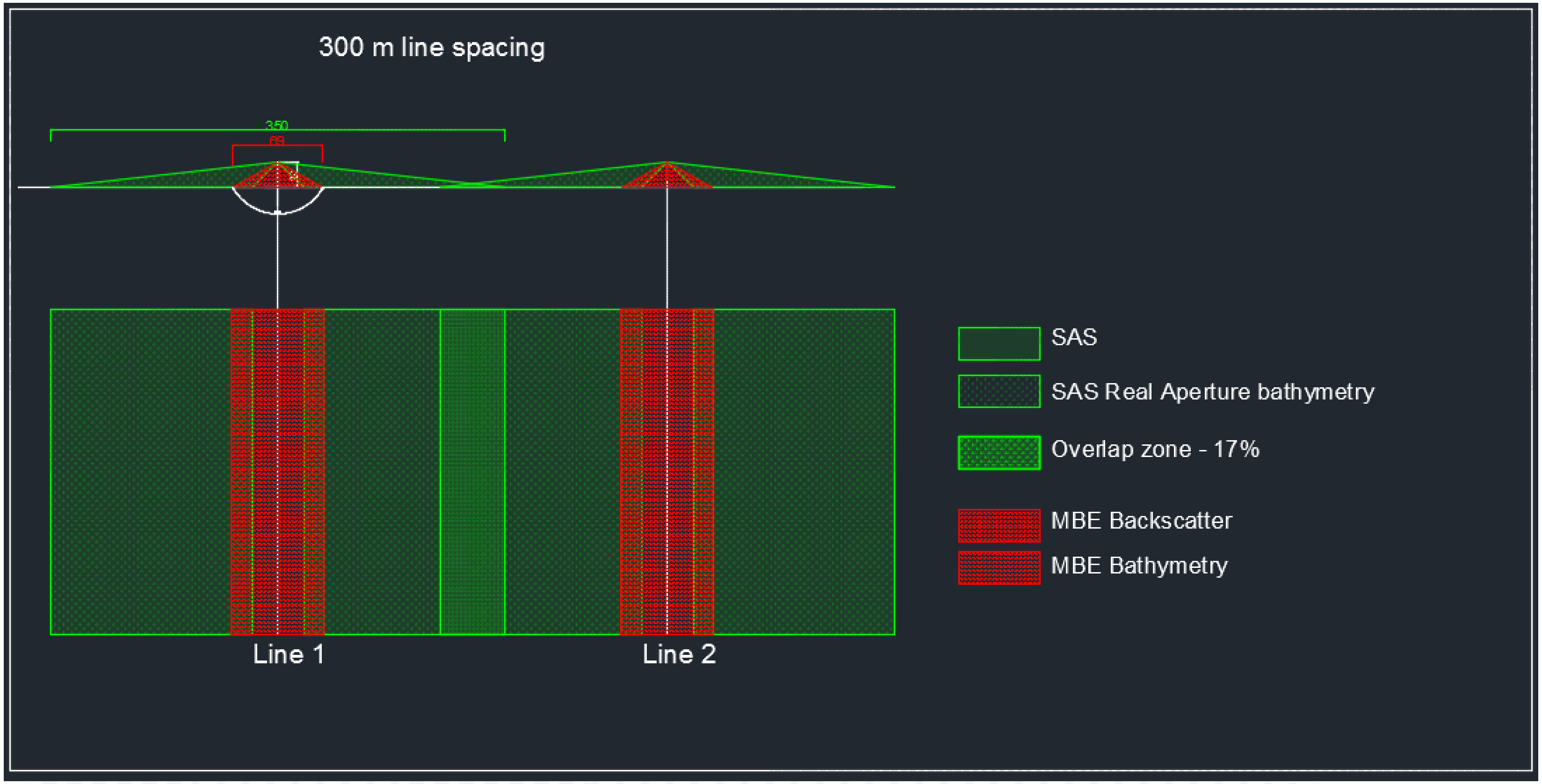

HISAS – range vs speed - test

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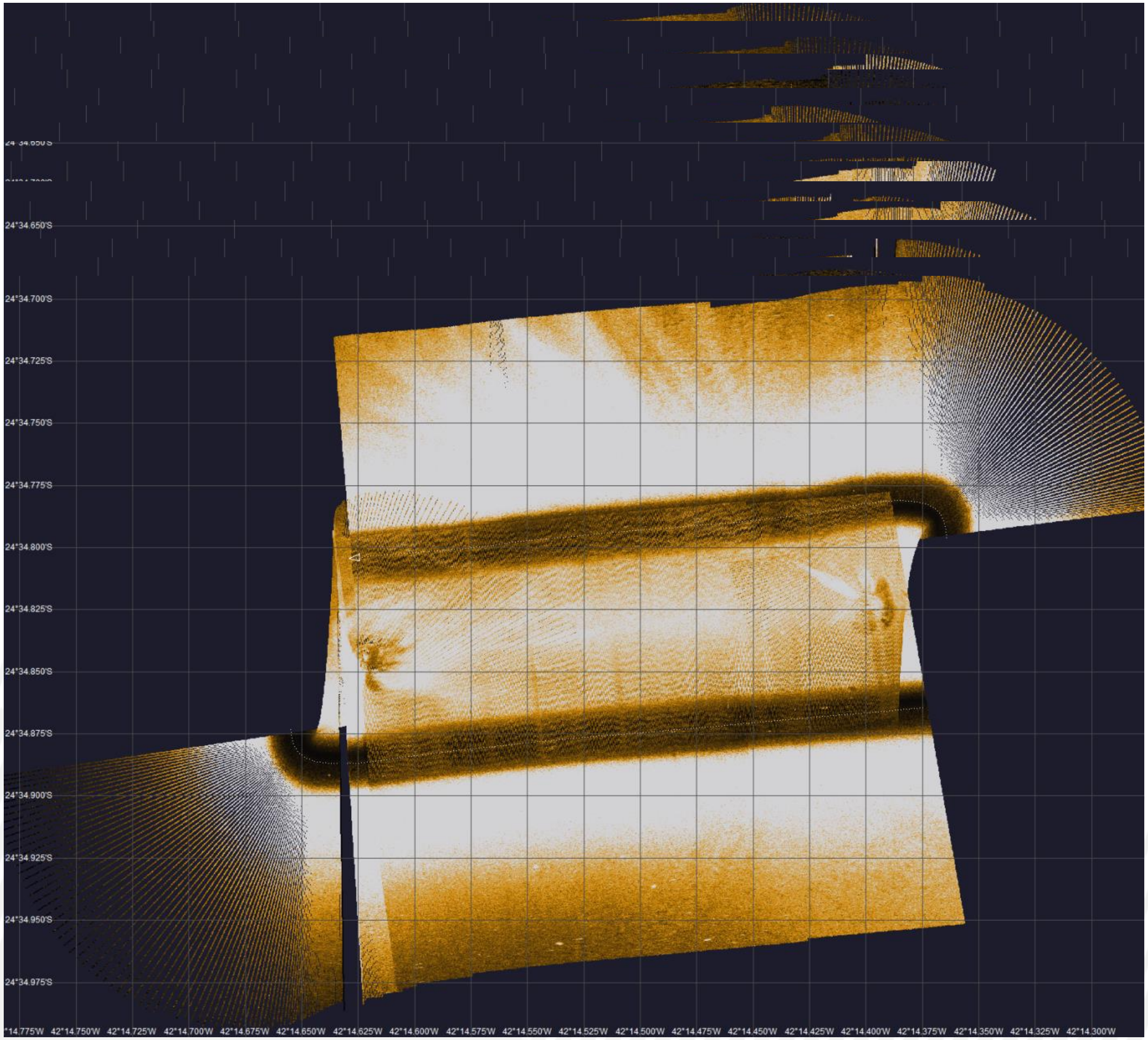
- Test of relation between HISAS range and speed

Line	Altitude (m)	Speed (knots)
1	30	3,0
1A	30	3,0
2	30	4,0
2A	30	4,0
3	30	3,0
3A	30	3,0
4	30	4,0
4A	30	4,0
5	20	3,0
5A	20	3,0
6	20	4,0
6A	20	4,0
7	20	3,0
7A	20	3,0
8	20	4,0
8A	20	4,0
9	30	3,0
9A	30	3,0
10	30	4,0
10A	30	4,0
11	30	3,0
11A	30	3,0
12	30	4,0
12A	30	4,0
13	20	3,0
13A	20	3,0
14	20	4,0
14A	20	4,0
15	20	3,0
15A	20	3,0
16	20	4,0
16A	20	4,0



Real Aperture bathymetry processing

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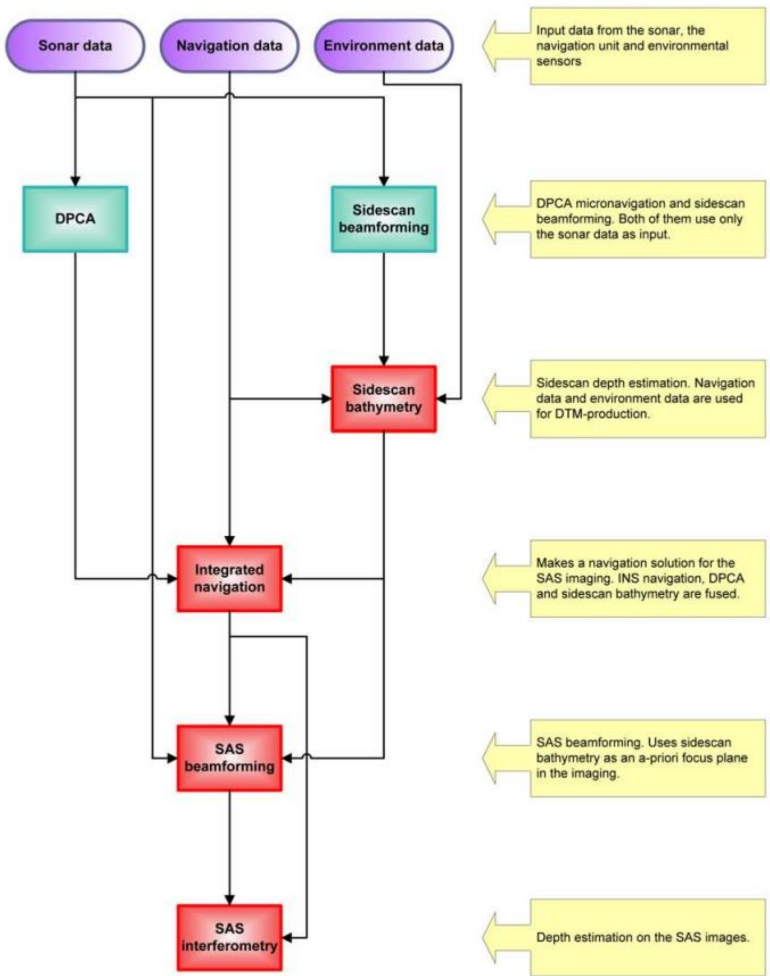

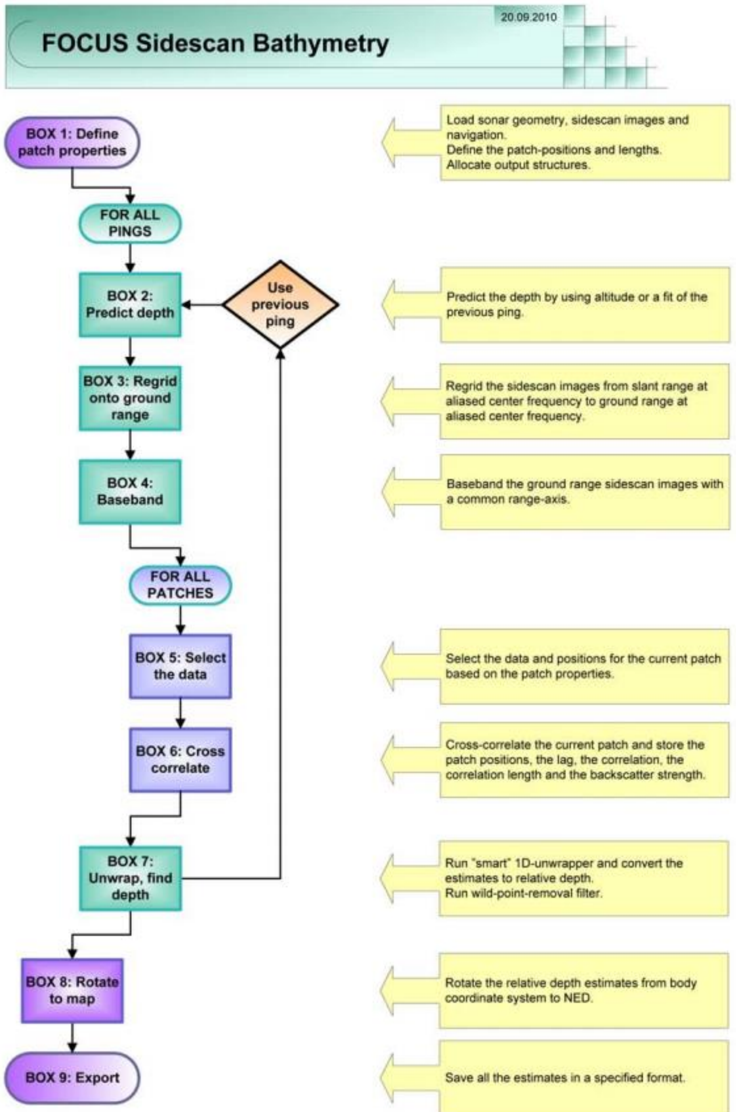

Bathymetry data

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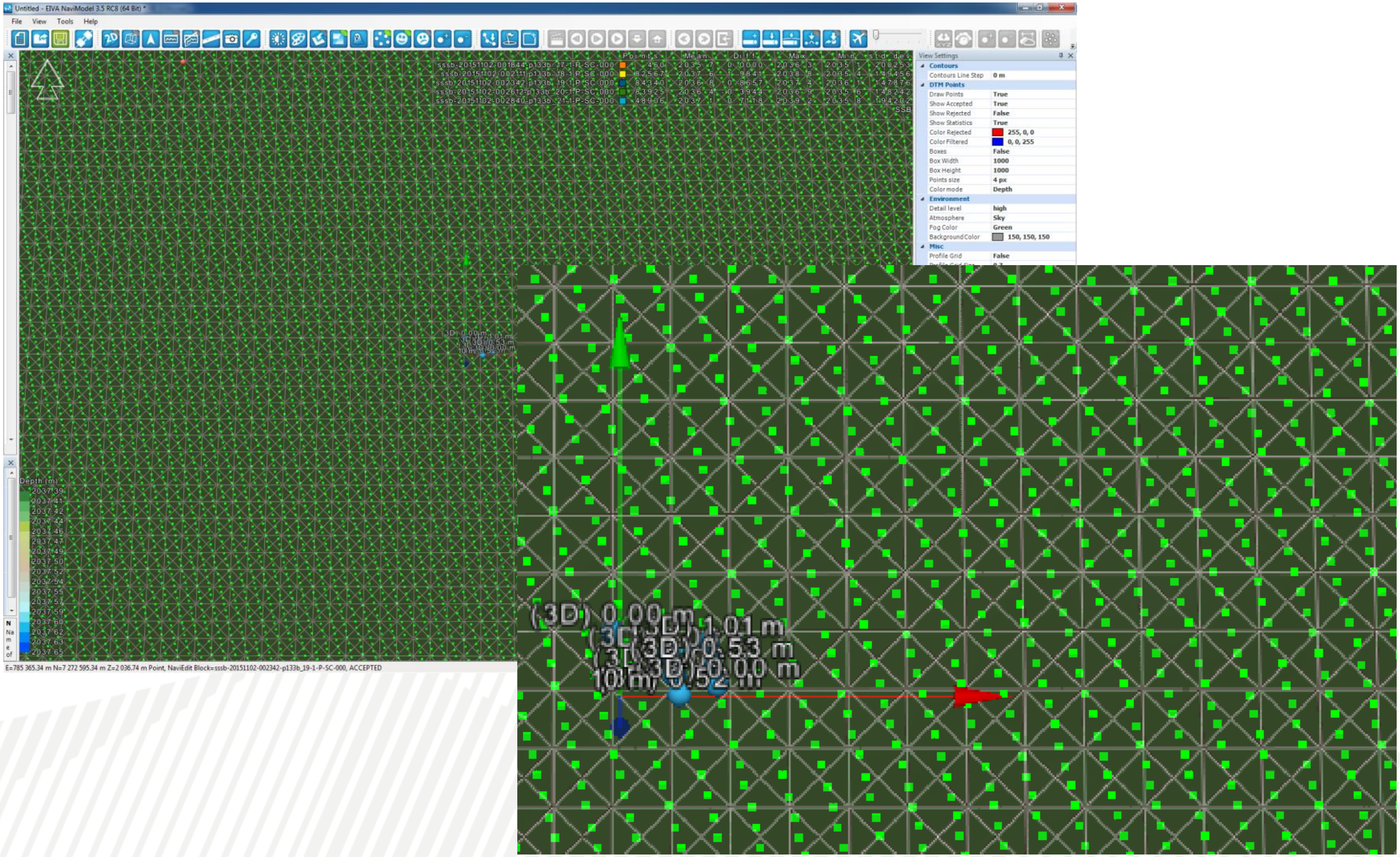


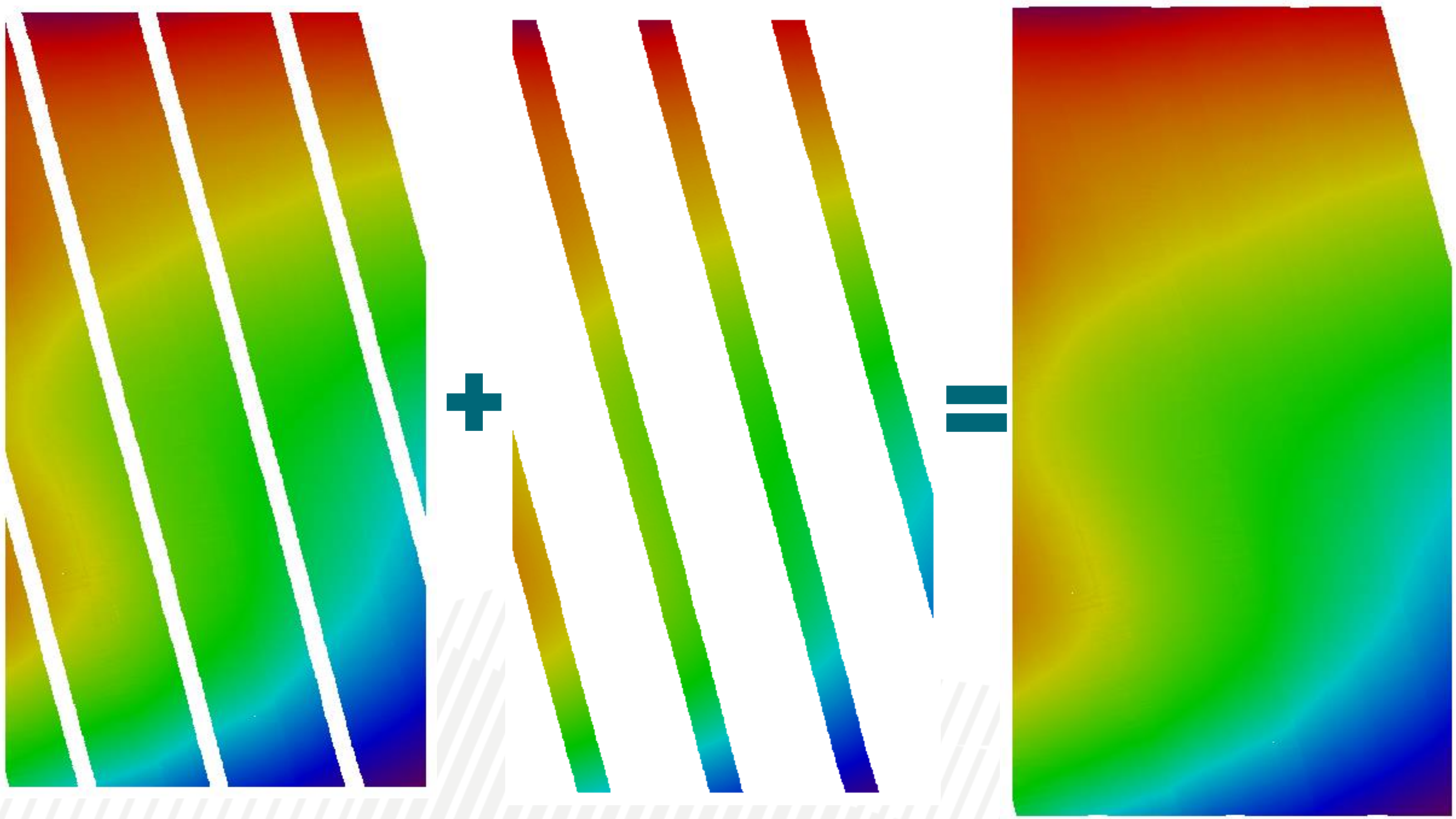
Griding pattern of real aperture bathymetry from HISAS 1032 (ssb files)

Data have equidistant “beam spacing” and distance between points are 0.5 m along track, 1m across track.

This allows gridding at 1.5 x 1.5 m cells with 4 beams in each cell.

Libra project – Data examples

Data products – combination of EM2040 MBE and HISAS 1032 Real Aperture Sonar Bathymetry



Left: At 300m line spacing and with full resolution on real aperture bathymetry from HISAS 1032, the data can be gridded at 1.5 m cells.

Middle: Data below the AUV from EM2040 can be gridded at 0.4m. Data overlaps with HISAS data.

Both DTM maintain a minimum of 4 pings/beams per grid cell.

Right: Data from HISAS and EM2040 combined.

Summary - Conclusions

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- Fantastic tool for both object search, and seabed mapping
- Some improvements needed in order to streamline production
  - Make sure you have enough diskspace.. ☺
- Careful planning of mission required


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