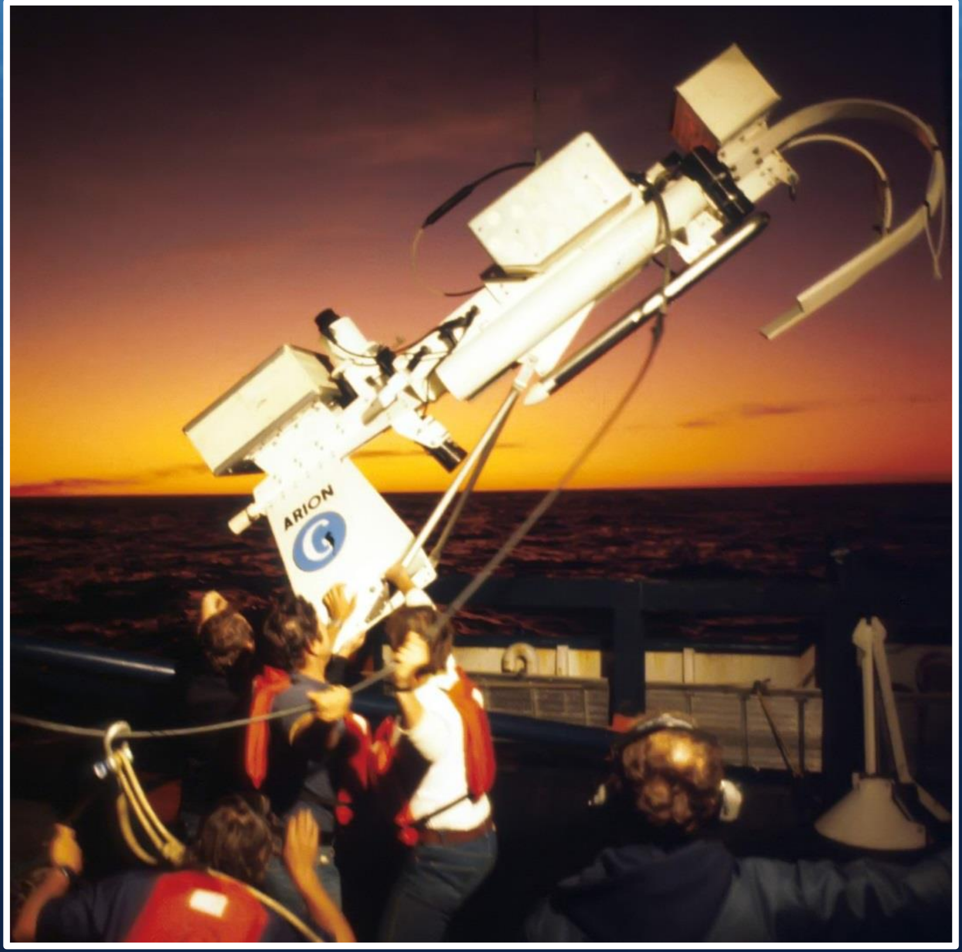
FUNDAMENTALS of SIDE SCAN SONAR

Rev 3

This presentation** __is not meant to be stand-alone__**, and it is best complimented with an instructor. However, most of the slides are self-explanatory.



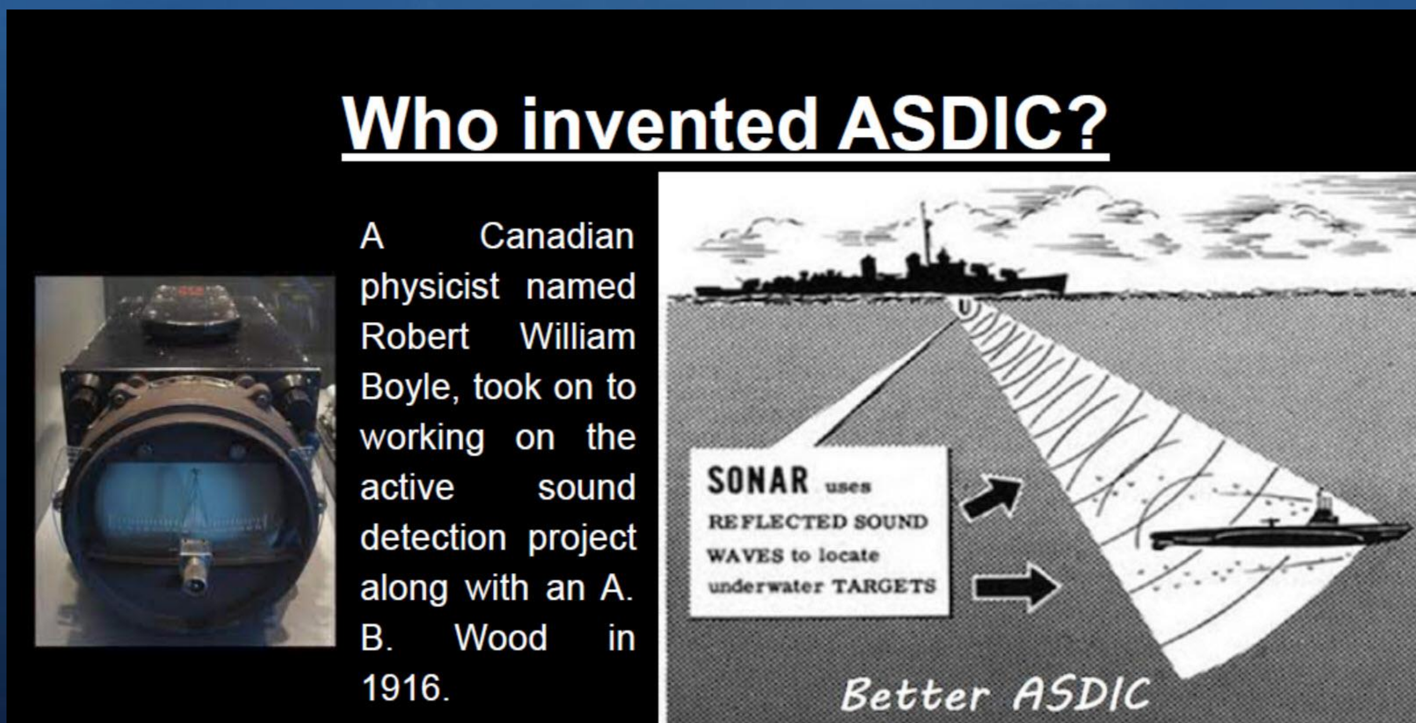
Content Outline

I. SSS History
II. SSS Principles
III. SSS Data Interpretation
IV. Field Operations
V. Applications & Cool Images

I. SSS History

The Roots of SSS go back to early 1900's when ASDIC Sonar was developed for locating enemy submarines.

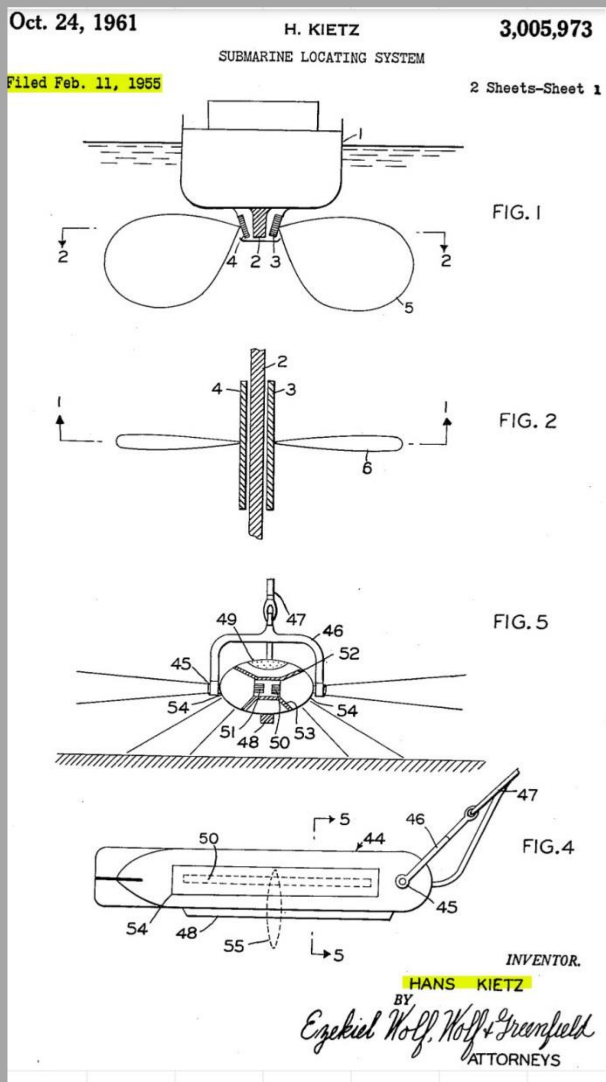
ASDIC Sonar was a search light sonar, but when directed to the side it would produce a crude low resolution seafloor image

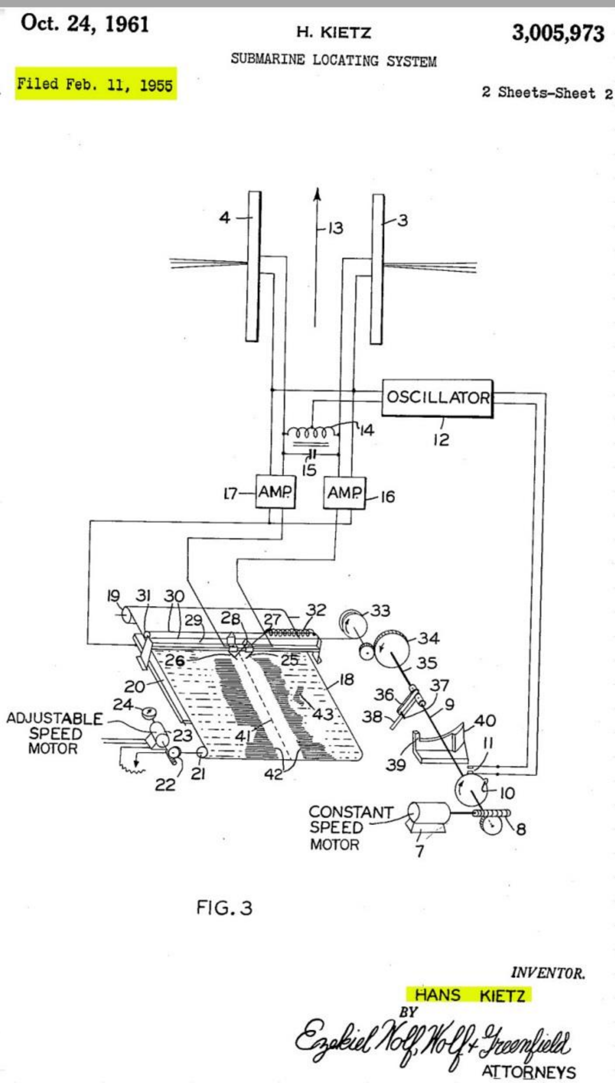


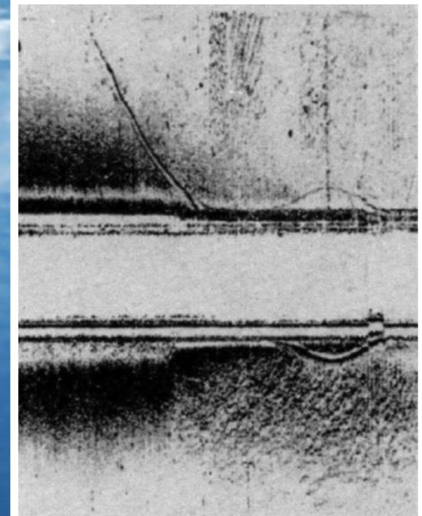
I. SSS History

First SSS Concept –Dr Hans Kietz Filed German Patent

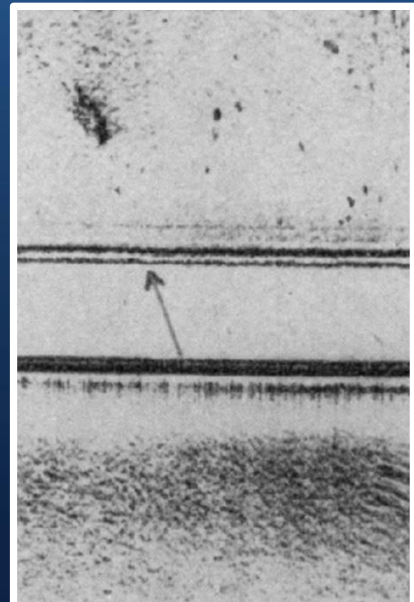
February 11, 1955







Drag Scar - Kietz



Shipwreck - Kietz

I. SSS History

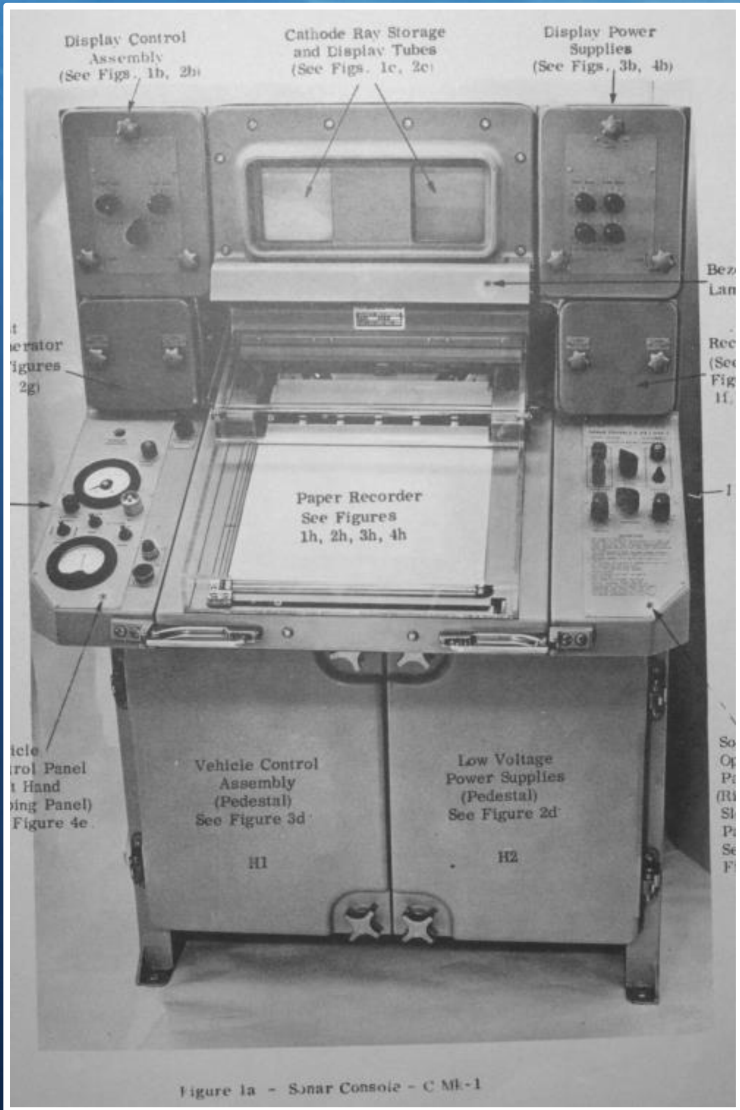


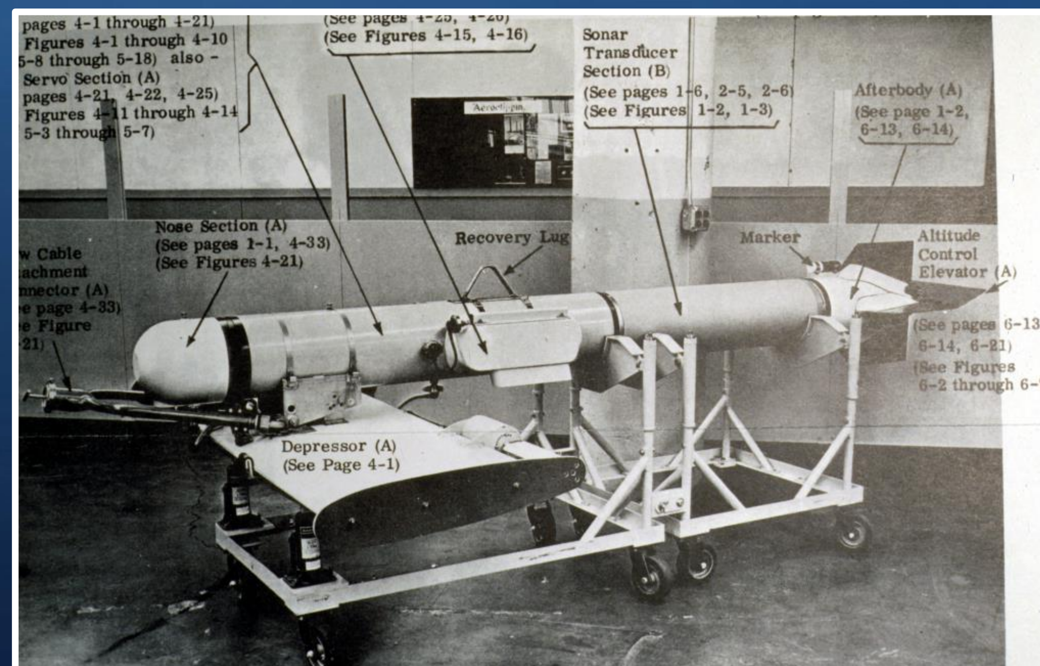
Figure 1a - Sonar Console - C Mk-1

THE FIRST USA SIDE SCAN SONAR

1954 Dr Julius Hagemann outlines Multi-Towfish SSS concept – Files Patent August 4 1958

1957 Navy issues contract to Westinghouse to build the first towed SSS

C-Mk-1 Shadowgraph



I. SSS History

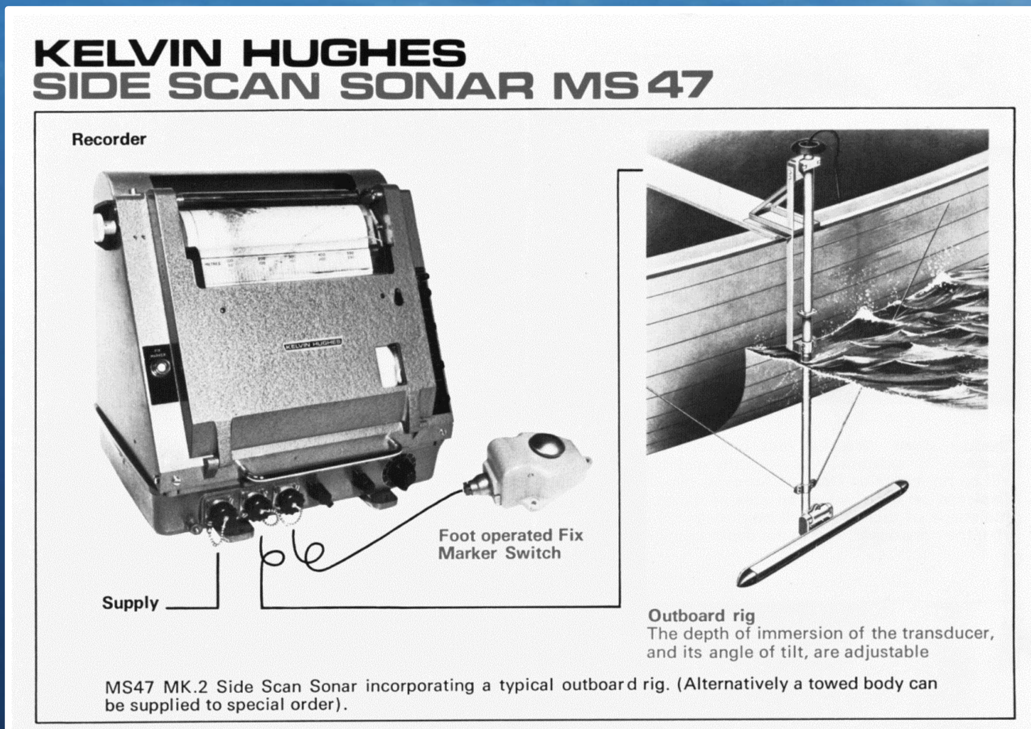
First Commercial SSS Development

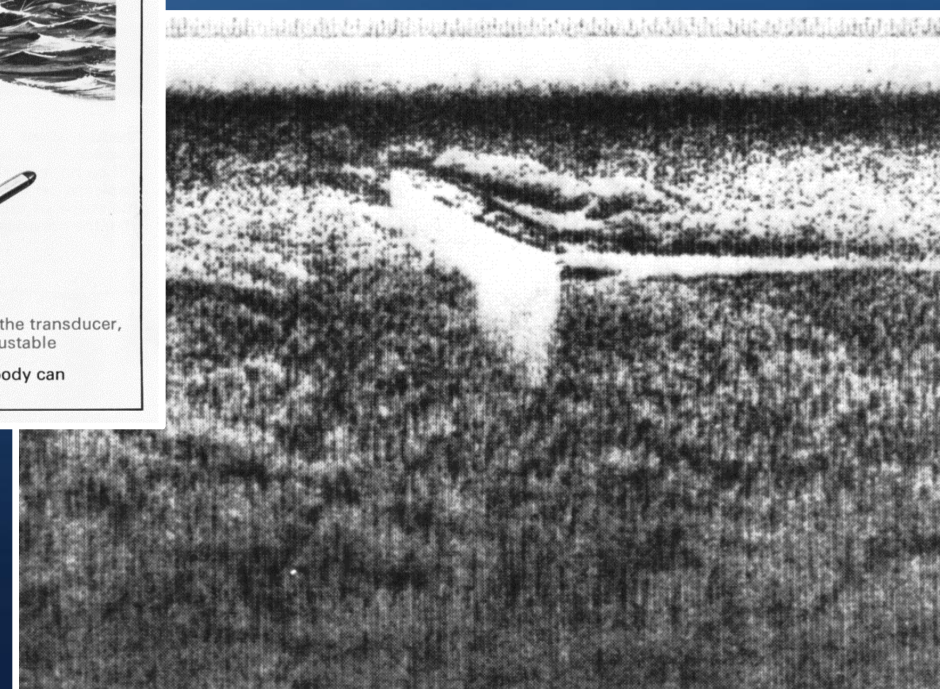
Kelvin Hughes in UK
1960

EG&G in USA
1965

I. SSS History

Kelvin Hughes in UK 1960



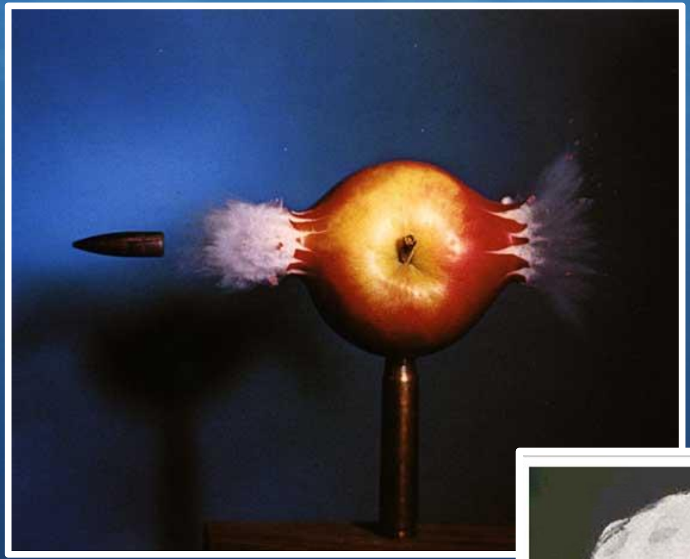


48 kHz @ 550 m Range

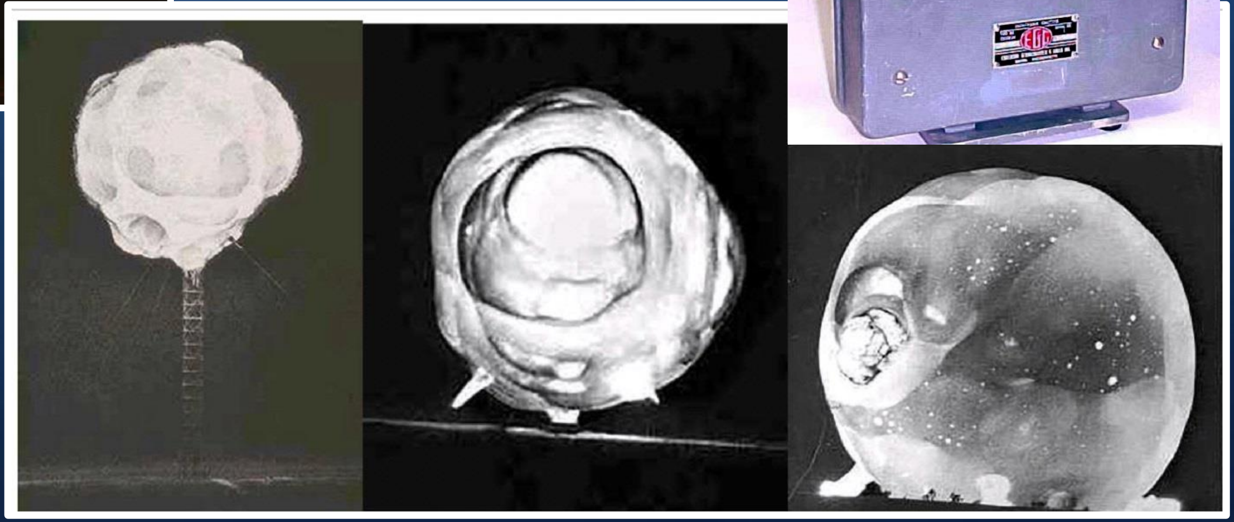
I. SSS History

“Doc” Edgerton “AKA Pa Pa Flash”

He was a very interesting Dude with amazing accomplishments



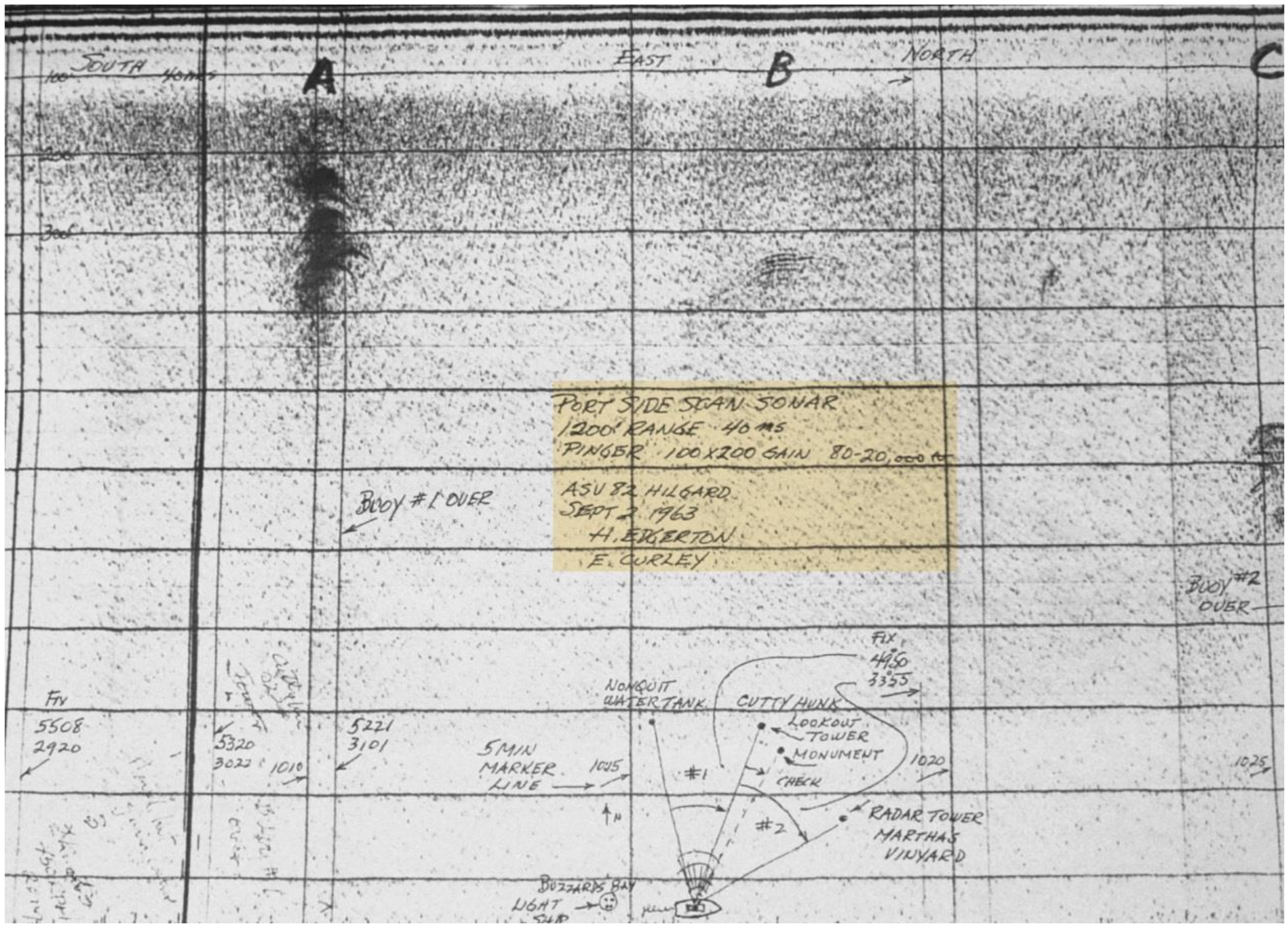
Edgerton Rapatronic Camera captures images of 1st Atomic Bomb Explosion



I. SSS History

EG&G

“Doc” Edgerton 1st SSS Image



I. SSS History

EG&G -Boston MA
(AKA EdgeTech)

Marty Klein with the first
EG&G Side Scan System

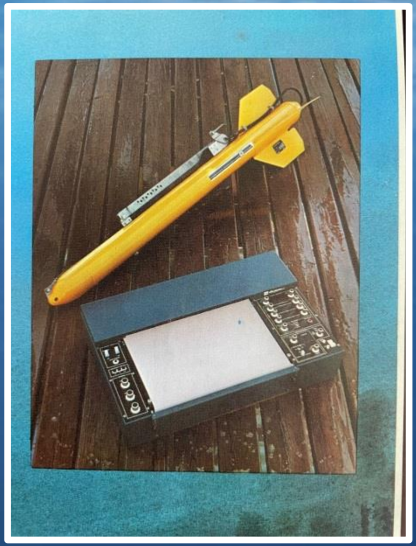
Doc Edgerton with EG&G Model 259
SSS Introduced in 1967
105 kHz @ 500 m Range

I. SSS History

Commercial SSS Development 1970's & 1980's

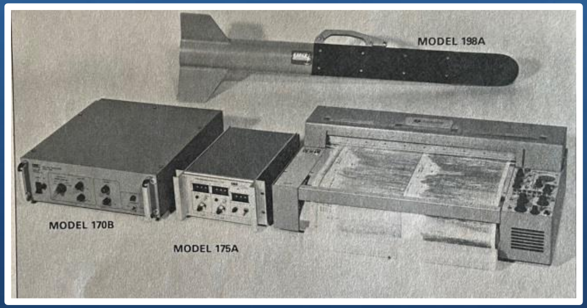
EG&G (EdgeTech)

UDI



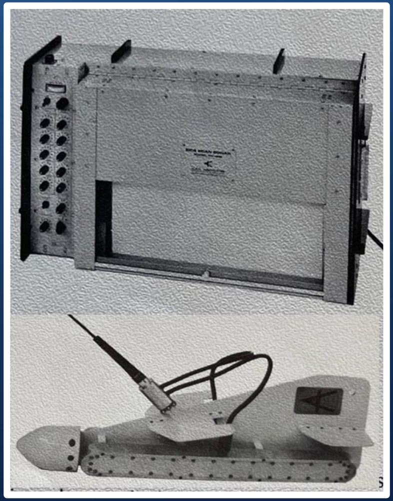
EDO Western

Furuno



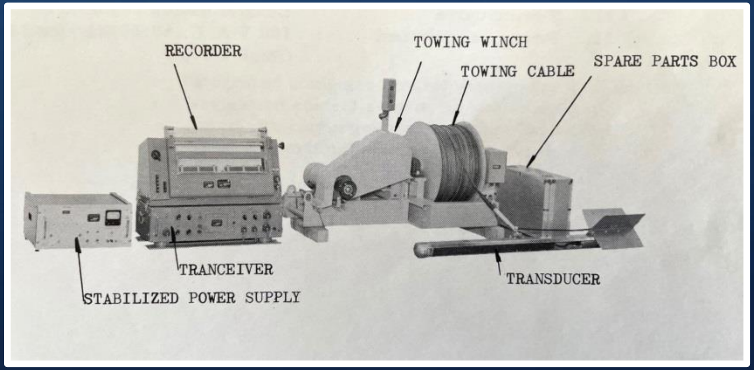
O.R.E.

Datasonics



Klein

Wesmar



Nippon Electric Corp.

Also Electrospace

I. SSS History

Todays Commercial SSS Manufacturers

1979 Klein 531T System

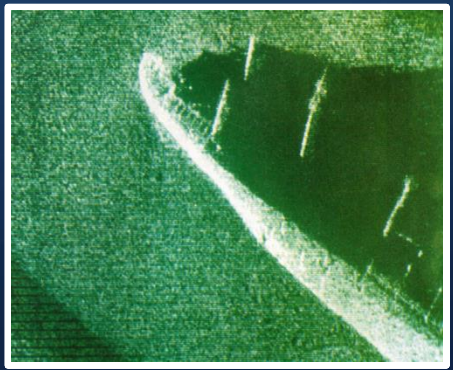
- EdgeTech
- Klein
- MarineSonic
- Kongsberg
- Deep Vision
- Imagenex
- JW Fisher
- TriTech
- Kracken
- Sonardyne
- C-Max
- SonarTech
- Falmouth Scientific

I. SSS History

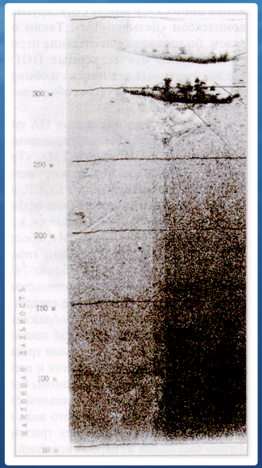
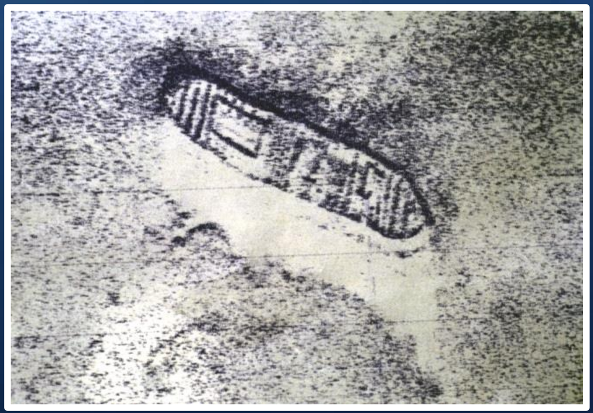
Military SSS Development 1970's & 1980's


Thompson DUBM-41 SSS - French Navy


MDA AN-SQS 511 Canadian Navy

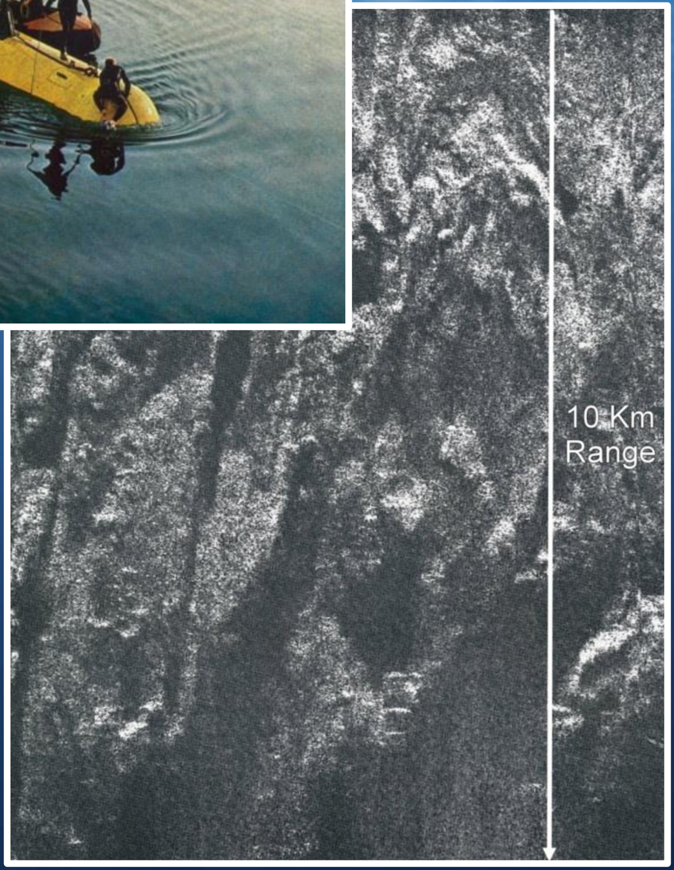
Westinghouse SSS - US Navy

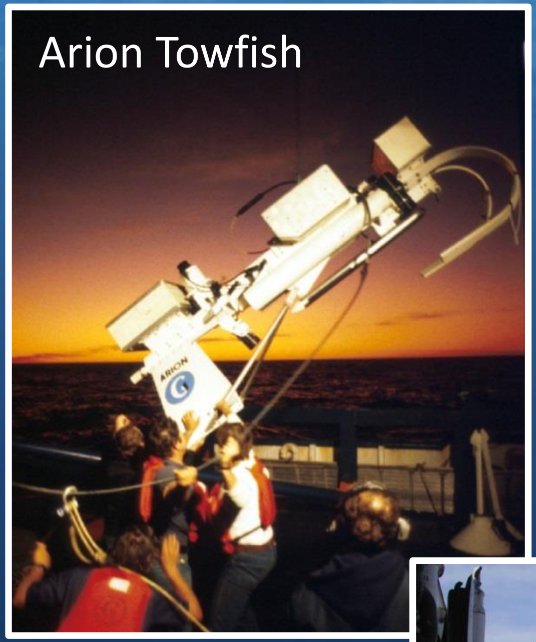
Soviet Era SSS

I. SSS History

Unique SSS Development 1970's & 1980's



GLORIA Mk1 & Mk2 LONG RANGE SSS
22 km range @ 6.5 kHz
National Oceanography Centre, Southampton UK



I. SSS History

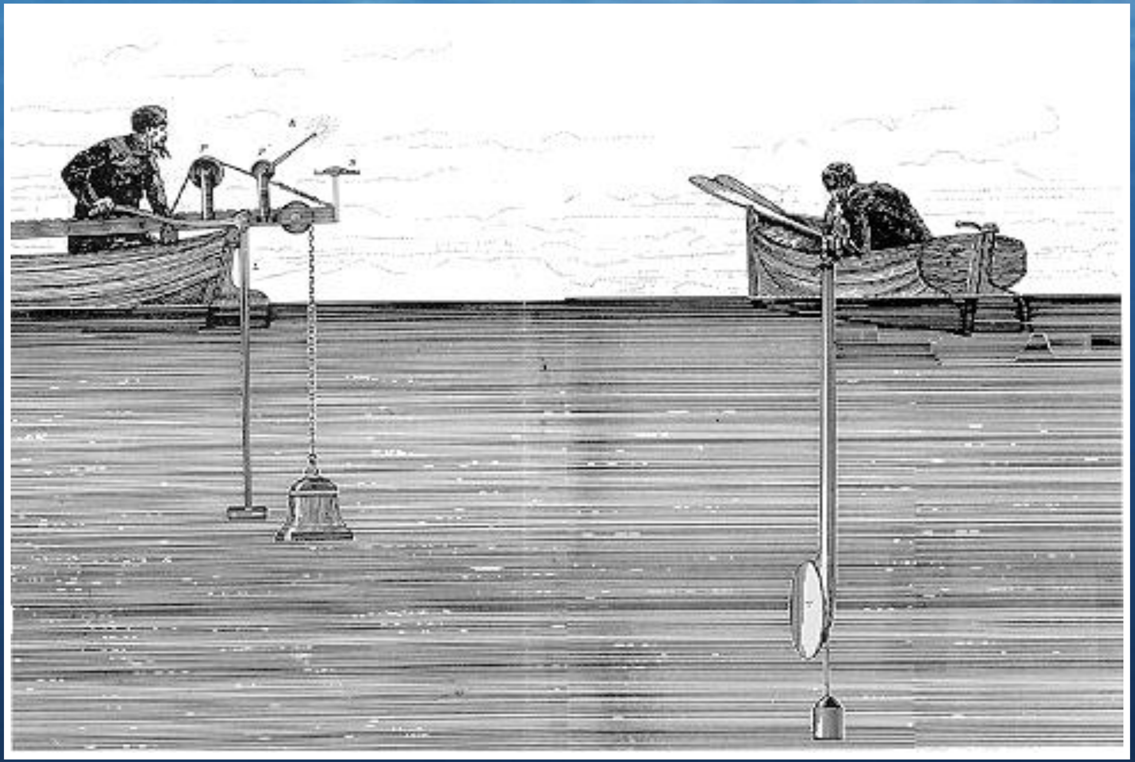
Consumer SSS Development 1990 to Date

The first consumer SSS was introduced by Humminbird and today there are at least a half dozen

Humminbird
Garmin
Lowrance
RayMarine
Simrad
Furuno

II. SSS Principles

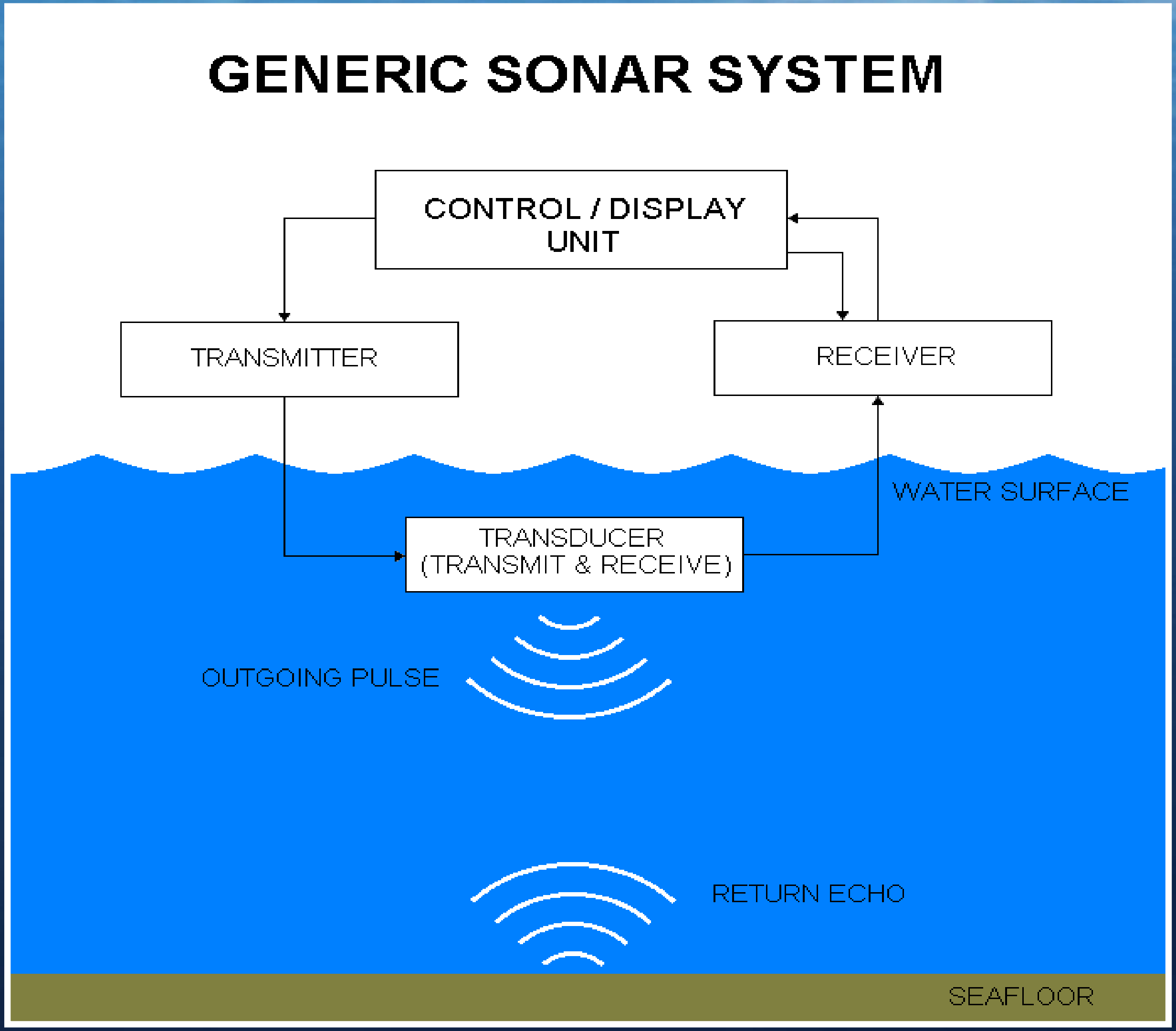
Speed of Sound



1826 Swiss Physicist J. D. Colladon Measures Speed of Sound in Water
Approximately 1500 m/sec and proved it was independent of Frequency

II. SSS Principles

Basic Sonar System Components



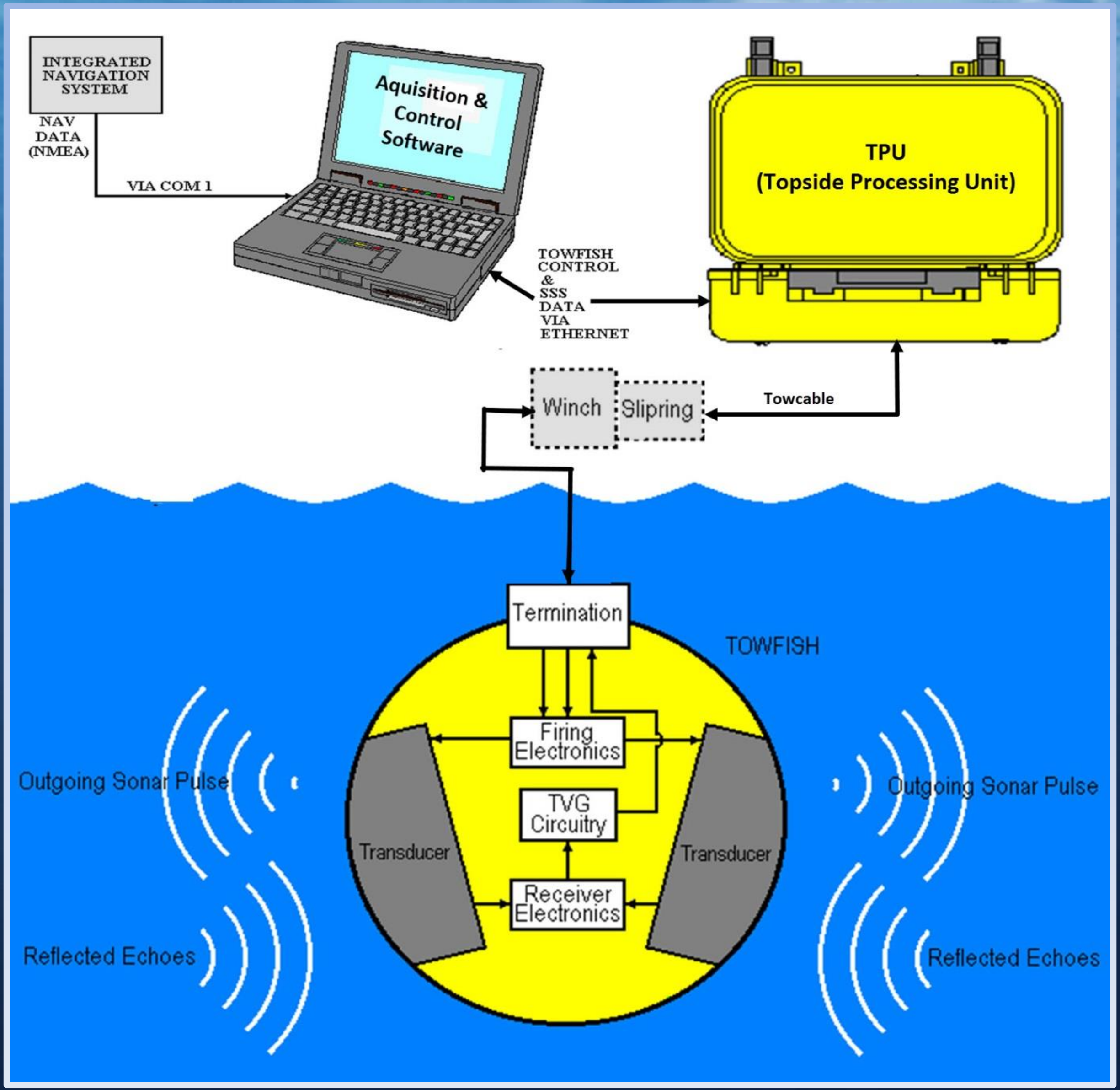
II. SSS Principles

SSS Features

- SIDEWAYS LOOKING
- NARROW HORIZONTAL BEAM
- WIDE VERTICAL BEAM
- TWO SIDES
- TOWED BODY DECOUPLES SHIP MOVEMENT
- TOWFISH IS BELOW SURFACE NOISE

II. SSS Principles

SSS Block Diagram

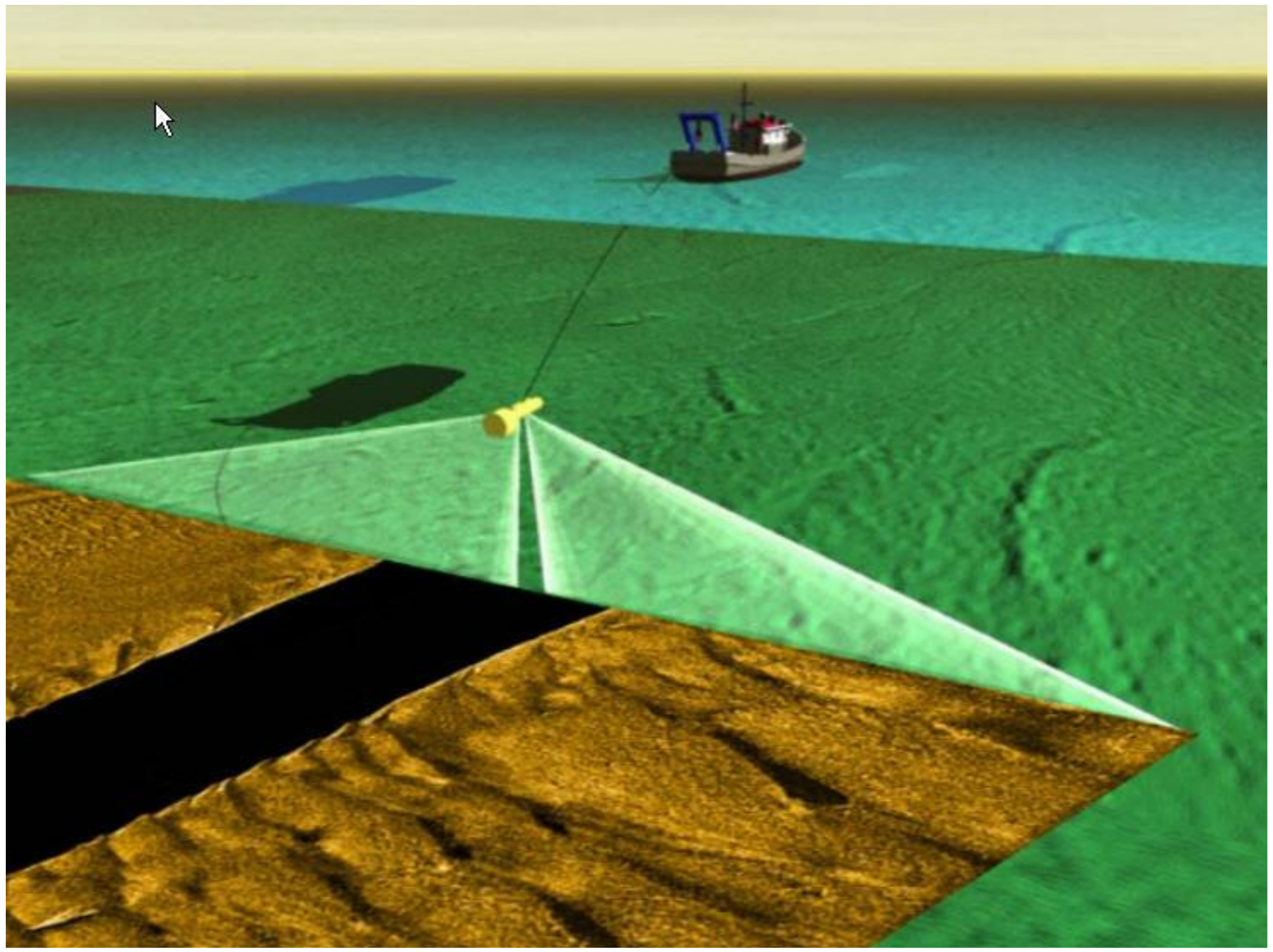


II. SSS Principles

SSS System

II. SSS Principles

SSS Image Creation



Drawing Courtesy of Vince Capone

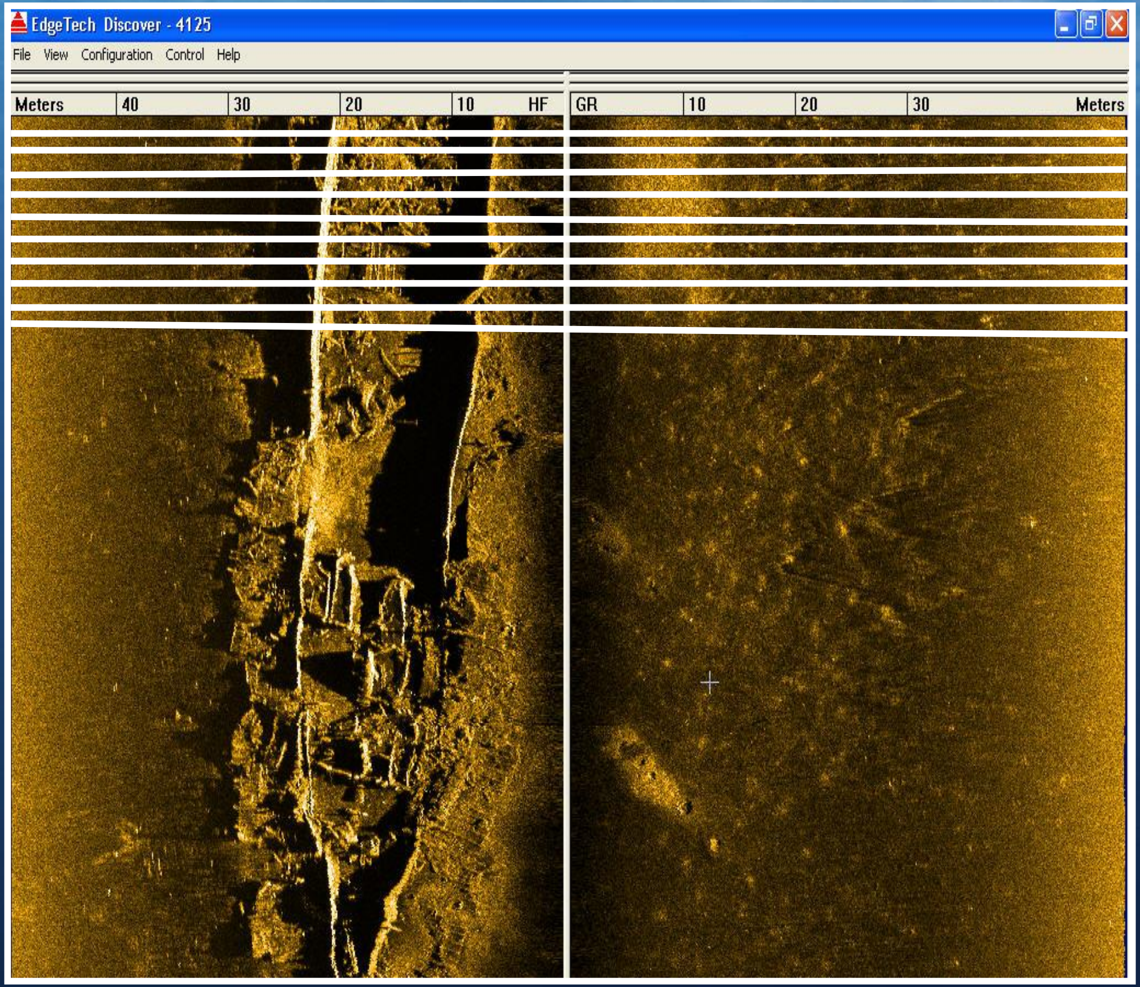
II. SSS Principles

Line Scanning Imaging Technique

Line Scanning – If a feature is sliced into strips as above picture (left), then reassembled in order you get the image back (right). This is the process in how seafloor images are made of the seafloor. A narrow acoustic beam slices consecutively the seafloor then presents the scan lines in order on the computer screen to create a seafloor acoustic picture.

II. SSS Principles

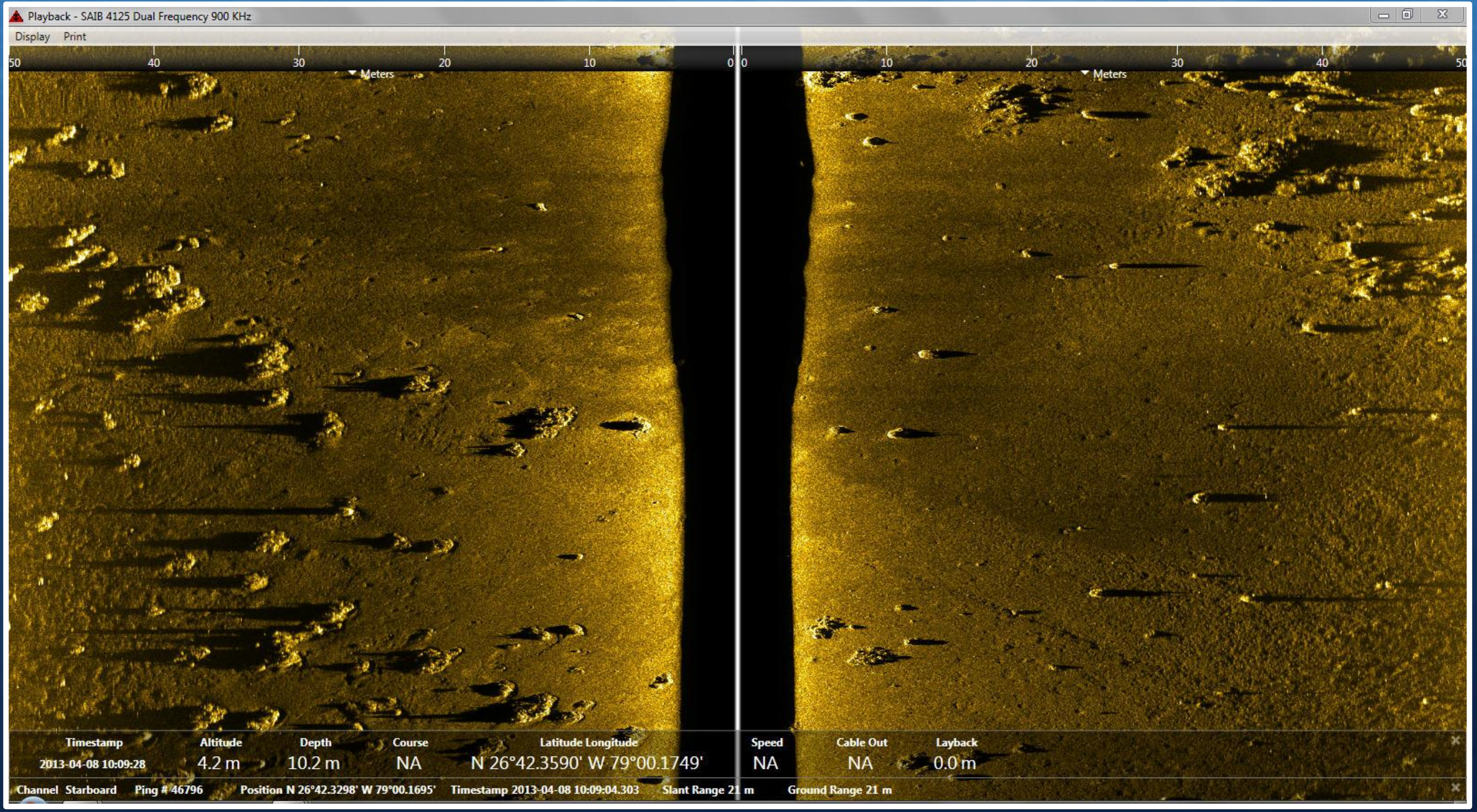
Line Scanning Imaging Technique



II. SSS Principles

Line Scan SSS Image

Acoustic Slices Mapped in Order Create Seafloor Image



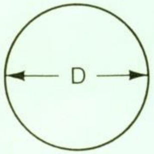
II. SSS Principles

Transducer Concepts: Beam Directivity

Piezoelectric Ceramics

Plane Circular Source (baffled)

The directional characteristics are symmetrical about the axis normal to the array face and form a conical beam along the array axis. For a circular piston with uniform surface displacement the pressure field is shown as:

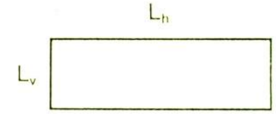


Some simplified approximations for the beamwidth (BW)

$$BW_{deg} \approx \frac{3600}{f_{kHz} \cdot D_{in}} \text{ or } \frac{91{,}440}{f_{kHz} \cdot D_{mm}} \text{ [degrees]}$$

Square or Rectangular Source (baffled)

The directional characteristics of any plane rectangular, or square, source in any normal plane is the same as the product of the directional characteristics of two line sources of dimensions equal to the length and width of the sides.



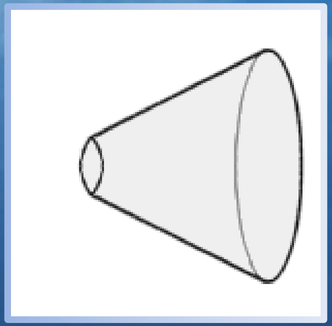
L_h, L_v = Active dimensions of the face [inches]

$$BW_{deg} \approx \frac{3000}{f_{kHz} L_h} \text{ or } \frac{3000}{f_{kHz} L_v} \text{ [degrees]}$$

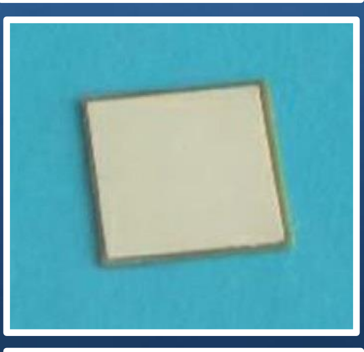
II. SSS Principles

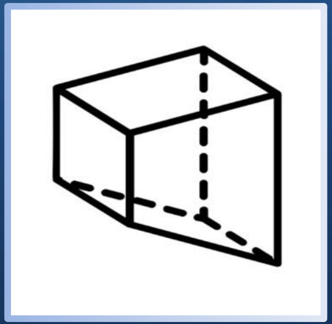
Transducer Concepts: SSS Transducer Beam Shapes

DISK

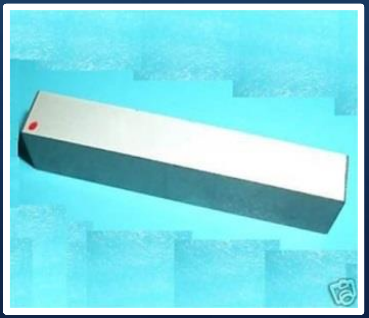


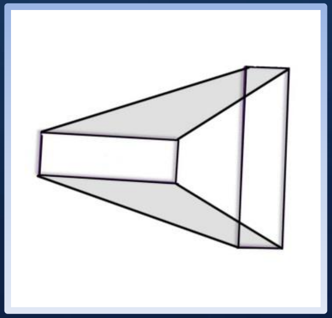
SQUARE PLATE





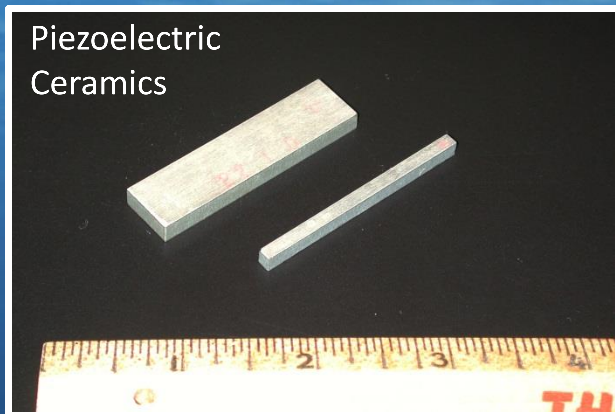
RECTANGULAR PLATE

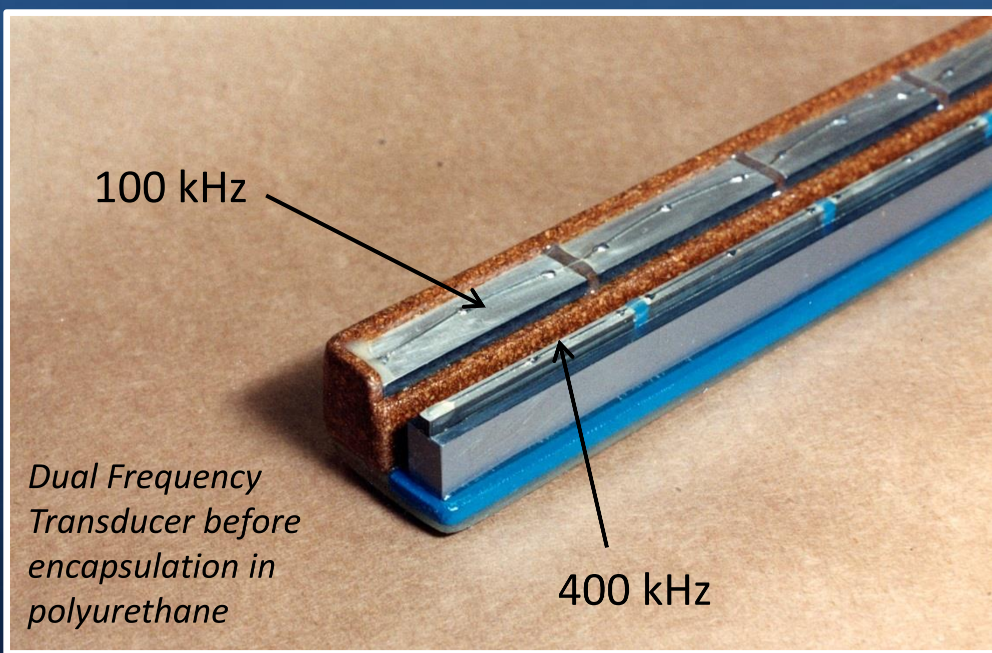




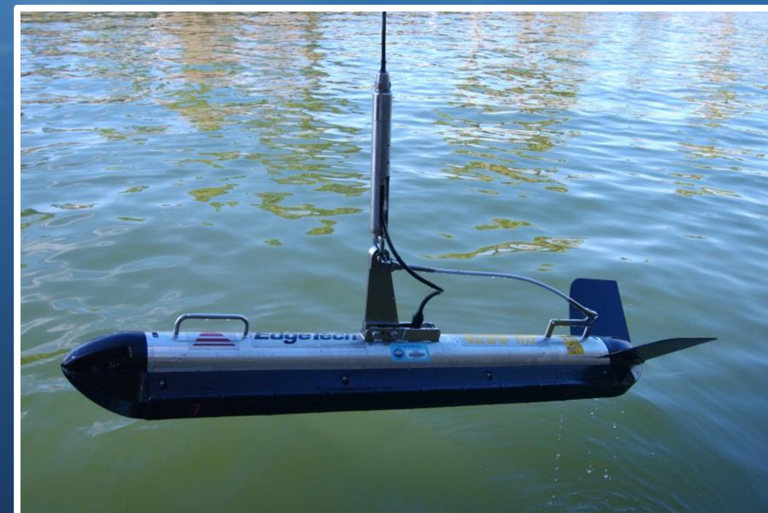
II. SSS Principles

Transducer Concepts: SSS Transducer Construction



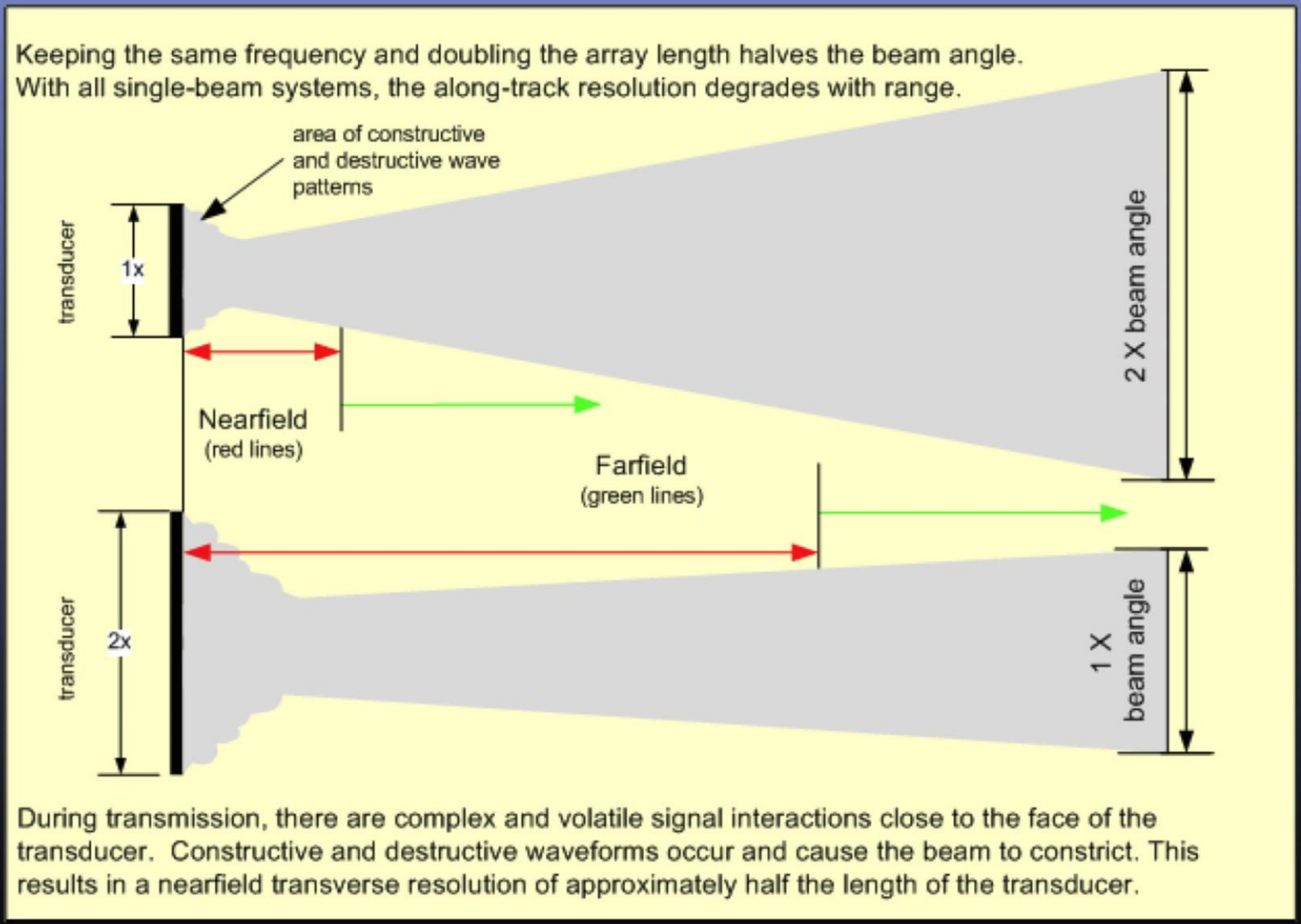


Dual Frequency Transducer before encapsulation in polyurethane



II. SSS Principles

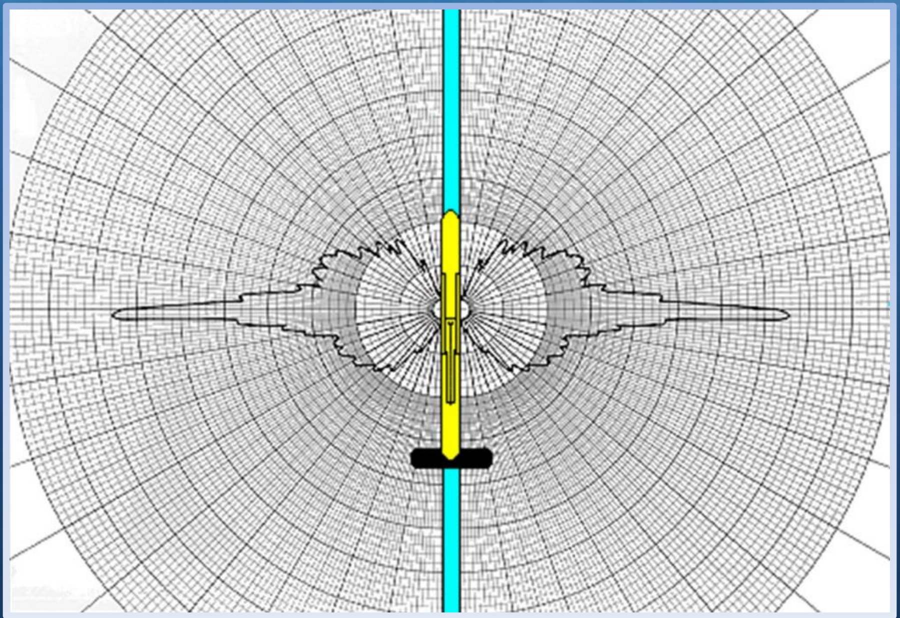
Transducer Concepts: Beam Width vs Array Length



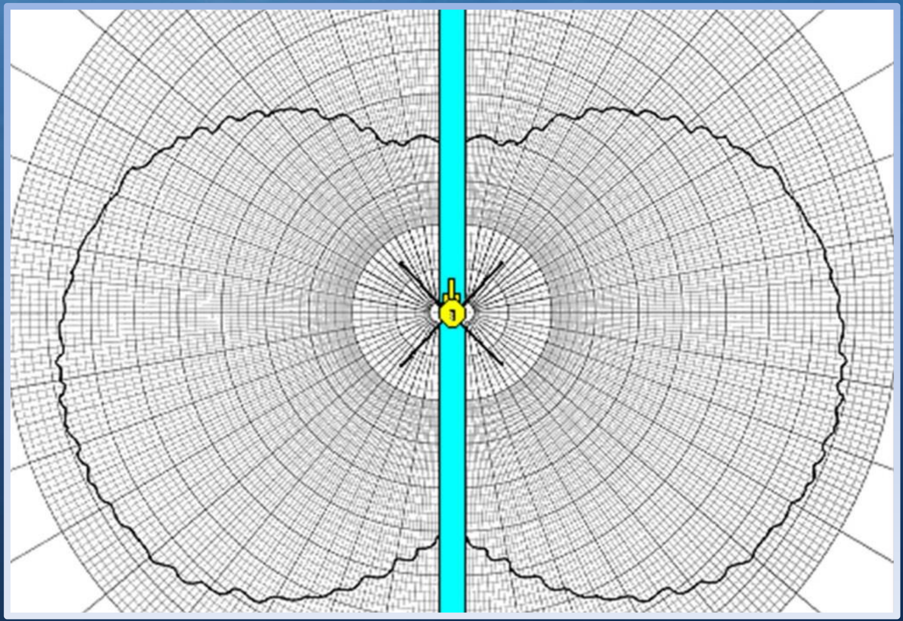
Drawing courtesy M.W. Atherton, Echoes and Images

II. SSS Principles

SSS Vertical & Horizontal Transmit & Receive Beam Shape and Theorem of Reciprocity

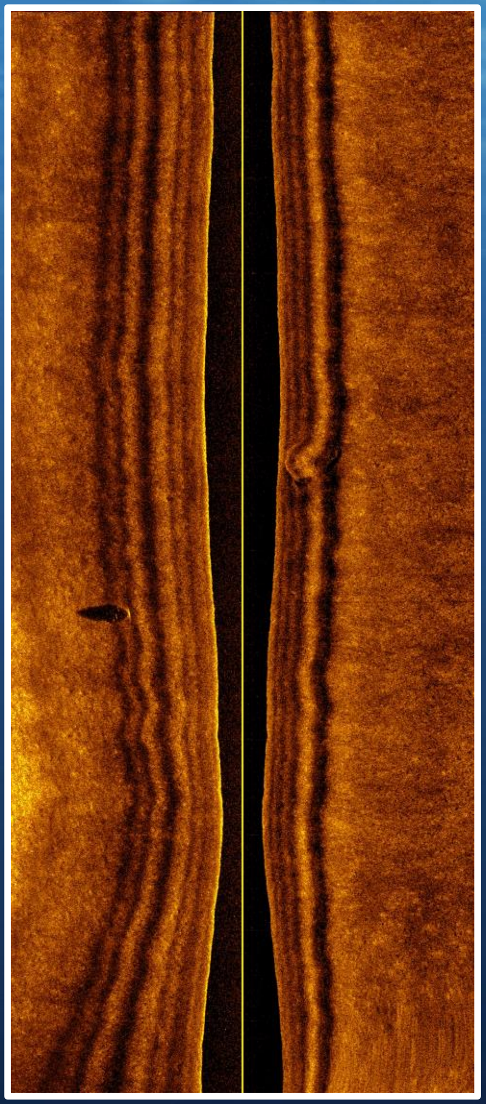


Horizontal Beam is the same for both Transmit & Receive Mode

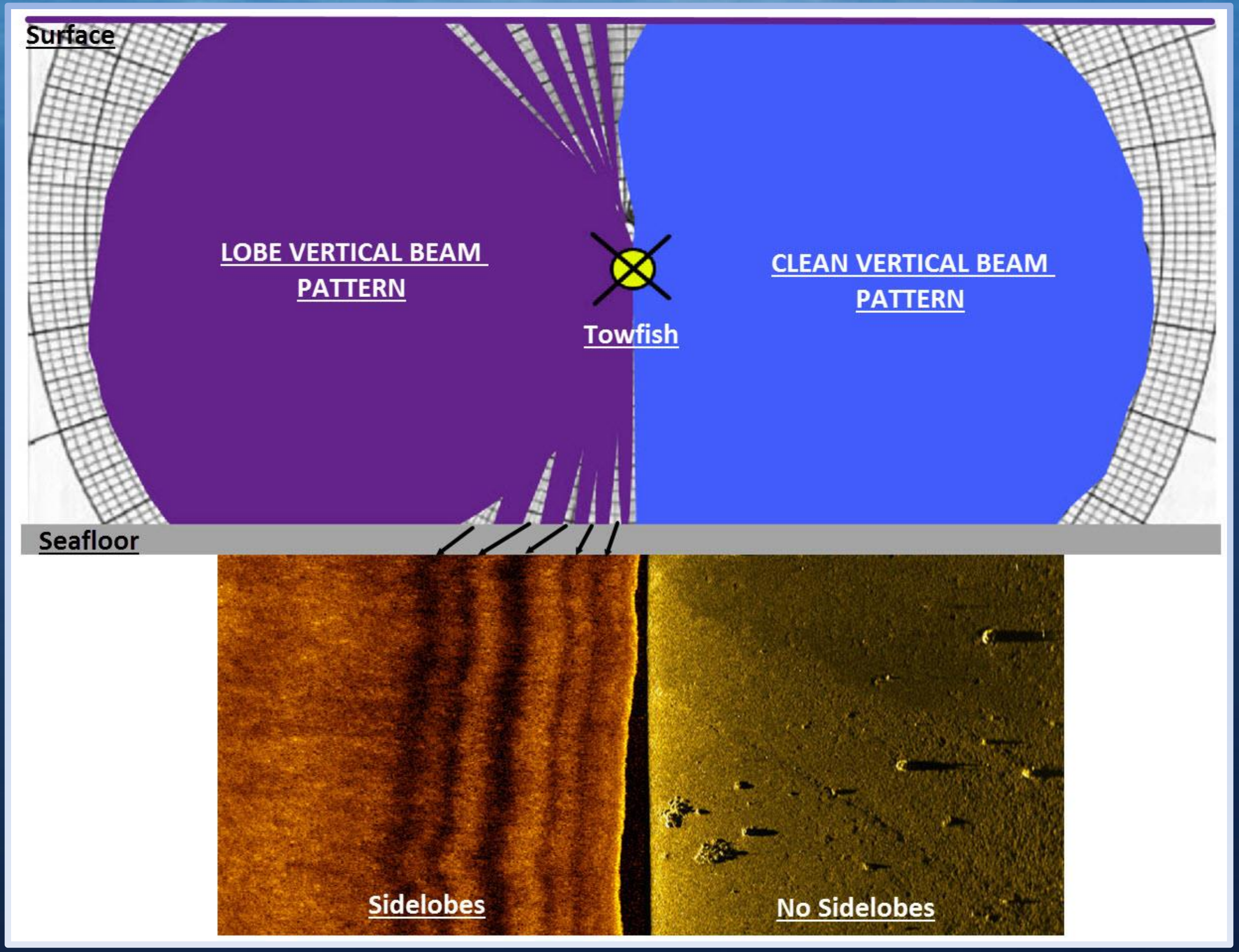


Vertical Beam is the same for both Transmit & Receive Mode

II. SSS Principles

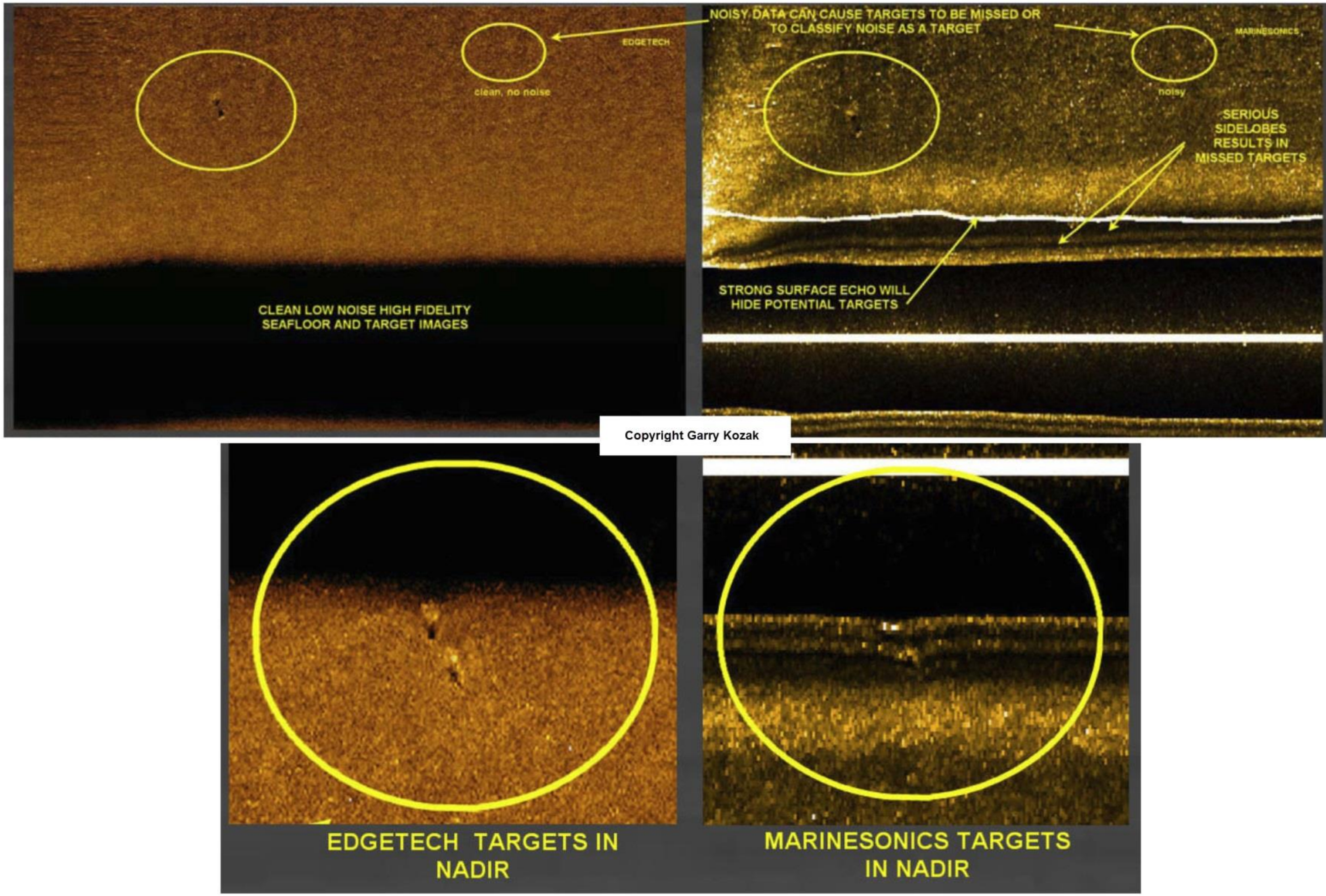


Vertical Beam Sidelobe Artifacts



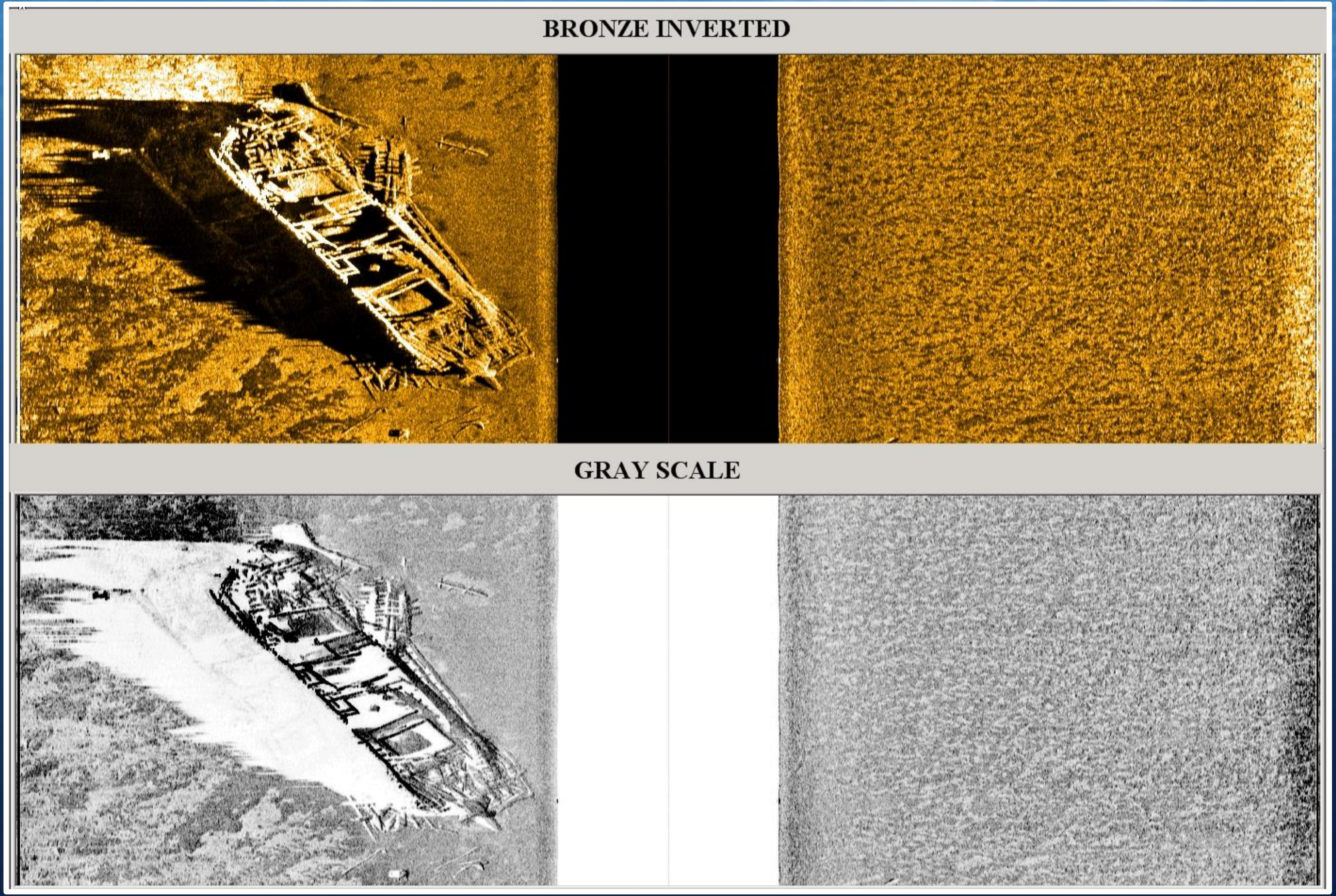
II. SSS Principles

Vertical Sidelobe Impact on Target Detection



II. SSS Principles

SSS Image Display Color



II. SSS Principles

SSS Performance Considerations

Ping Rate-------------------- Determined by Sonar Range Scale Setting

Source Level
Frequency
--------------------------- Sonar Operational Maximum Range

Pulse Length / Bandwidth -------------- Range Resolution

Beam Directivity ------------------------- Along-Track Resolution

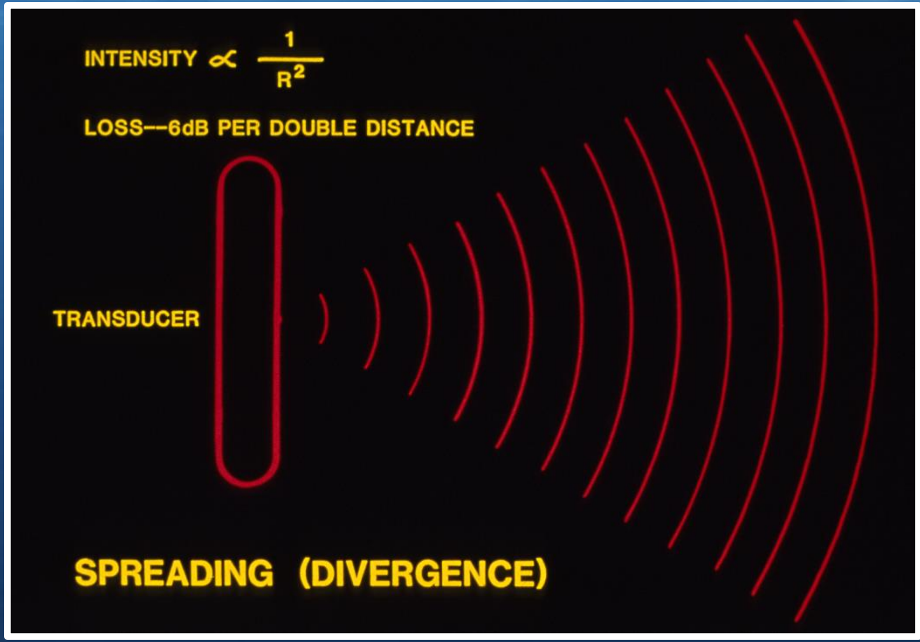
II. SSS Principles

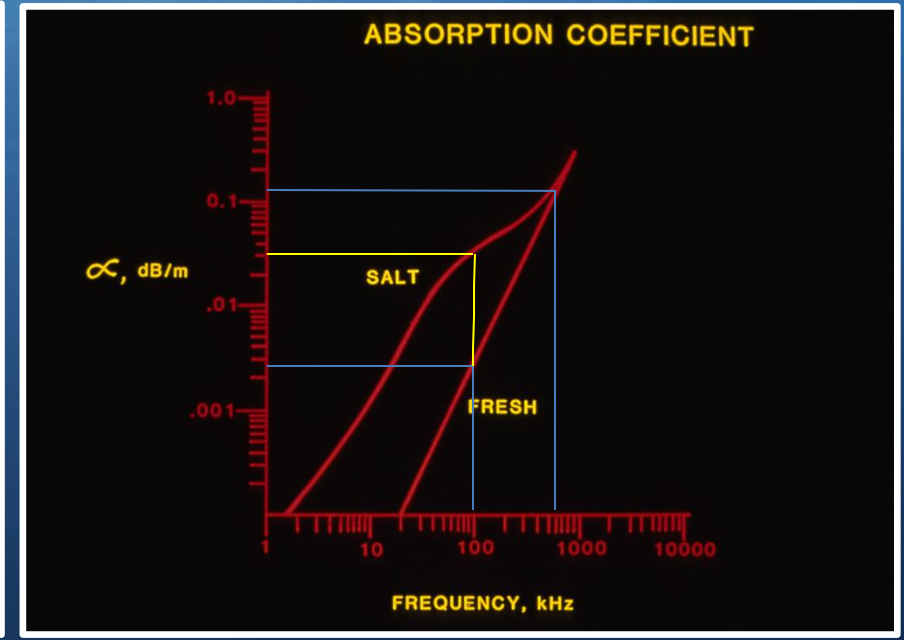
SSS Ping Rate

Sonar Range Scale (Meters)	Pings per Second
25	30
37.5	20
50	15
75	10
100	7.5
150	5
200	3.75
250	3
300	2.5
400	1.875
600	1.25
750	1

II. SSS Principles

Acoustics & Sonar Maximum Range





Low frequencies, under 400 kHz, have higher absorption in Sea water vs fresh water. The result is less operational range.

II. SSS Principles

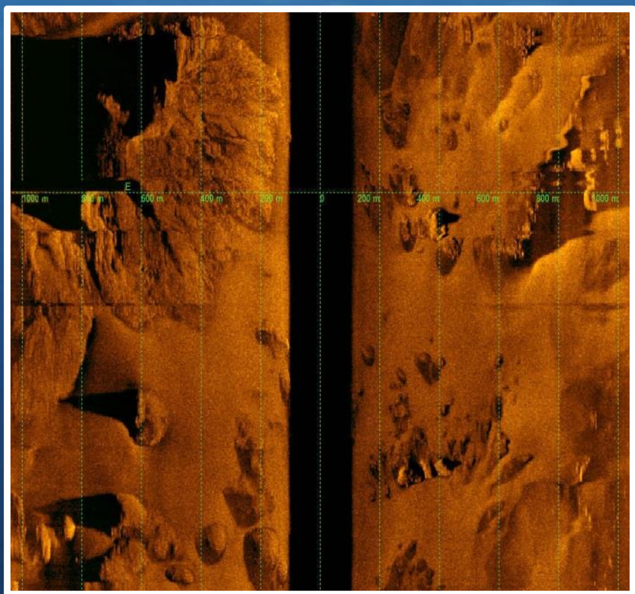
Sonar Operational Maximum Range

NOMINAL CENTER FREQUENCY	TYPICAL RANGE
75 kHz	1094 yds *(1000m)*
120 kHz	547 yds *(500 m)*
230 kHz	328 yds (300 m)
400 kHz	219 yds *(200 m)*
540 kHz	164 yds *(150 m)*
850 kHz	82 yds *(75 m)*
1600 kHz	38 yds *(35 m)*

II. SSS Principles

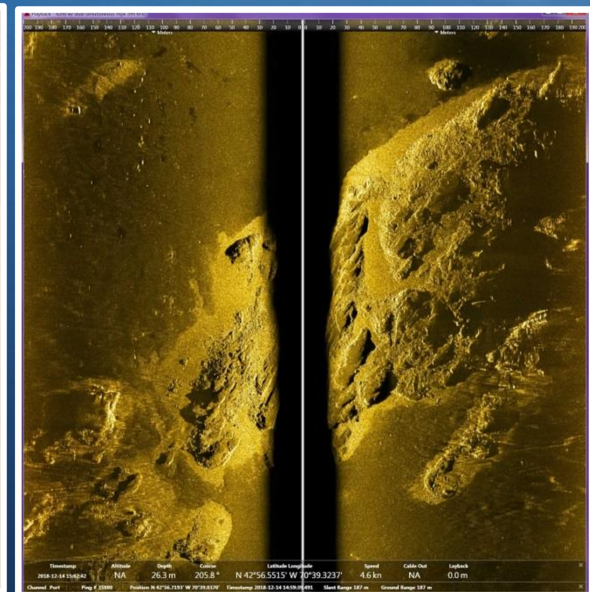
Sonar Operational Maximum Range

EdgeTech 75 kHz



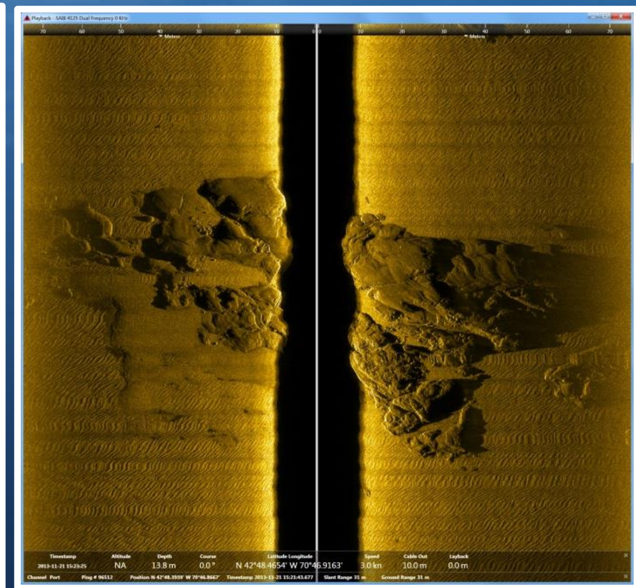
2200 Meters

EdgeTech 400 kHz



400 Meters

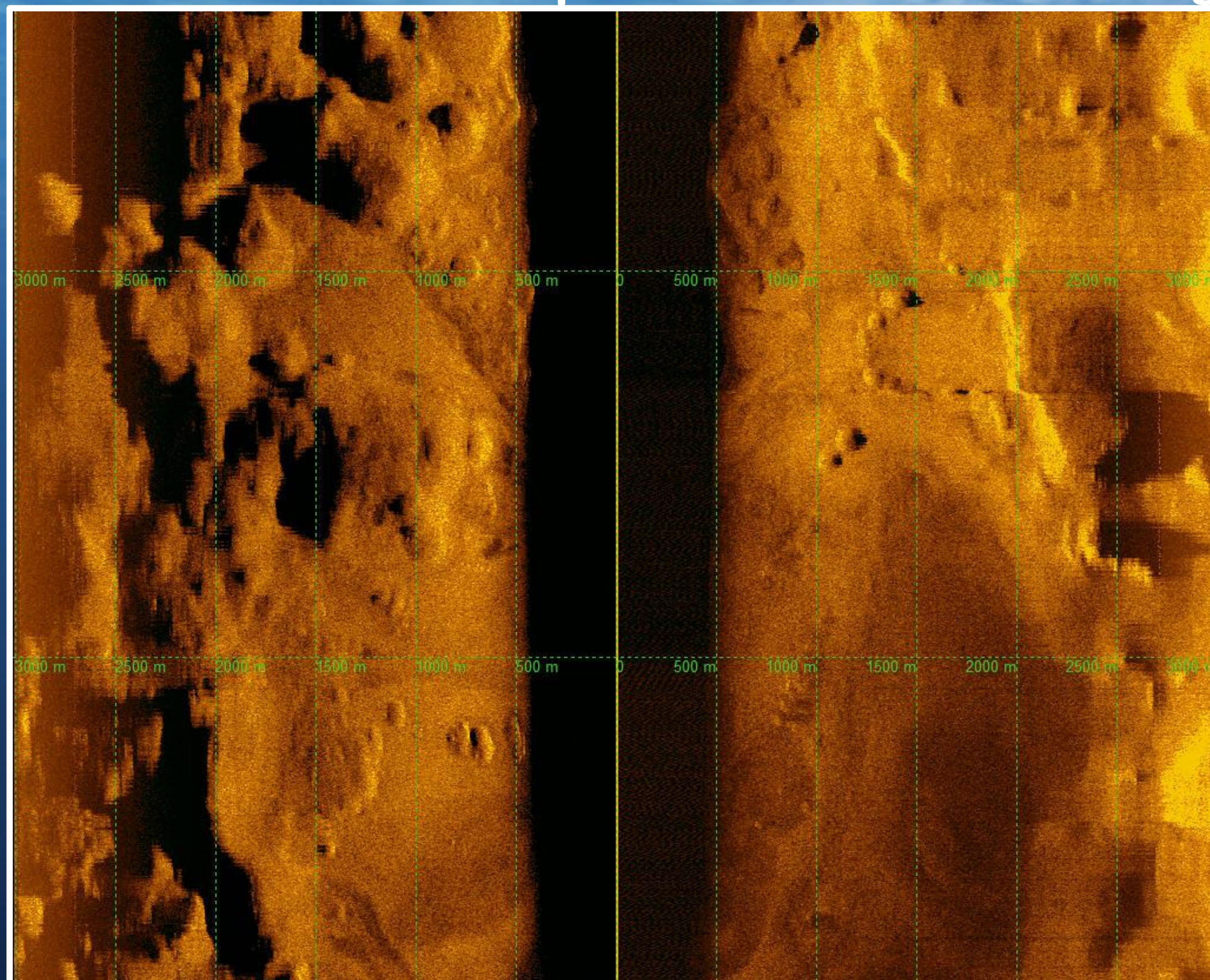
EdgeTech 900 kHz



150 Meters

II. SSS Principles

I.S.T SeaMarc 30 kHz Operational Maximum Range



6000 Meters

II. SSS Principles

Along Track Resolution

Narrower Horizontal Beam Widths Result in Higher Along Track Resolution

Transducer Length

75 kHz ---------------- 1.27 m
120 kHz -------------- 0.76 m
230 kHz -------------- 0.63 m
410 kHz -------------- o.53 m
580 kHz -------------- 0.45 m
850 kHz -------------- 0.30 m
1600 kHz------------- 0.15 m

II. SSS Principles

Along Track Resolution

Near Field

Along Track Resolution in Near Field Approximately = Array Length

75 kHz ---------------- 1.27 m
120 kHz -------------- 0.76 m
230 kHz -------------- 0.63 m
410 kHz -------------- o.53 m
580 kHz -------------- 0.45 m
850 kHz -------------- 0.30 m
1600 kHz------------- 0.15 m

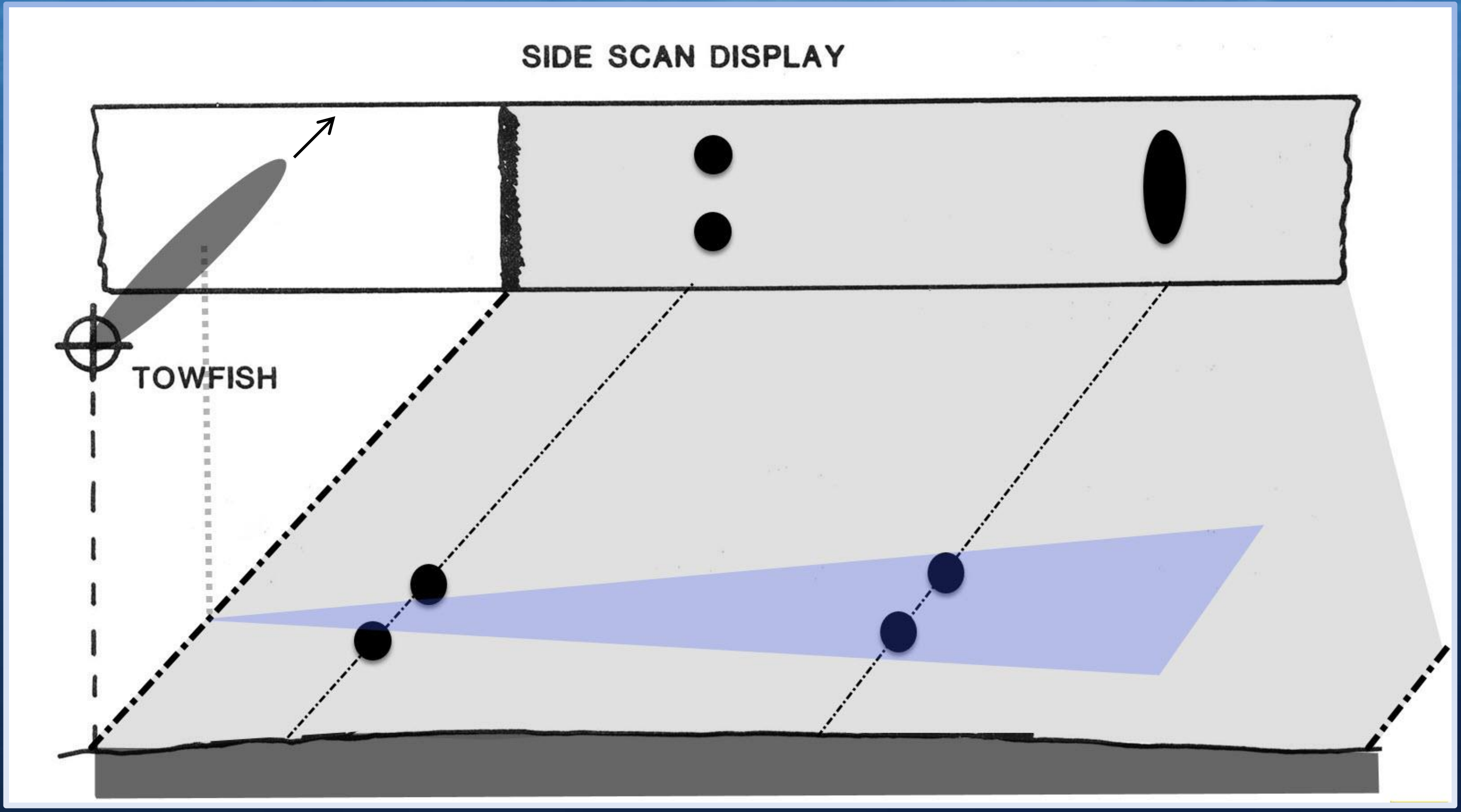
Far Field @ 100 Meter Range

Angle/55 x Range = Beam Width

75 kHz: 1.3 degree ---------------- 2.36 m
120 kHz: 0.7 degree -------------- 1.27 m
230 kHz: 0.44 degree -------------- 0.8 m
410 kHz: 0.30 degree -------------- 0.54 m
580 kHz: 0.26 degree -------------- 0.47 m
850 kHz: 0.23 degree -------------- 0.42 m
1600 kHz: 0.20 degree ------------- 0.36 m

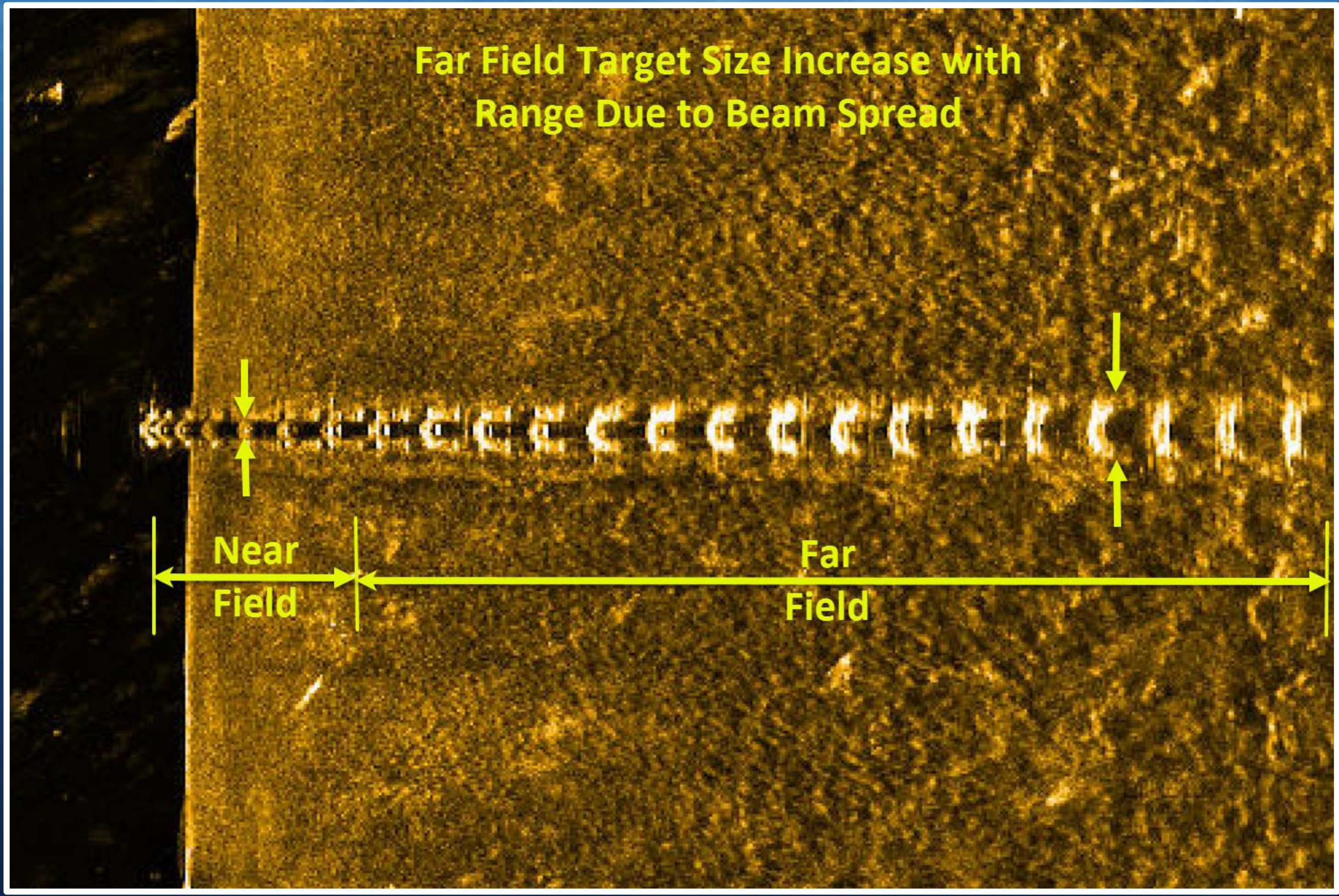
II. SSS Principles

Along Track Resolution



II. SSS Principles

Along Track Resolution



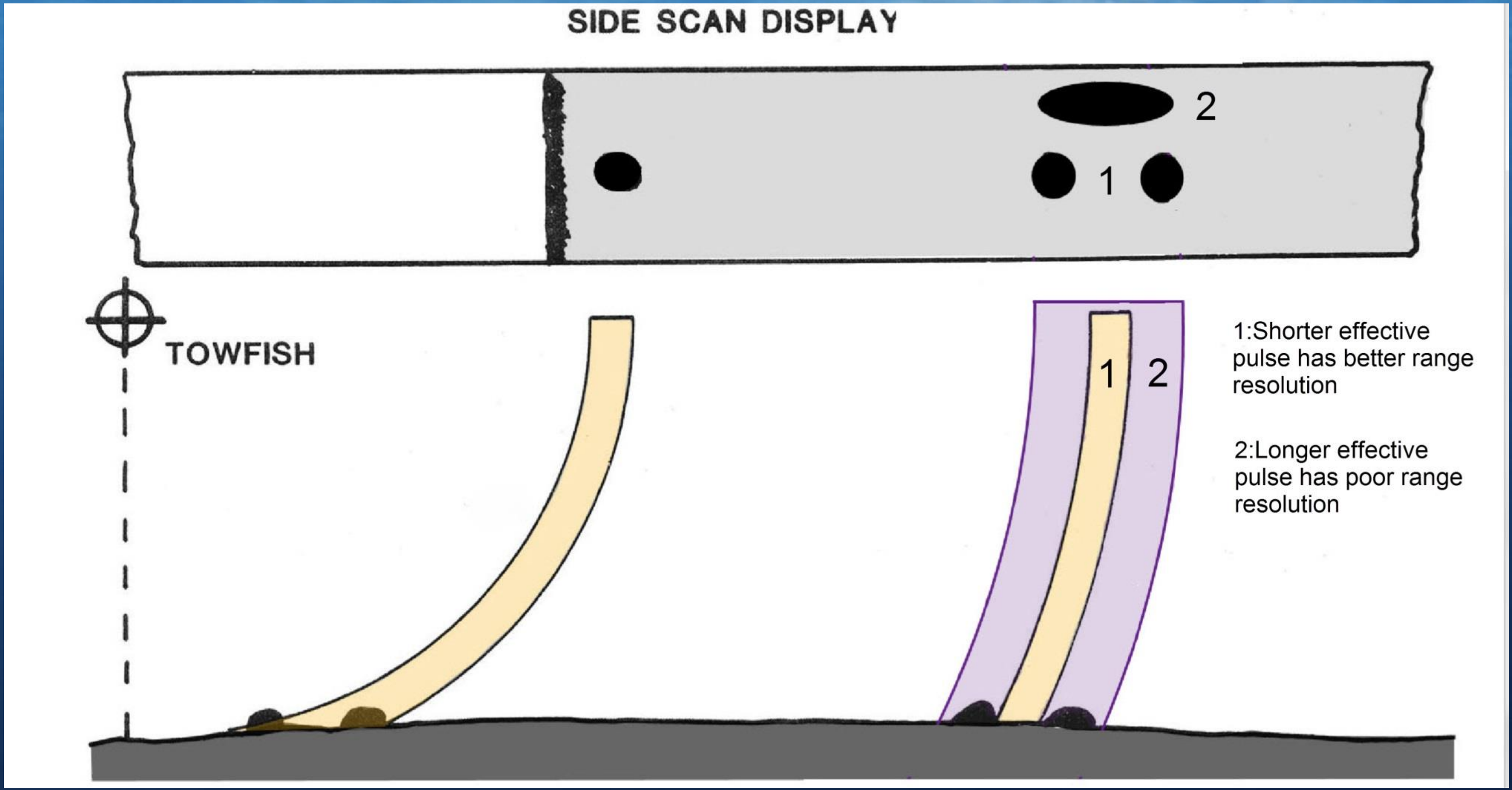
II. SSS Principles

Across Track (Range) Resolution

Shorter Transmit Pulses or Wider Chirp Bandwidth Result in Higher Range Resolution

II. SSS Principles

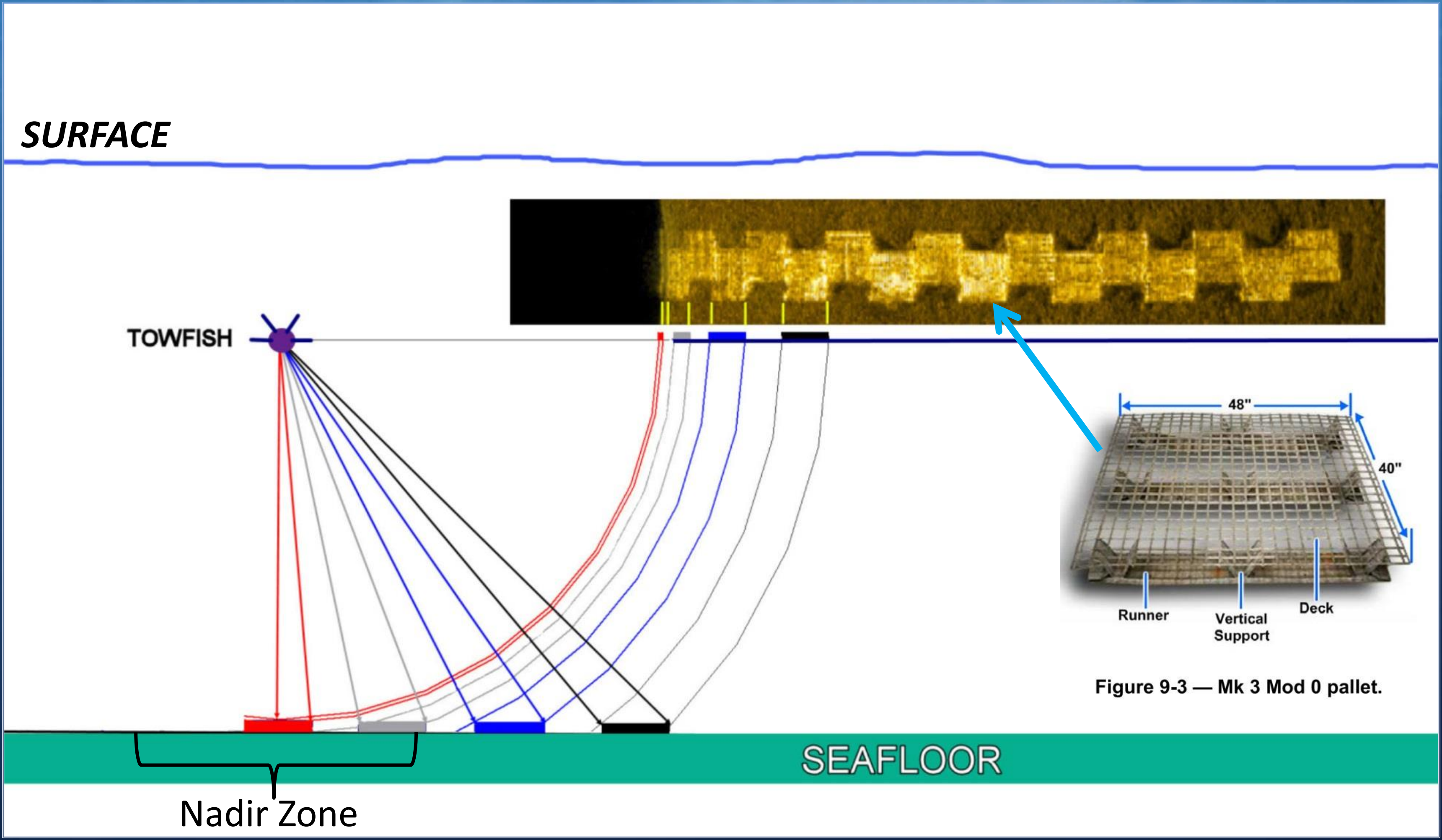
Across Track Resolution



Shorter Transmit Pulses or Wider Chirp Bandwidth Result in Higher Range Resolution

II. SSS Principles

Nadir Compression



II. SSS Principles

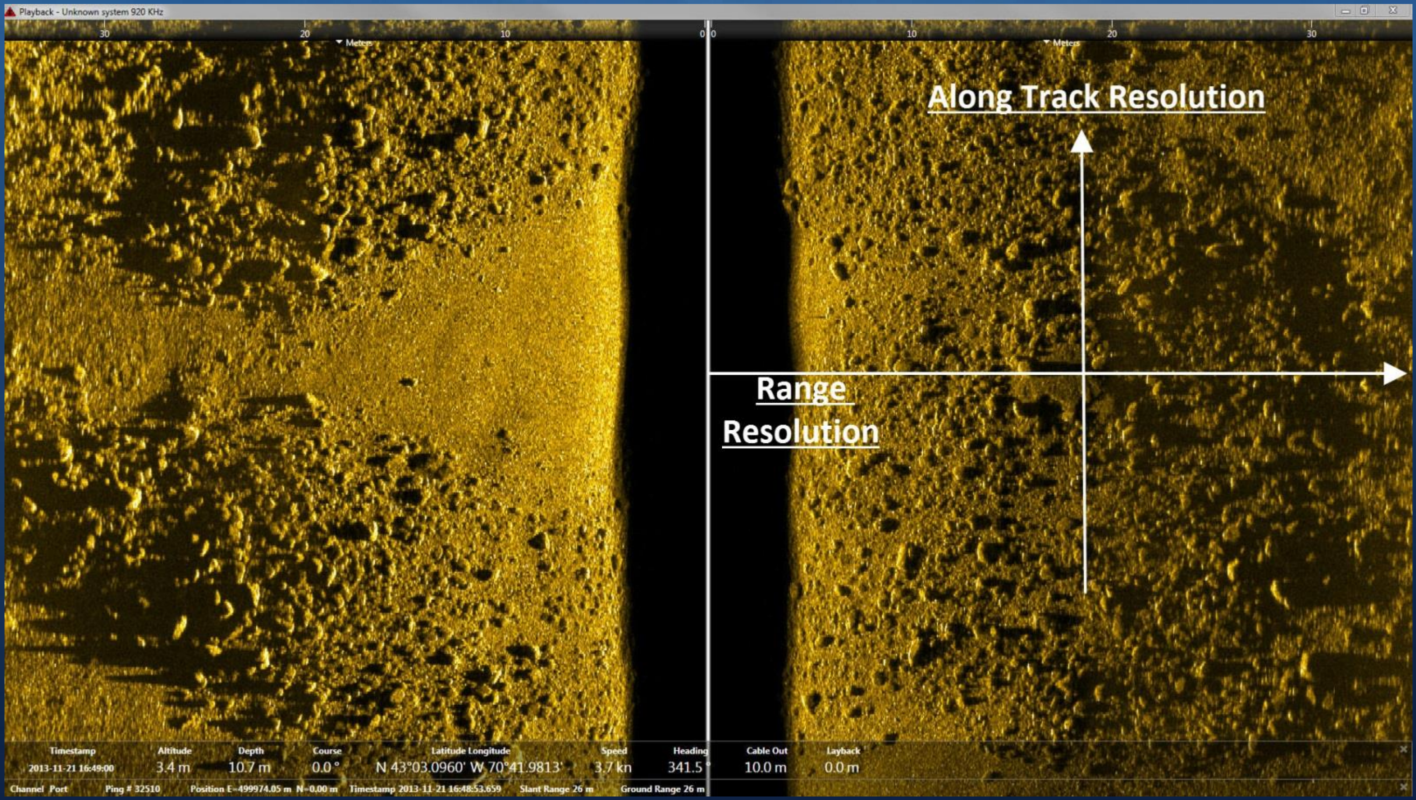
Across Track Resolution

FREQUENCY	ACROSS TRACK RESOLUTION
75 KHz	12cm (4.72”)
120 KHz	8.0cm (3.15”)
230 KHz	3.0cm (1.18”)
410KHz	2.3cm (0.91”)
580KHz	1.5cm (0.59”)
900 KHz	1.0cm (0.59”)
1600KHz	0.6cm (0.24”)

II. SSS Principles

Target Detection and Resolution

Side Scan Sonar target ***detection*** is the capacity to determine *the presence or absence of targets* whereas the ***resolution*** is the capacity to *resolve two closely separated targets*.



II. SSS Principles

Target Detection Factors

NOAA, the US Government charting and obstruction survey agency, has determined for obstruction surveys from real world trials and experience that side scan sonar requires a minimum of 3 pings on a target to ensure 100% detection of a target.

The number of esonifications a target receives is dependent on:

1. The Length of the array & the horizontal beam angle (determines seafloor along-track esonification foot print)
2. The sonar ping rate (sonar range scale)
3. The tow speed the target is passed by...

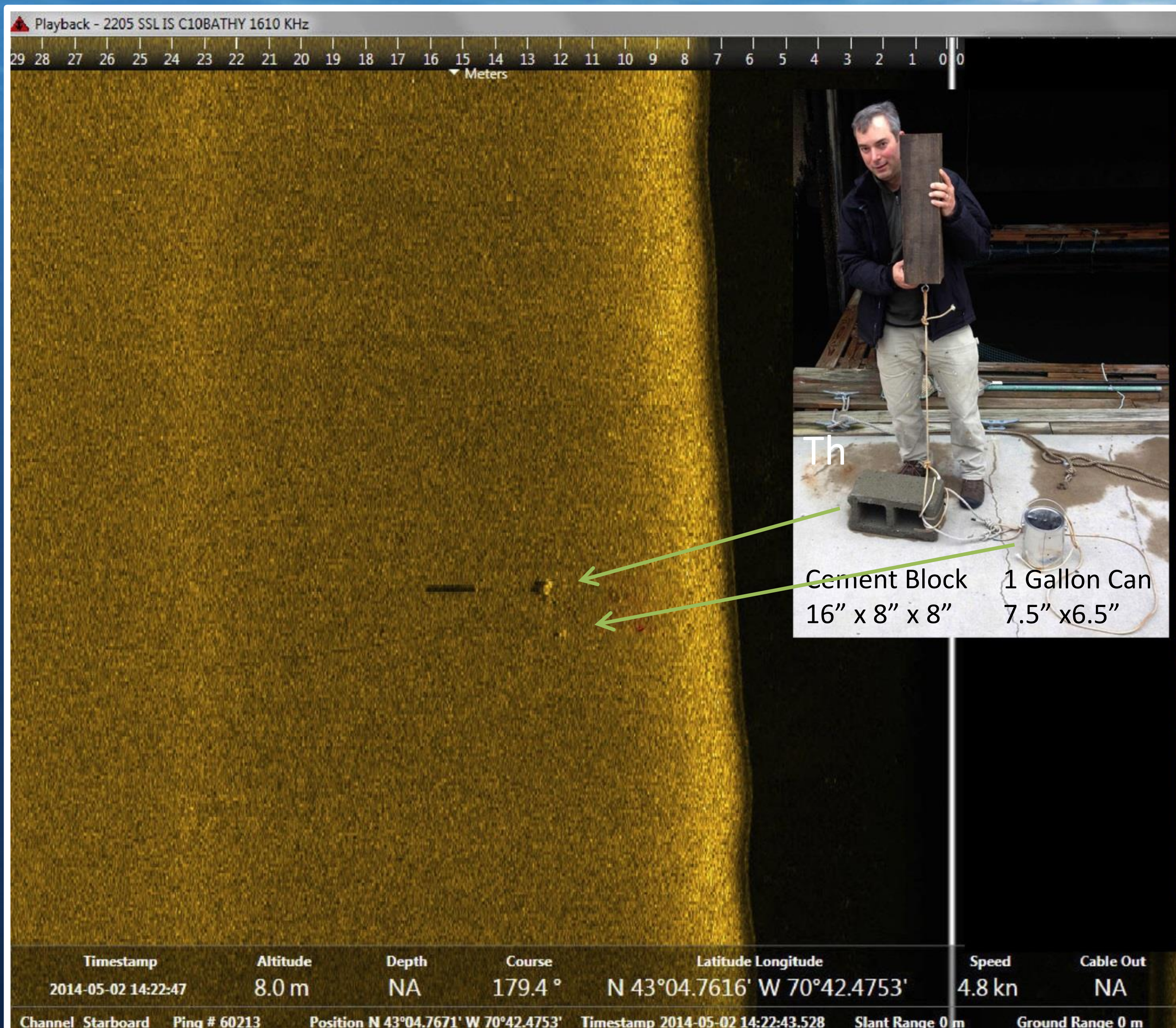
Pings on Target per Meter = Ping Rate (Pings/Second:Set by Range Scale) / Tow Speed (M/second)

II. SSS Principles

Target Detection

Minimum Along-Track Target Dimension to Meet NOAA 3 Ping Specification vs. Towspeed				
Tow Speed in Knots	100 m Range	150 m Range	200 m Range	300 m Range
	7.5 ping/sec	5 ping/sec	3.75 ping/sec	2.5 ping/sec
1	.24m	.36m	.48m	.72m
1.5	.36 m	.54m	.72m	1.08m
2	.48m	.72m	.96m	1.44m
2.5	.6m	.9m	1.2m	1.8m
3	.72m	1.08m	1.42m	2.16m
3.5	.84m	1.26m	1.68m	2.52m
4	.96m	1.44m	1.92m	2.88m
4.5	1.08m	1.62m	2.16m	3.24m
5	1.2m	1.8m	2.4m	3.6m

II. SSS Principles



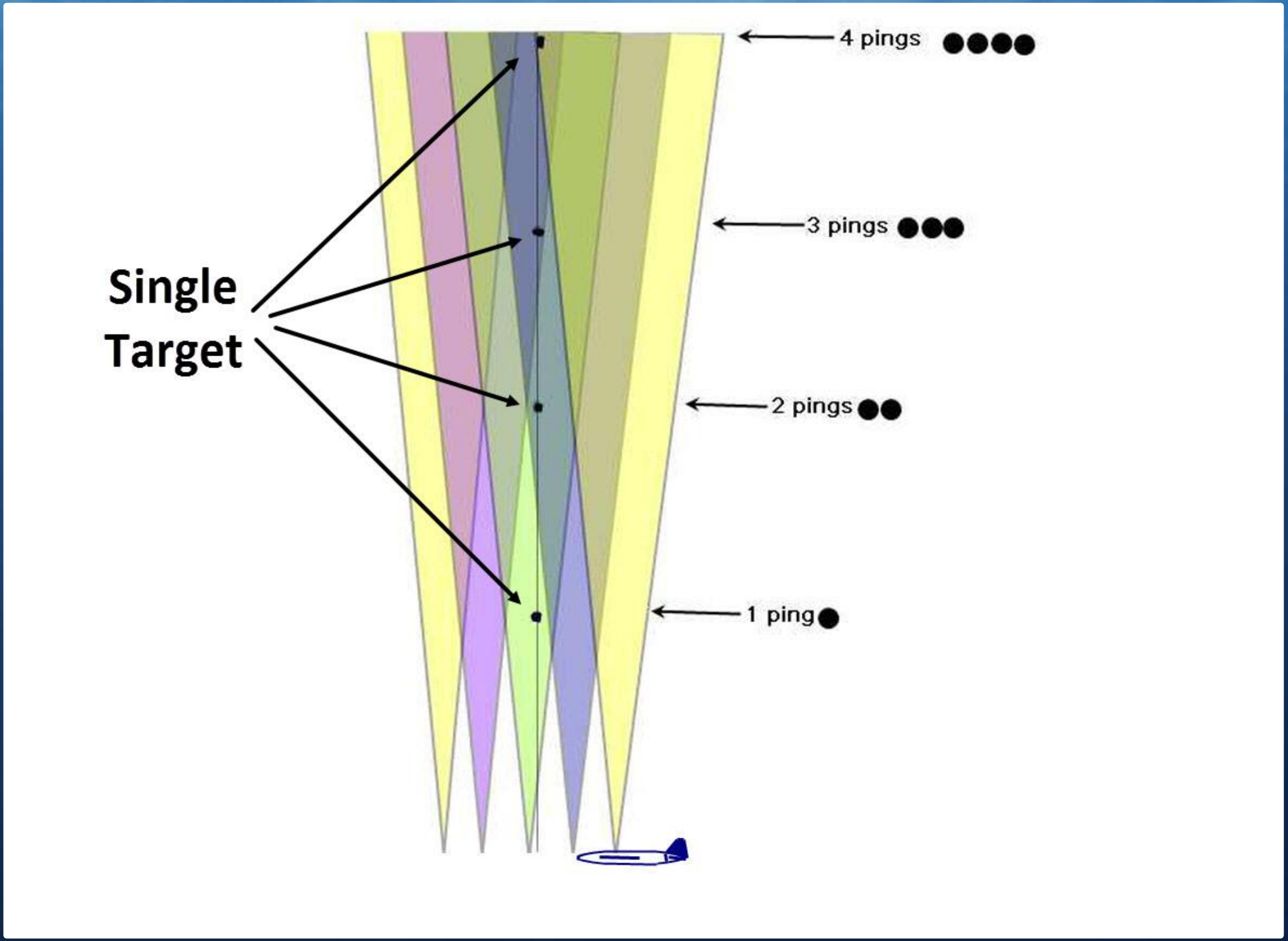
Target Detection

The small target sonar data was made at 4.8 knots on a 30 meter range scale. This gives perspective on detectability of very small targets.

II. SSS Principles

Target Detection

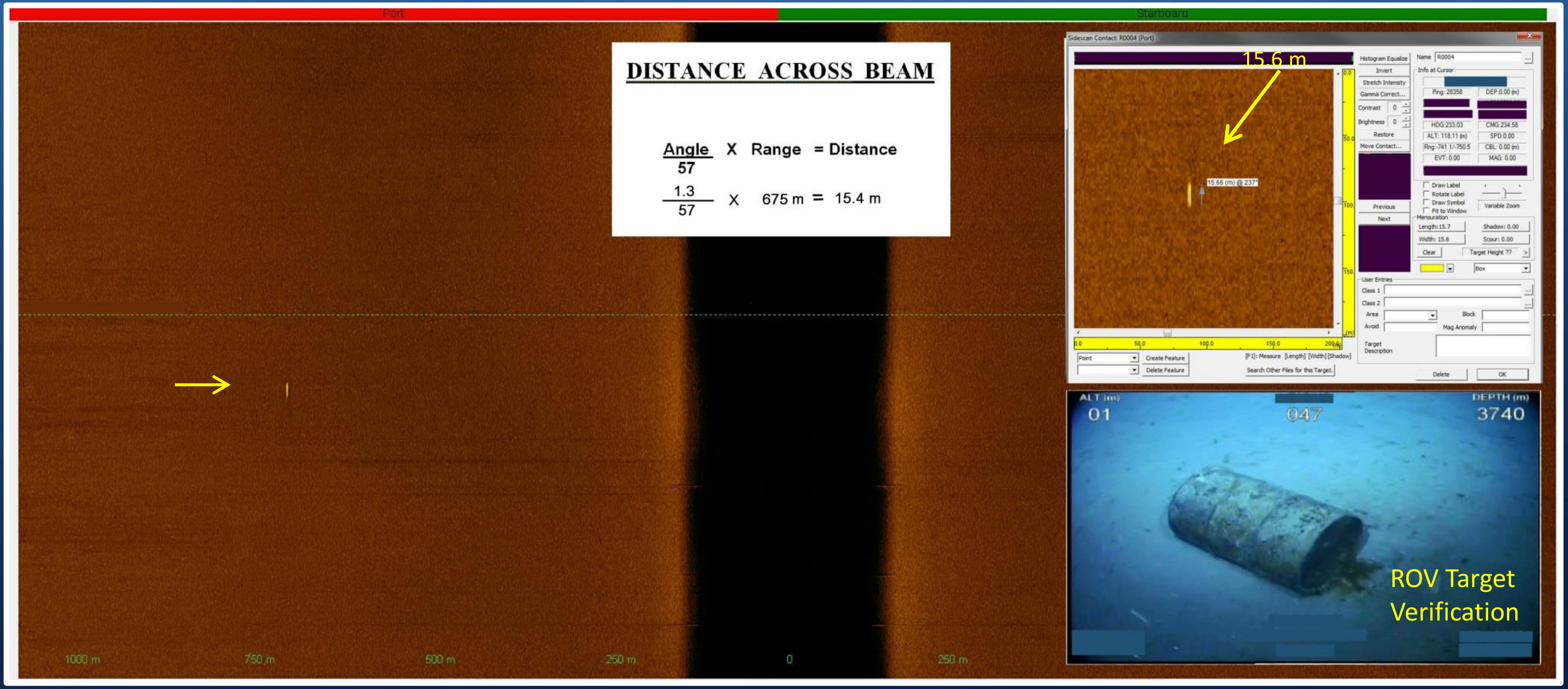
A wider horizontal beam, though it has lower along track resolution at the outer ranges, enhances target detection by the fact that more pings will hit the target



II. SSS Principles

Target Detection

A target detected at a 675 m range measures 15.6 m in length. A ROV visual was performed to classify the target, it was a 1 meter long Drum. The math for a horizontal beam angle 0f 1.3 degrees @ 675 m range agrees with what size the target should appear on the sonar display.

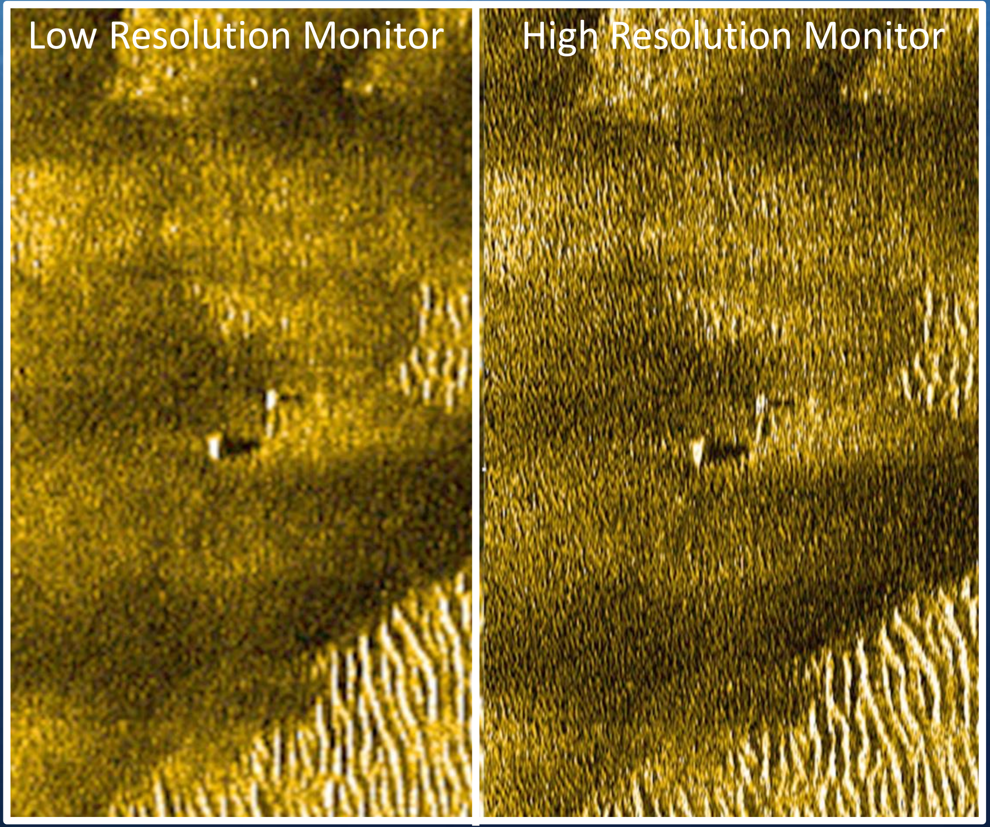


II. SSS Principles

Target Detection & Sonar Display Resolution

An often overlooked factor in viewing sonar data for the highest image resolution as well as probability of detecting small targets is the ***display resolution***.

Example:
-SSS is run on a 100 meter range @ 600 kHz with a Sonar Range Resolution of 1.5 cm
-The SSS data is displayed on a monitor of 1280 x 1024 resolution
-1 channel of SSS data @ 100 meters is mapped into the 640 pixels
-The scale of 1 display pixel is 10000 cm/640=15.6 cm
-Therefore the full SSS resolution of 1.5 cm will not be displayed with a display resolution of 15.6 cm/pixel



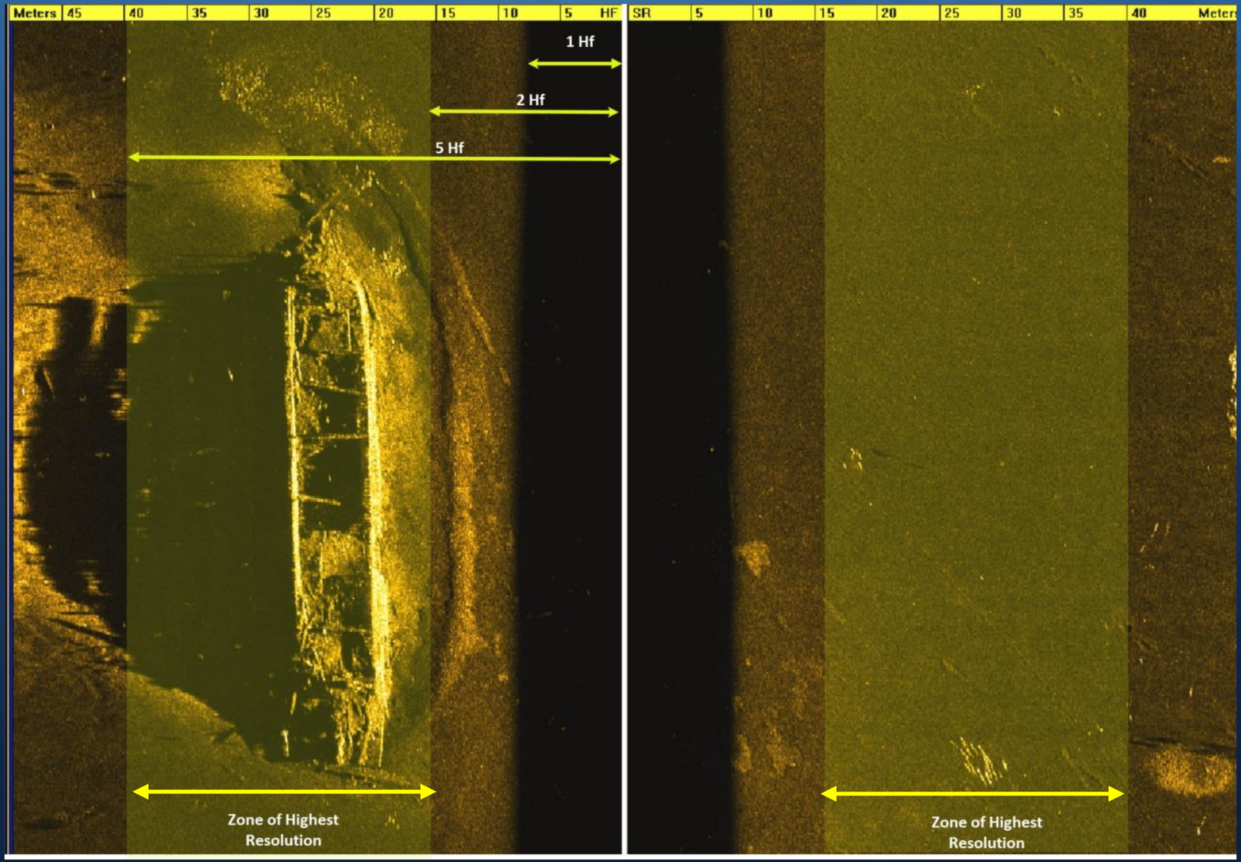
To maximize SSS resolution when viewing data, a large monitor (ie 30 "+) and a minimum of 4k display resolution should be used.

II. SSS Principles

Kozak's Law LOL

On a SSS record there is a zone which balances along track resolution with range resolution that will result in the highest resolution image of a target or feature. This zone is a function of towfish altitude (Hf) and is bounded in range defined by 2Hf to 5Hf in range. Acoustic shadowing of targets are also enhanced in this zone.

The following Image illustrates where this optimum imaging area on SSS data is located.



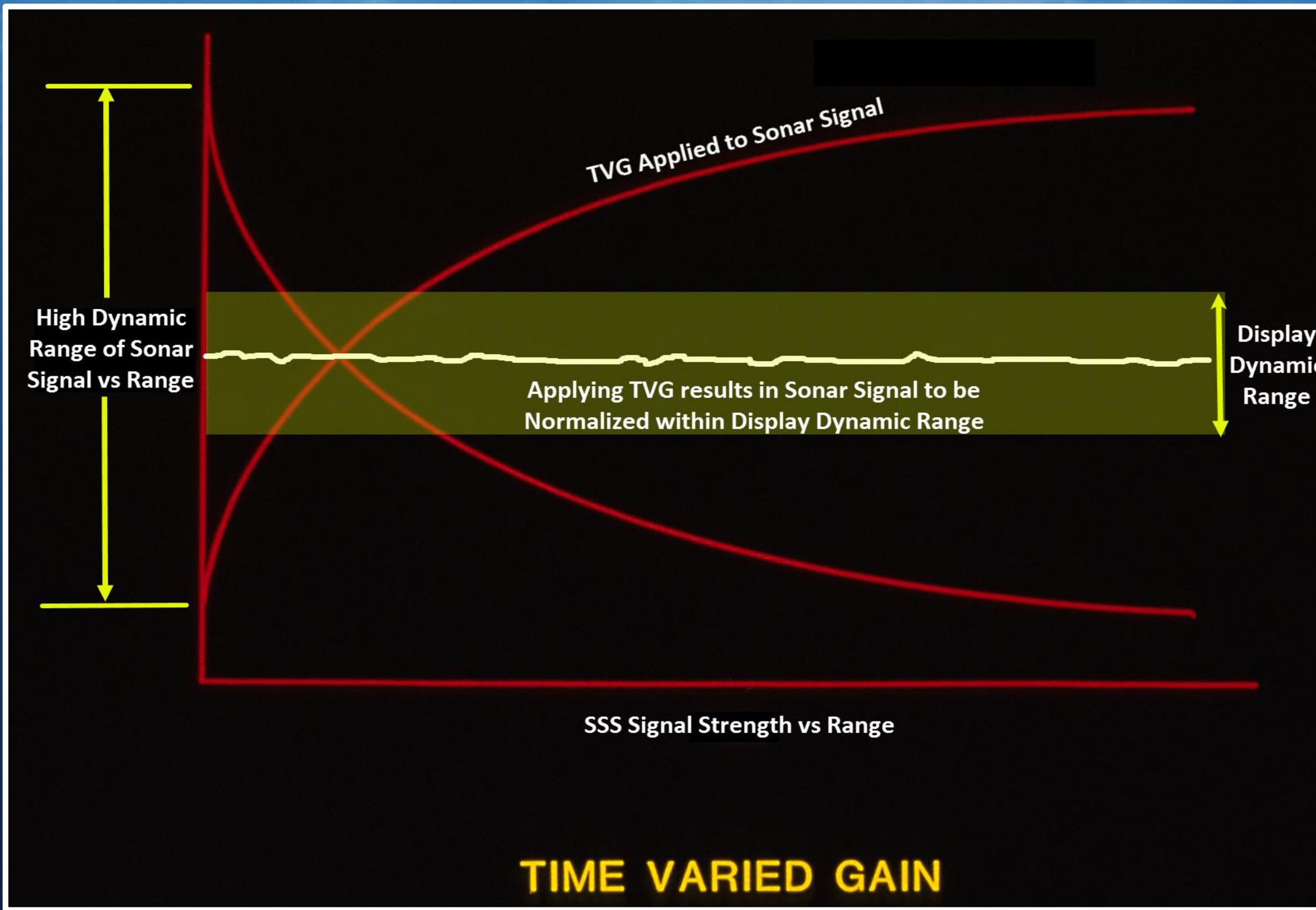
II. SSS Principles

Frequency & Resolution

II. SSS Principles

Time Variable Gain (TVG)

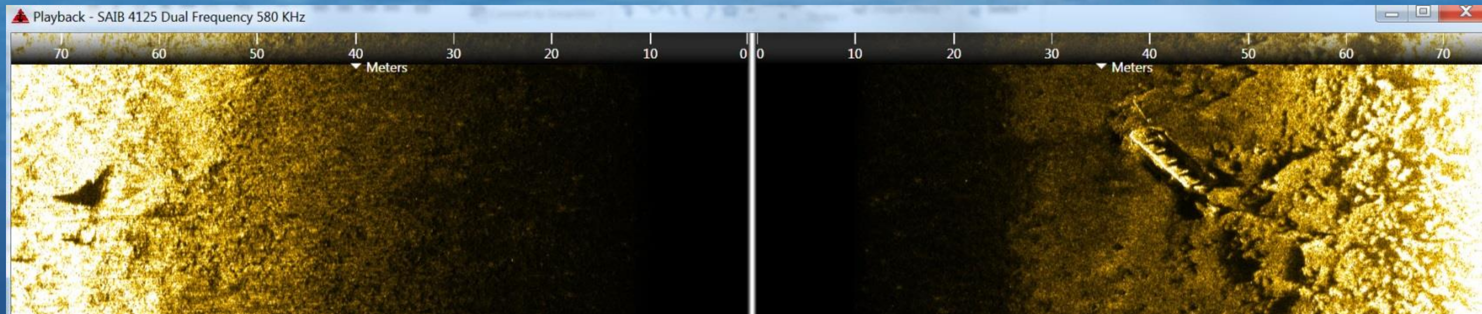
The Magic Sauce to High Fidelity SSS Images



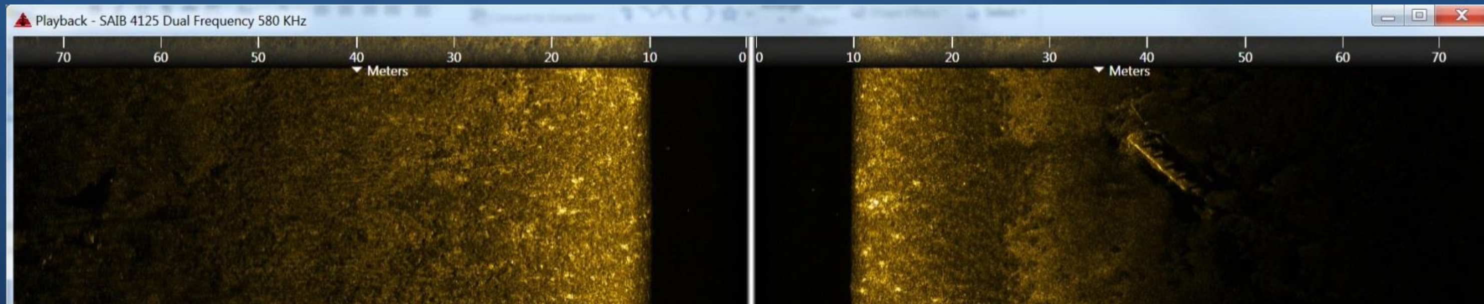
II. SSS Principles

Time Variable Gain (TVG)
The Magic to High Fidelity SSS Images

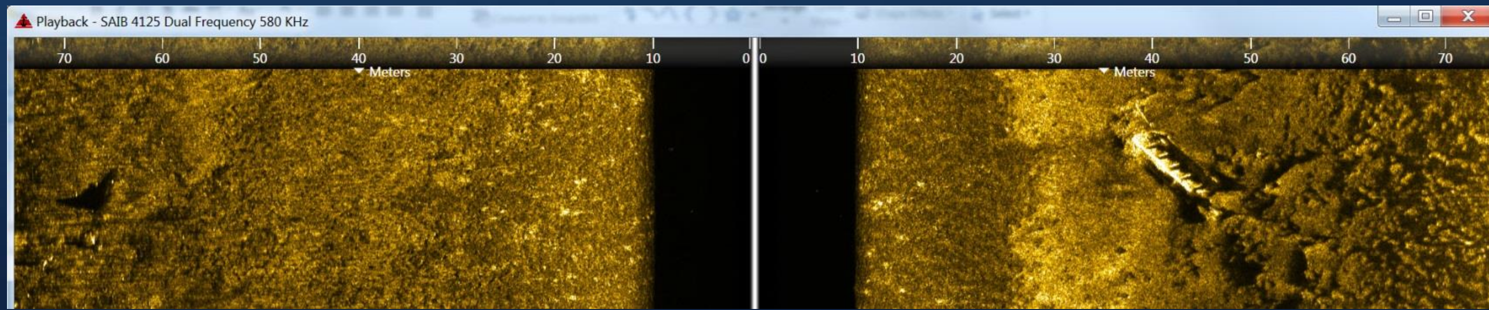
Poor TVG
Near Gain



Poor TVG
Far Gain

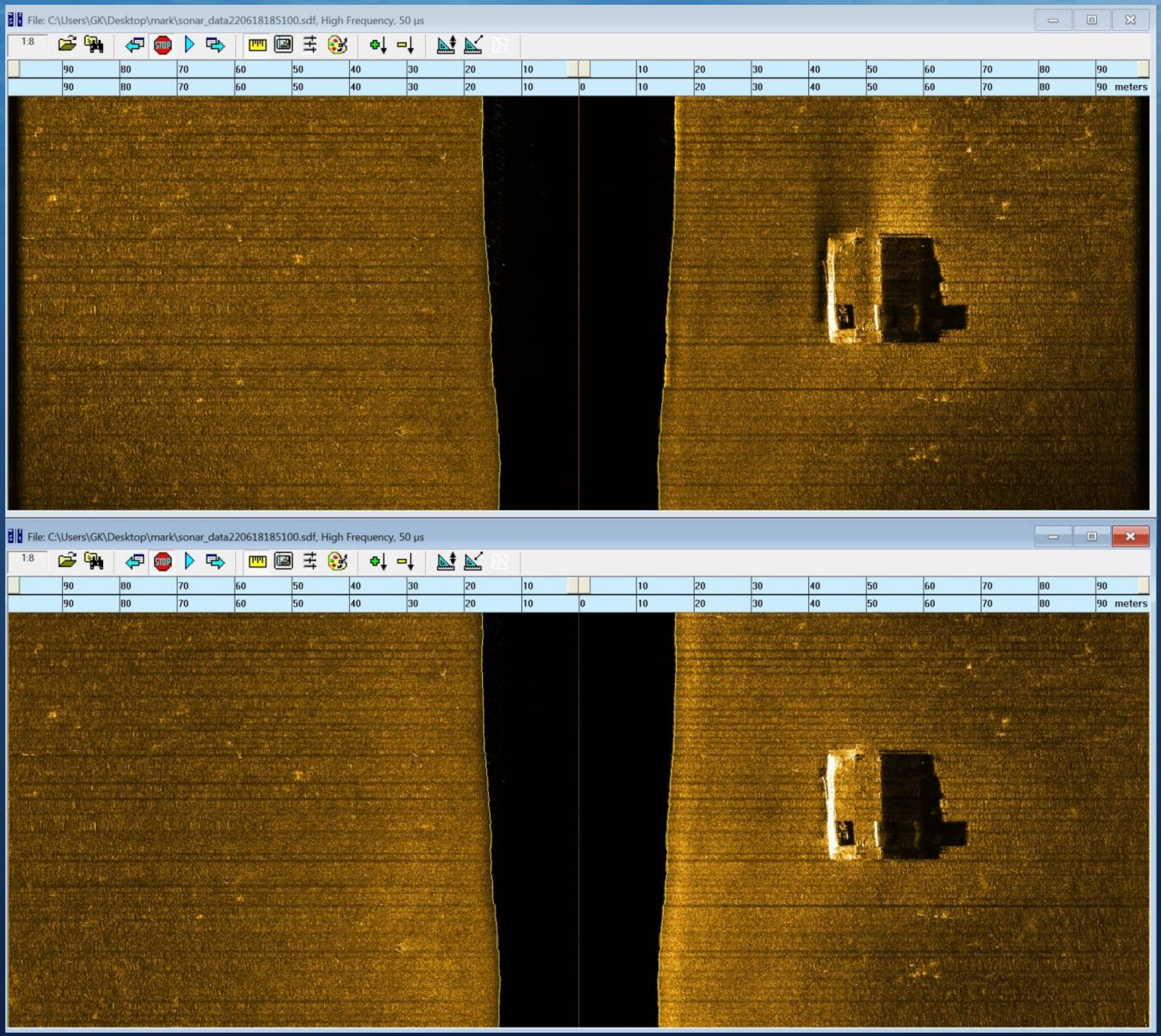


Good TVG
Gain &
Properly
Normalized
Data



II. SSS Principles

Auto TVG Artifacts vs Manual TVG

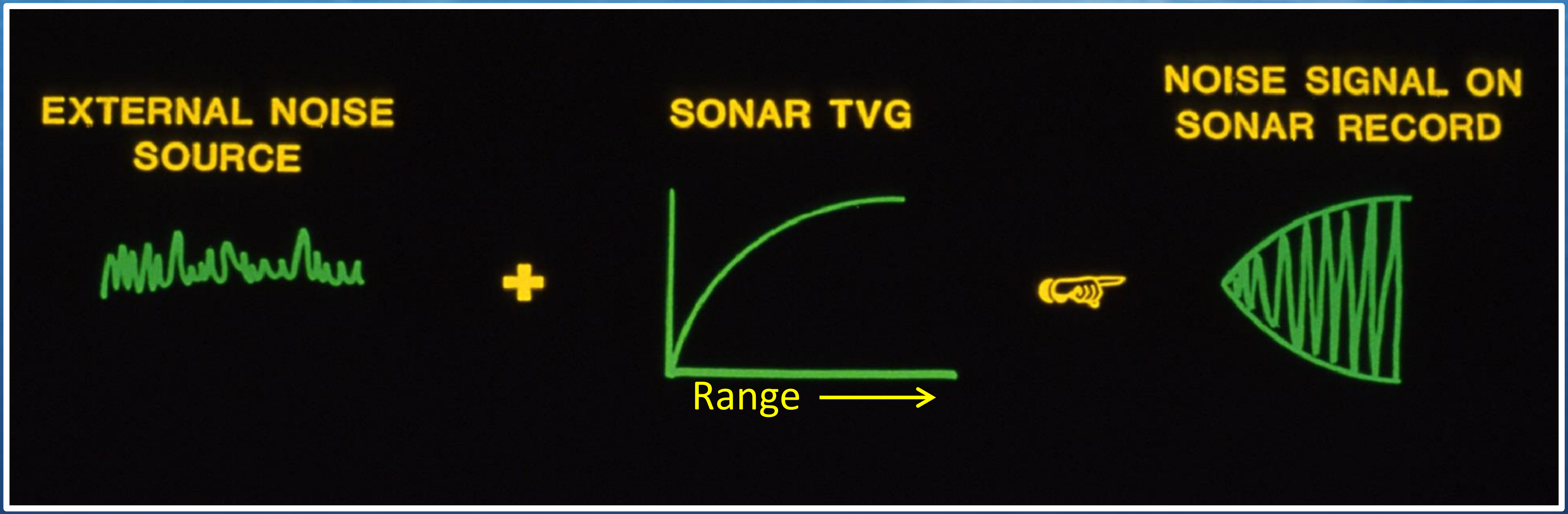


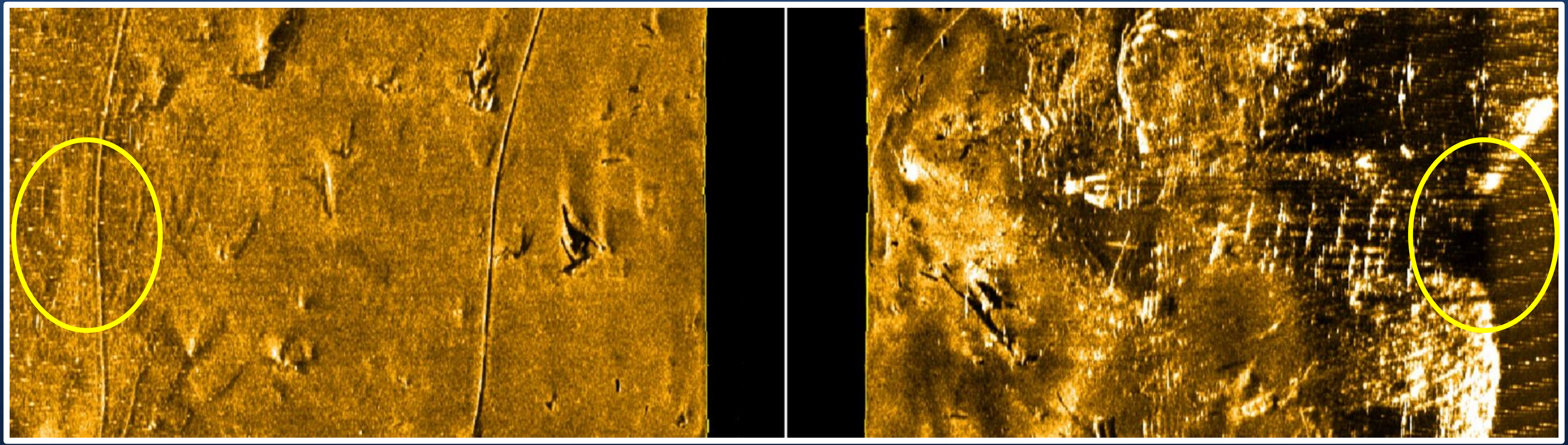
Auto TVG

Manual TVG

II. SSS Principles

Time Variable Gain (TVG) & Noise





II. SSS Principles

SSS Scale Distortion

Conventional SSS data displays have always had scale distortions when a target or feature is displayed on the screen (in the old days on paper).

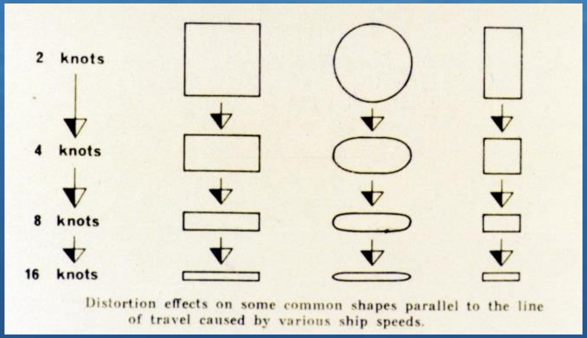
The along track direction has a scale distortion that results from a combination of sonar ping rate, tow speed and the sonar display resolution.

The across track direction suffers from a non-linear data compression of features in the nadir zone.

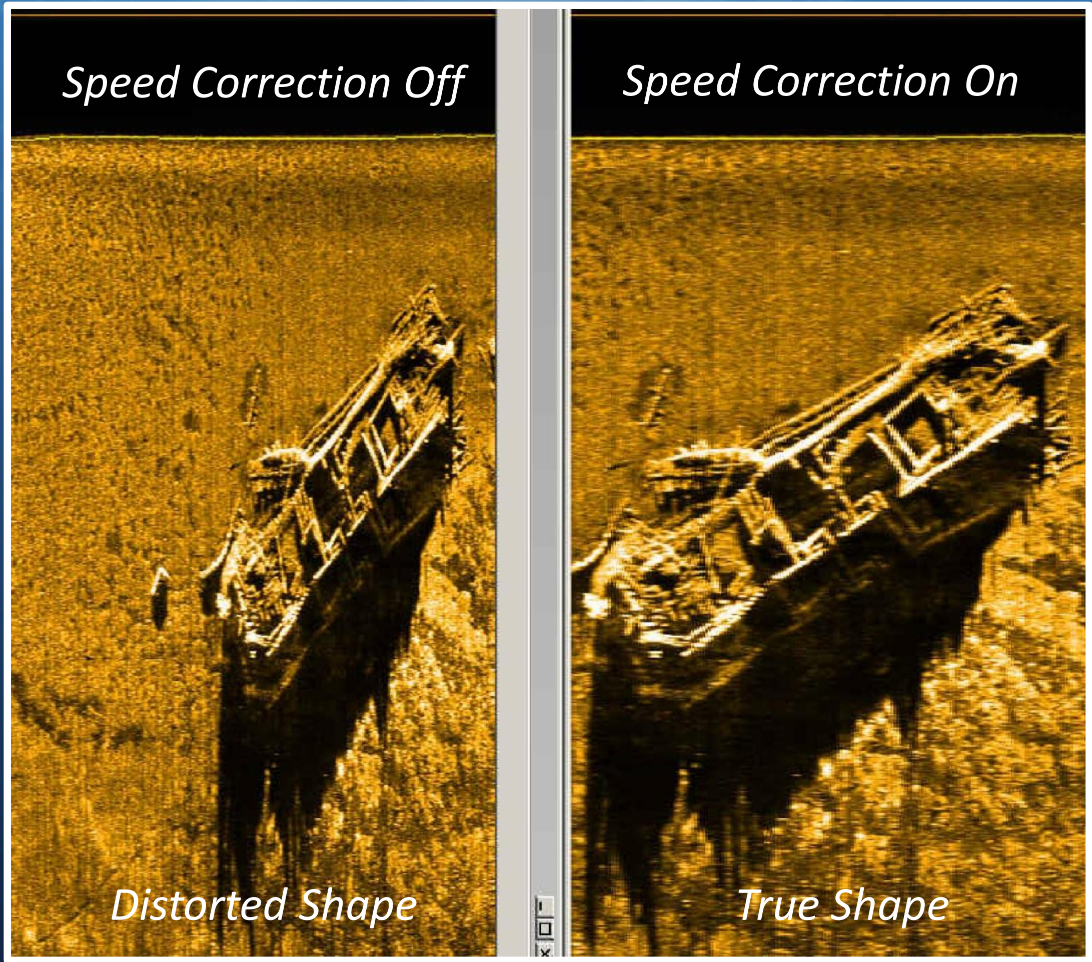
Modern SSS systems today can correct for these 2 scale distortions by using both the tow speed, sonar ping rate, display resolution and towfish altitude to show a 1:1 scale corrected feature. Simply put the features are displayed in true shape with no distortion.

II. SSS Principles

Speed Correction



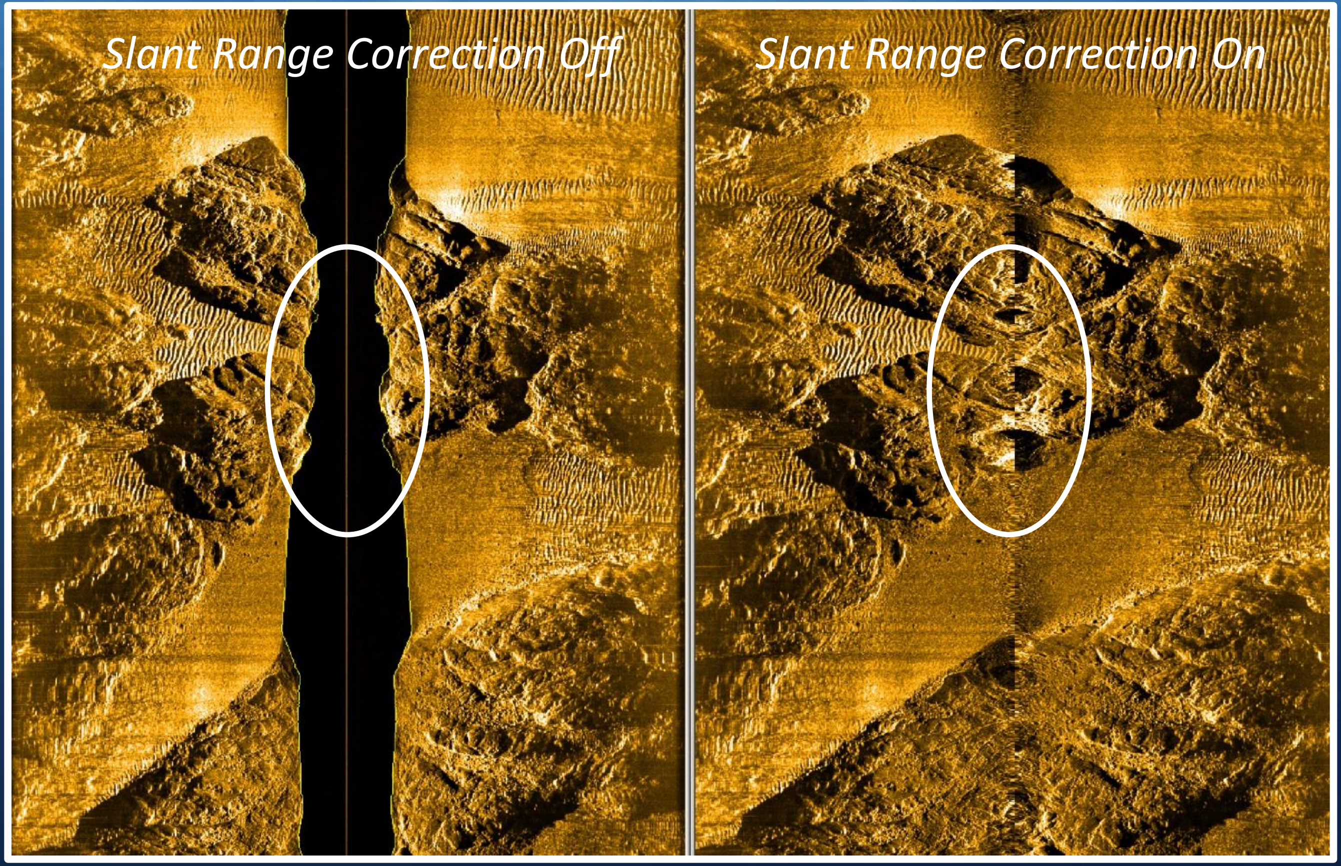
On a set range scale (ping rate) as a pass is made by a target at faster speeds, the target is pinged less, resulting in it being compressed in the along track direction. When speed correction is active it will correct the along track scale to remove this distortion.



II. SSS Principles

Slant Range Correction

The Nadir zone beneath the towfish has a non-linear scale compression of features in the across track direction. Computer algorithms, if given towfish altitude, can remap the data in this zone to remove the scale compression, thus maintaining a linear scale. This is called Slant Range Correction



II. SSS Principles

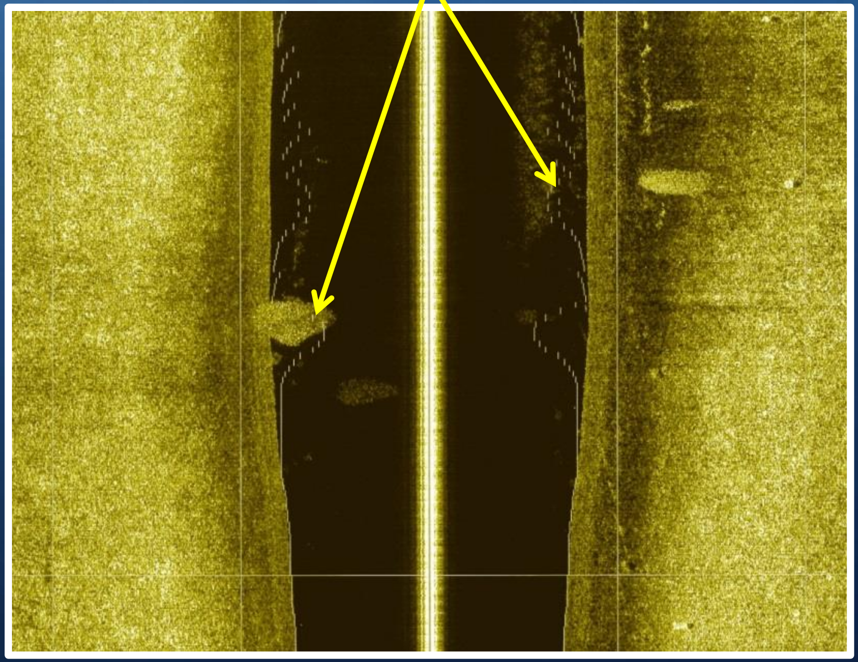
Altitude Tracking

All modern SSS systems today have Altitude Tracking. Altitude information is used for :

1. *Slant Range Correction*
2. *Target Height Measurement*
3. *Towfish Height Above Seafloor Alarm*
4. *Auto TVG.*

However, accurate tracking can be temperamental in shallow water and on certain bottom types. Never trust altitude display when surveying as the indicator of height of towfish above the seafloor since they can be fooled by mid-water anomalies or noise. Always use by eye water column and first bottom return for true towfish altitude.

Altitude Tracker confused by mid-water anomalies



II. SSS Principles

Other Side Scan Sonar Types

- Focused SSS: *Purpose – To improve along-track resolution*
  Mechanical Focus
  Electronic Focus

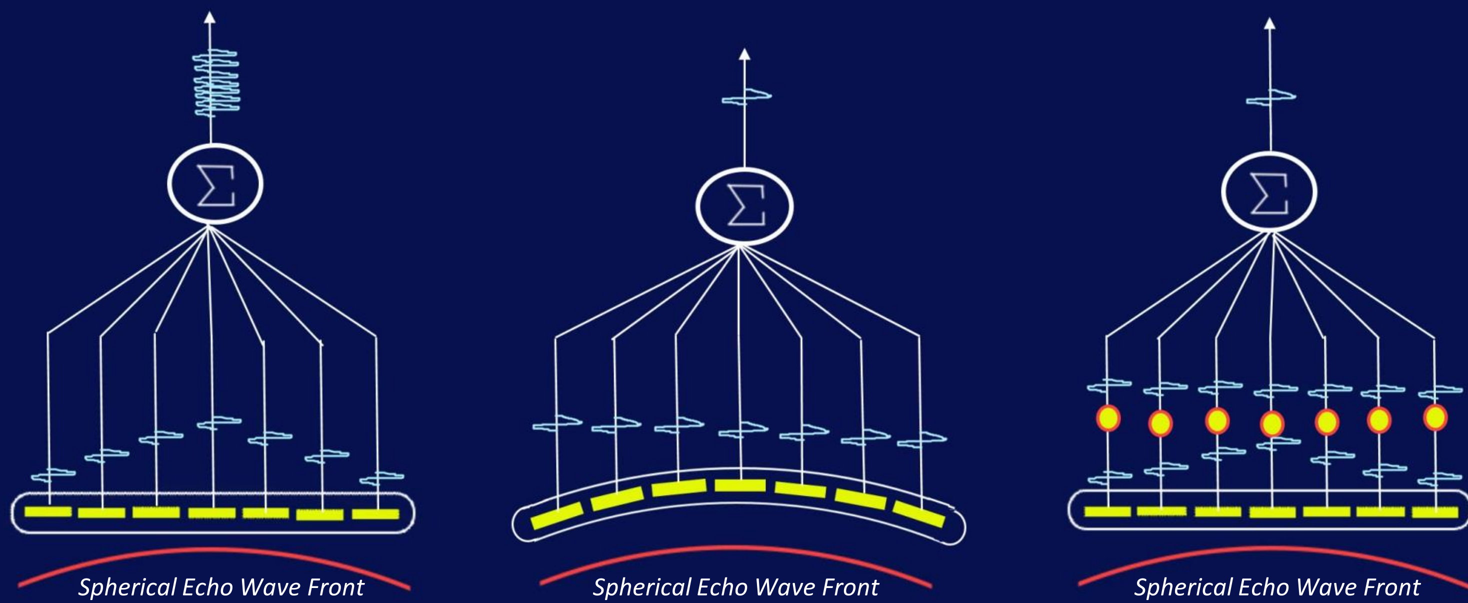
- High Speed SSS: *Purpose – To maintain along-track resolution at higher tow speeds*

- Synthetic Aperture SSS: *Purpose – To improve along-track resolution*

II. SSS Principles

Other Side Scan Sonar Types

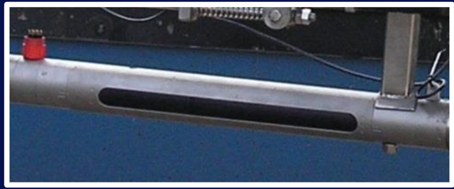
Focused Side Scan Sonar



Standard Line Array Not Focused

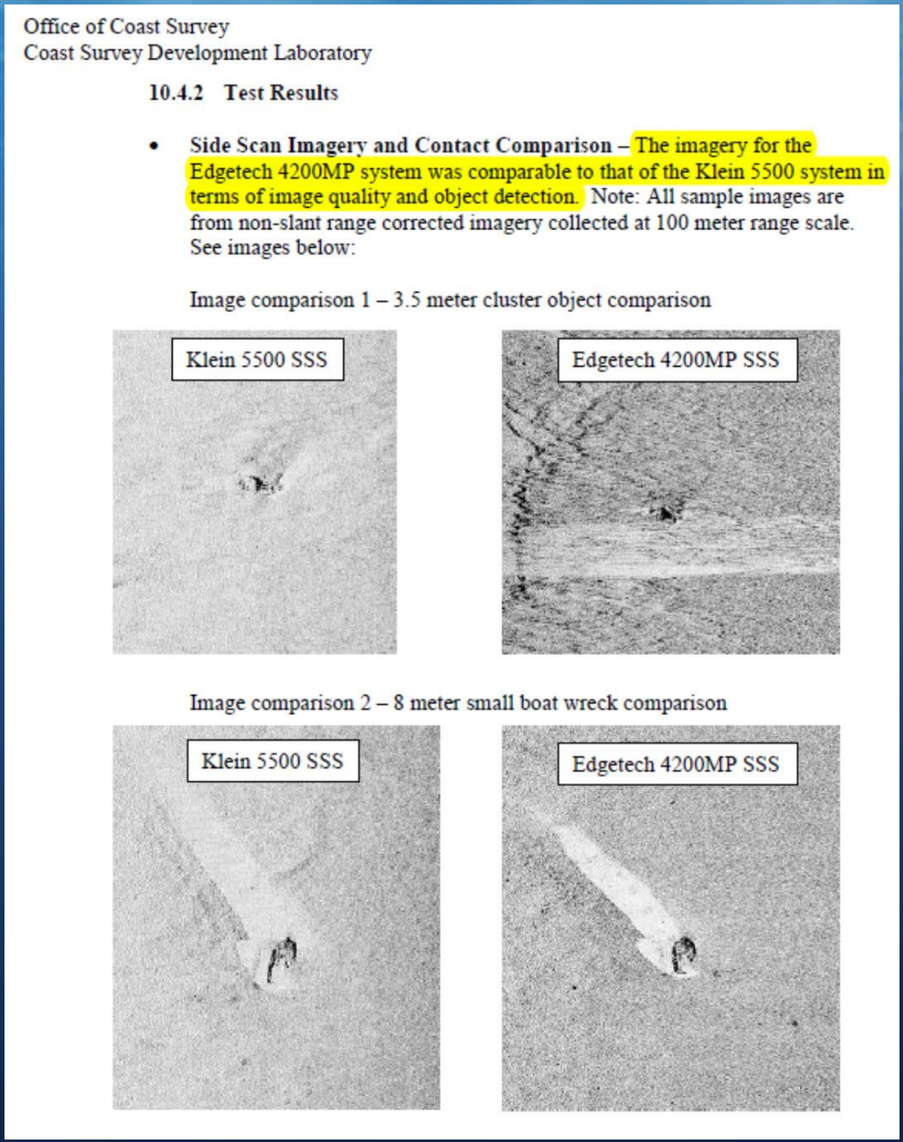
Mechanical Focused Array

Electronically Focused Array



II. SSS Principles

Other Side Scan Sonar Types


Office of Coast Survey
Coast Survey Development Laboratory

10.4.2 Test Results

- **Side Scan Imagery and Contact Comparison** – The imagery for the Edgetech 4200MP system was comparable to that of the Klein 5500 system in terms of image quality and object detection. Note: All sample images are from non-slant range corrected imagery collected at 100 meter range scale. See images below:

Image comparison 1 – 3.5 meter cluster object comparison

Klein 5500 SSS

Edgetech 4200MP SSS

Image comparison 2 – 8 meter small boat wreck comparison

Klein 5500 SSS

Edgetech 4200MP SSS

High Speed Side Scan Sonar Techniques

Single Beam SSS Systems have a reduction in along track resolution at higher tow speeds, caused by fewer pings on a target. To solve this, two techniques are used to counter this at high tow speeds, e.g. 10 knots. They are 1) Multi-Beam and 2) Multi-Ping techniques. NOAA has tested both types and concluded that the two techniques, though technically different, produce essentially the same output data product. The advantage of a multi-ping system over multi-beam system is cost, a multi-beam towfish costs on average 3+ times more than a multi-pulse towfish.

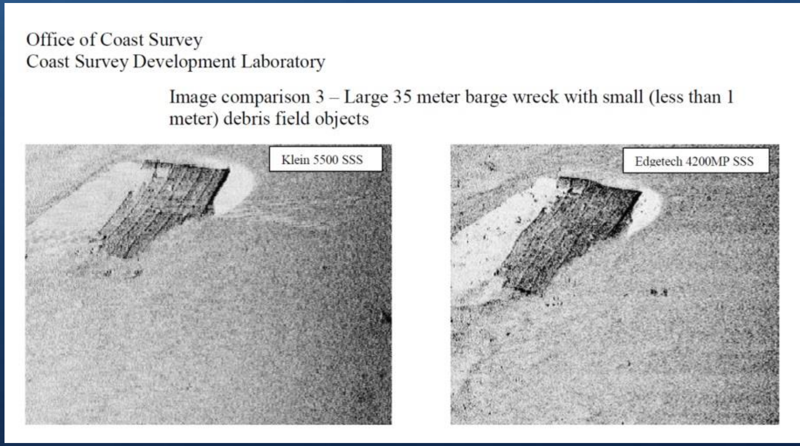

Office of Coast Survey
Coast Survey Development Laboratory

Image comparison 3 – Large 35 meter barge wreck with small (less than 1 meter) debris field objects

Klein 5500 SSS

Edgetech 4200MP SSS

Multi-Beam vs Multi-Ping Data @ 8 knots

II. SSS Principles

Other Side Scan Sonar Types

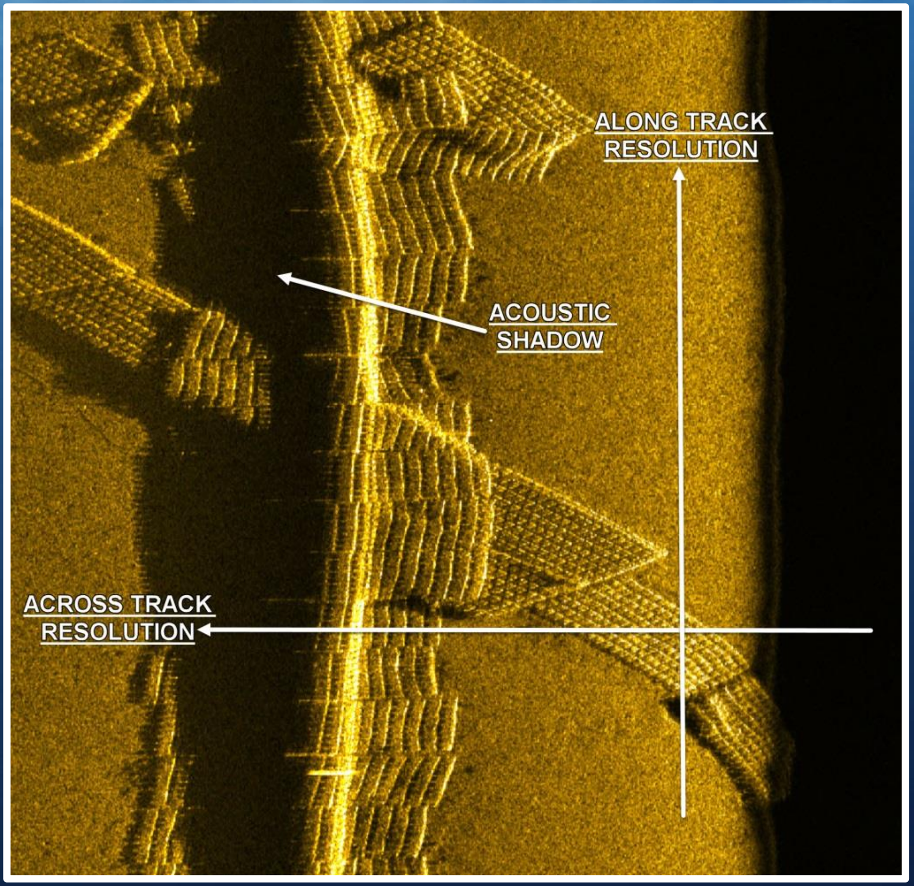
Synthetic Aperture Side Scan Sonar

The Holy Grail Search for Higher Resolution SSS Images

The resolution of a sonar image is comprised of three components:

1. Across- track Resolution
2. Along-track Resolution
3. Acoustic Shadow Clarity

Synthetic Aperture Processing Techniques ONLY Benefits Along-Track Resolution



II. SSS Principles

Other Side Scan Sonar Types

Synthetic Aperture Side Scan Sonar

The Holy Grail Search for Higher Resolution SSS Images

Observed SAS Problems

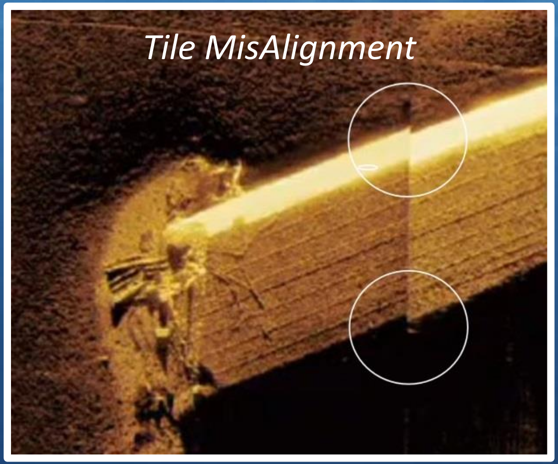
- Data is geo-referenced processed image files(Tiles) and not raw sonar data
- SAS Tile Misalignment
- Tiles vary in gain and gamma correction
- Image smearing
- Poor nadir 1st bottom return compared to RAS (Real Aperature Sonar)
- Acoustic shadow softening
- Data volumes are very large compared to RAS
- Mosaic's are created using geo-referenced image tiles and do not use raw sonar data making large mosaics challenging.

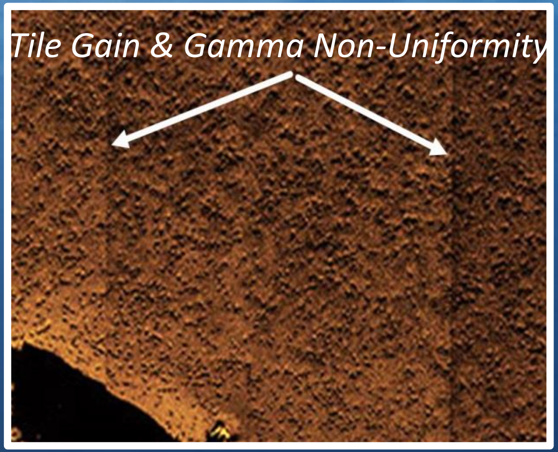
II. SSS Principles

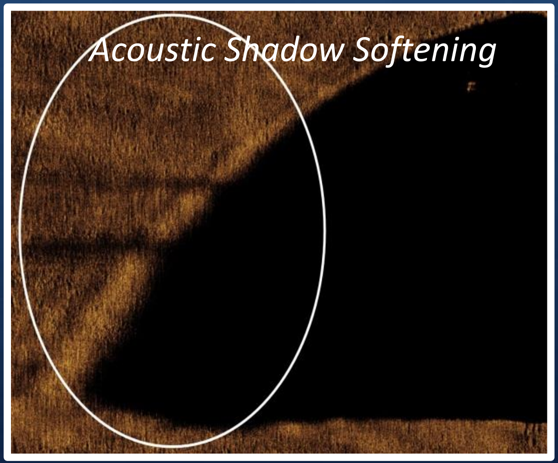
Other Side Scan Sonar Types

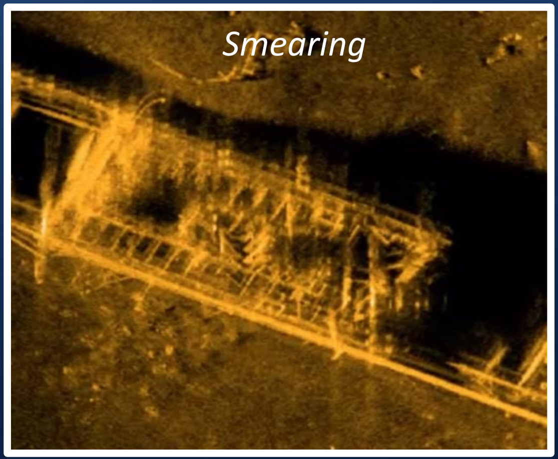
Synthetic Aperture Side Scan Sonar

Observed SAS Problems







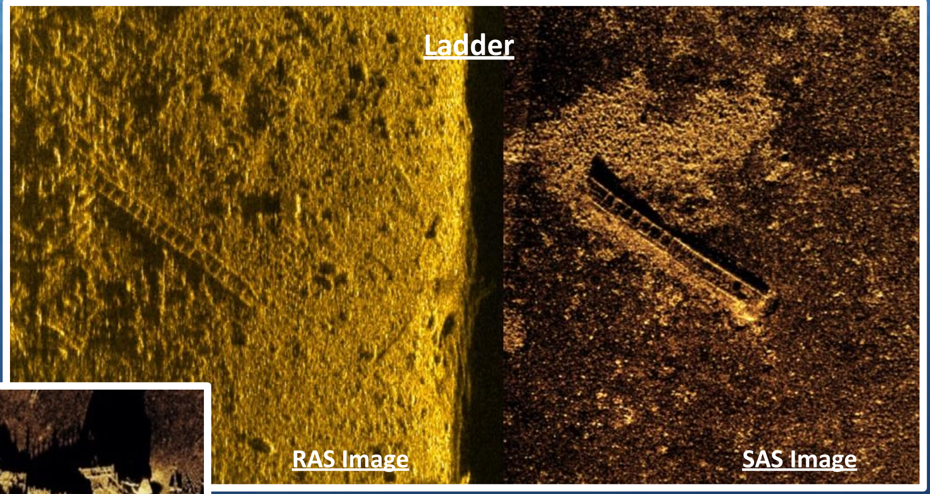


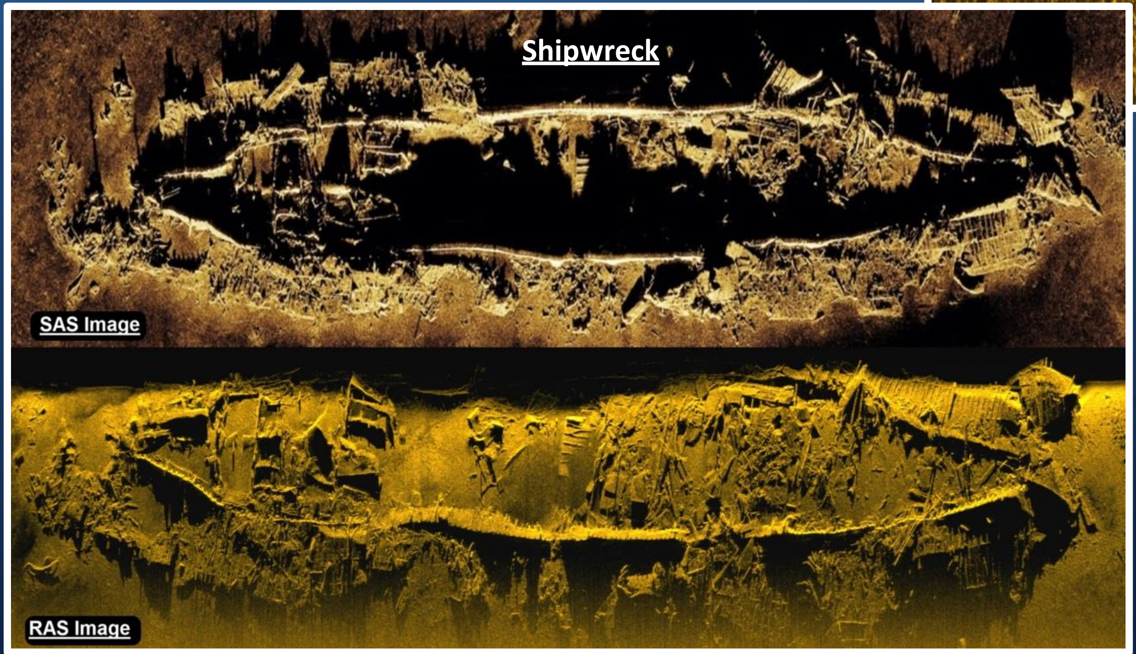
II. SSS Principles

Other Side Scan Sonar Types

Synthetic Aperture Side Scan Sonar

Question: Can a RAS (Real Aperture Sonar) system generate an equivalent resolution target image compared to a SAS system?





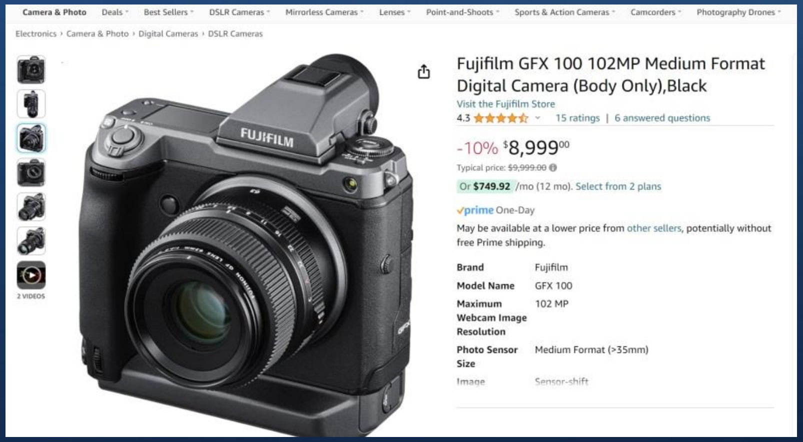
Answer: YES

II. SSS Principles

Other Side Scan Sonar Types

Synthetic Aperture Side Scan Sonar

The debate on the advantage of SAS over RAS systems will continue ,but one must ask the question, does the complexity and high cost of SAS systems being upwards of 10 times of RAS systems, give a proportional increase in data resolution? Simply put, does a SAS system costing 10 times more give a 10 fold increase in image clarity? As in photography, do you need the highest pixel camera available, e.g. 102 MP Fujifilm GFX, to make a good picture, or will a simple iPhone image give the user everything he needs at 1/10th the cost. The iPhone is capable of taking a picture that rivals the expensive high resolution camera. Food for thought 🙂

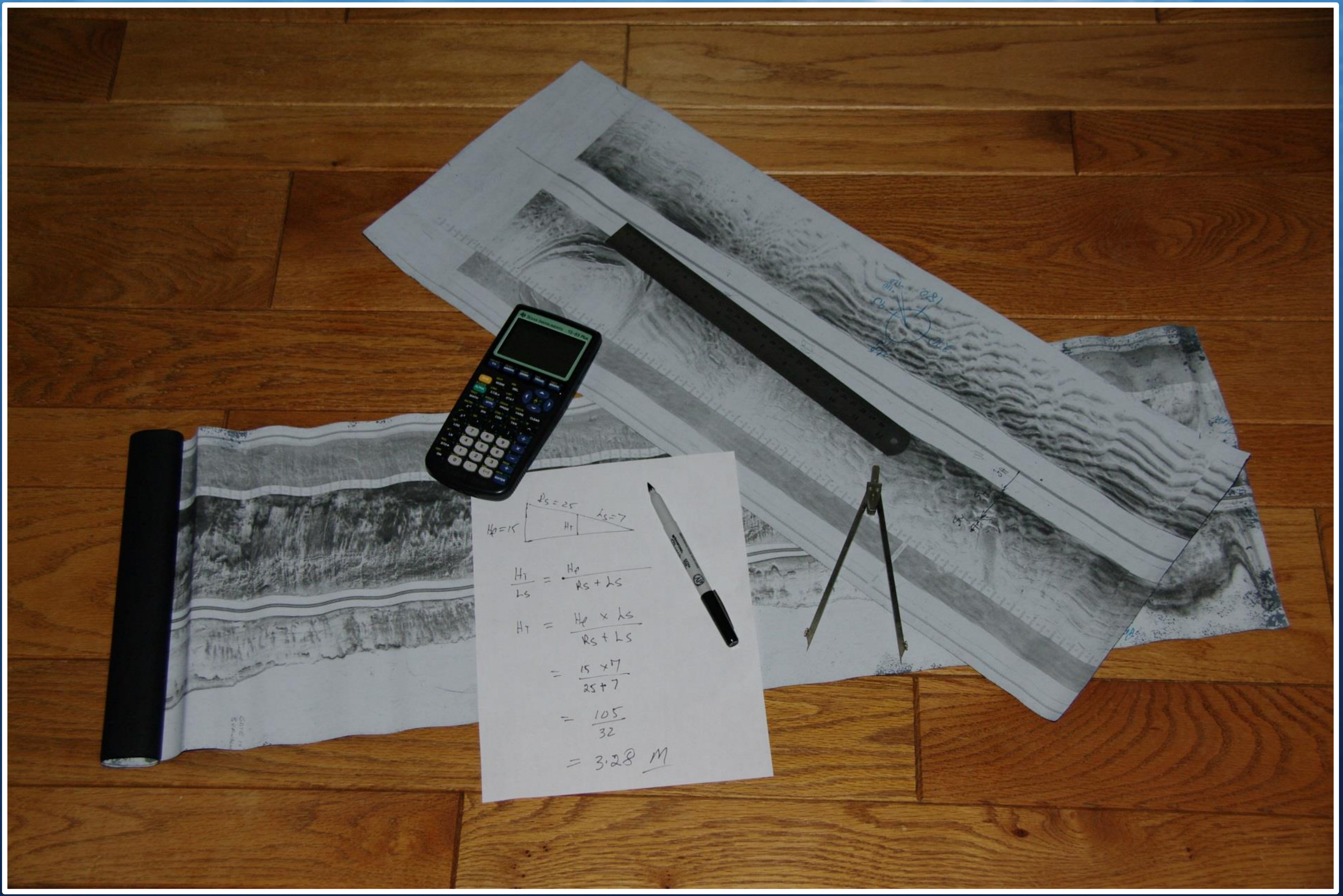


This @ $9000

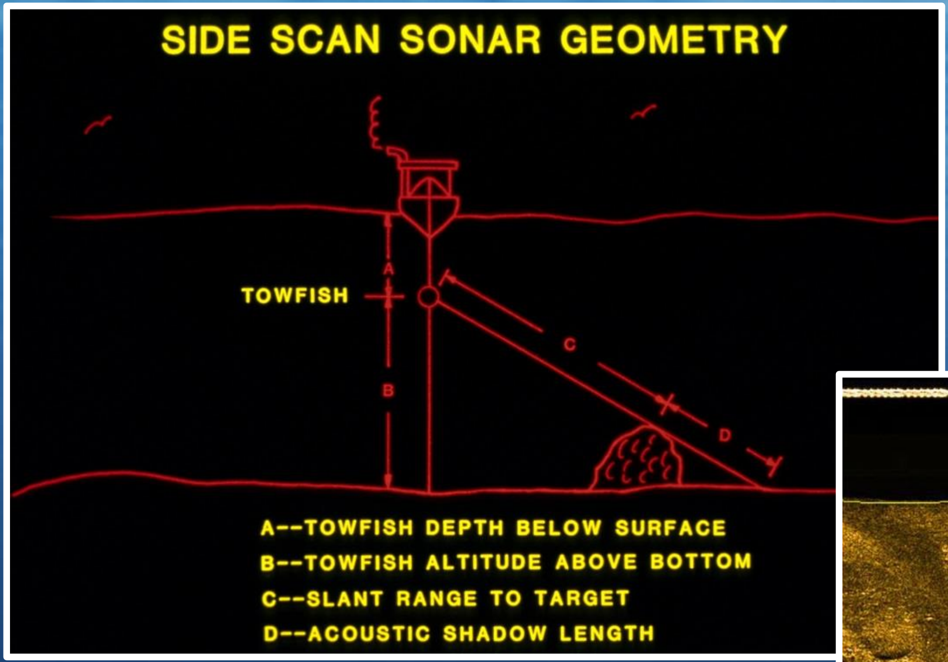
OR

This @ $900

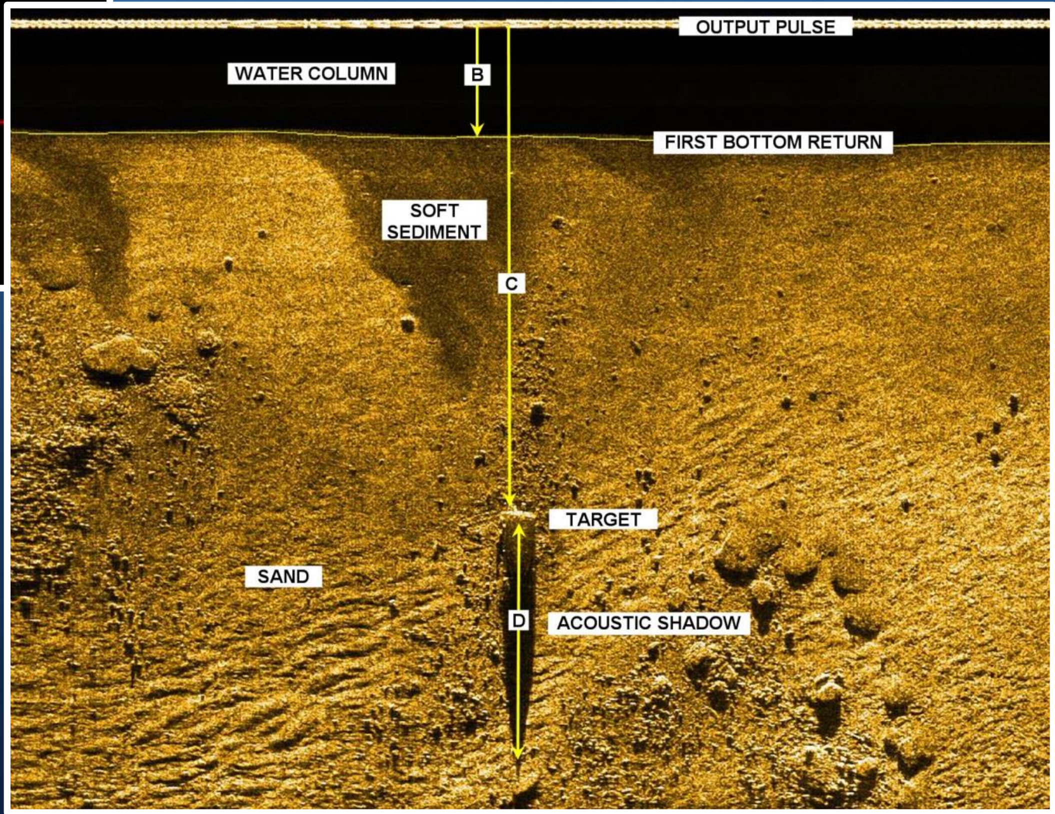
III. SSS Data Interpretation



III. SSS Data Interpretation

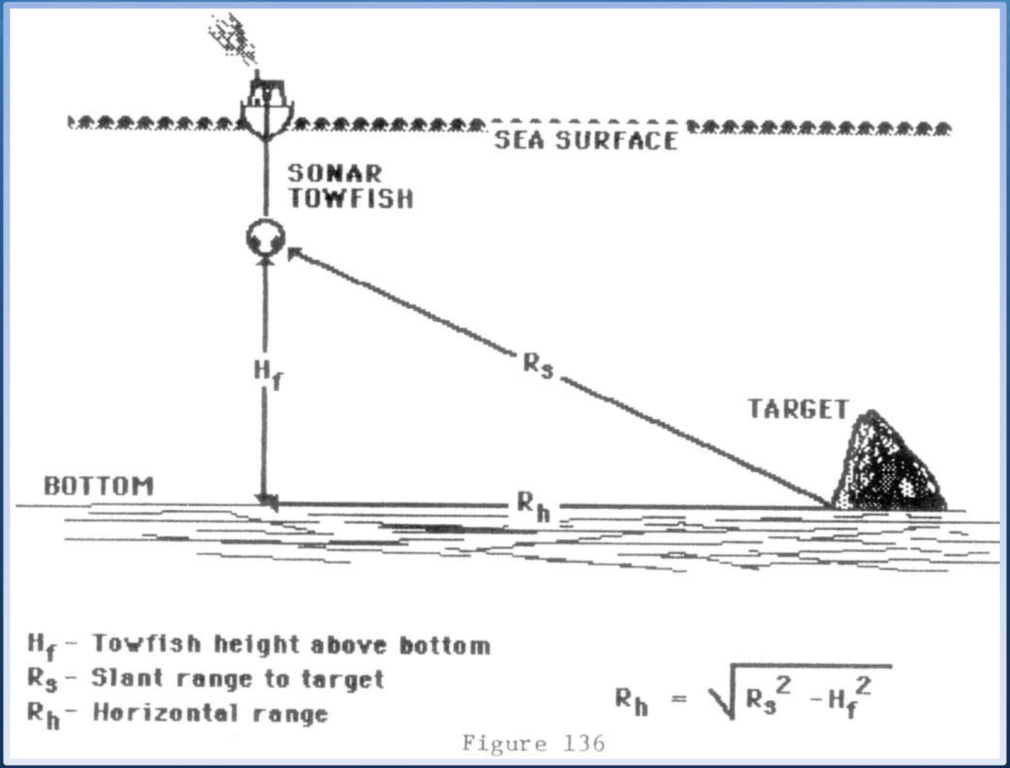


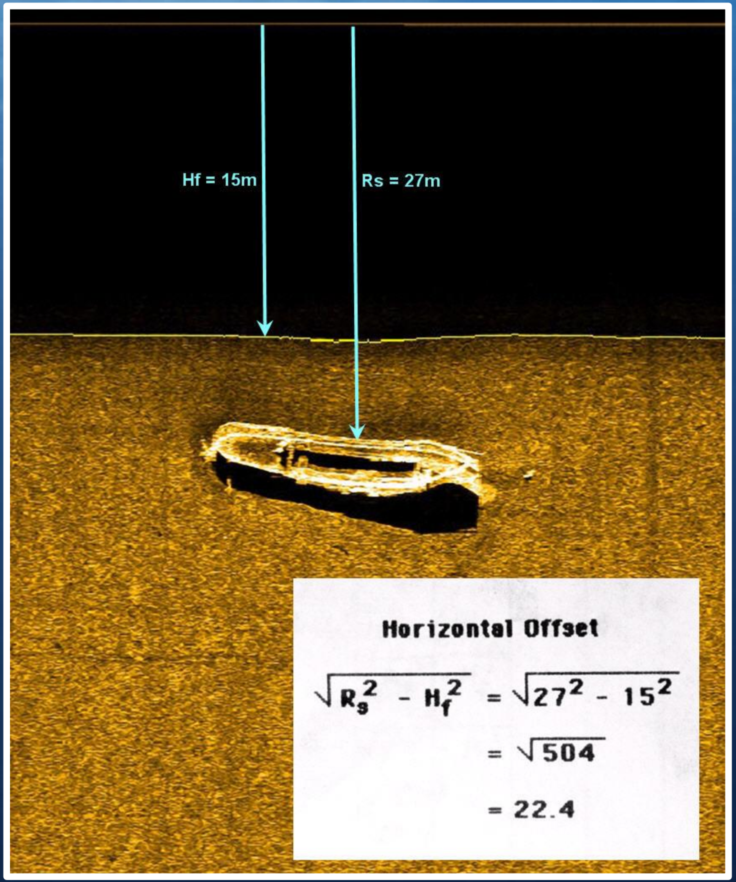
SSS Image Geometry



III. SSS Data Interpretation

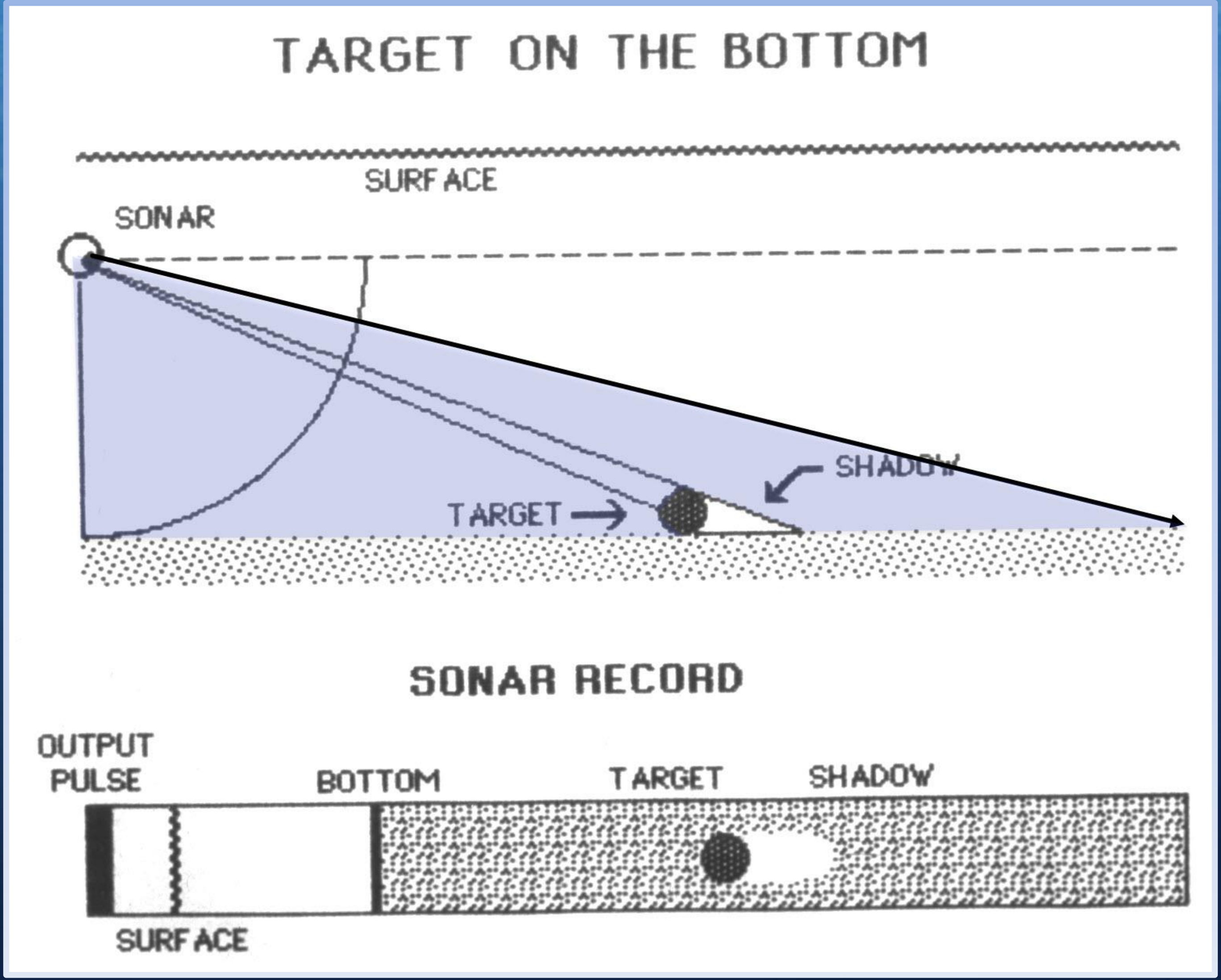
Slant vs Horizontal Range





III. SSS Data Interpretation

Acoustic Shadows

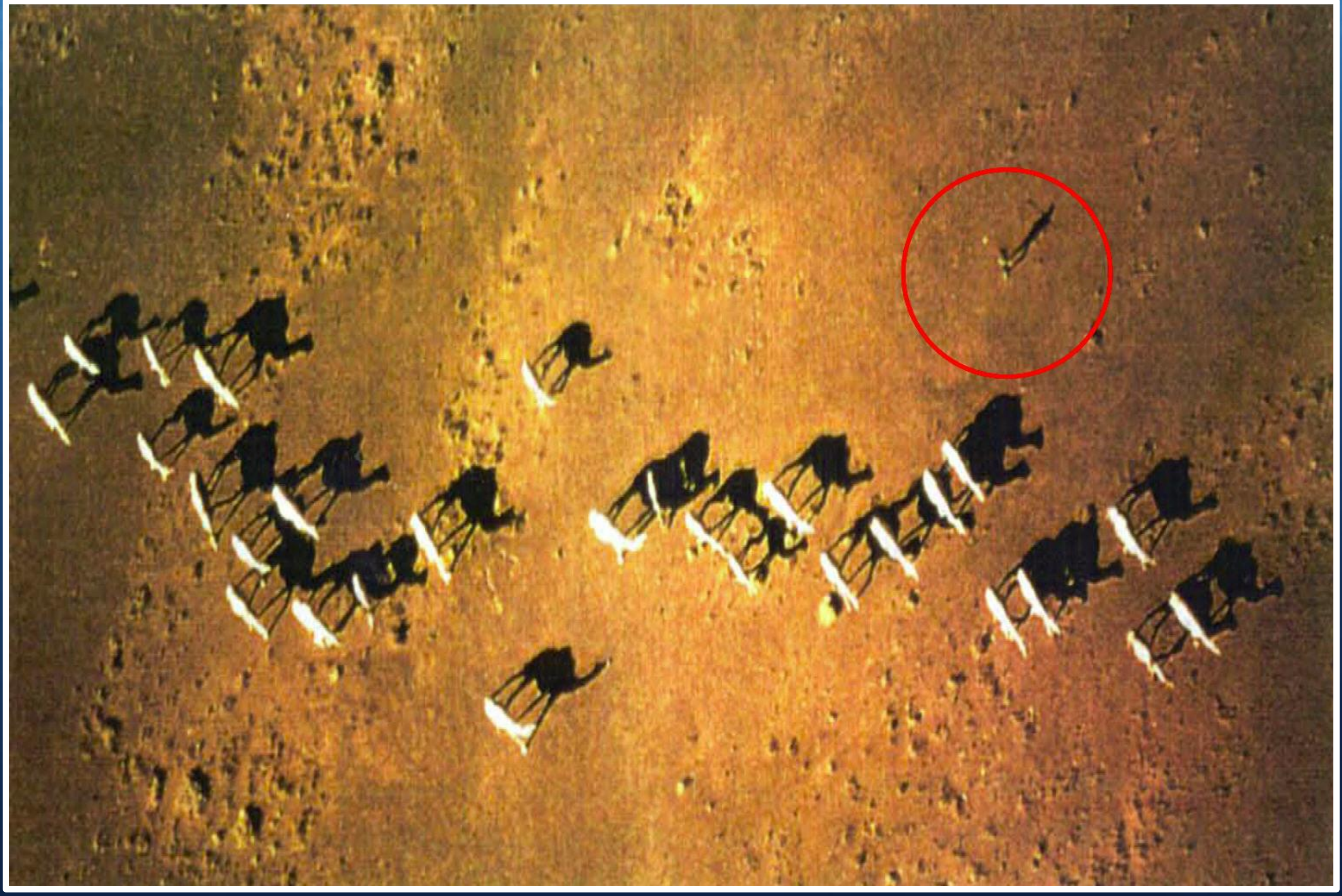


III. SSS Data Interpretation

Shadows – What are the Objects in Aerial Photo
The Shadows have been removed in Photoshop

III. SSS Data Interpretation

Shadows – They Are Really Important to Assist in Target Classification

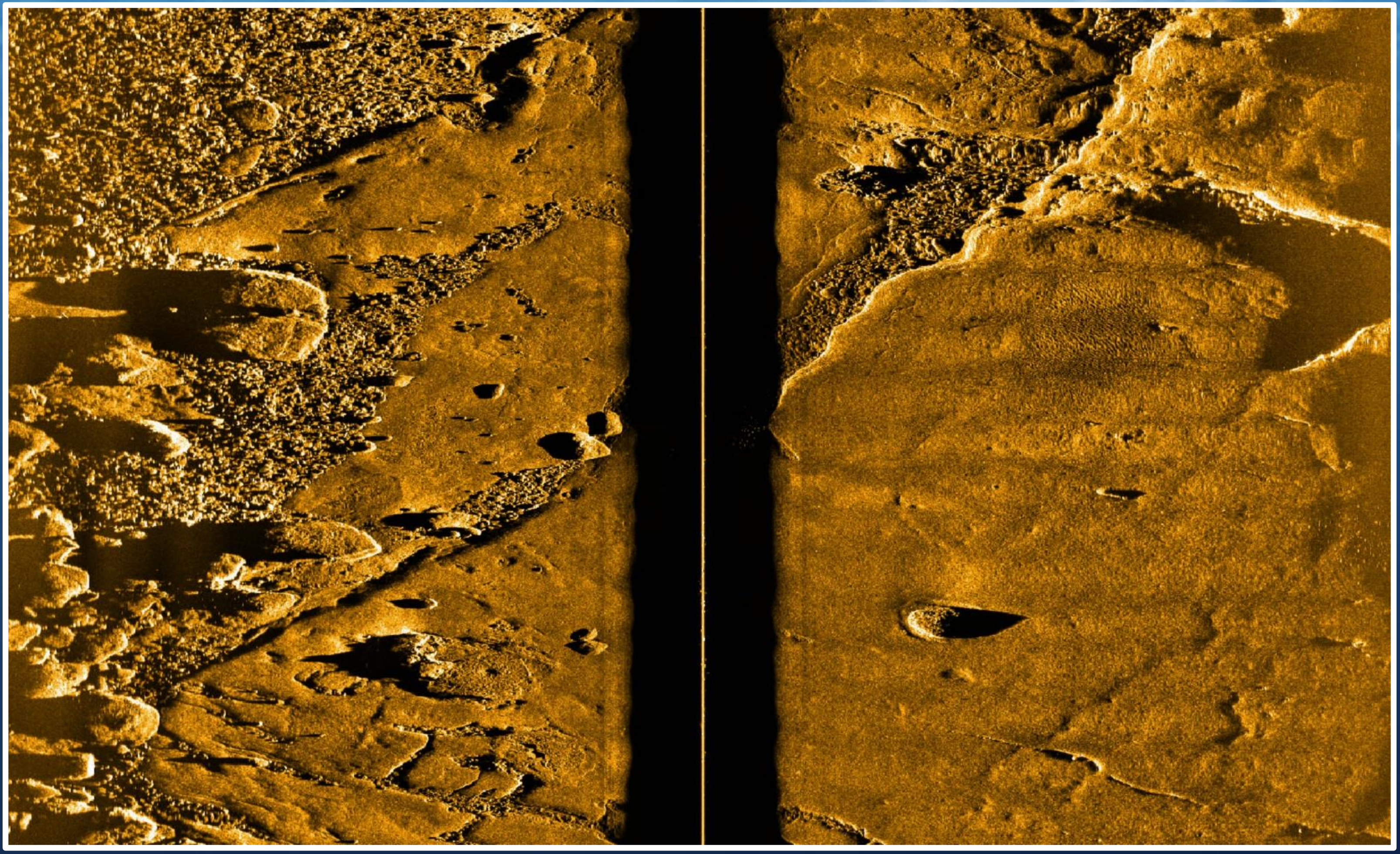


III. SSS Data Interpretation

Acoustic Shadows

III. SSS Data Interpretation

Acoustic Shadows

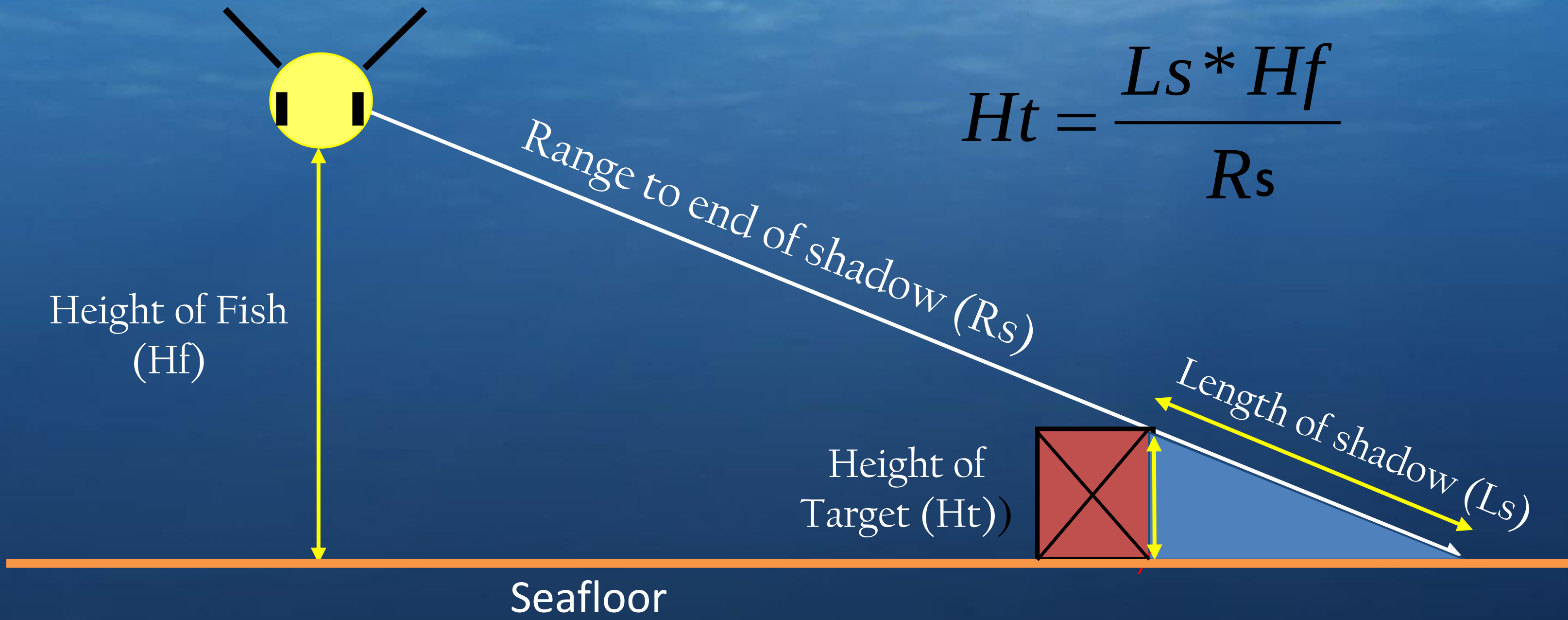


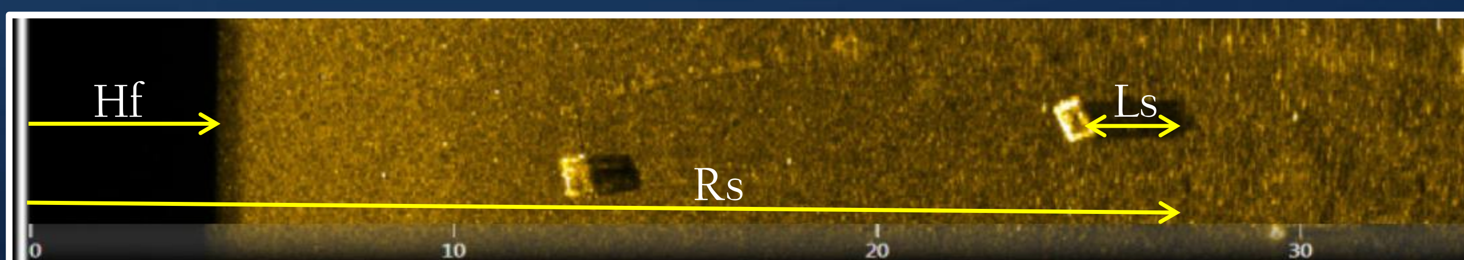
Boulders & Rocks on Geologic out cropping with Gravel in Depressions

III. SSS Data Interpretation

Target Height Calculation Using Acoustic Shadow

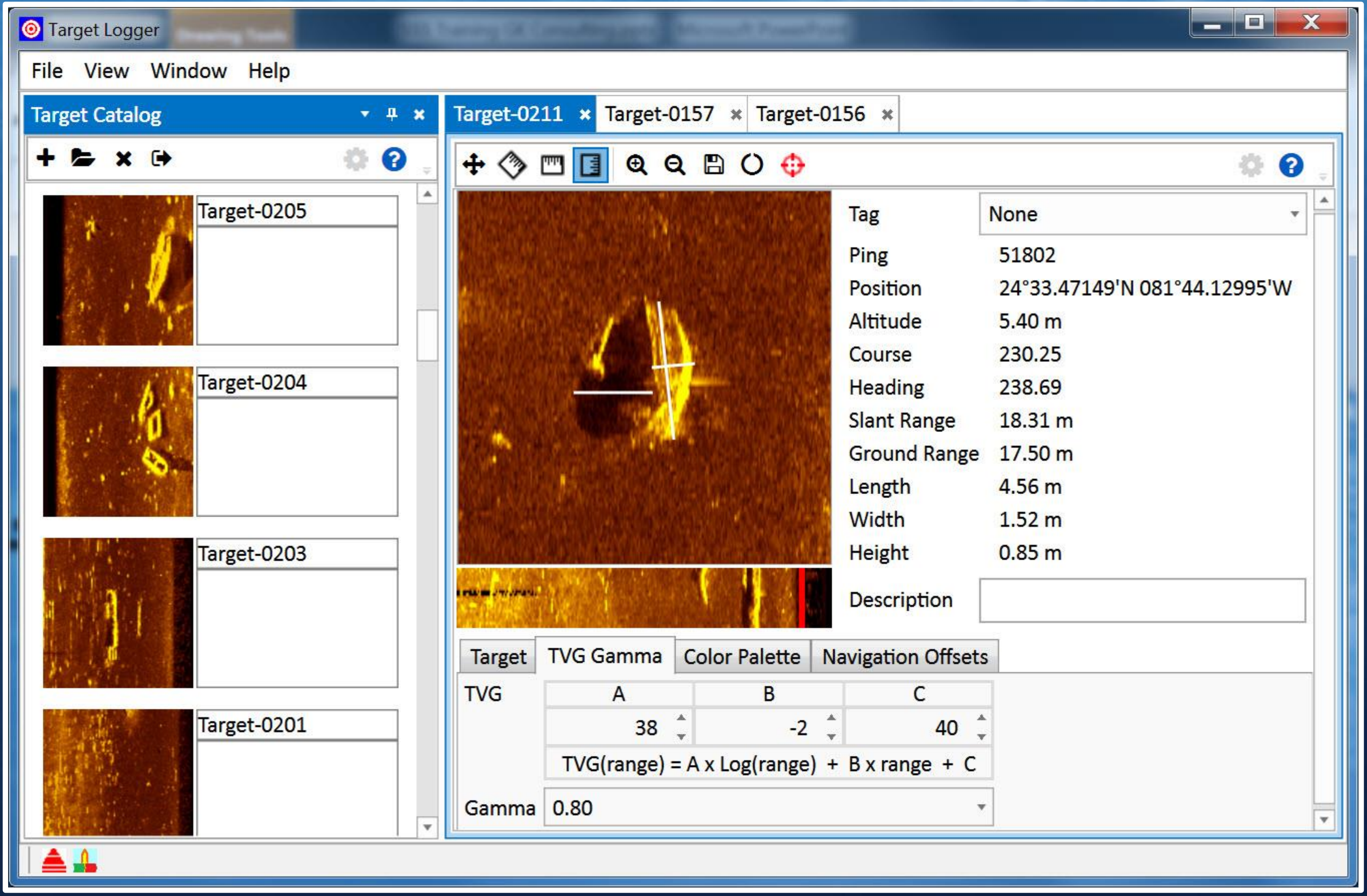
$$Ht = \frac{Ls * Hf}{Rs}$$





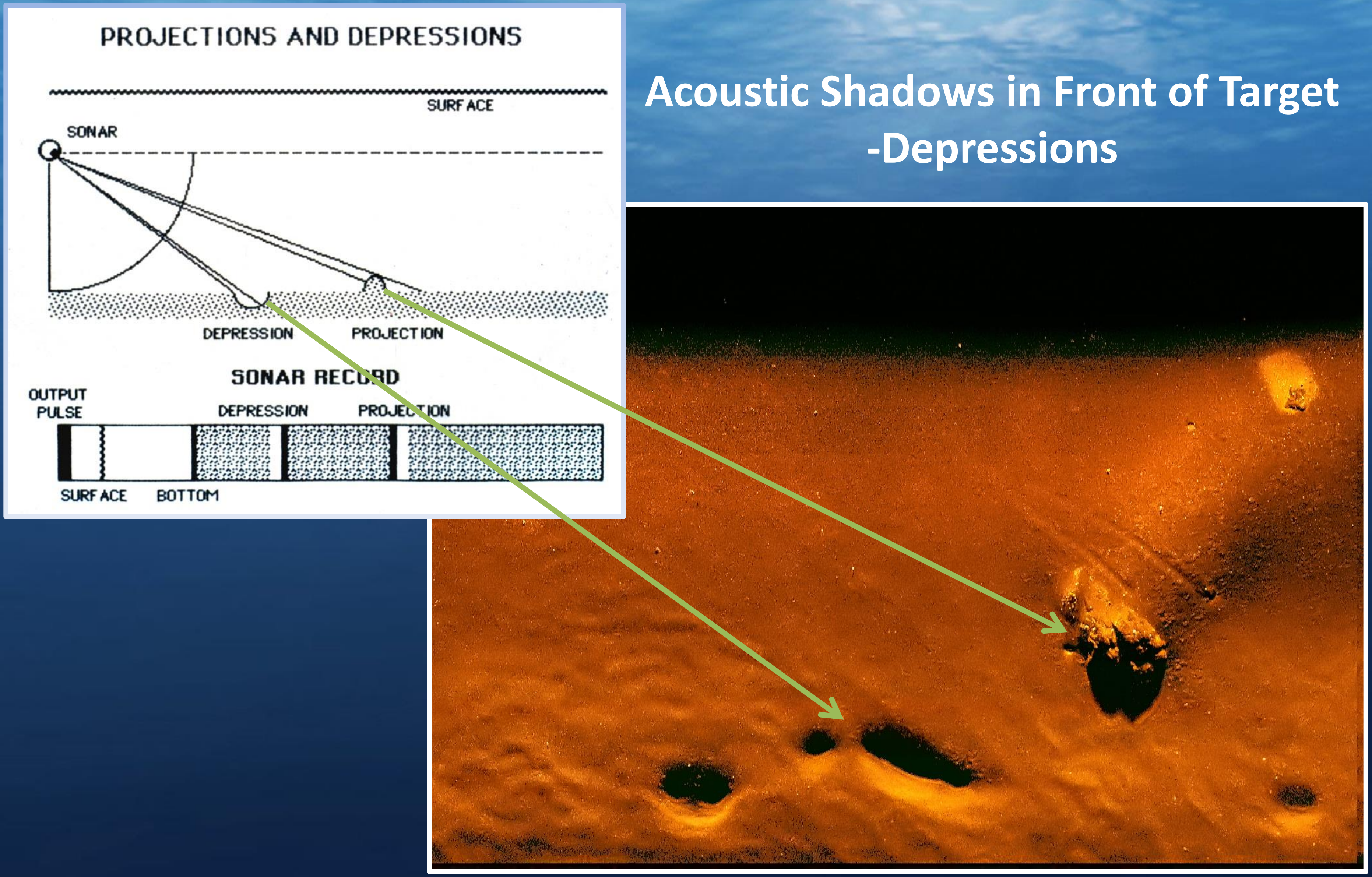
III. SSS Data Interpretation

Target Measurement



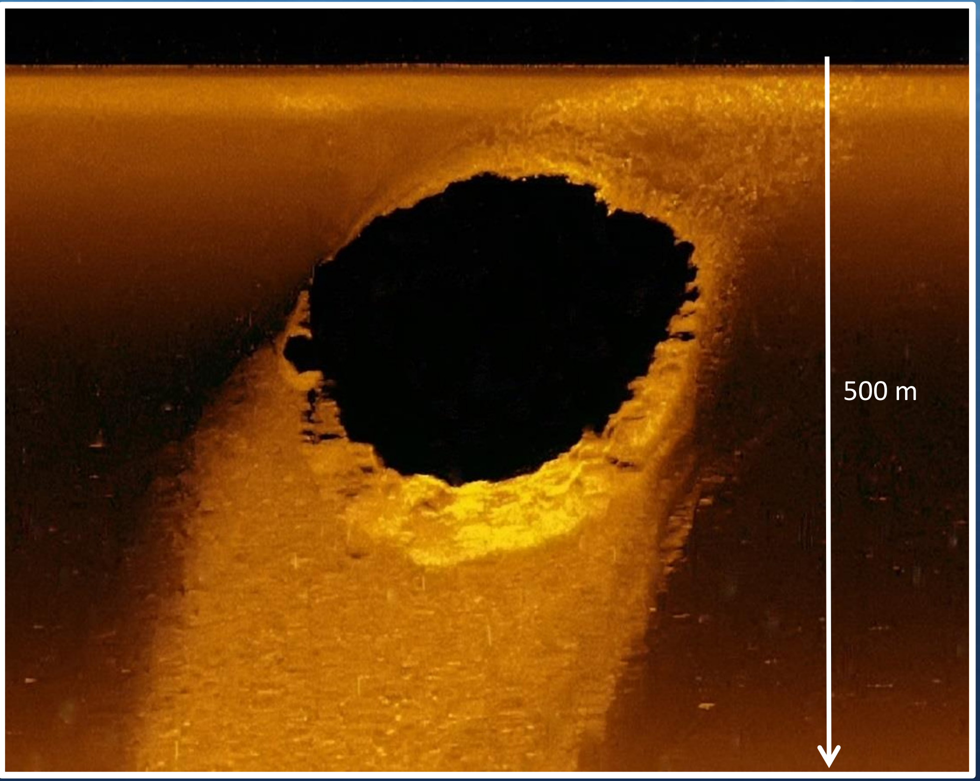
III. SSS Data Interpretation

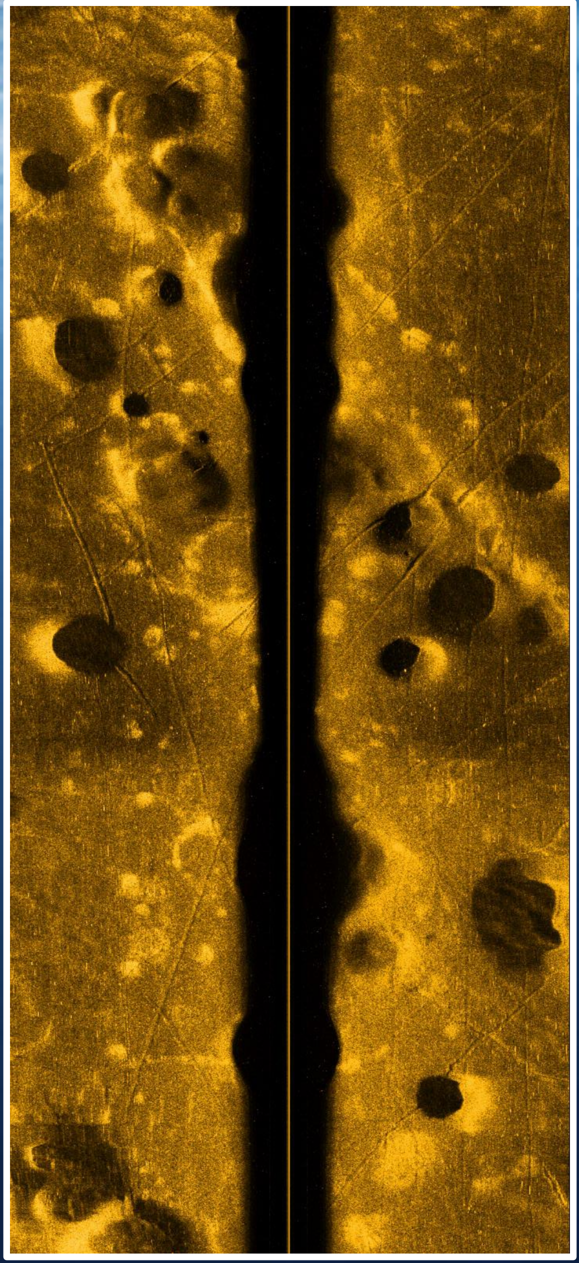
Acoustic Shadows in Front of Target
-Depressions



III. SSS Data Interpretation

Acoustic Shadows in Front of Target

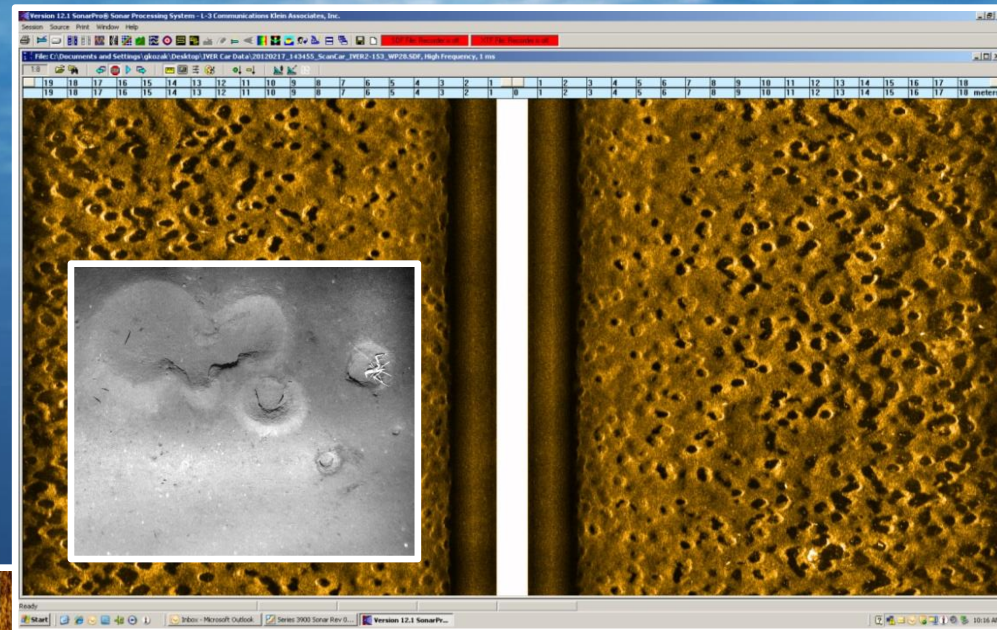


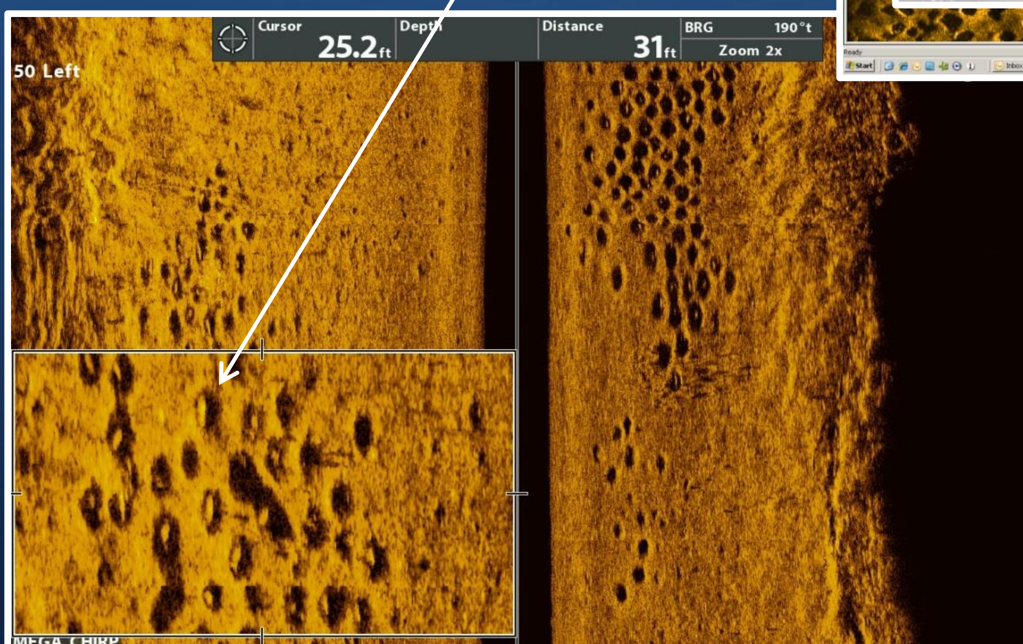


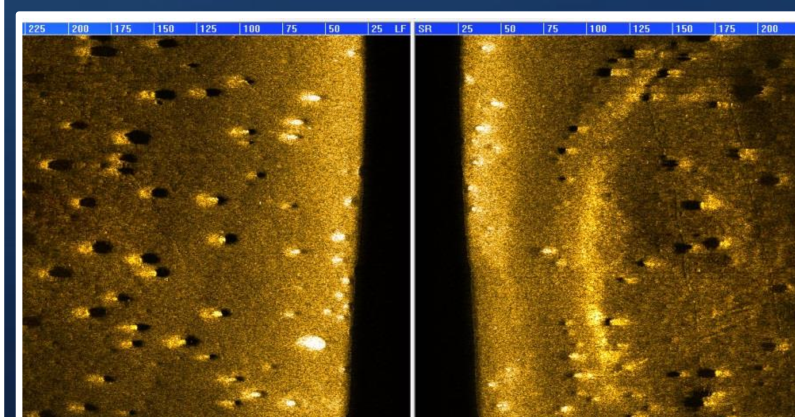
Gas Blowout Craters

III. SSS Data Interpretation

Critter Pock Marks

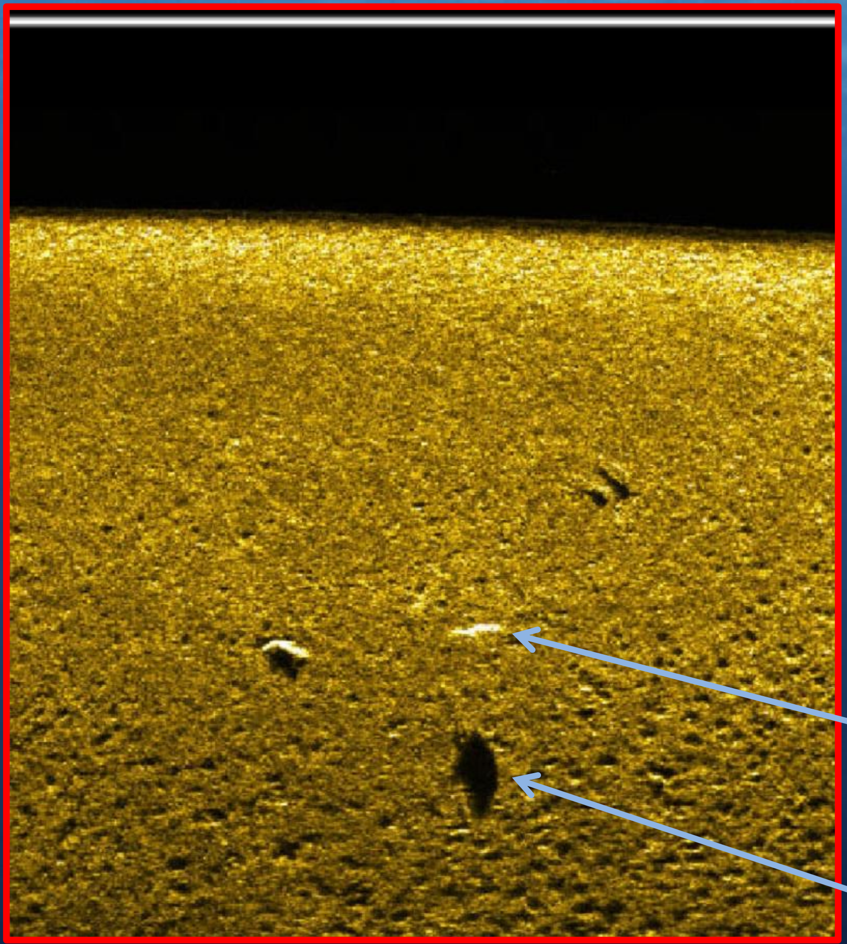


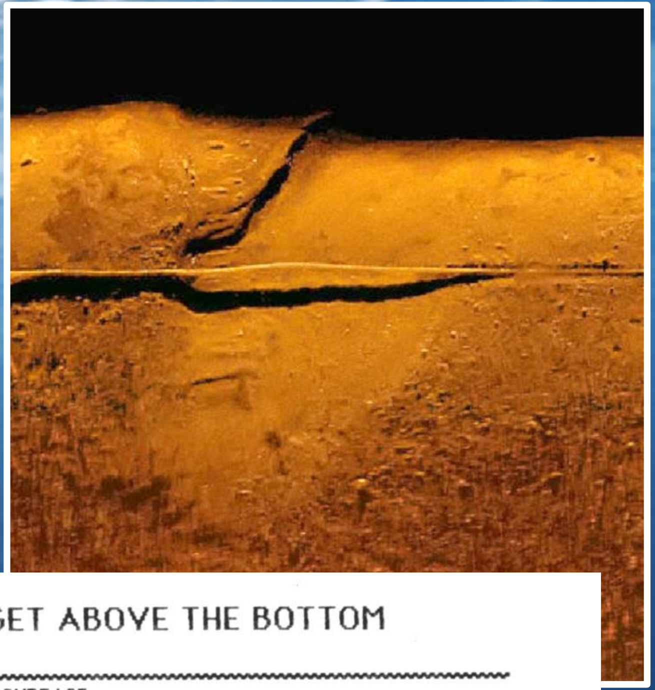


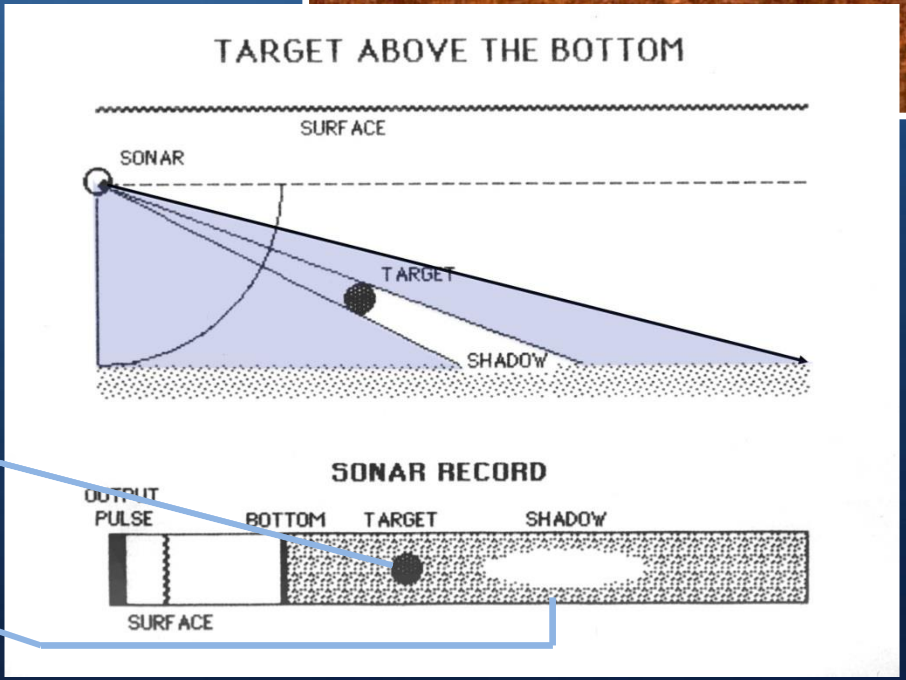


III. SSS Data Interpretation

Separated Shadow from Target

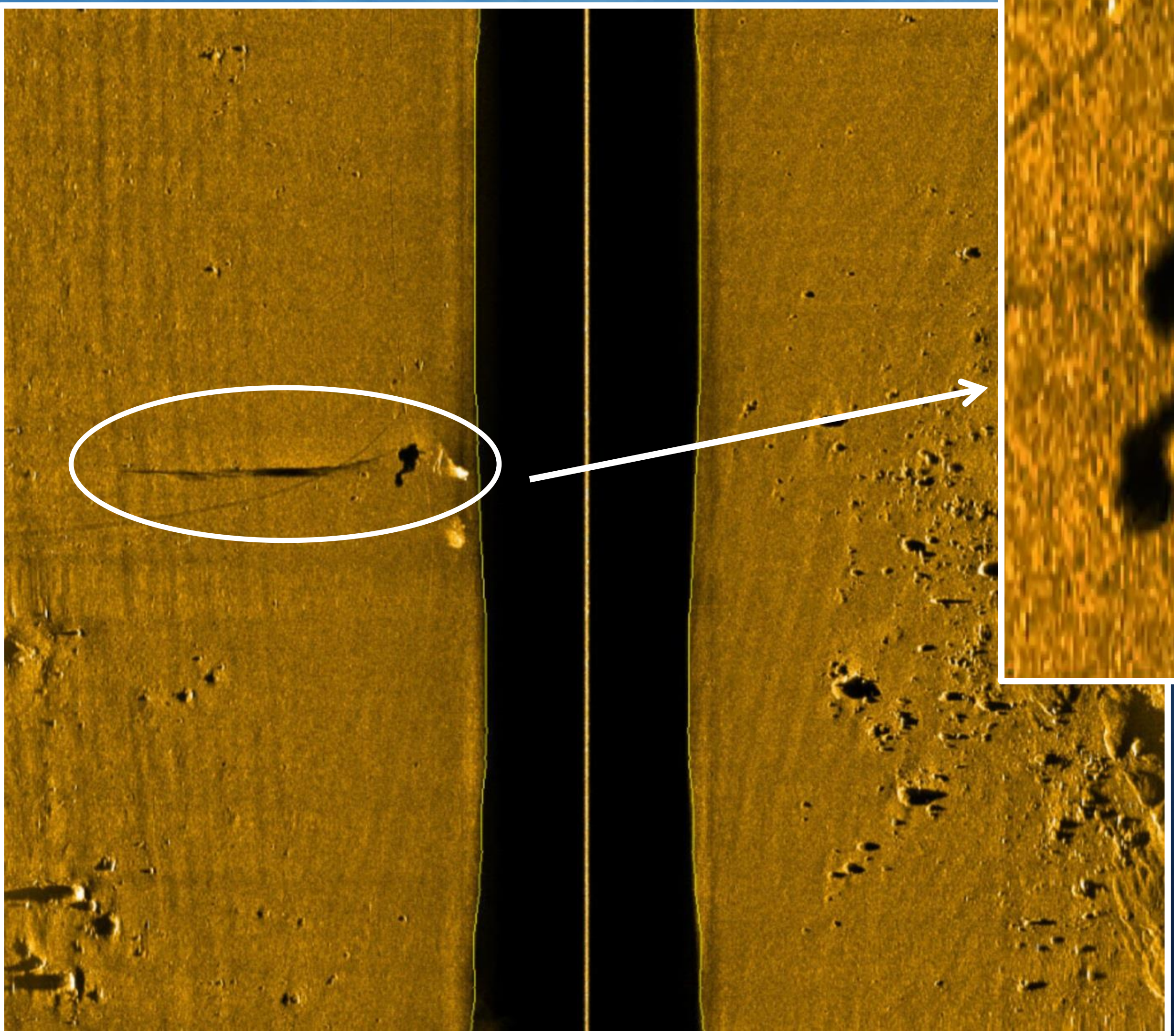


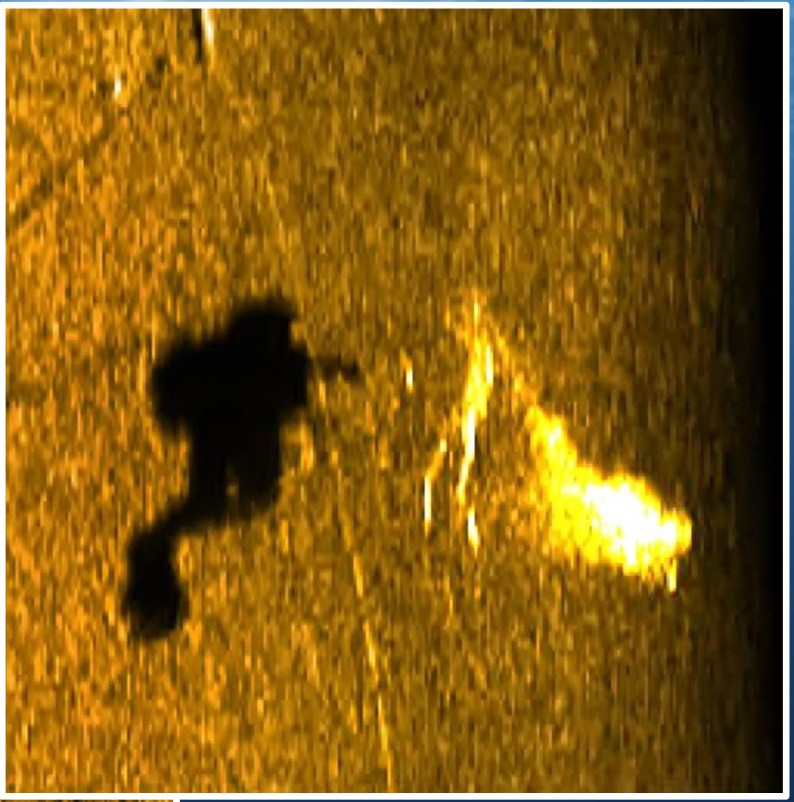




III. SSS Data Interpretation

Separated Shadow from Target

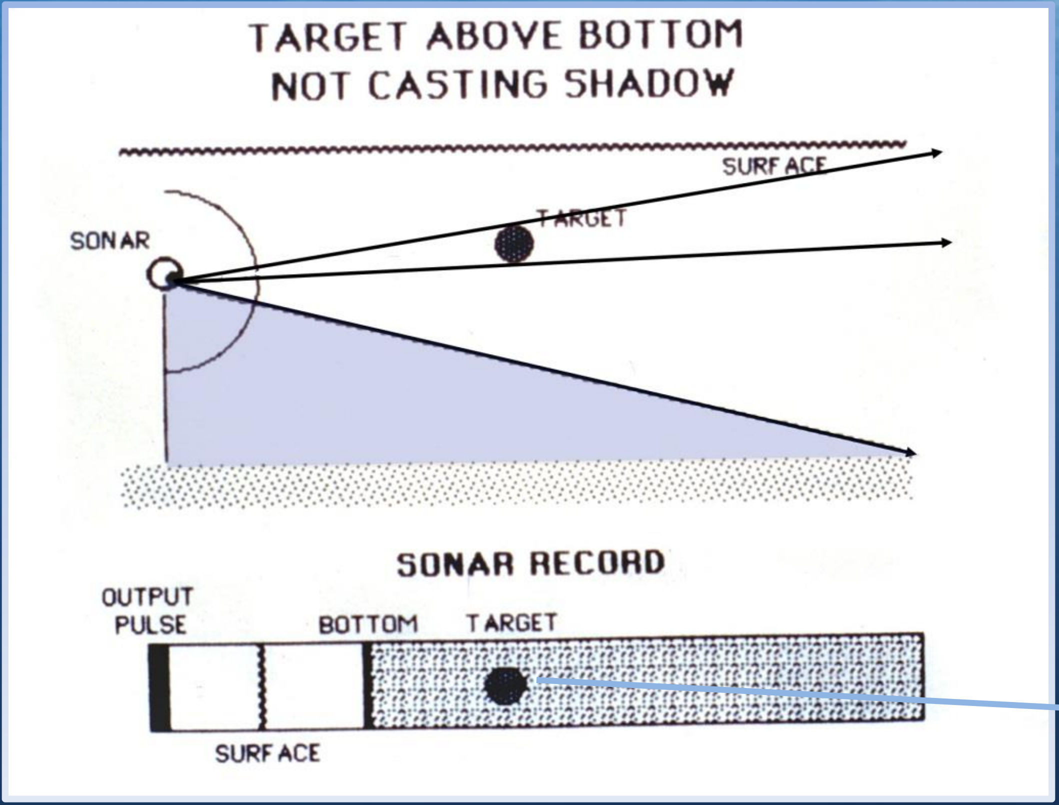


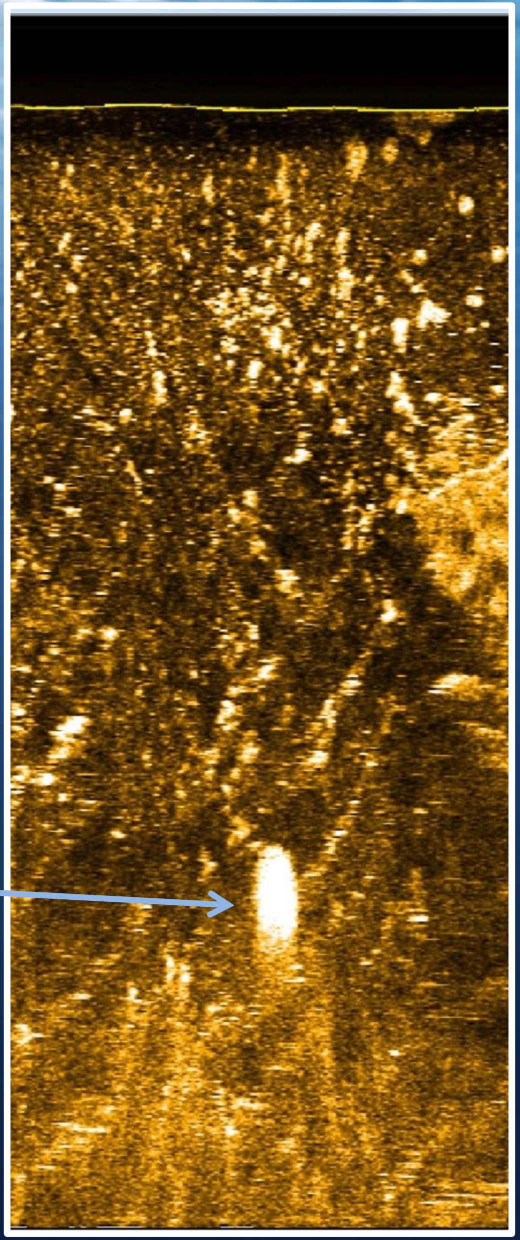


Diver swimming above seafloor

III. SSS Data Interpretation

Acoustic Shadows & Mid-Water Target

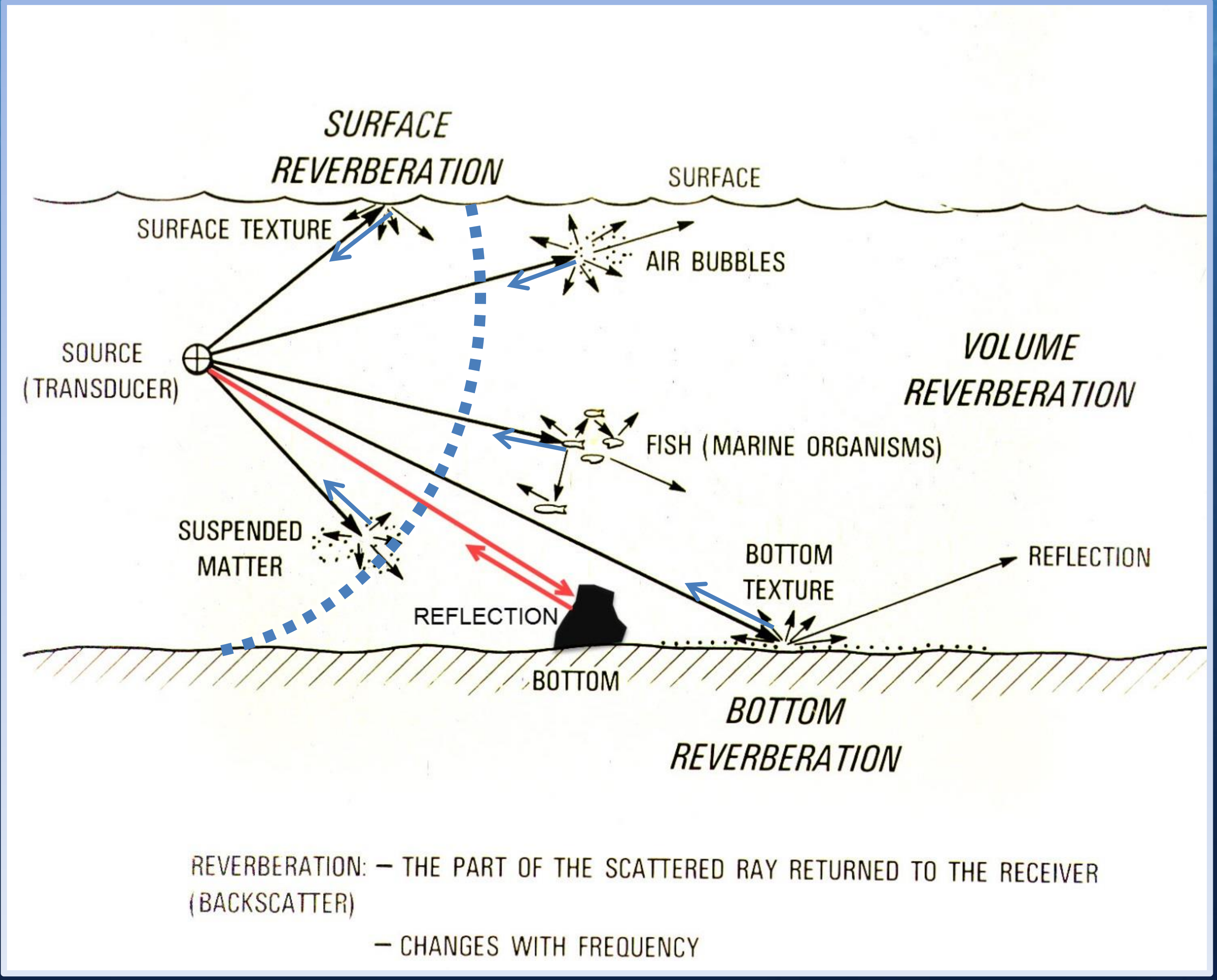




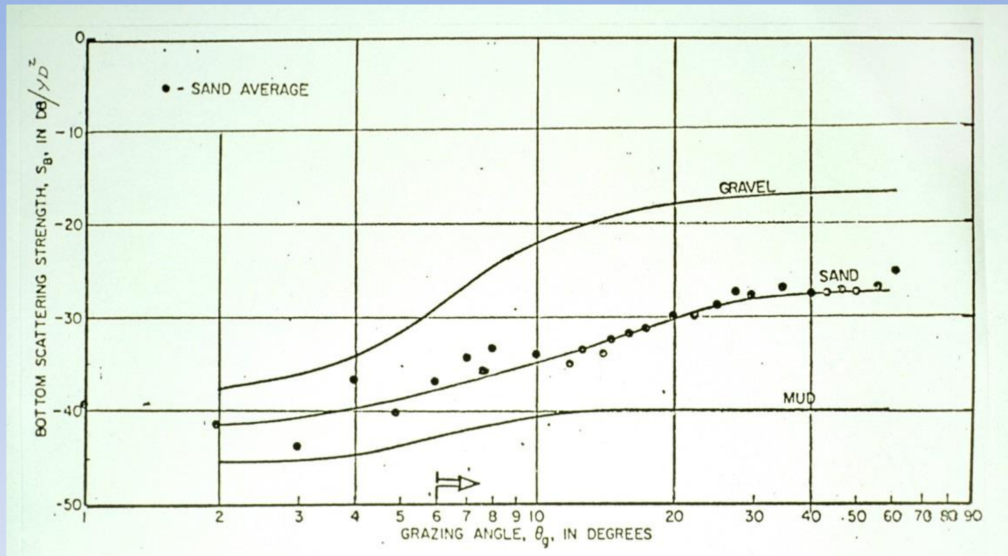
Repeatability Test: A second pass at a later time

III. SSS Data Interpretation

Scattering & Back Scatter

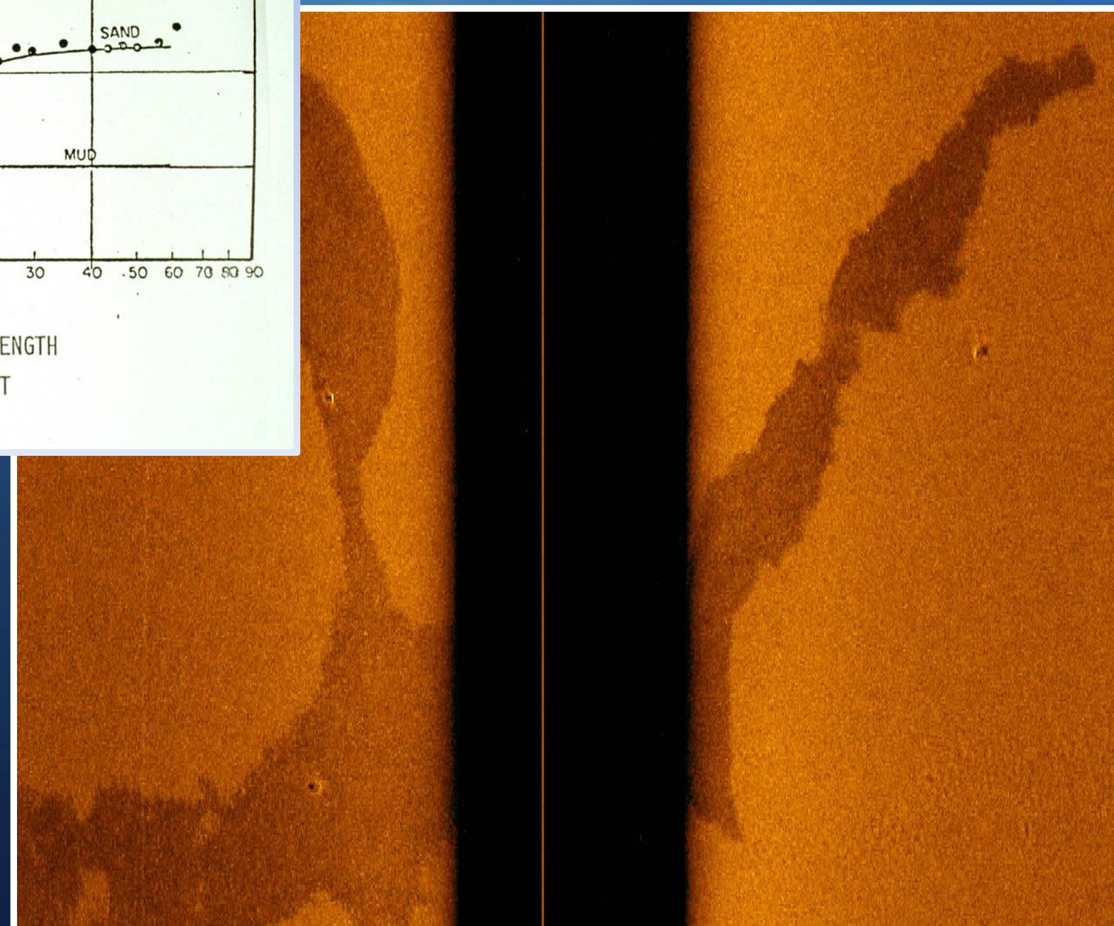


III. SSS Data Interpretation



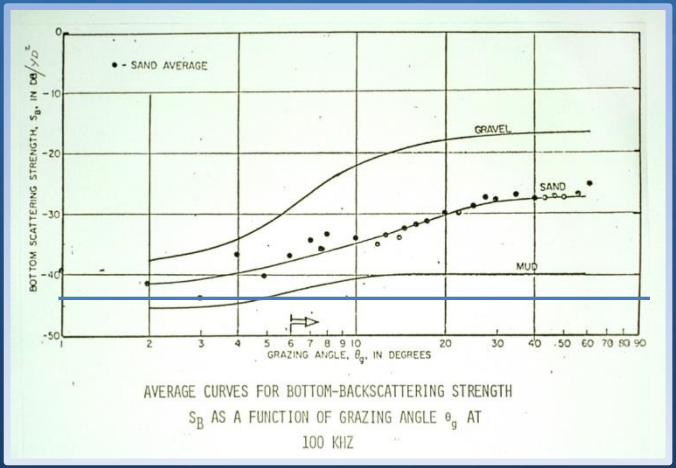
AVERAGE CURVES FOR BOTTOM-BACKSCATTERING STRENGTH S_B AS A FUNCTION OF GRAZING ANGLE θ_g AT 100 KHZ

Seafloor BackScatter

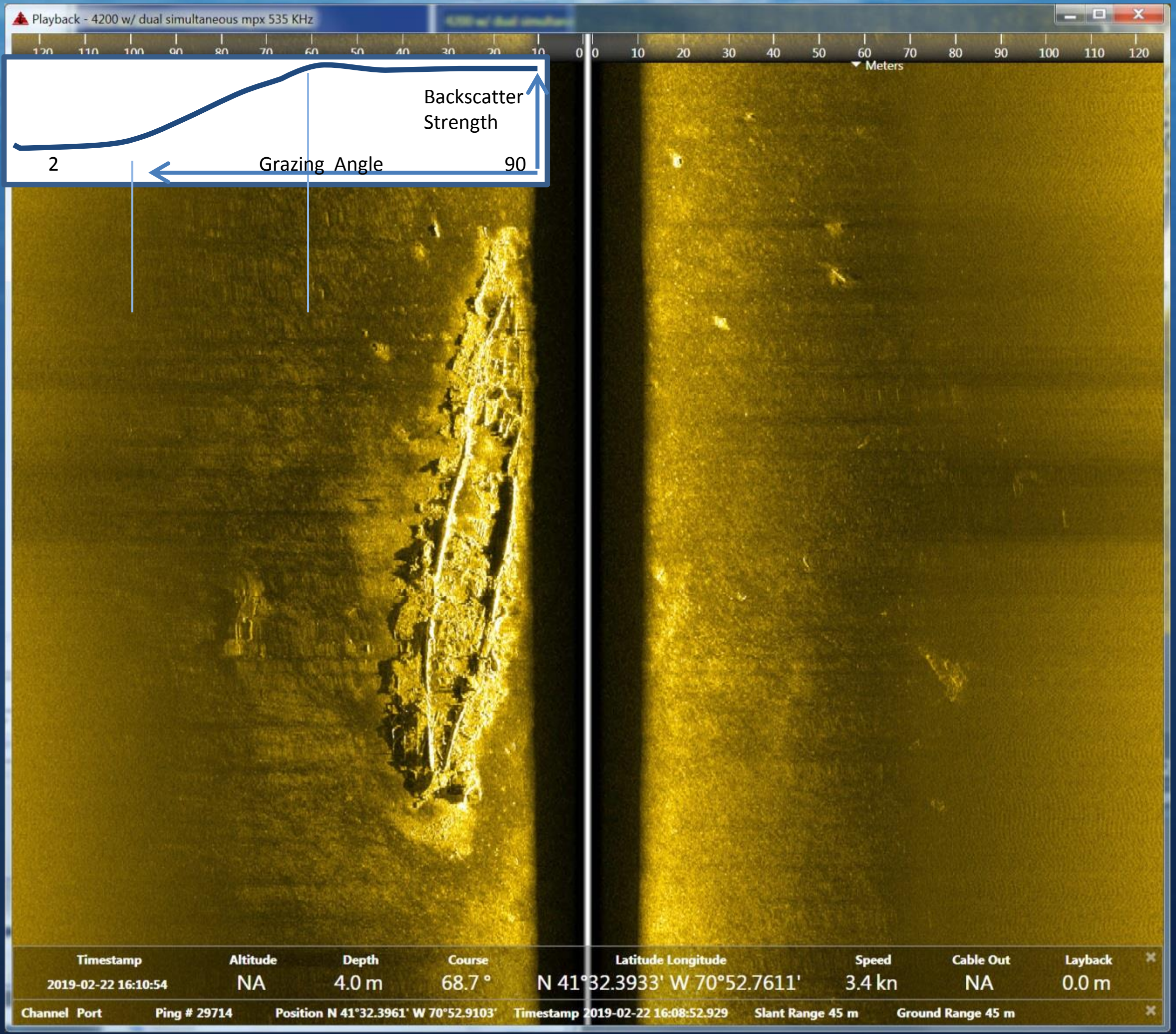


III. SSS Data Interpretation

Backscatter Range

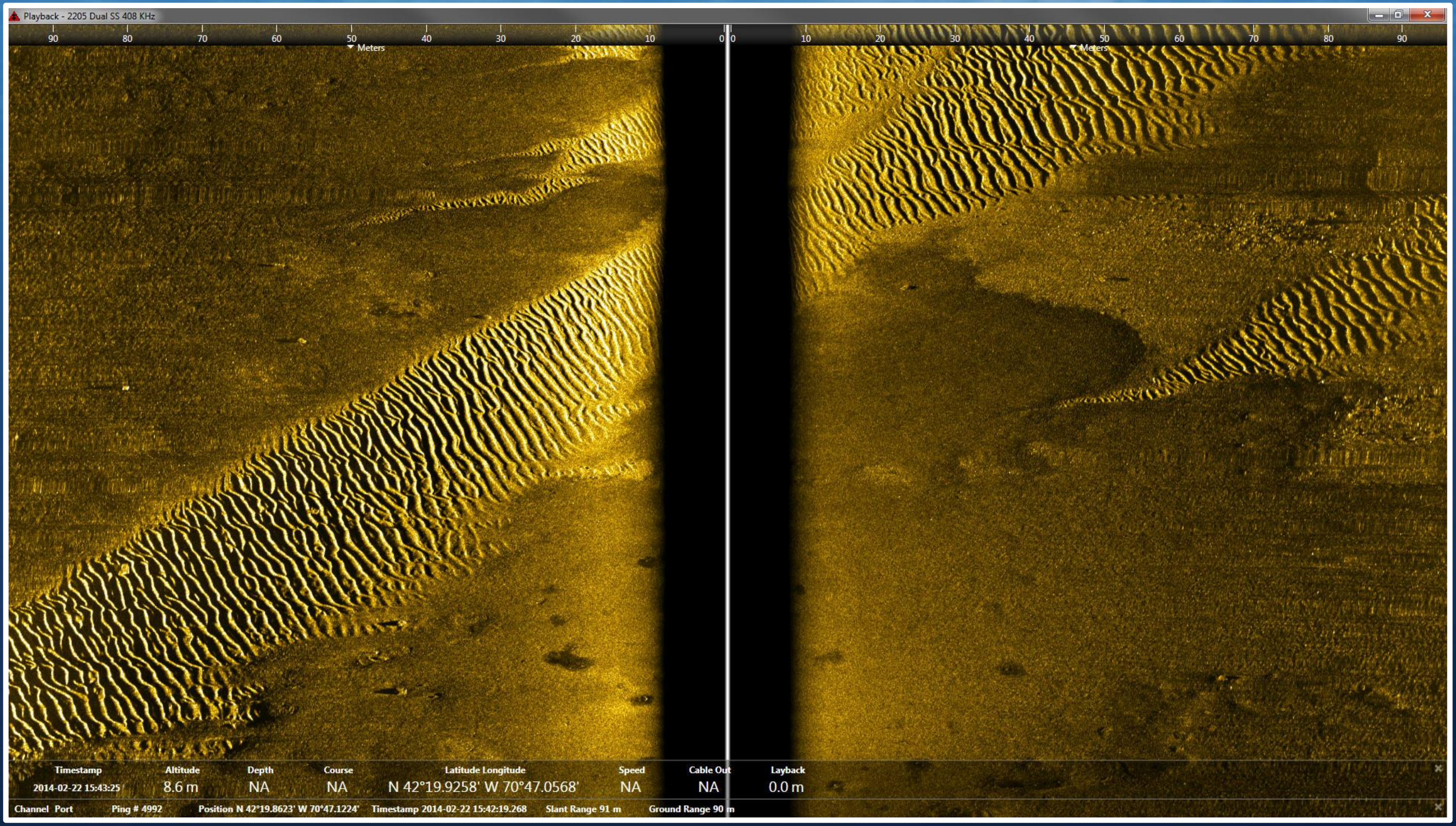


AVERAGE CURVES FOR BOTTOM-BACKSCATTERING STRENGTH S_B AS A FUNCTION OF GRAZING ANGLE θ_g AT 100 KHZ



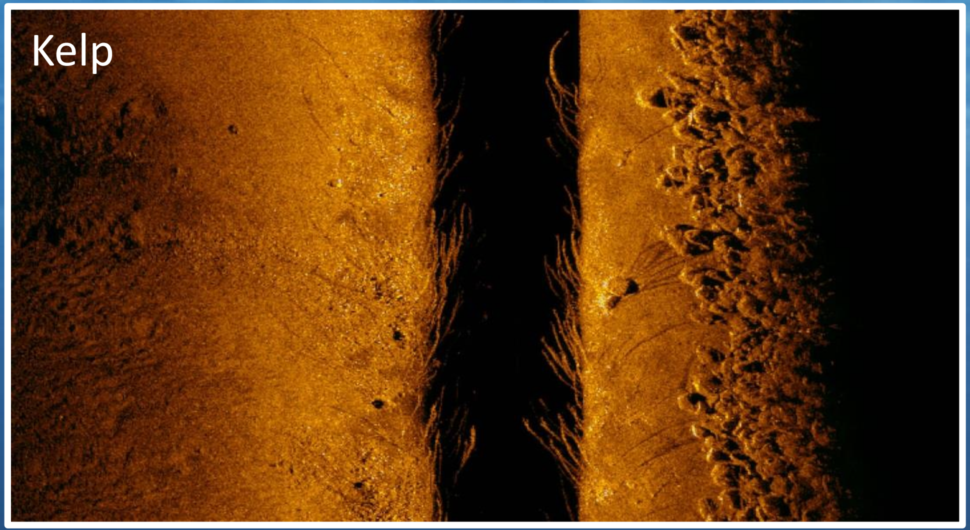
III. SSS Data Interpretation

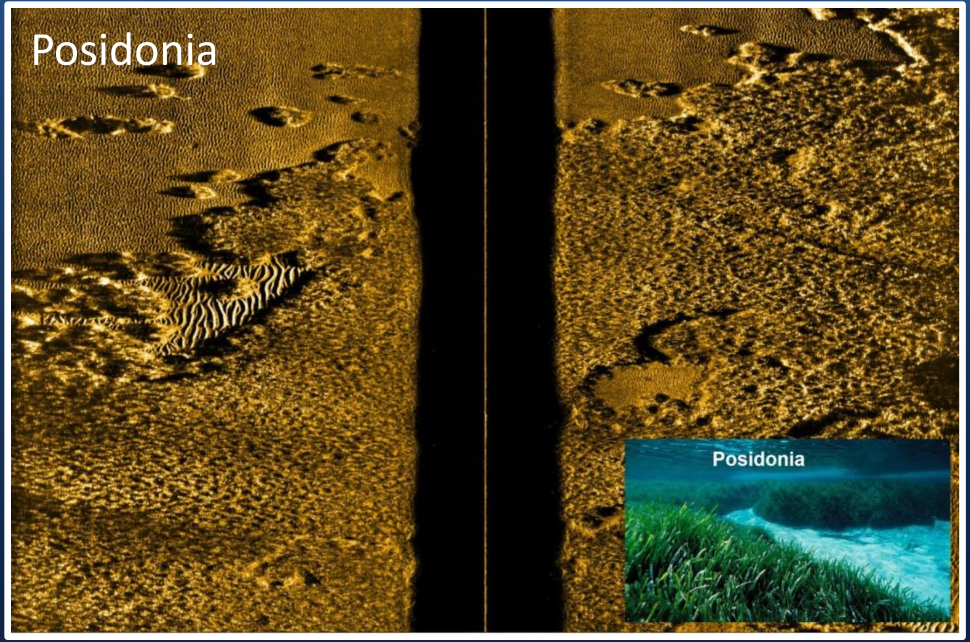
Reflection & Backscatter

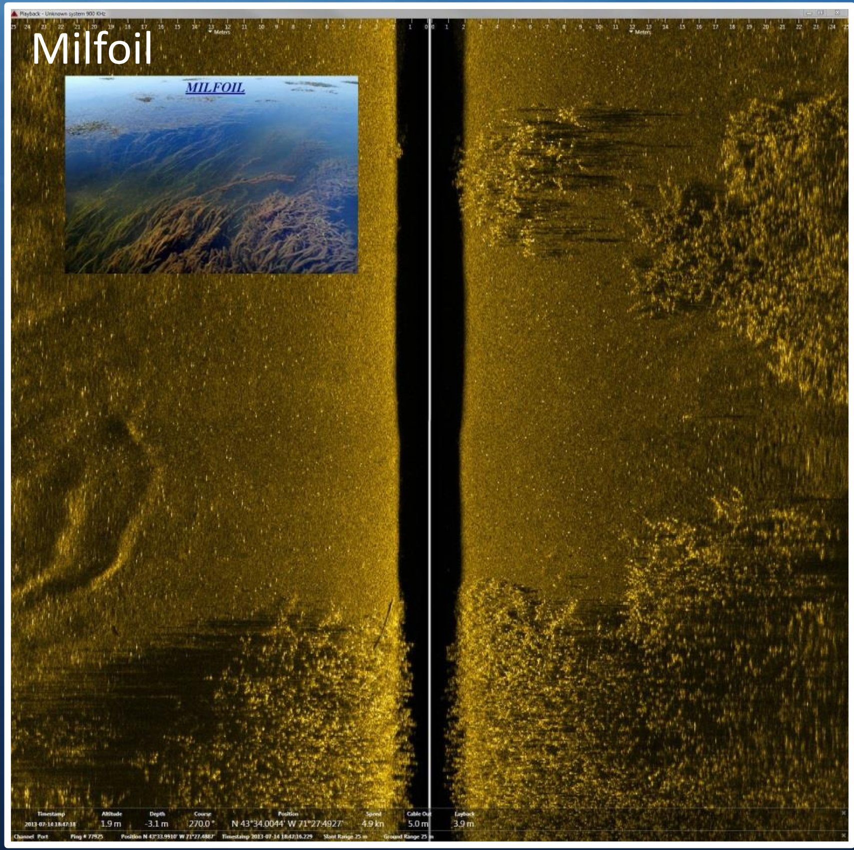


III. SSS Data Interpretation

Vegetation

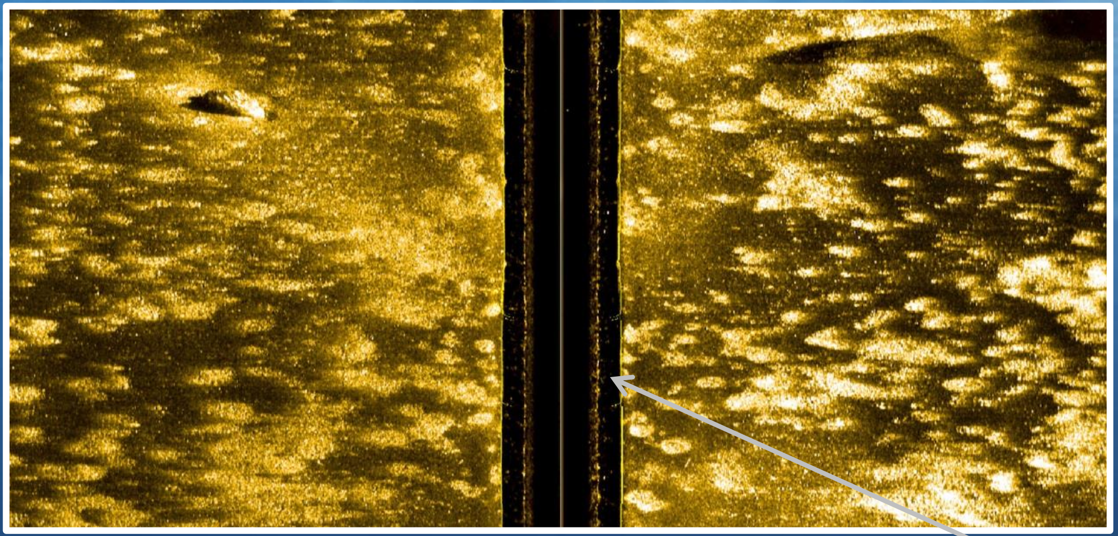


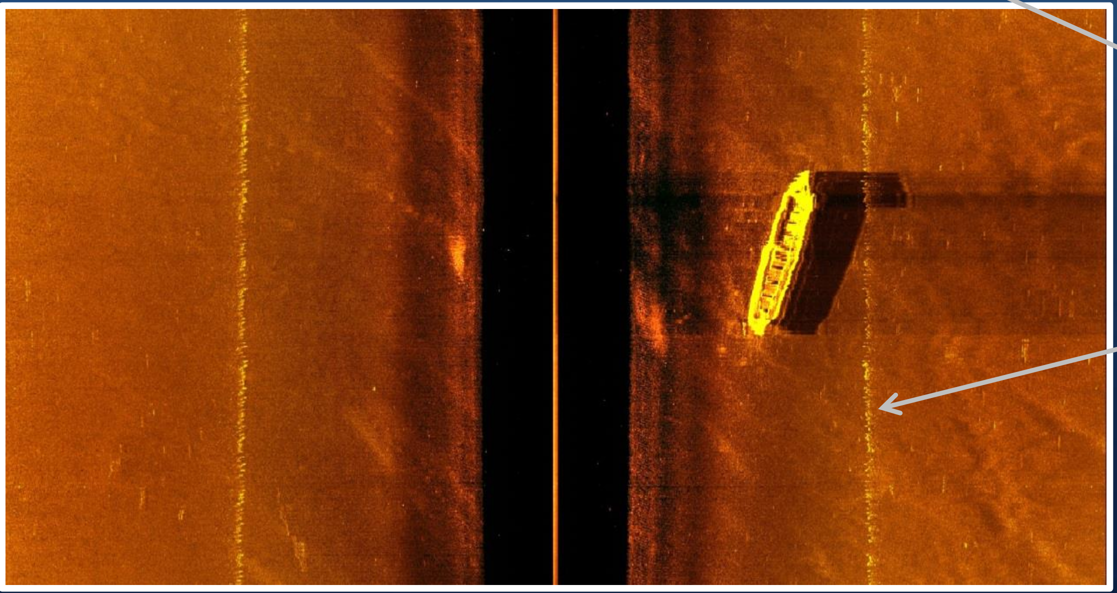


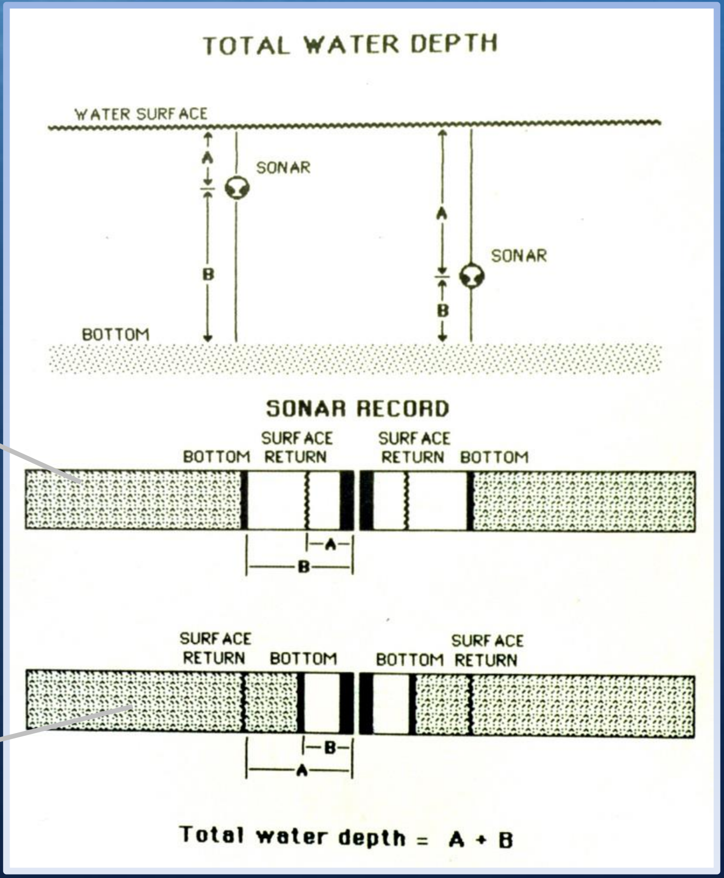


III. SSS Data Interpretation

Surface Return

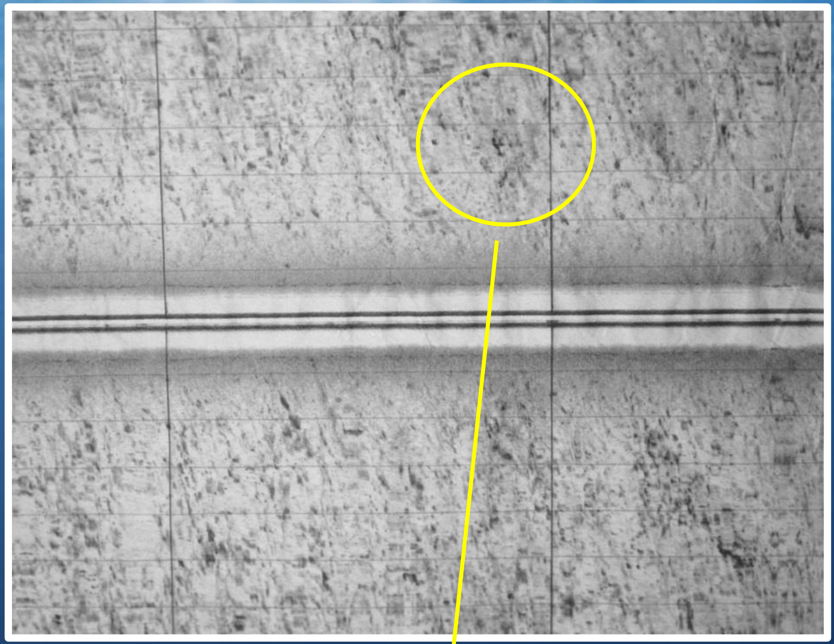


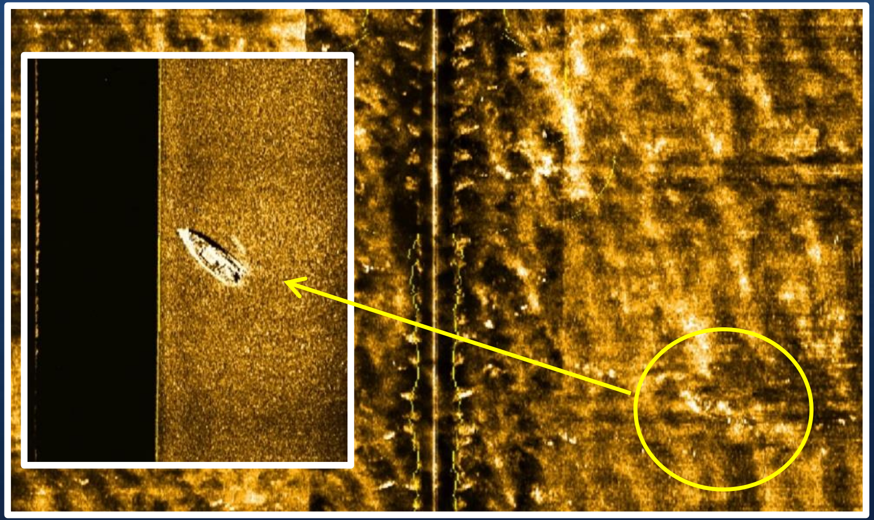




III. SSS Data Interpretation

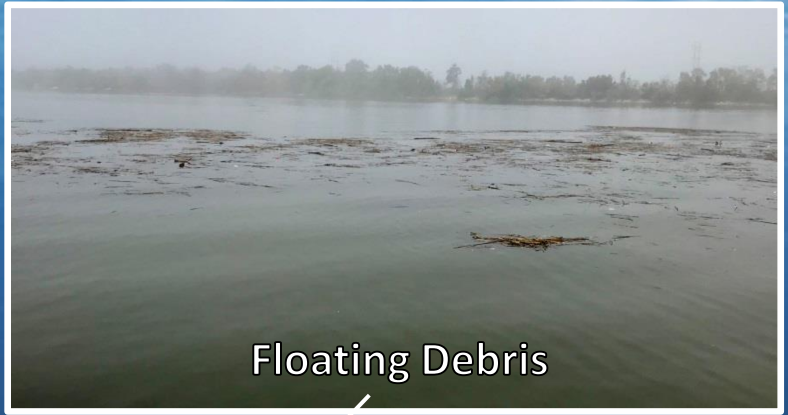
Surface Clutter

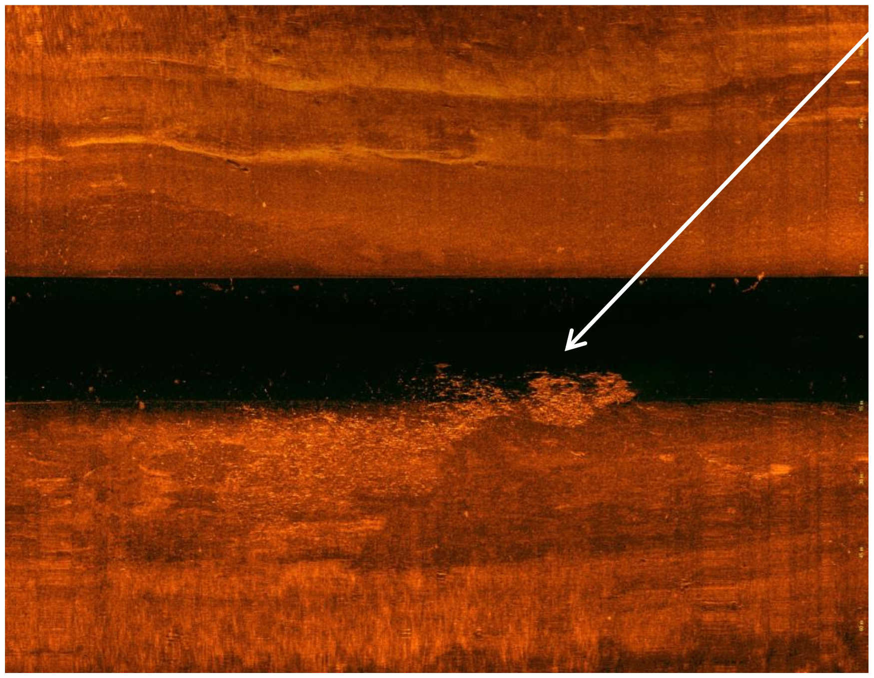


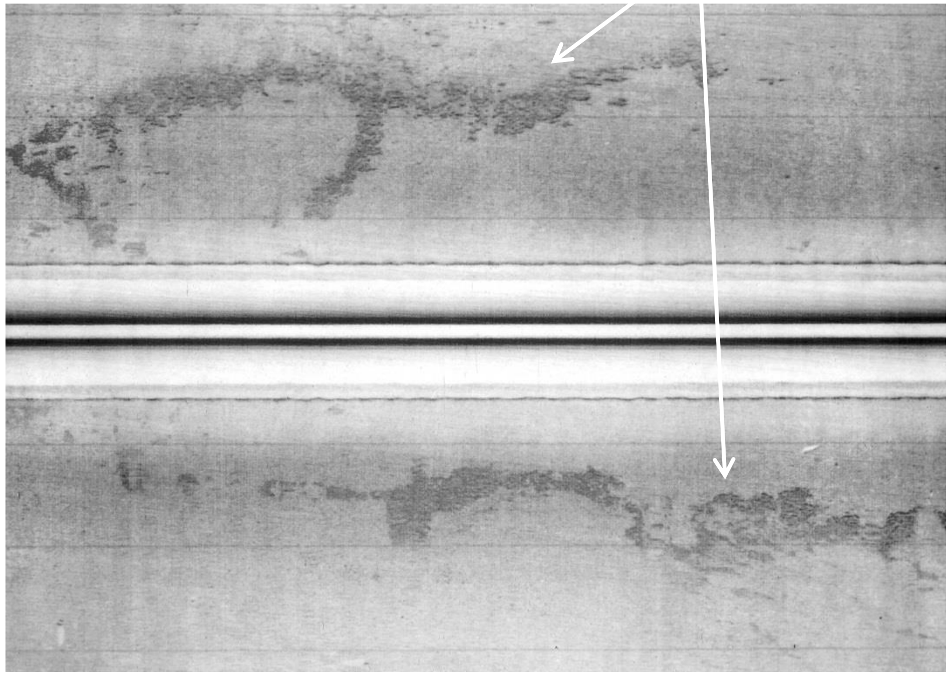


III. SSS Data Interpretation

Surface Targets

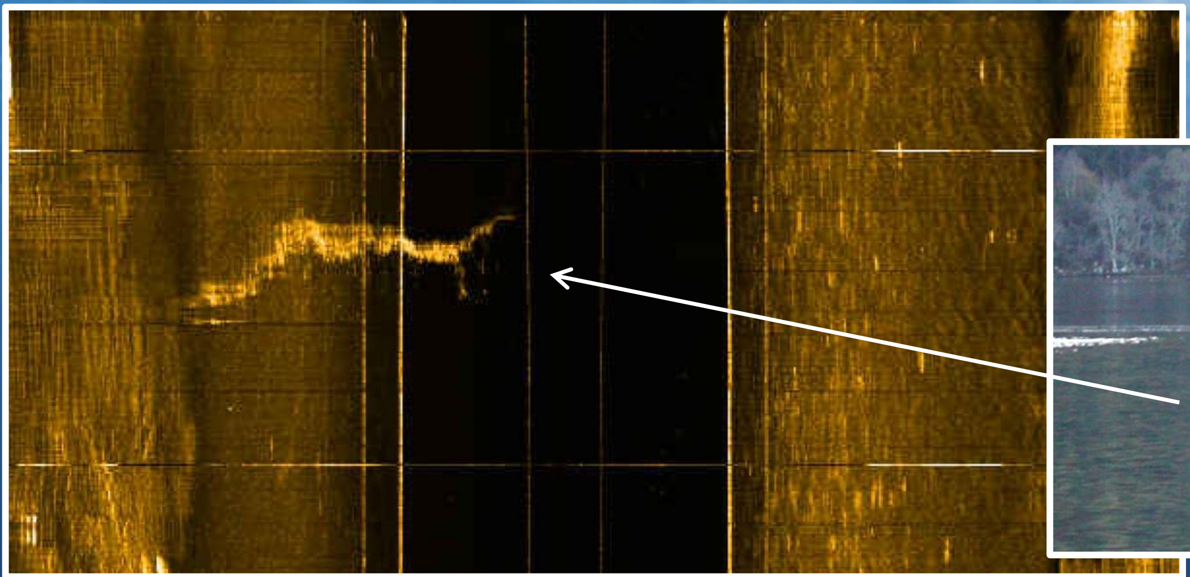


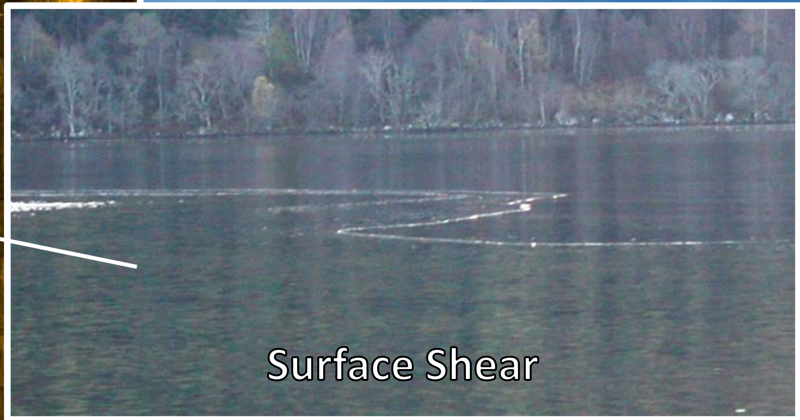


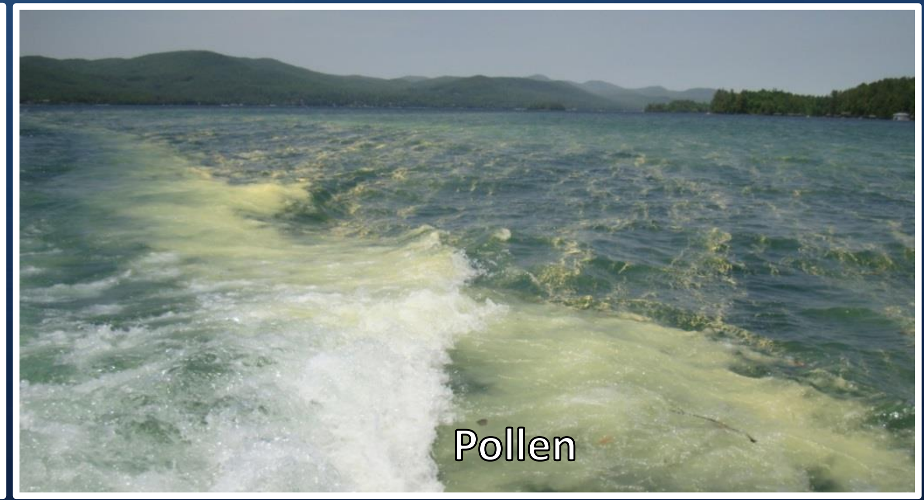


III. SSS Data Interpretation

Surface Targets

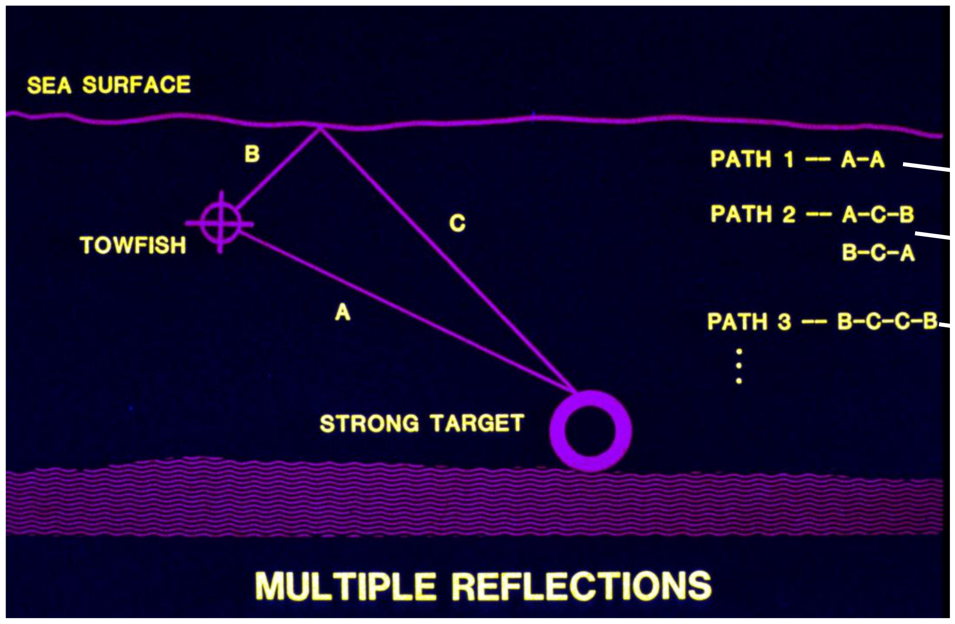


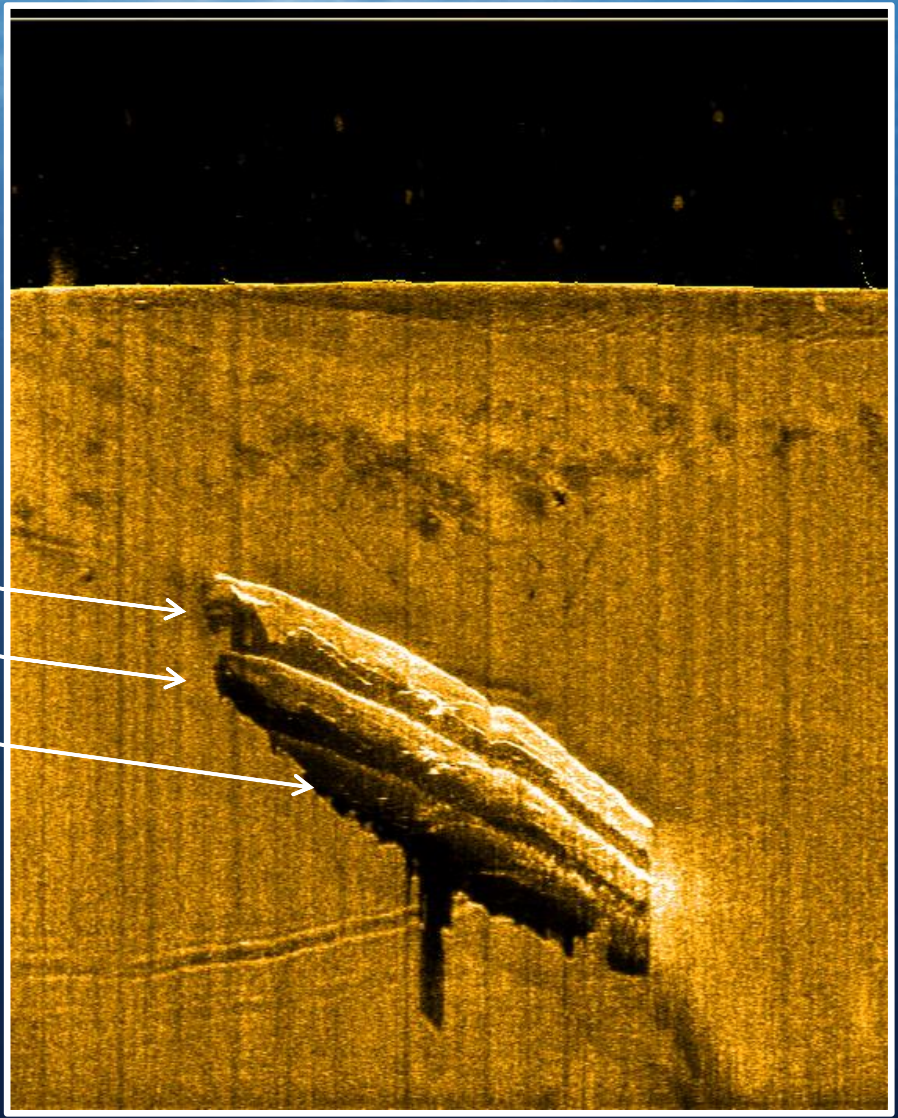




III. SSS Data Interpretation

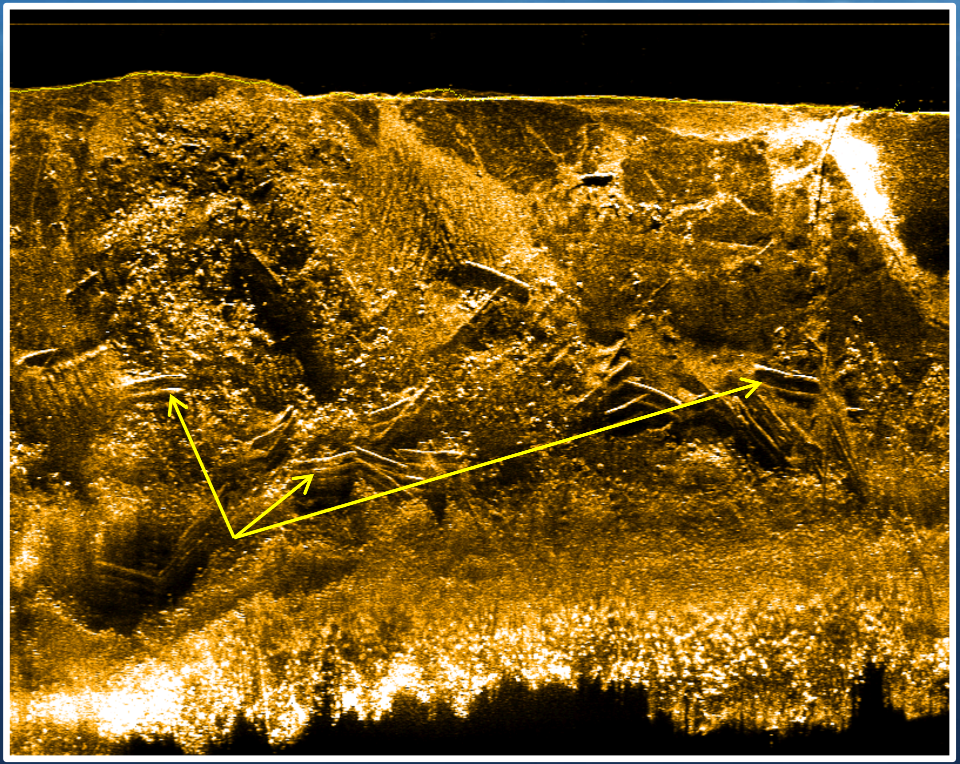
Multipath

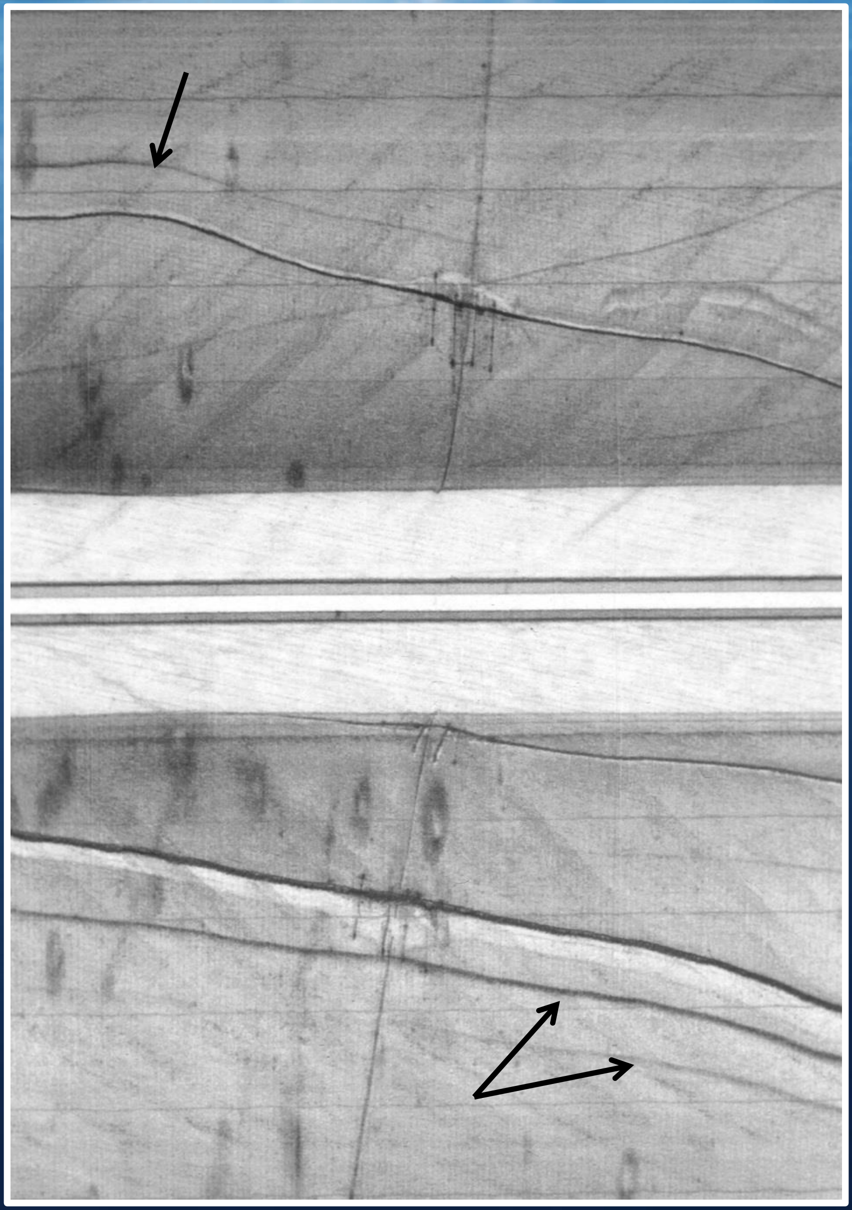




III. SSS Data Interpretation

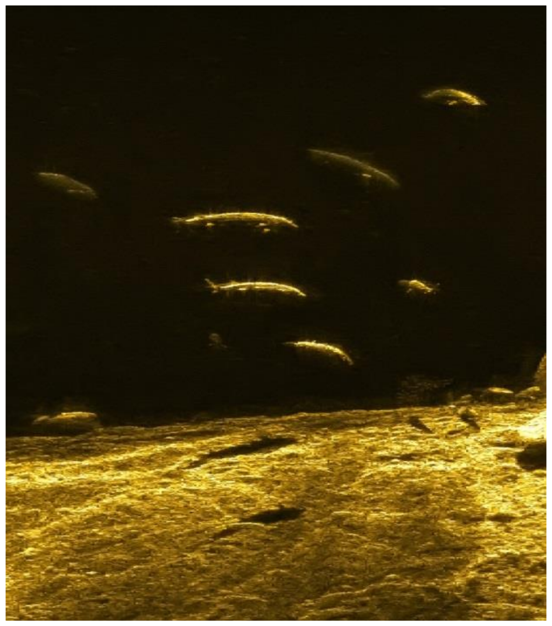
Multipath

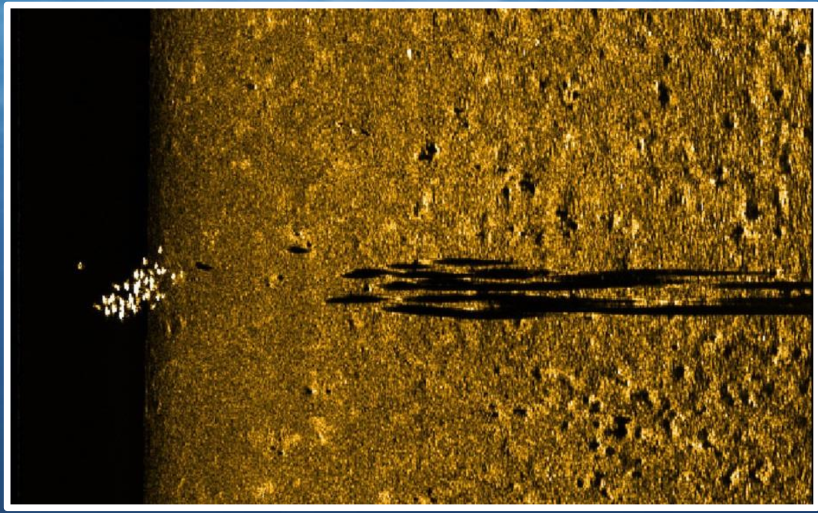


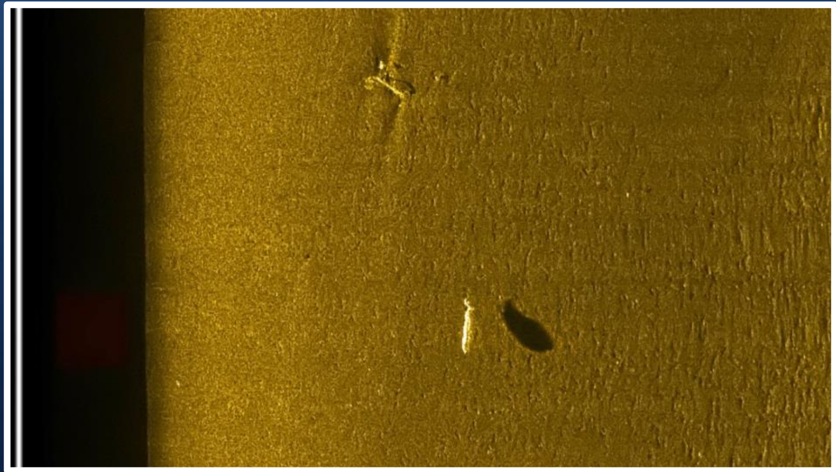


III. SSS Data Interpretation

Mid-Water Targets: Fish

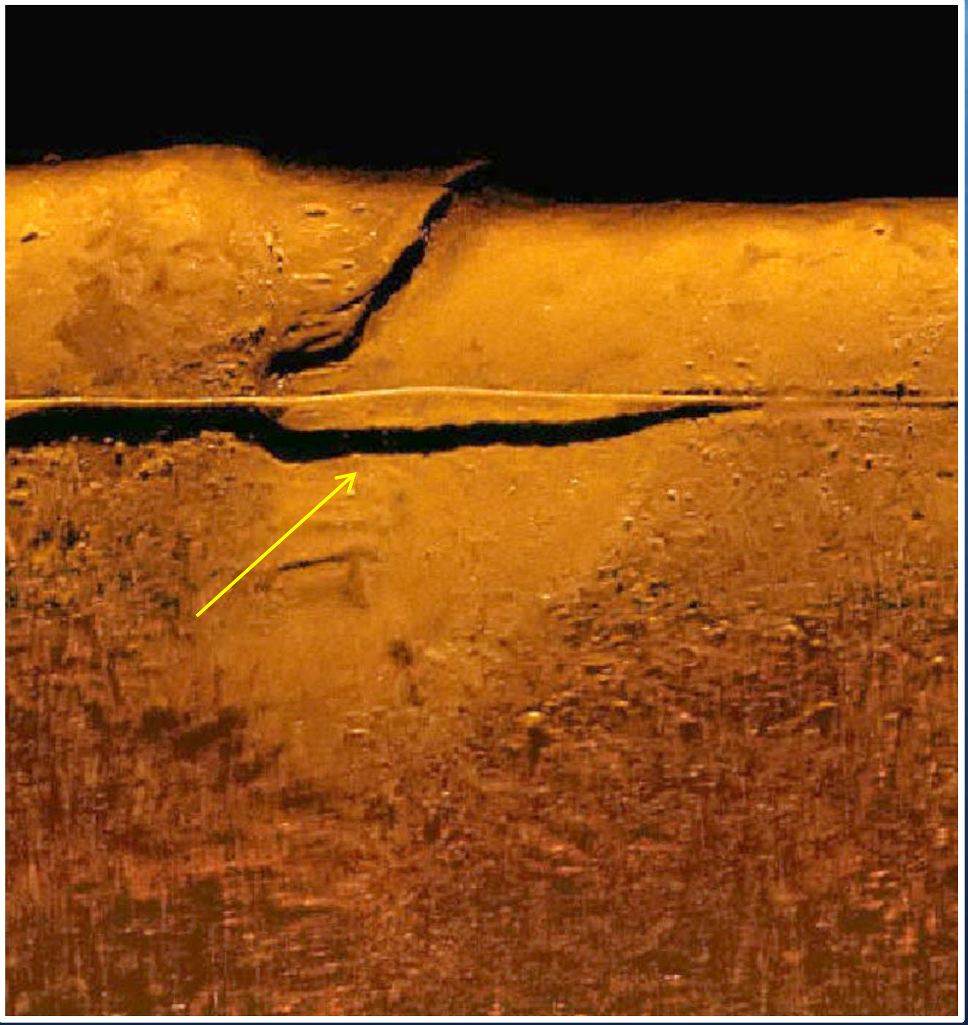


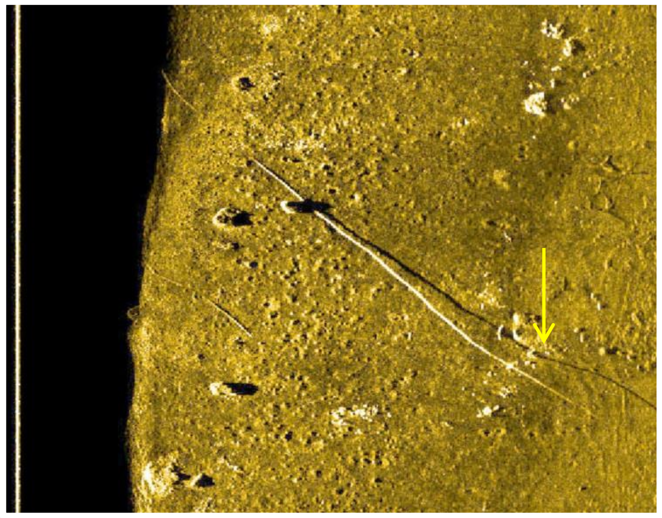


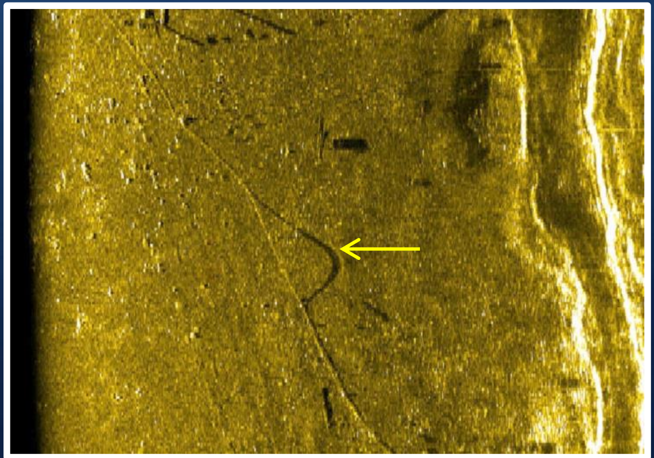


III. SSS Data Interpretation

Suspension's: Pipelines & Cables



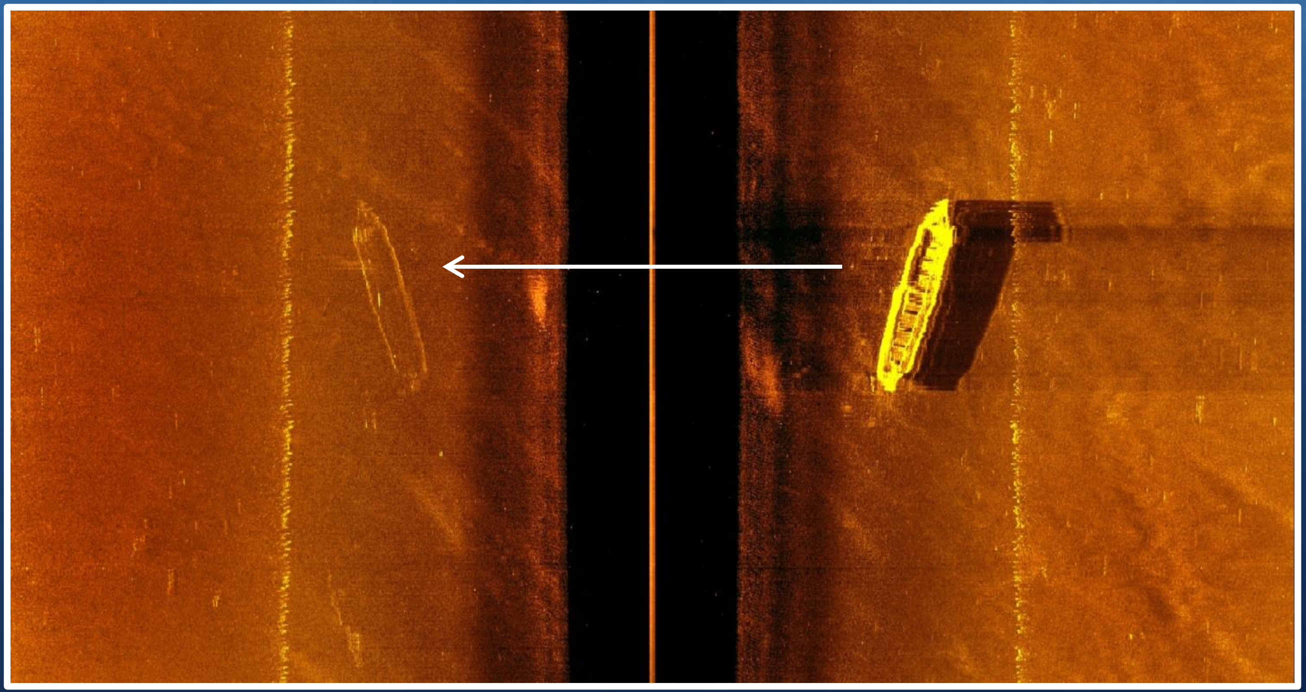


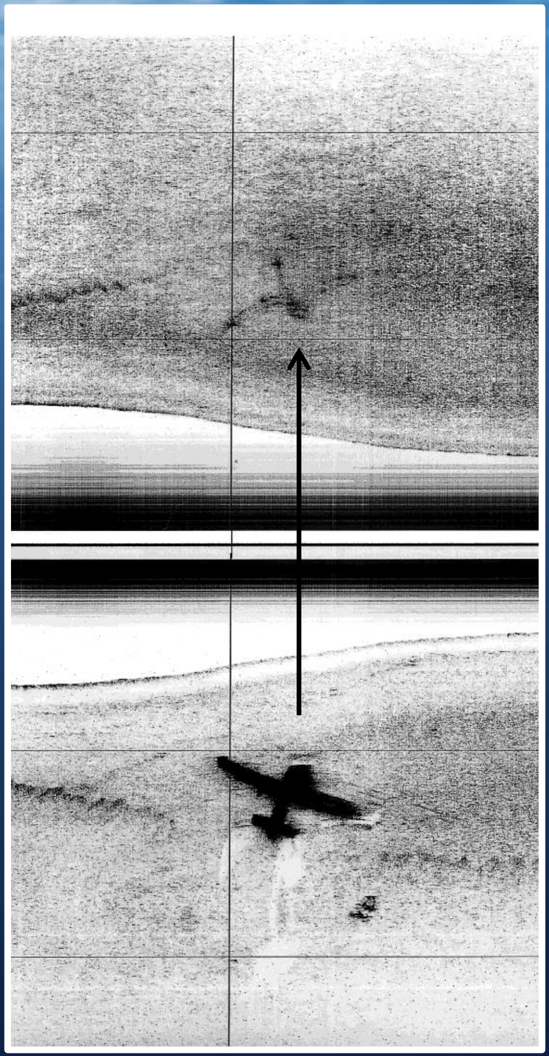


III. SSS Data Interpretation

Cross Talk

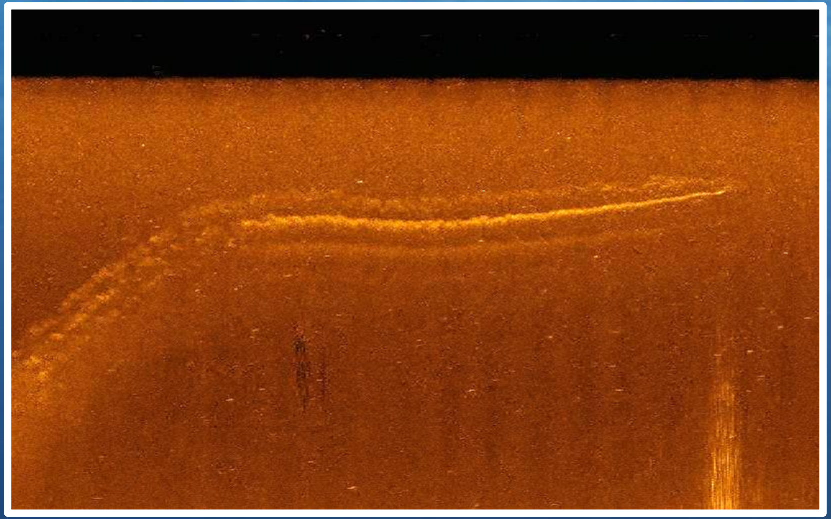
Strong Reflective Targets can Acoustically Cross-Talk to the other Channel

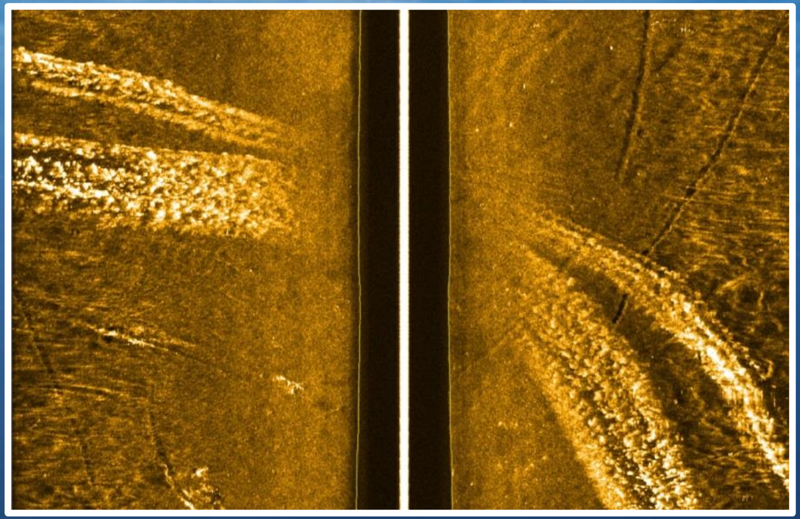


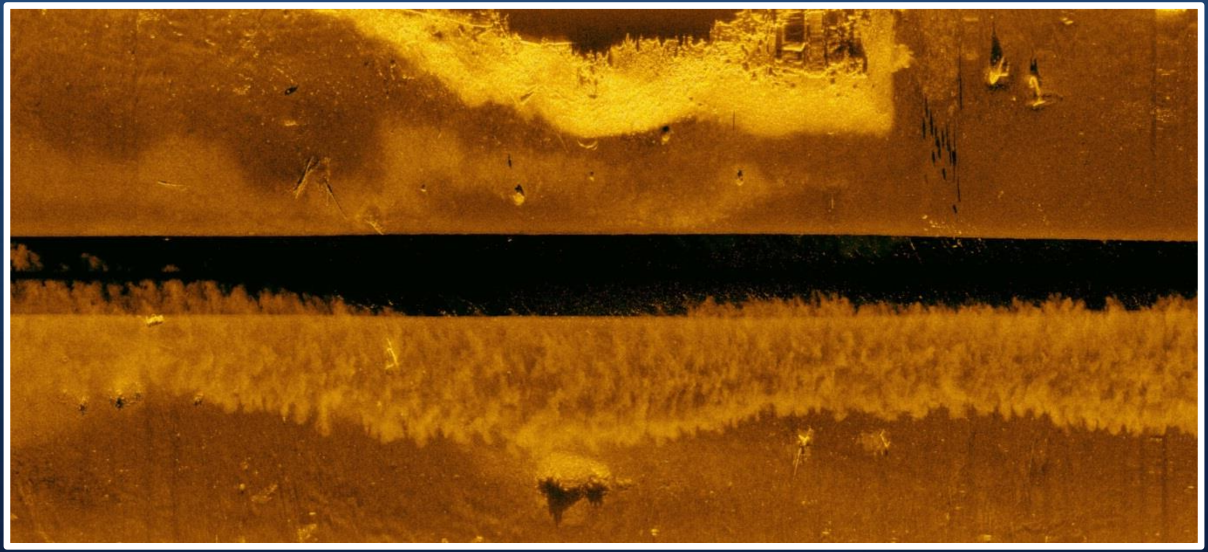


III. SSS Data Interpretation

Boat Turbulence

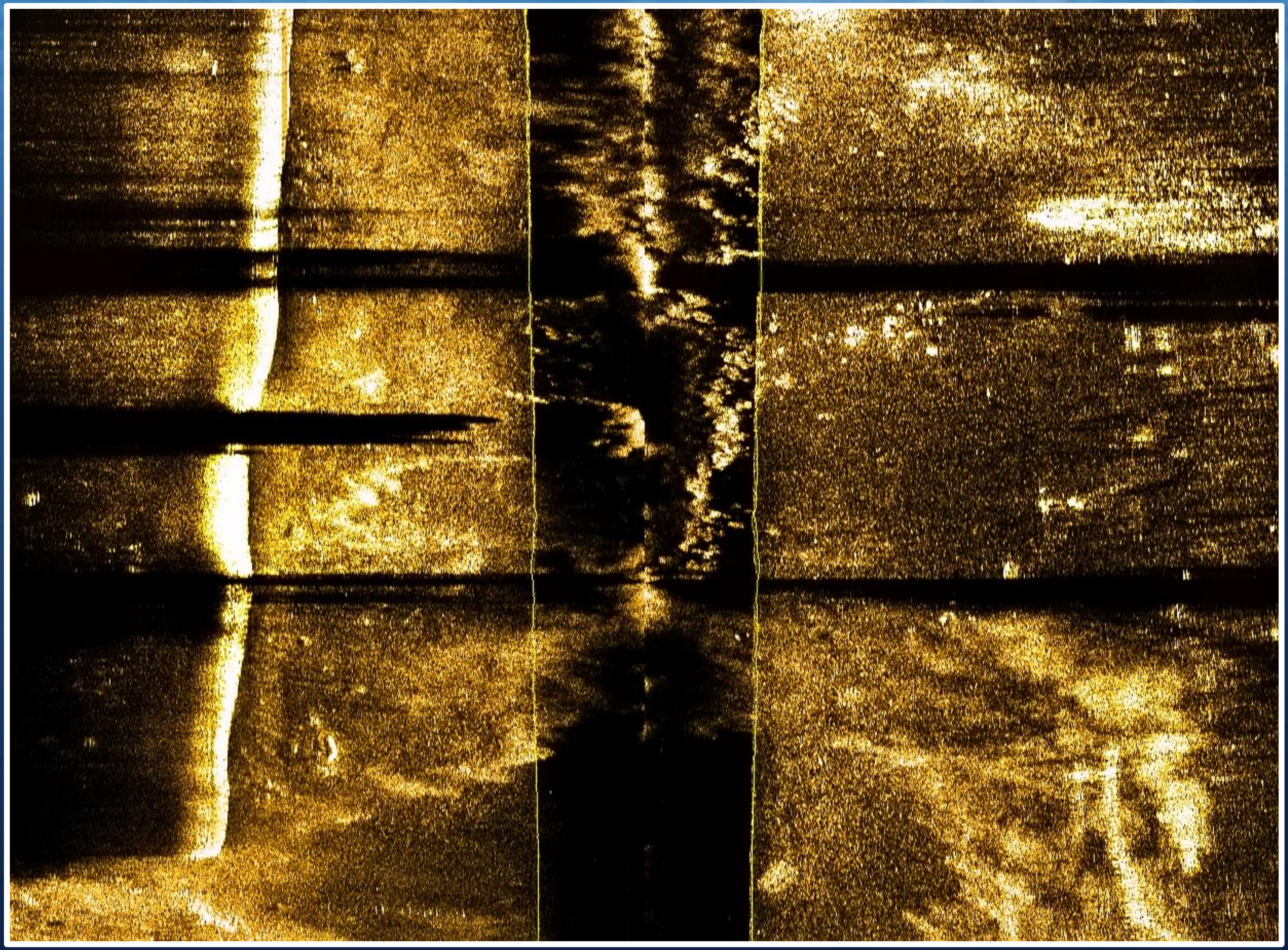






III. SSS Data Interpretation

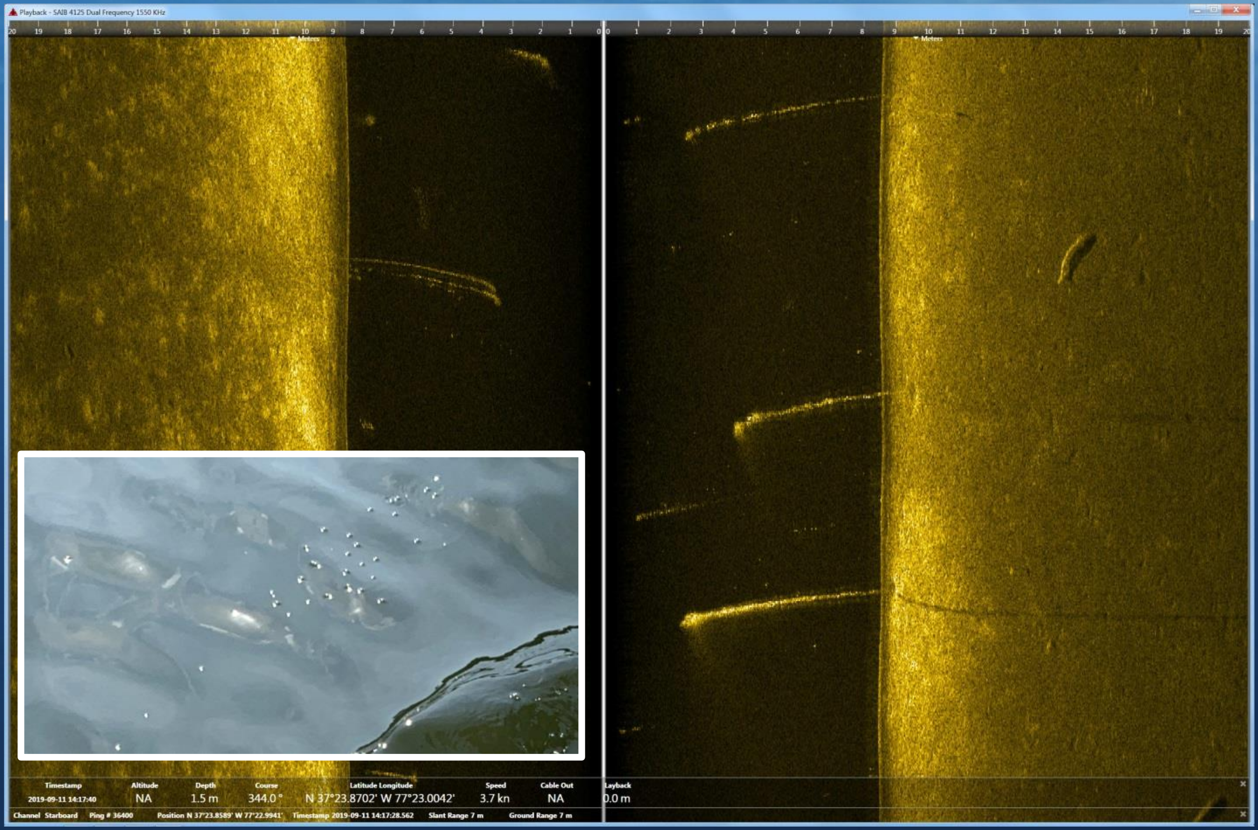
Quenching



III. SSS Data Interpretation

Gas Bubbles

6 inch Pipeline Gas Leak



Gas Leaking from Seafloor

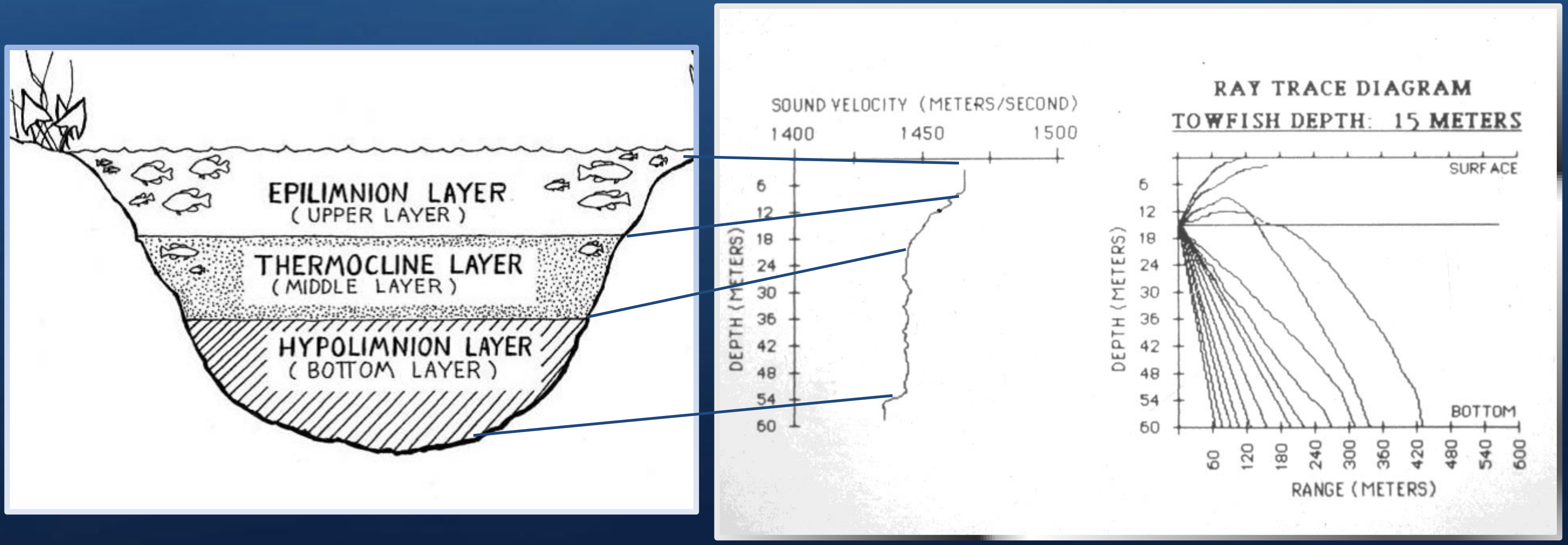
III. SSS Data Interpretation

Refraction

The bending or curving of a sound ray that results when the ray passes from a region of one sound velocity to a region of a different sound velocity

VELOCITY GRADIENT FACTORS

1. Temperature (most significant)
2. Salinity
3. Pressure (Depth)



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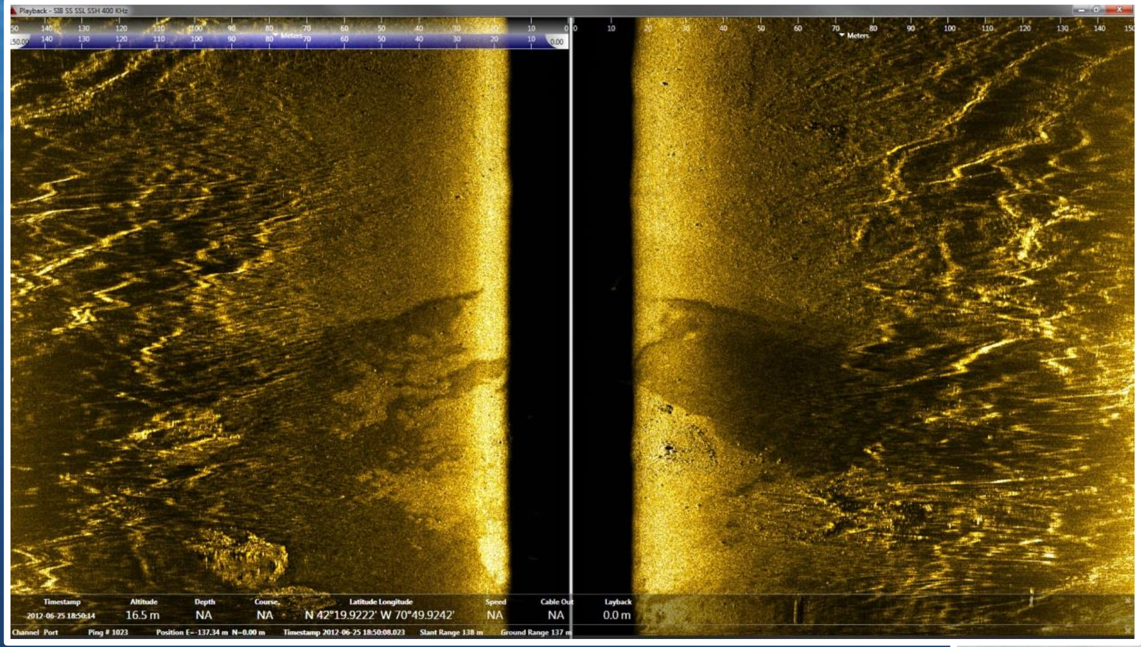
III. SSS Data Interpretation

Refraction



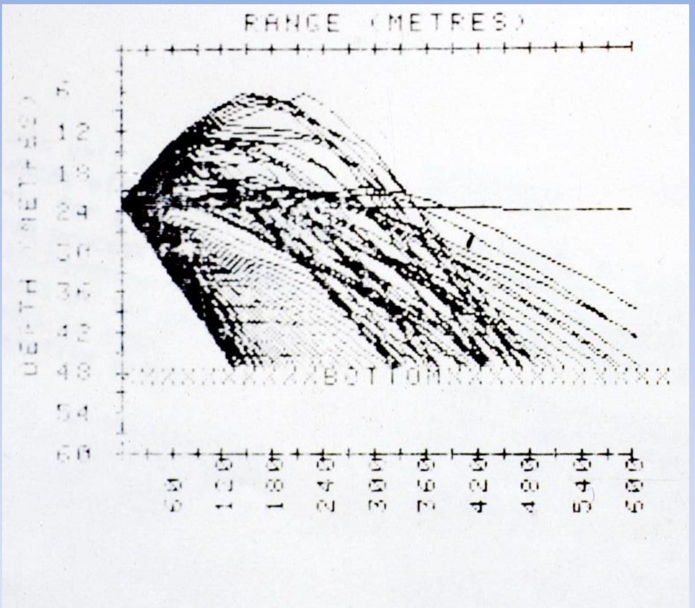
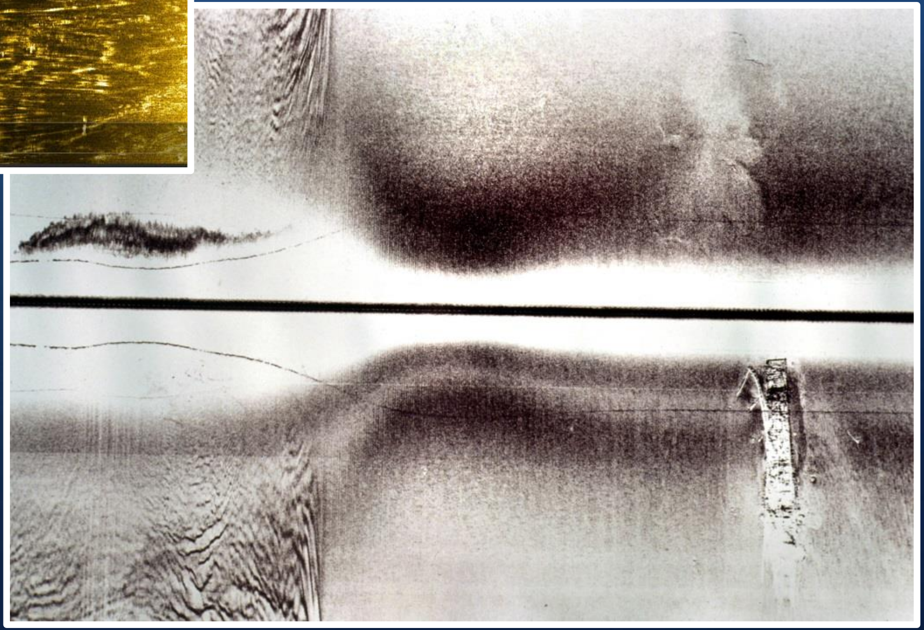


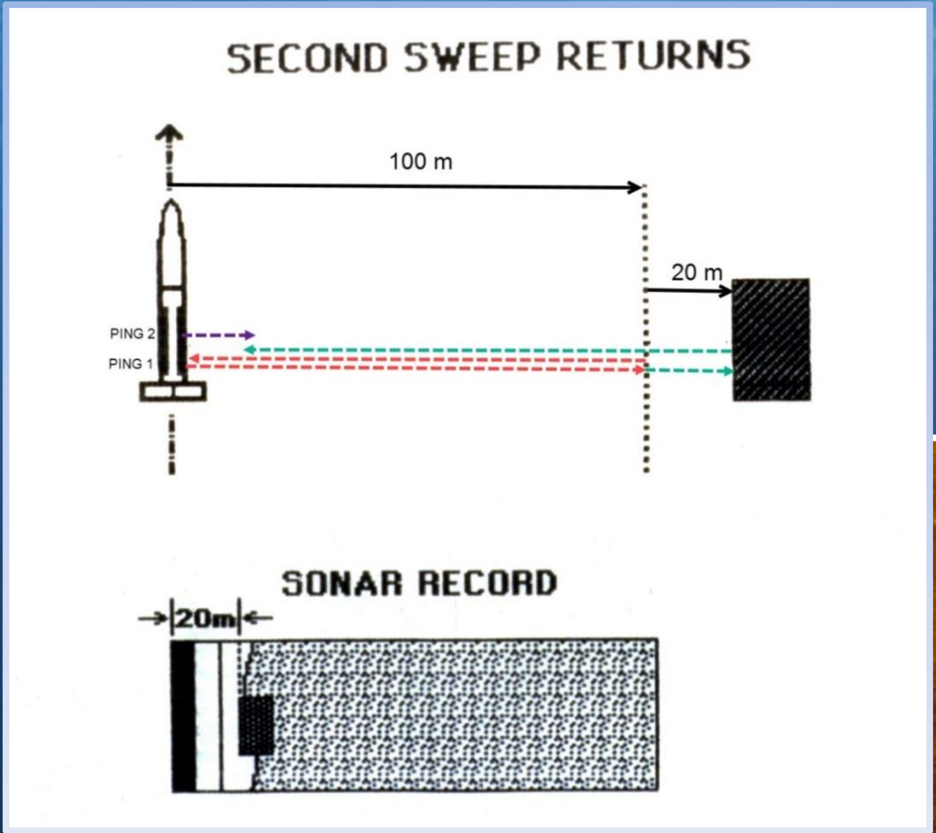
Figure 6. Ray-trace WA-018 (Fish at 23m)

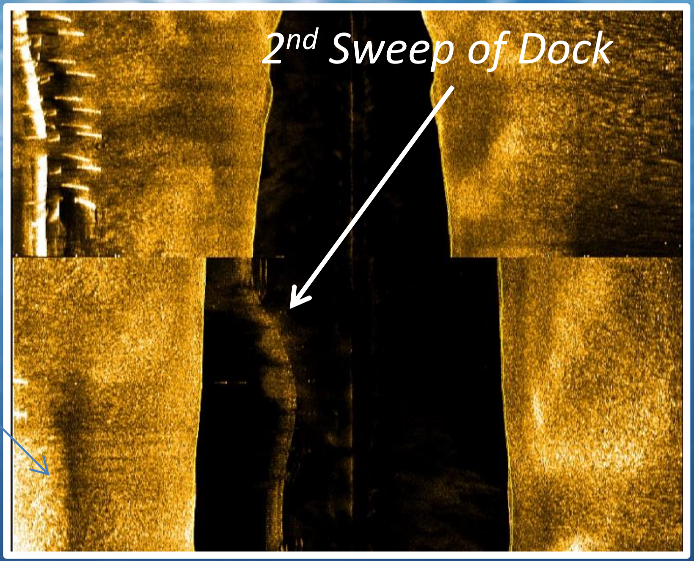


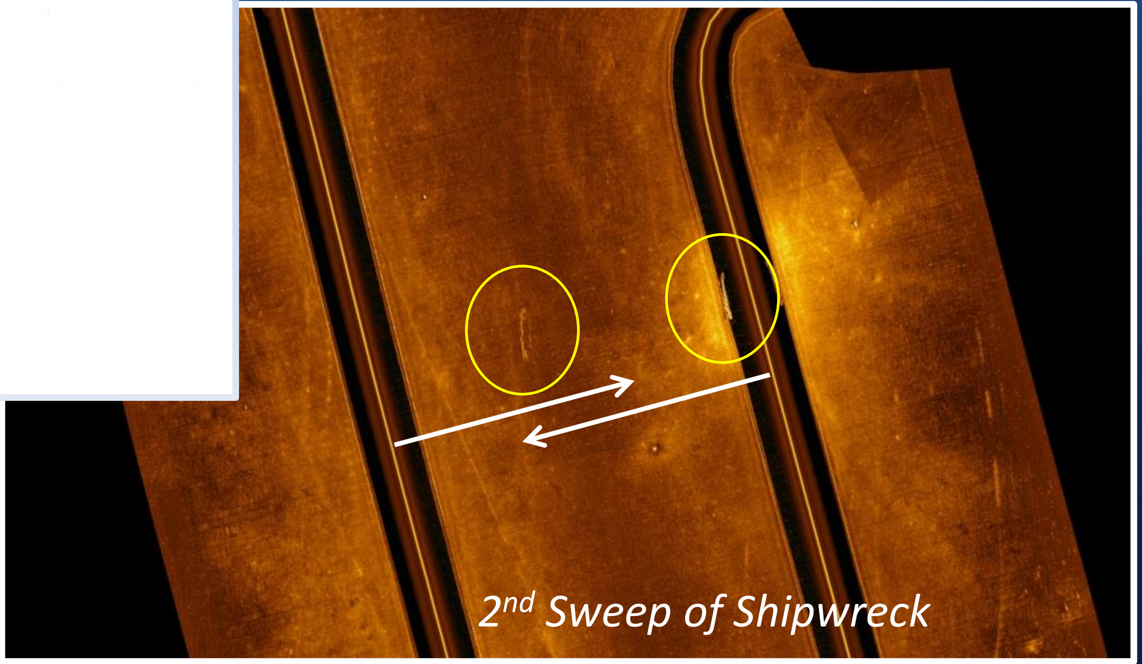
Refraction effects may be reduced by adjusting towfish depth

III. SSS Data Interpretation

2nd Sweep Return



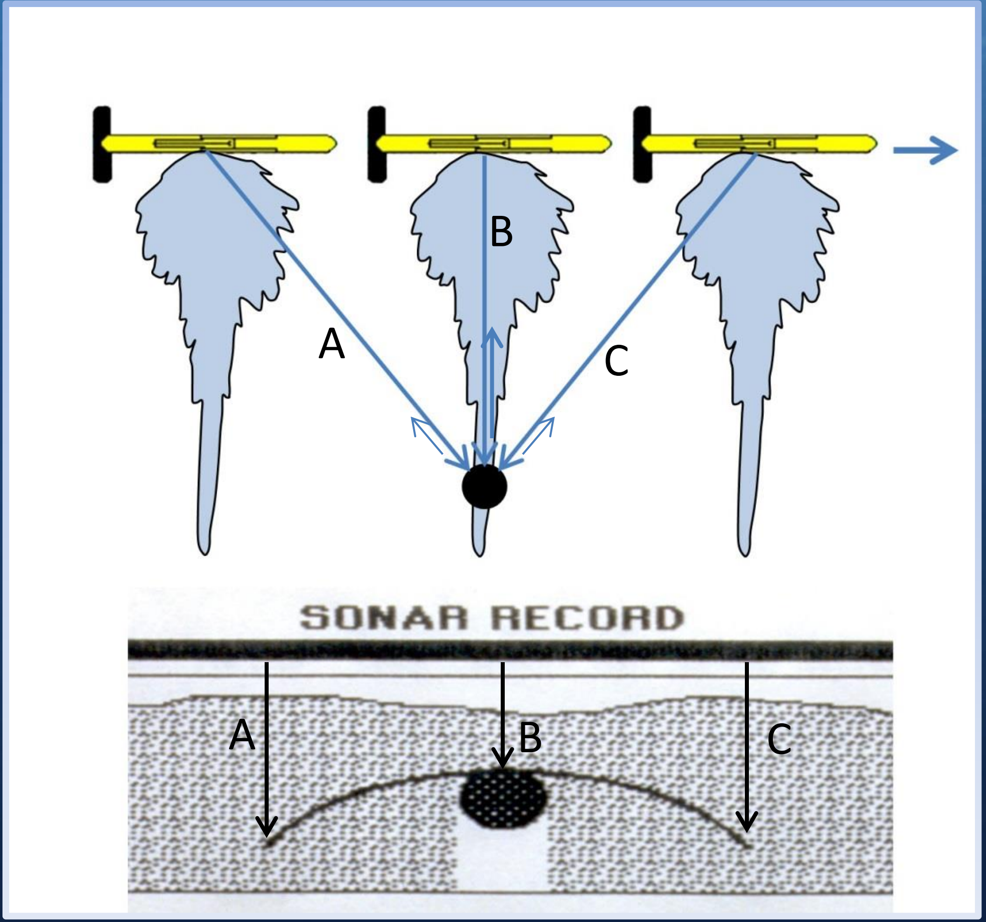


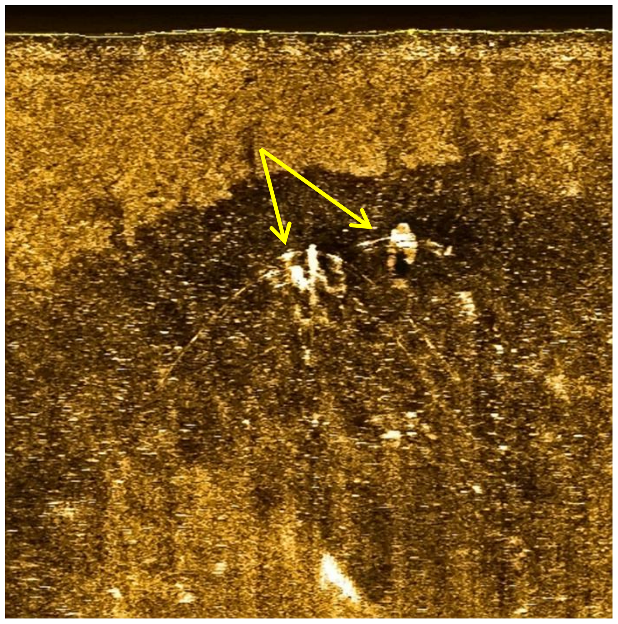


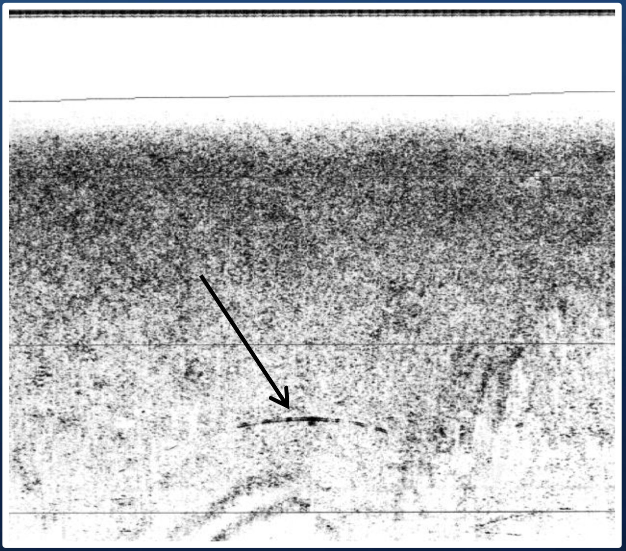
III. SSS Data Interpretation

Hyperbolic Artifact

Hyperbolic artifacts are produced from spherical or vertical cylindrical objects and shapes



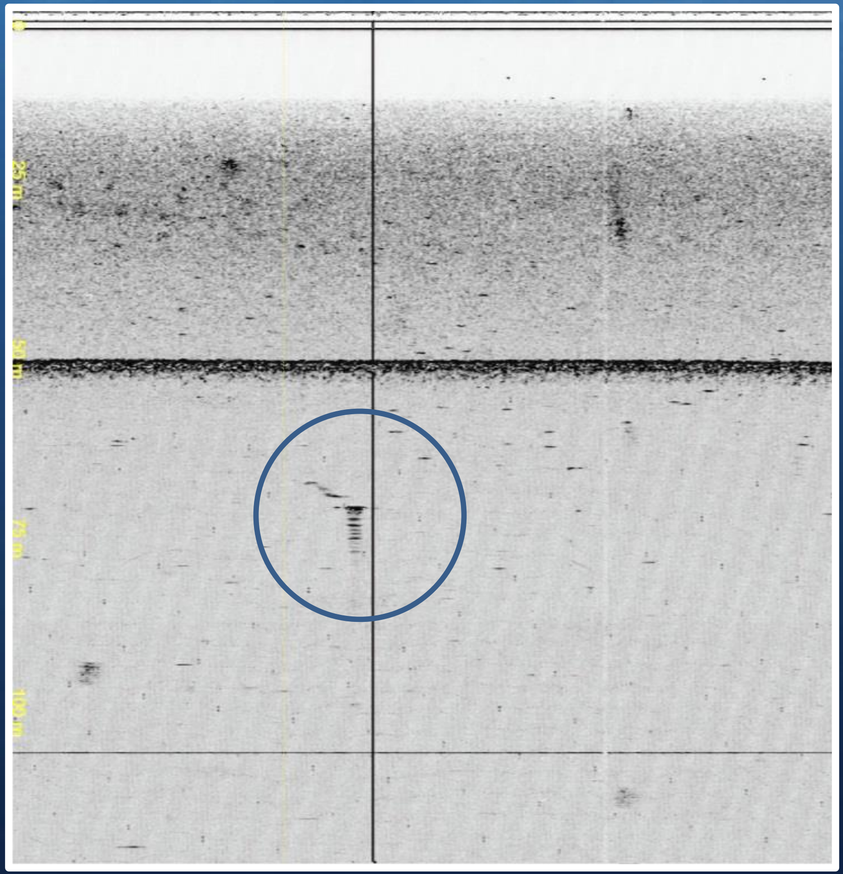


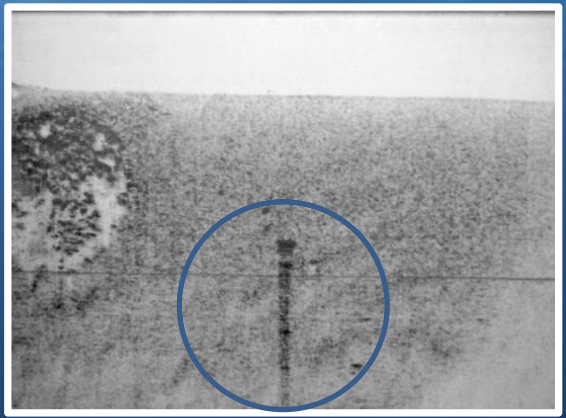


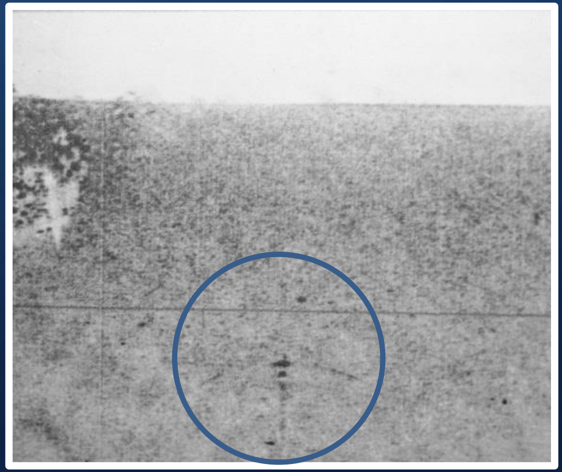
III. SSS Data Interpretation

Ringing

A water filled cavity such as a water filled steel drum when esonified by lower frequencies (ie 100 kHz)can produce an internal ringing artifact.





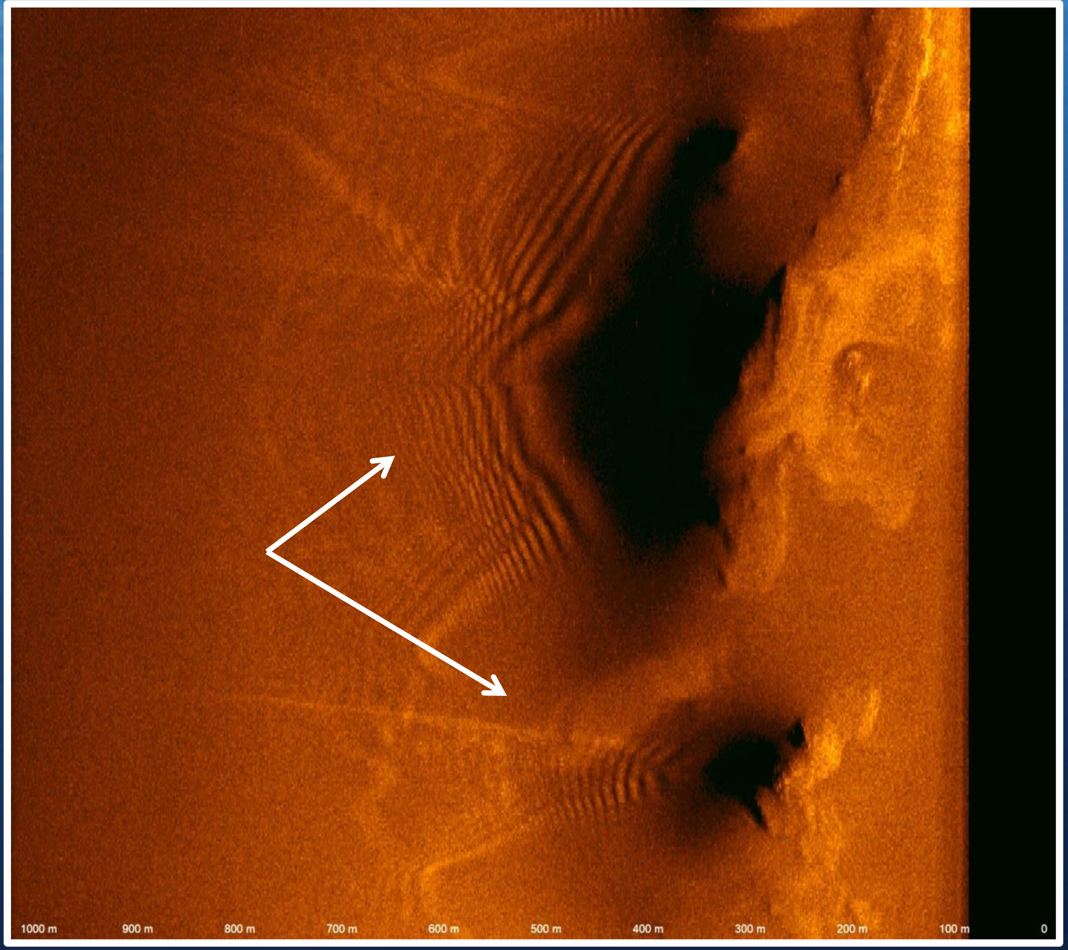


III. SSS Data Interpretation

Lloyd's Mirror Pattern

An interference pattern is produced as a result of the combination of the direct ray and reflected ray. This effect has been noted on low frequency, long range SSS data.

First documented in the publication "Sonographs of the Seafloor" By Belderson, Kenyon, Stride & Stubbs 1972

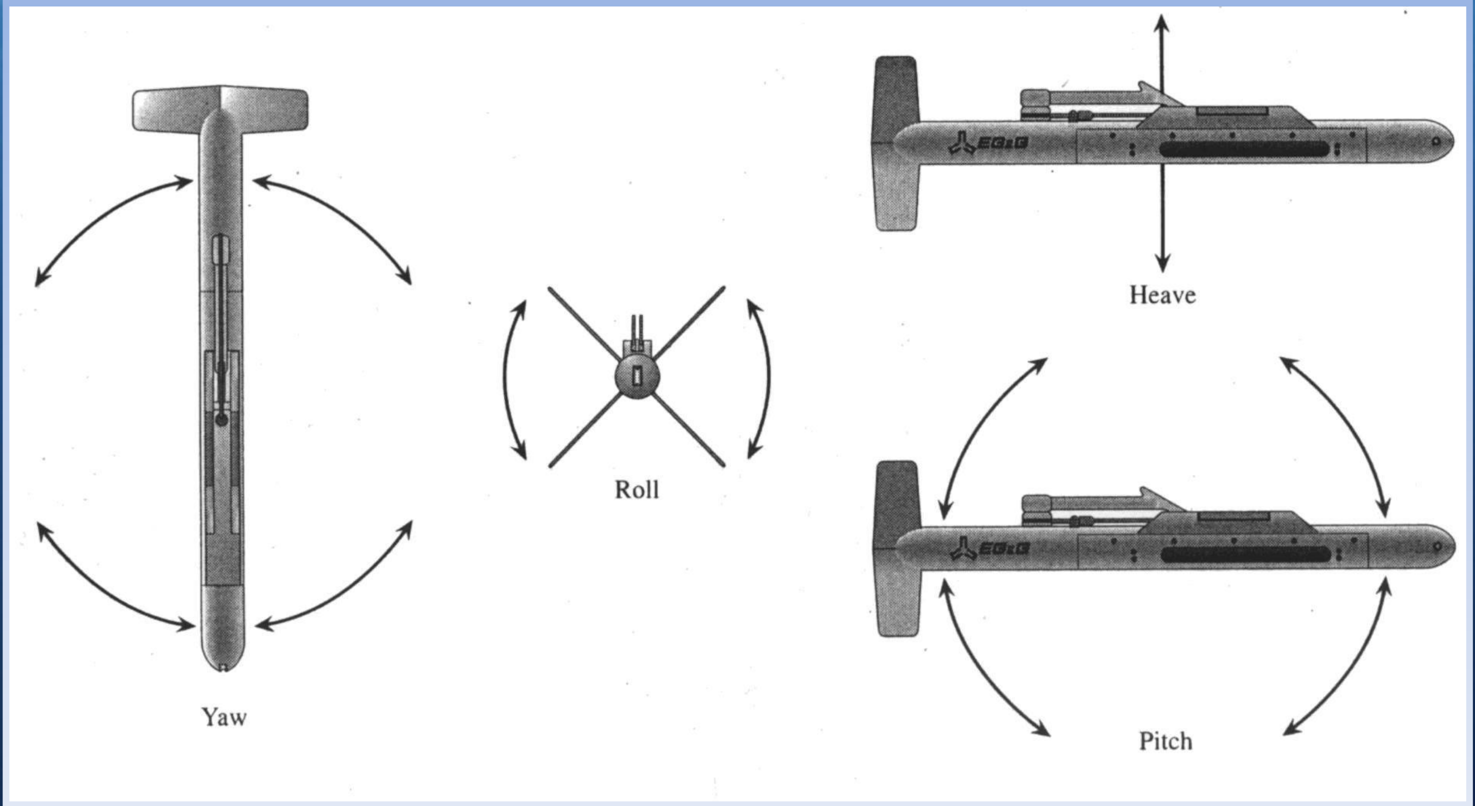


III. SSS Data Interpretation

Towfish Motion Distortion

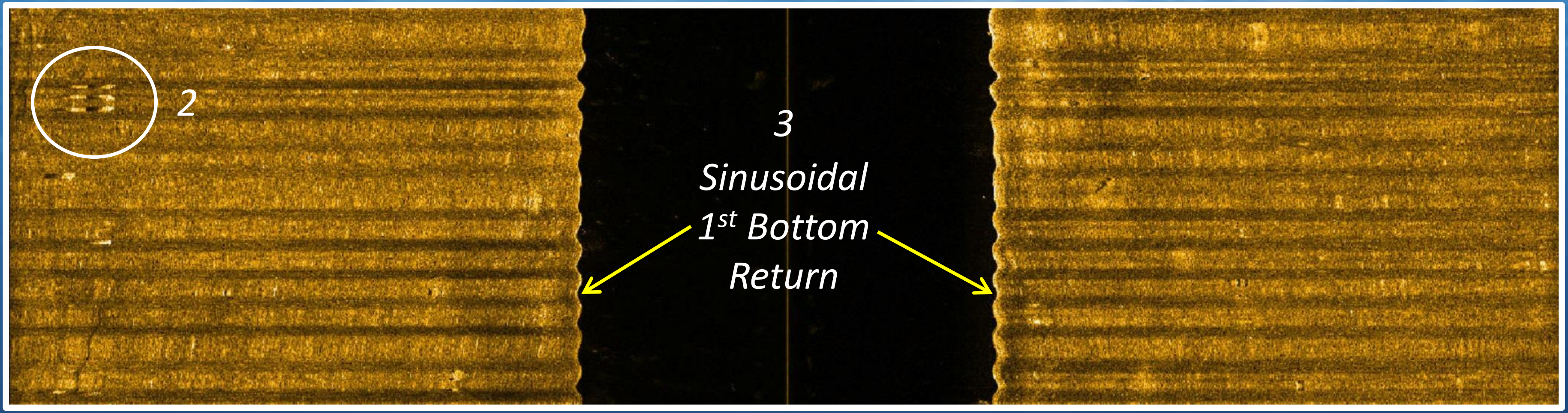
III. SSS Data Interpretation

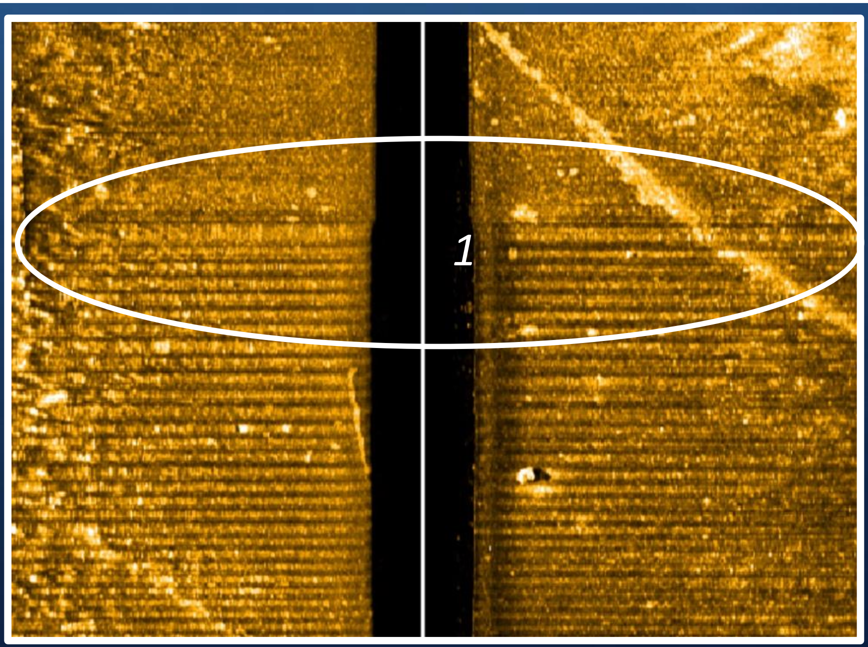
Towfish Motion Distortion



III. SSS Data Interpretation

Towfish Motion Distortion
Pitch





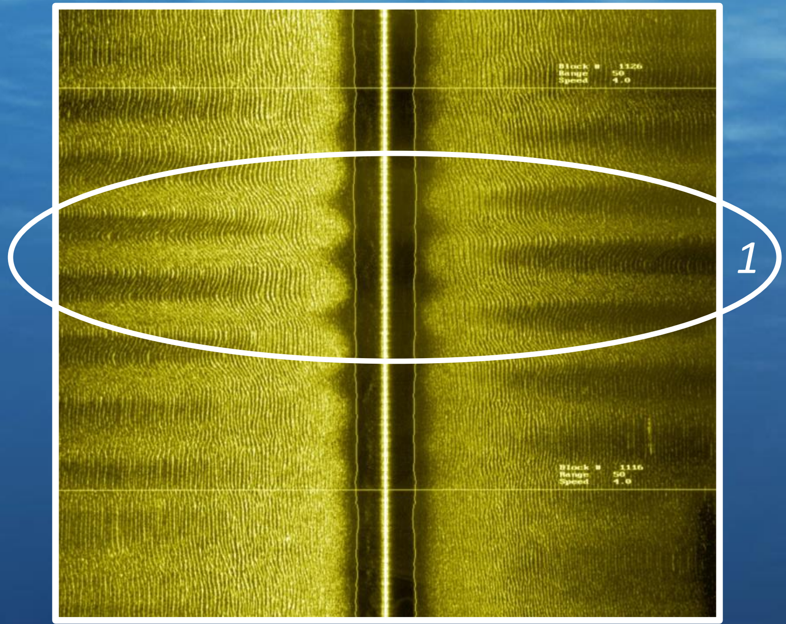
1. Synchronies Banding

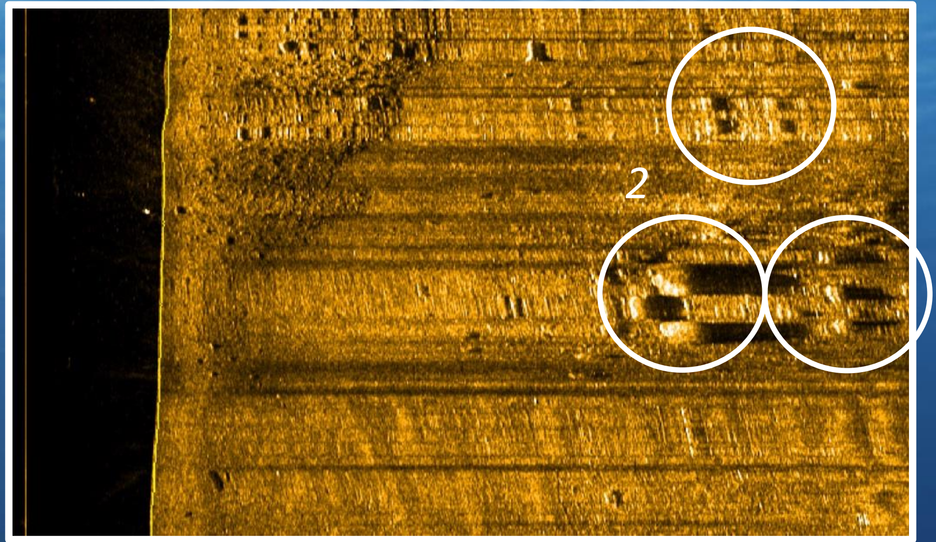
2.Multiple Targets

3. Sinusoidal 1st Bottom Return

III. SSS Data Interpretation

Towfish Motion Distortion
Yaw

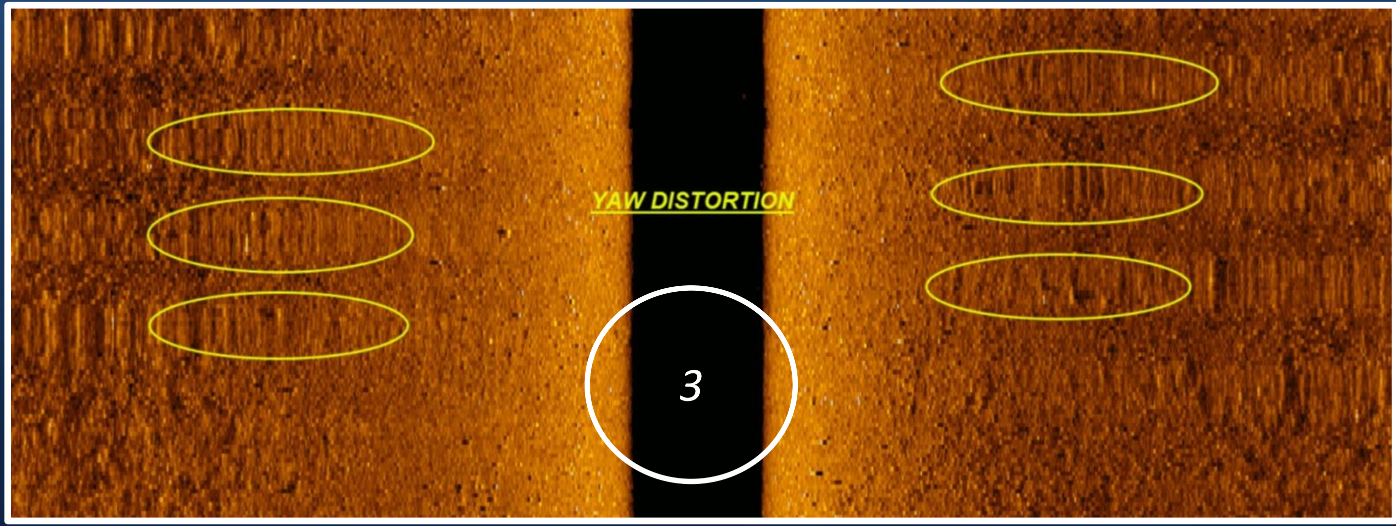




1. A-Synchronies Banding

2.Multiple Targets

3. Smooth 1st Bottom Return

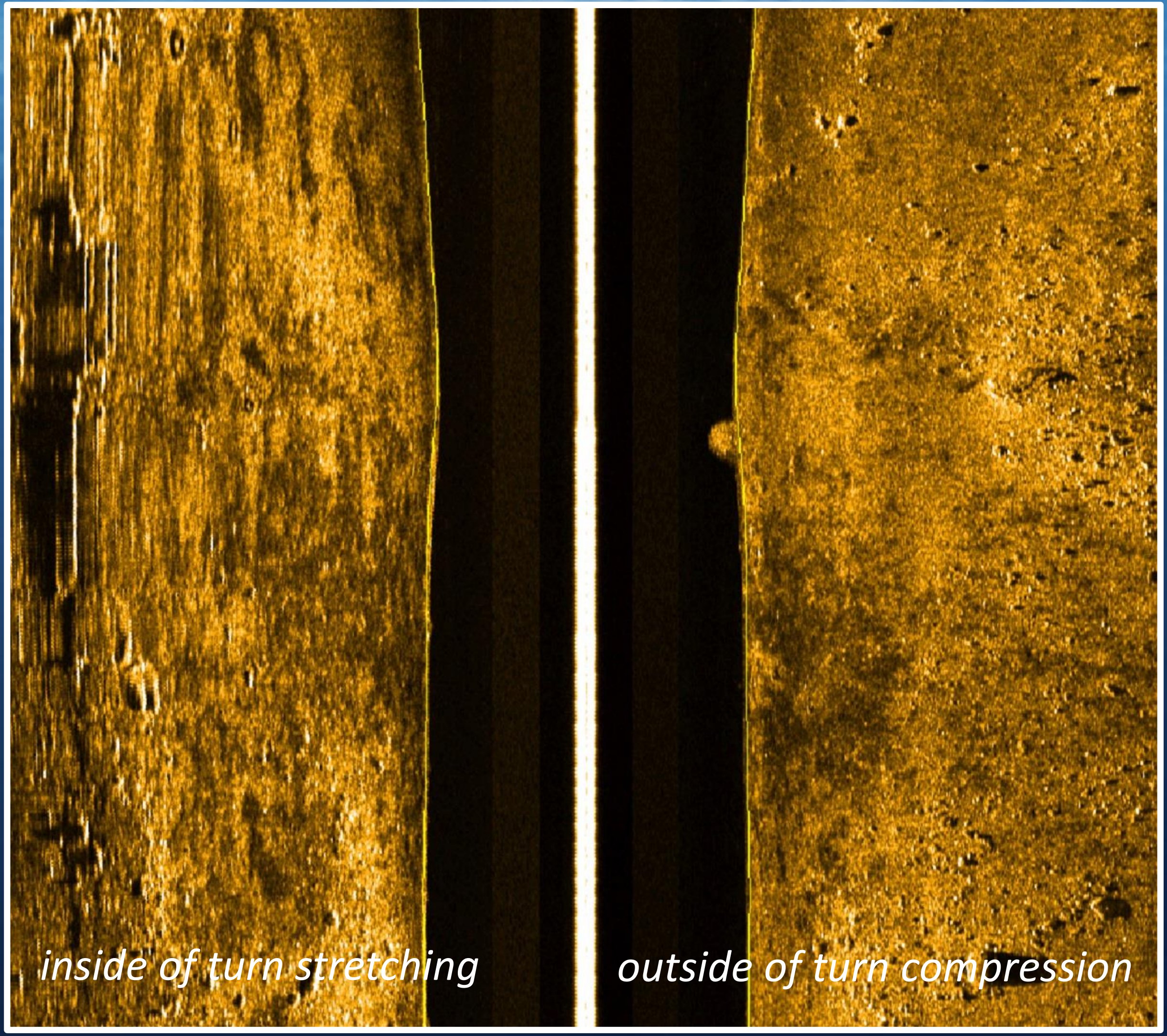


III. SSS Data Interpretation

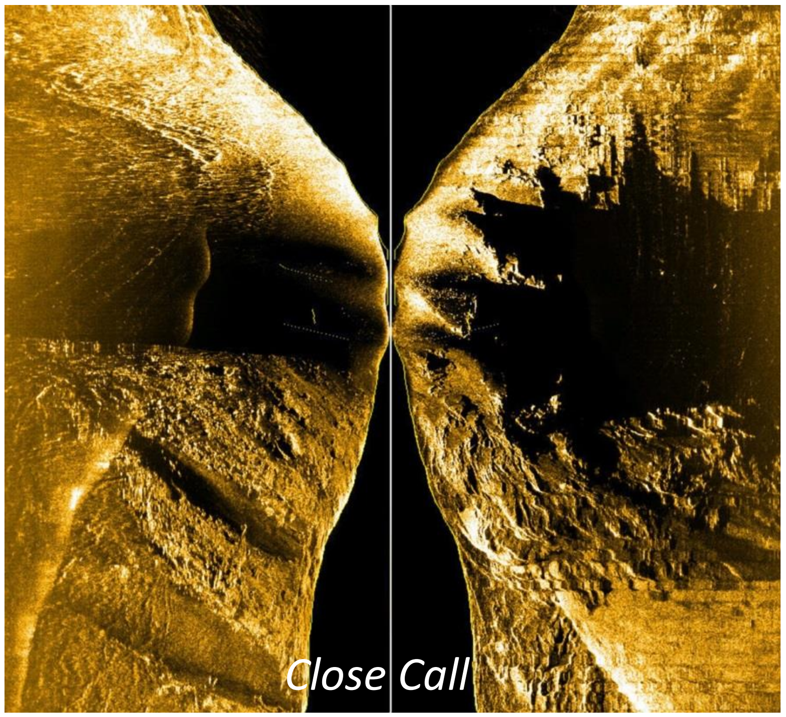
Towfish Motion Distortion
Turns

Turns cause feature stretching on inside of turn and feature compression on outside of turn

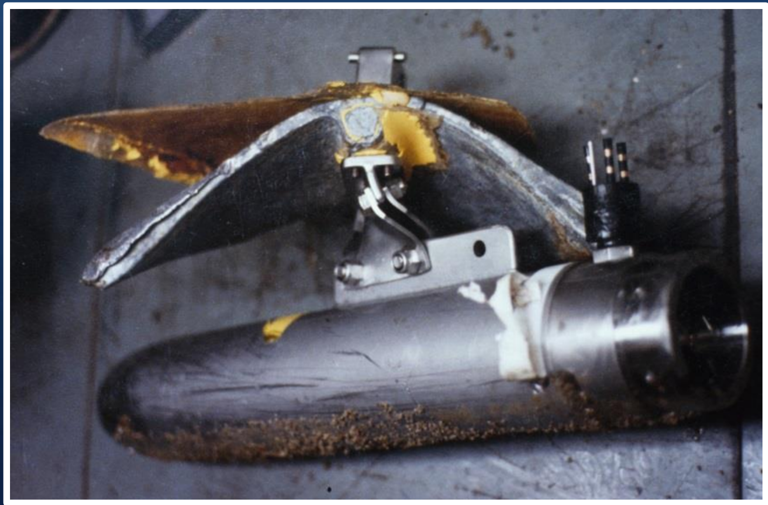
Do not use turn data in target analysis



III. SSS Data Interpretation



Hitting the Seafloor



III. SSS Data Interpretation

Noise

NOISE

Ambient

Self-Made

AMBIENT NOISE SOURCES

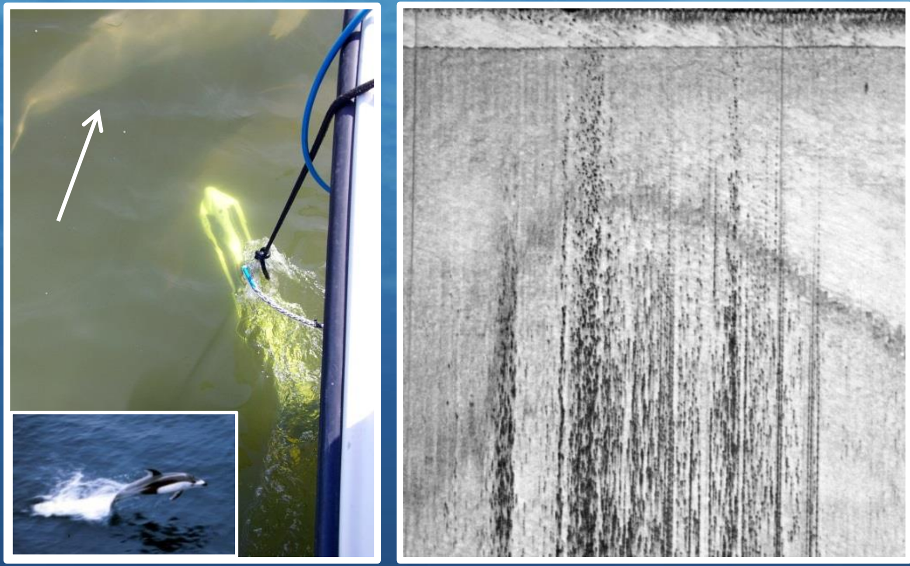
- Sea Surface
- Thermal
- Biological
- Rain
- Surf
- Flow
- Man-Made
- Terrestrial

SELF-MADE NOISE SOURCES

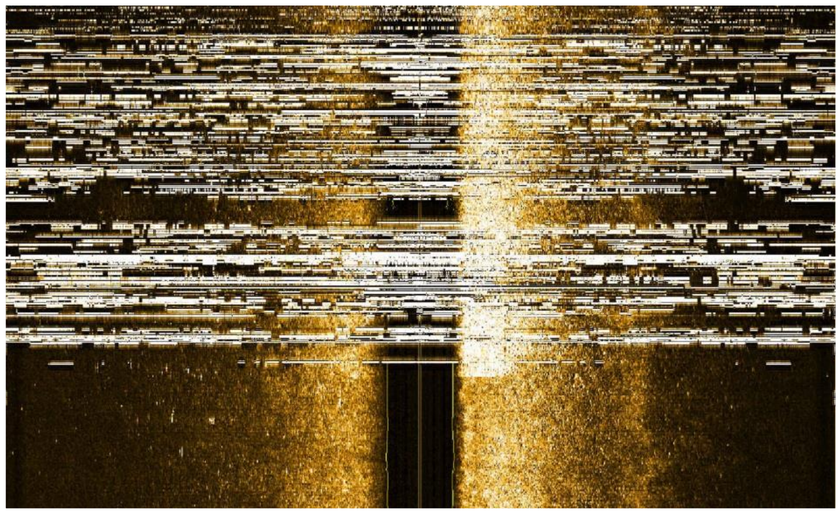
- Ship's Machinery
- Flow
- Other Instruments

III. SSS Data Interpretation

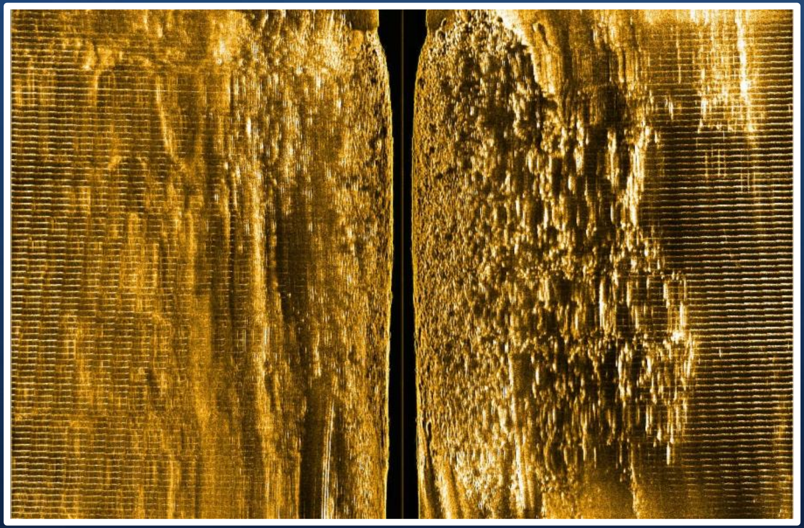
Noise



Porpoise Pings

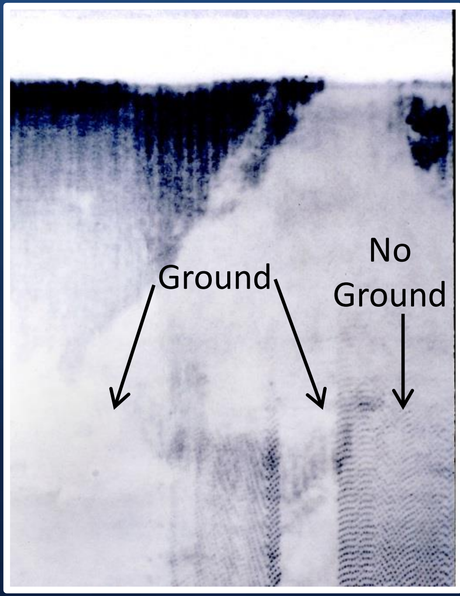


Electrical Noise: Slip Ring, Cable Failure, etc.



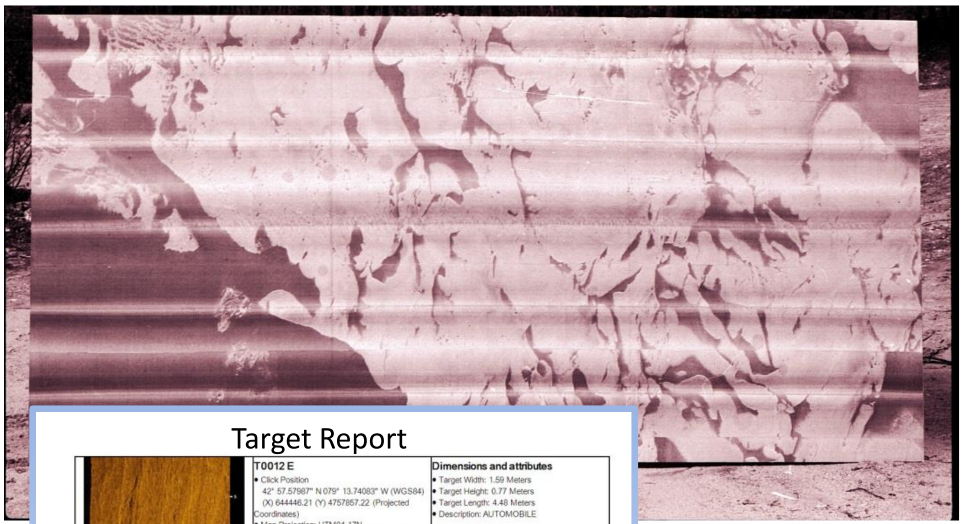
Echo Sounder Pings

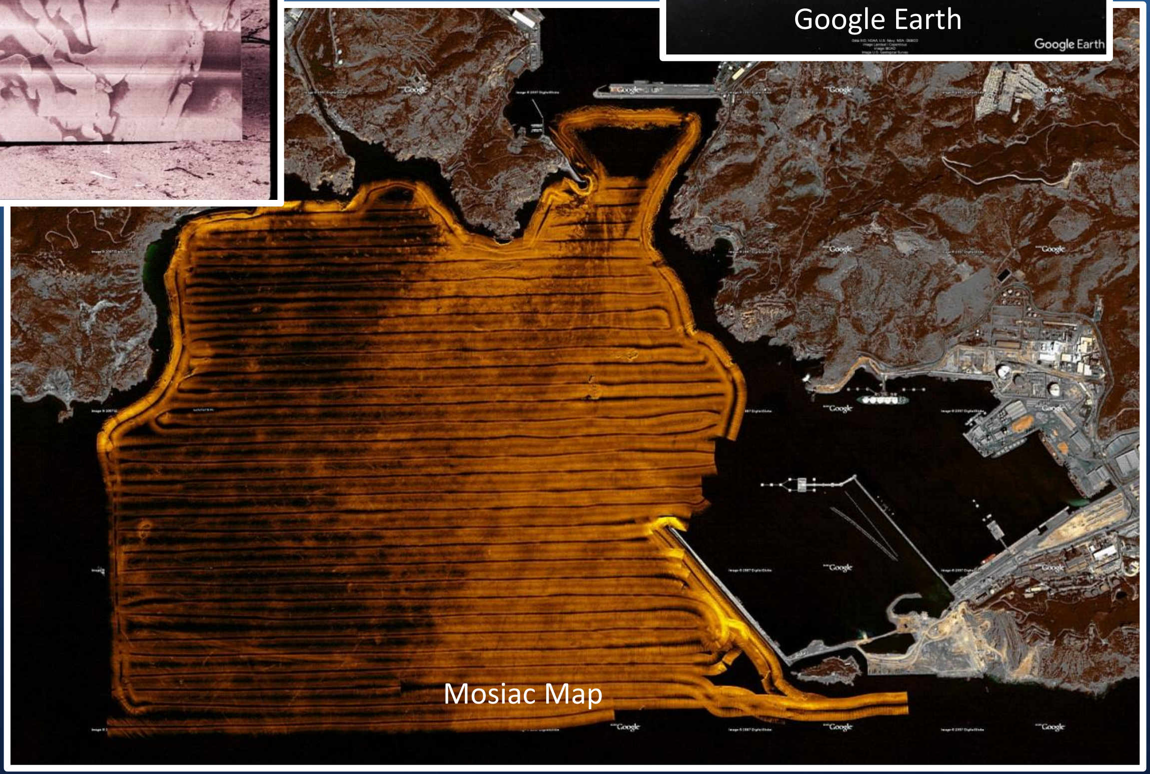
Sea Grounding the Sonar System

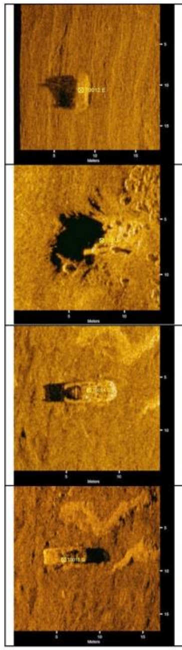


III. SSS Data Interpretation

Data Processing & Mosaics







Target Report

	T0012 E • Click Position 42° 57.57987" N 079° 13.74083" W (WGS84) (X) 644446.21 (Y) 4757857.22 (Projected Coordinates) • Map Projection: UTM84-17N • Acoustic Source File: C:\Users\GK\Desktop\St. Lawrence Seaway Demo\Welland Data\20190709171008.jsf • Range to target: 41.25 Meters • Fish Height: 8.74 Meters • Heading: 0.000 Degrees	**Dimensions and attributes** • Target Width: 1.59 Meters • Target Height: 0.77 Meters • Target Length: 4.48 Meters • Description: AUTOMOBILE
	T0013 F • Click Position 42° 57.49859" N 079° 13.77579" W (WGS84) (X) 644401.86 (Y) 4757705.77 (Projected Coordinates) • Map Projection: UTM84-17N • Acoustic Source File: C:\Users\GK\Desktop\St. Lawrence Seaway Demo\Welland Data\20190709171910.jsf • Range to target: 12.27 Meters • Fish Height: 8.18 Meters • Heading: 0.000 Degrees	**Dimensions and attributes** • Target Width: 4.92 Meters • Target Height: 0.00 Meters • Target Length: 5.59 Meters • Description: HOLE WITH WHAT APPEARS A PIPE
	T0014 G • Click Position 42° 57.47997" N 079° 13.75798" W (WGS84) (X) 644426.81 (Y) 4757671.82 (Projected Coordinates) • Map Projection: UTM84-17N • Acoustic Source File: C:\Users\GK\Desktop\St. Lawrence Seaway Demo\Welland Data\20190709171910.jsf • Range to target: 19.08 Meters • Fish Height: 8.64 Meters • Heading: 0.000 Degrees	**Dimensions and attributes** • Target Width: 1.80 Meters • Target Height: 1.16 Meters • Target Length: 4.98 Meters • Description: AUTOMOBILE
	T0015 G • Click Position 42° 57.48114" N 079° 13.75358" W (WGS84) (X) 644432.74 (Y) 4757674.11 (Projected Coordinates) • Map Projection: UTM84-17N • Acoustic Source File: C:\Users\GK\Desktop\St. Lawrence Seaway Demo\Welland Data\20190709174357.jsf • Range to target: 28.35 Meters • Fish Height: 10.59 Meters • Heading: 0.000 Degrees	**Dimensions and attributes** • Target Width: 0.00 Meters • Target Height: 0.00 Meters • Target Length: 0.00 Meters • Description: AUTOMOBILE

IV. Field Operations

Operational Considerations

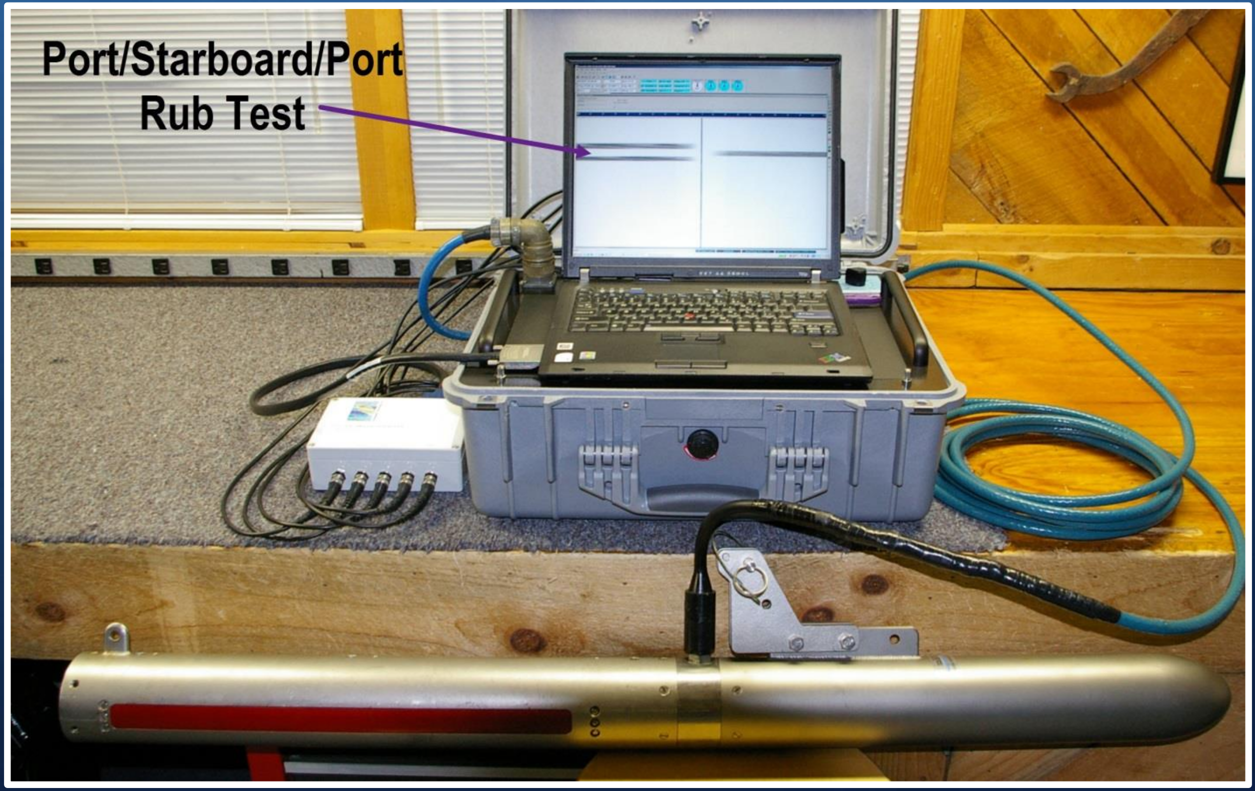
- *Mobilization Systems Check*
- *Pre-Survey Start "House Keeping"*
- *Survey Platform*
- *Towfish Frequency*
- *Range Scale*
- *Towing Speed*
- *Towfish Altitude*
- *Towing Method*
- *Towfish Deployment*
- *Cable Type*
- *Depressor*
- *Towfish Positioning*

IV. Field Operations

Mobilization Systems Check

When a system is mobilized for a search or survey, it is wise to completely assemble and connect every component and test that it is 100% operational. A "RUB TEST" is an important part of the test.

NOTE: Do not operate towfish in air for more than 30 mintes due to possible electronics overheating.



<u>IV. Field Operations</u>

Pre-Survey Start Housekeeping

- *Confirm GPS Navigation Input to Sonar*
- *Input to Sonar Software the X,Y,Z offsets from GPS Antenna to Towcable Tow Point*
- *Interface Cable counter to Sonar Software & Confirm operation OR Manually Input Cable out if no counter.*
- *Select Towfish Frequency*
- *Decide on Range Scale*
- *Decide Towing Speed*
- *Towfish Altitude*
- *If data is being used to create a mosaic, record each survey line as a single data file.*
- *When collecting data, <u>NEVER</u> select slant range correction to display the waterfall data. This cuts out the water column and you will not be able to monitor true towfish altitude off the seafloor.*

BE SURE TO START DATA LOGGING (Recording) <u>BEFORE</u> LINE START.

IV. Field Operations

Platform Selection

- STABLE PLATFORM
- LOW SPEED
- RESPONSIVE
- LOW NOISE OUTPUT
- CLEAN POWER
- ROOM FOR SIDE SCAN SONAR
- GOOD COMMUNICATIONS TO HELM
- HANDLING EQUIPMENT: A-FRAME, WINCH, ETC
- AIR CONDITIONING OR HEATED
- COFFEE, LOTS OF COFFEE

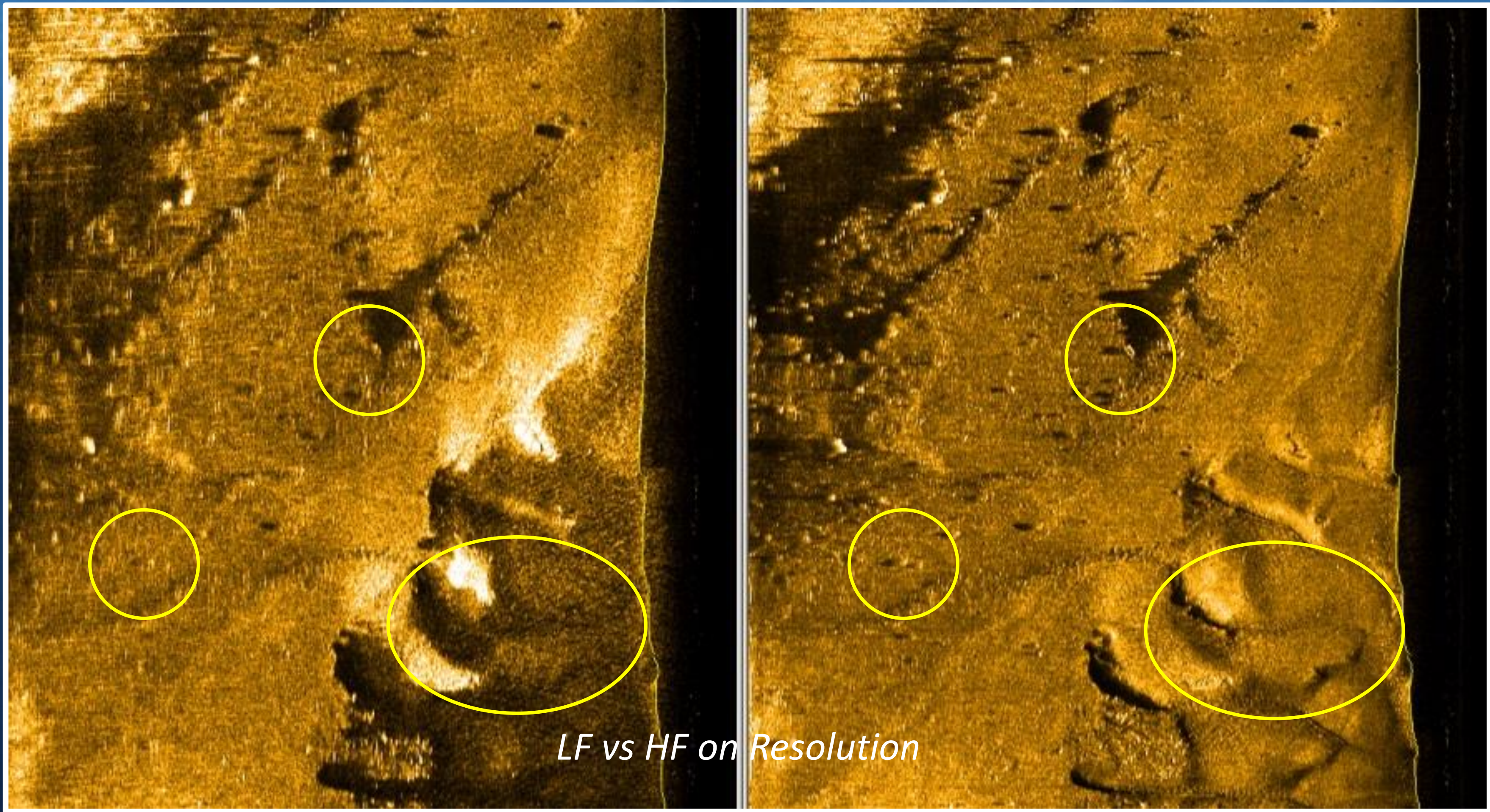
IV. Field Operations

Survey Platforms

IV. Field Operations

Range / Resolution Tradeoff

- Low Frequency gives long range but lower resolution
- High Frequency gives higher resolution but less range



LF vs HF on Resolution

IV. Field Operations

Towfish Altitude

General Surveying: 10% to 15% of the sonar range scale

Small Object Search: 5% to 10% of the sonar range scale

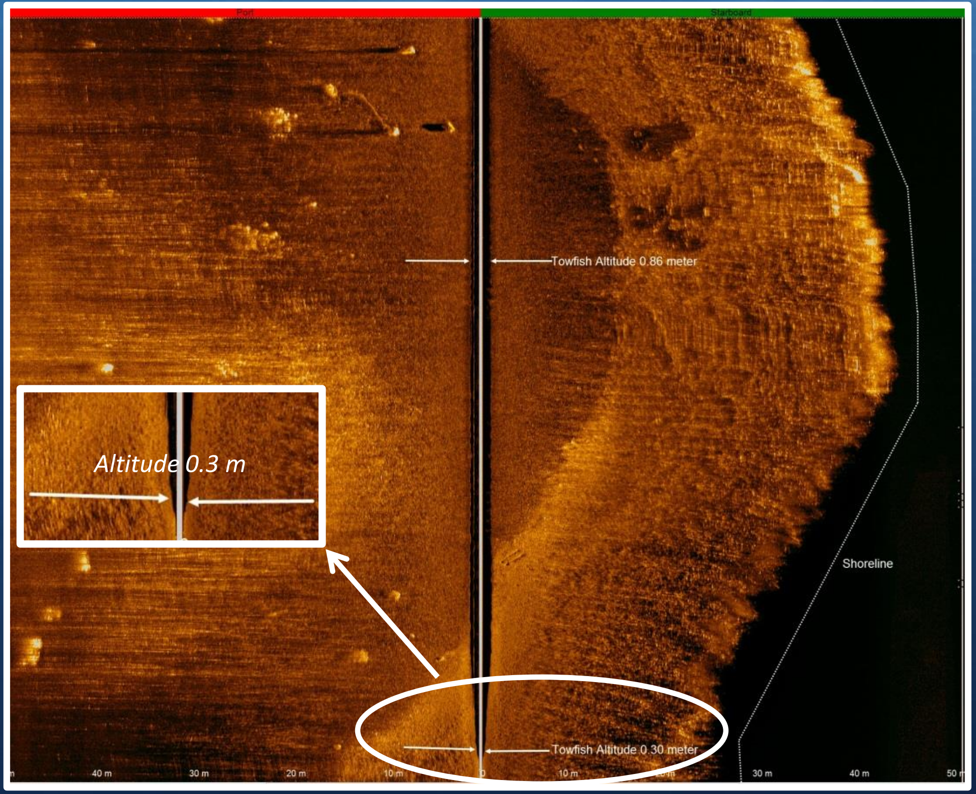
Mosaics: 10% to 20% of the sonar range scale

COMMON SENSE MUST BE USED IN RUGGED TERRAIN

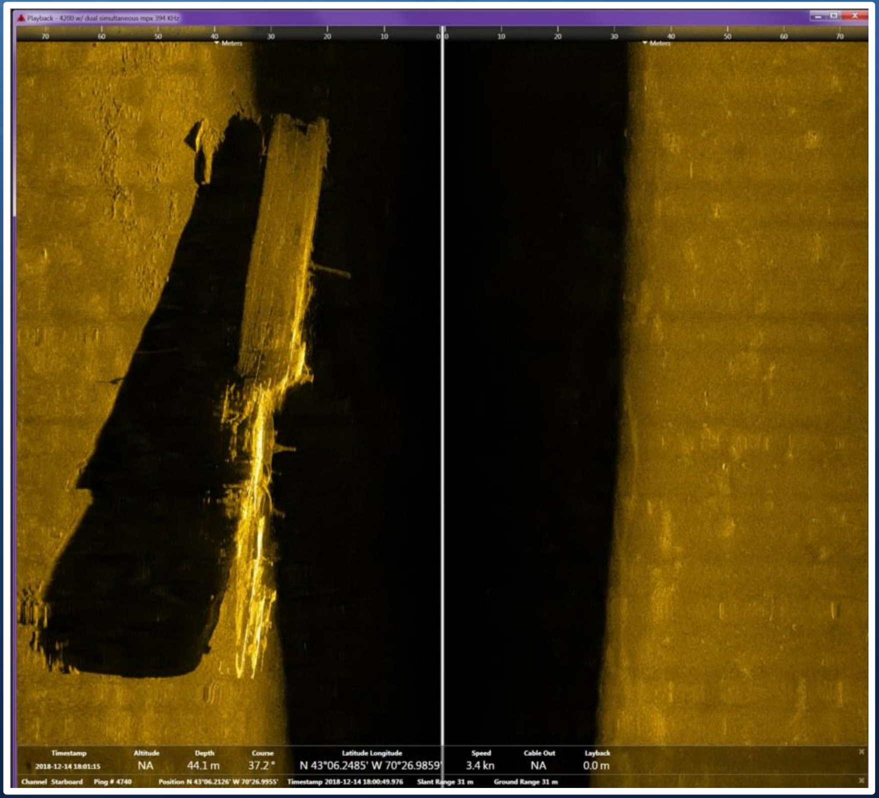
IV. Field Operations

Towfish Altitude – How Low, How High ?

Altitude Less Than 1% of Range Scale



Altitude Greater Than 40% of Range Scale

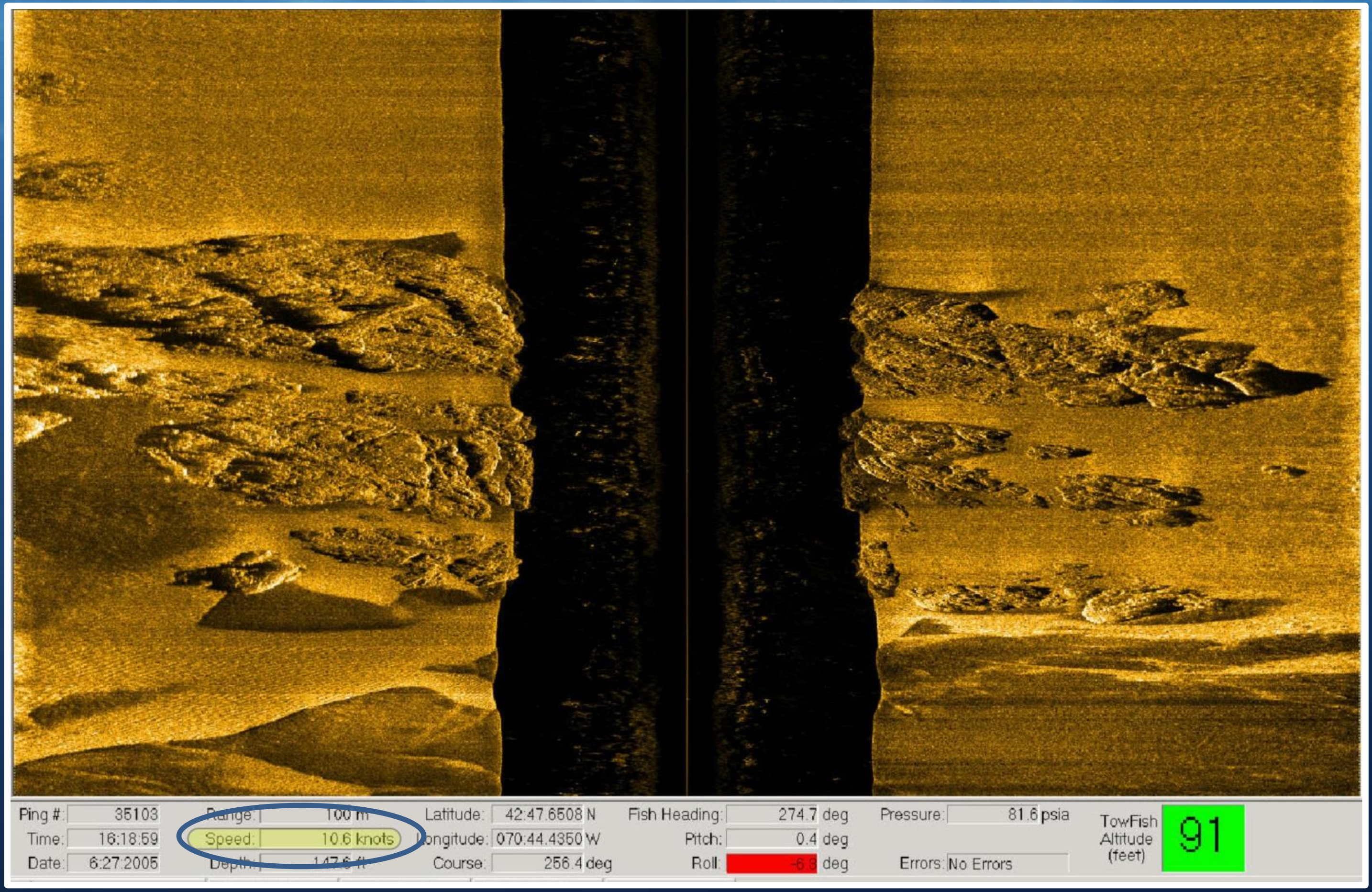


IV. Field Operations

Towing Speed

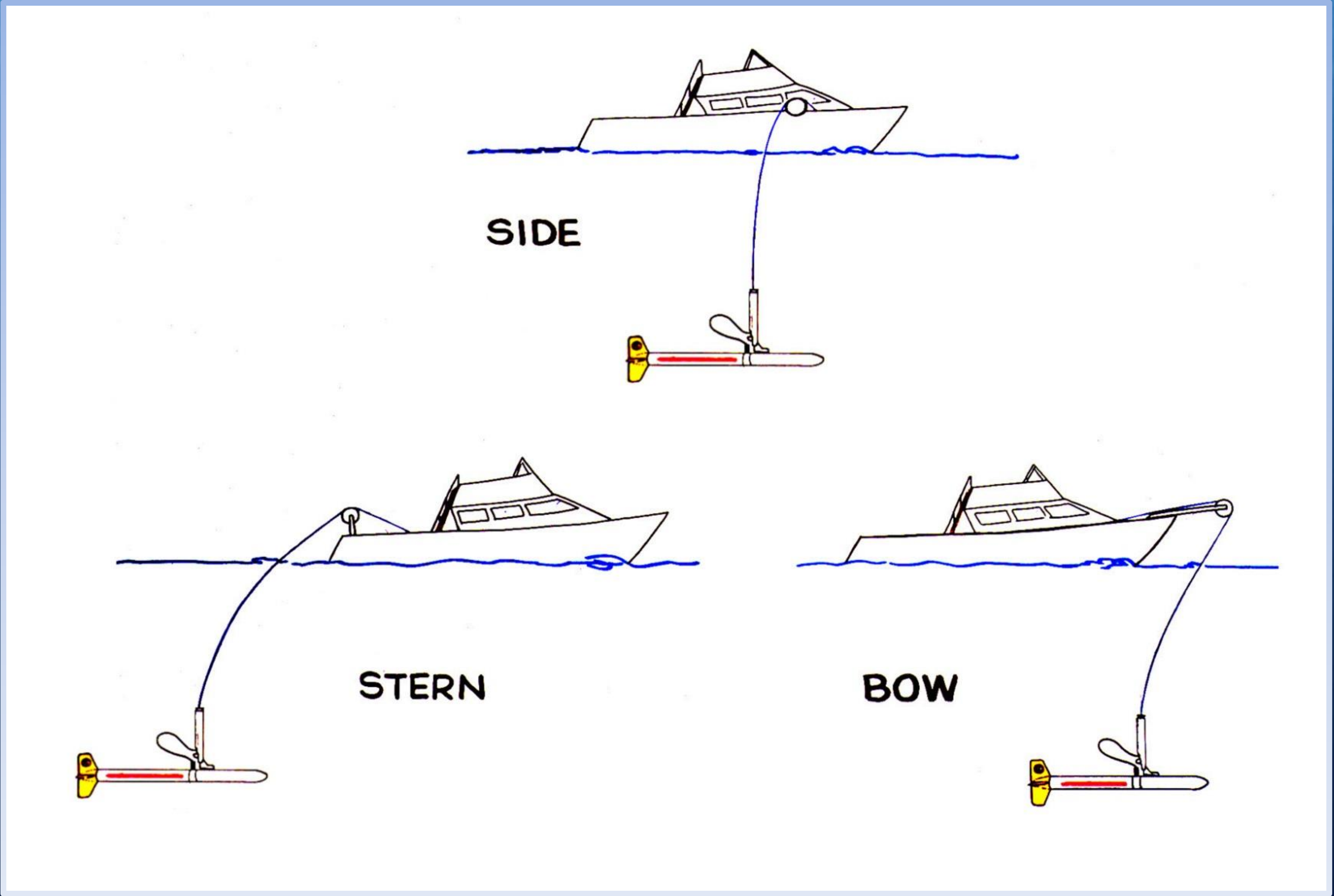
The best tow speed for the sonar is from 2.5 to 5 knots.

However acceptable data can still be made at higher tow speeds.



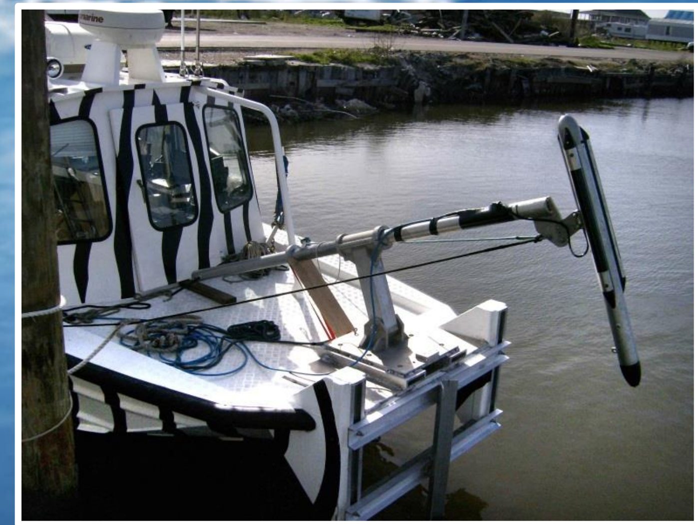
IV. Field Operations

Towing Methods



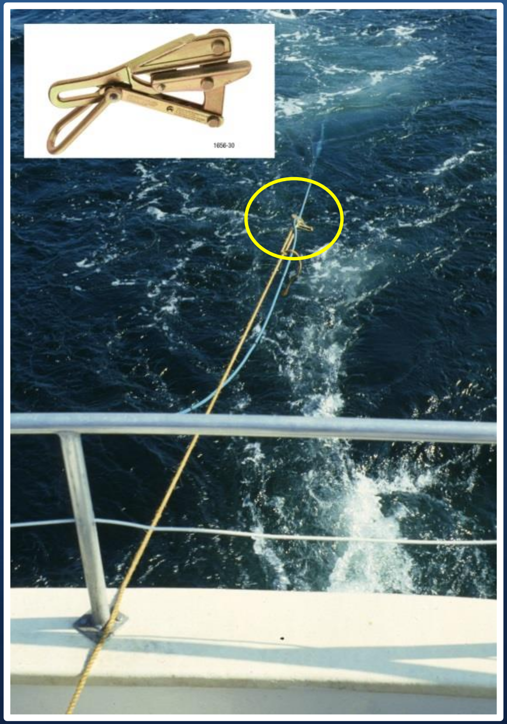
IV. Field Operations

Towing Methods



IV. Field Operations

Cable Types, Winches, Cable Counters, & Slip Rings



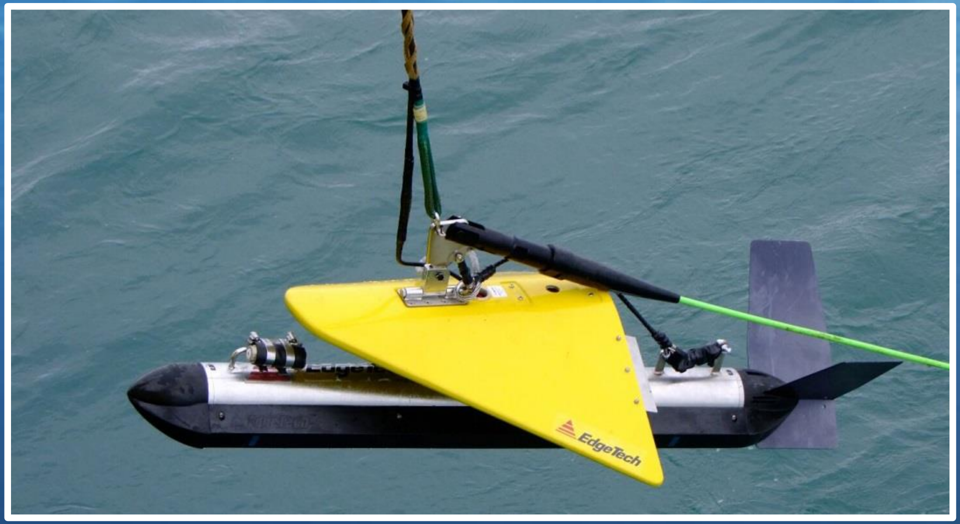
IV. Field Operations

Towfish Deployment

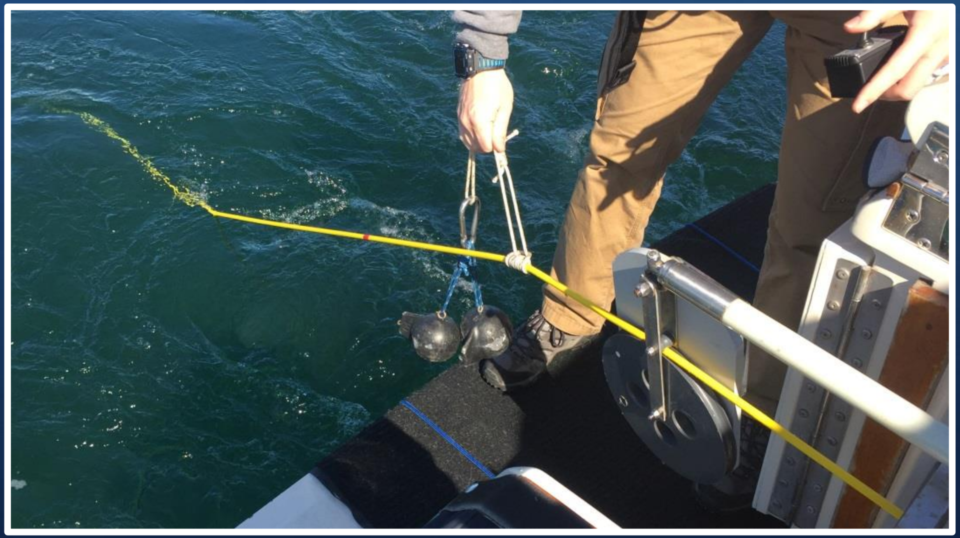
Points to be considered for deployment of Tow fish

- *Depth of search area, do you have a least 3x water depth of tow cable.*
- *Put out less tow cable then water depth initially.*
- *Are there currents in the search area? It may be better to go in a certain direction.*
- *Bottom type, (are there obstructions that the tow fish may get snagged on?*
- *Location of propeller of the ship, expected turning direction during deployment, location of cable holder.*
- *Take care not to step on cable, keep away from sharp objects and heat sources. Bending the cable with its radius less than 6 inches may cause damage to cable.*
- *Speed up before starting a turn.*

IV. Field Operations

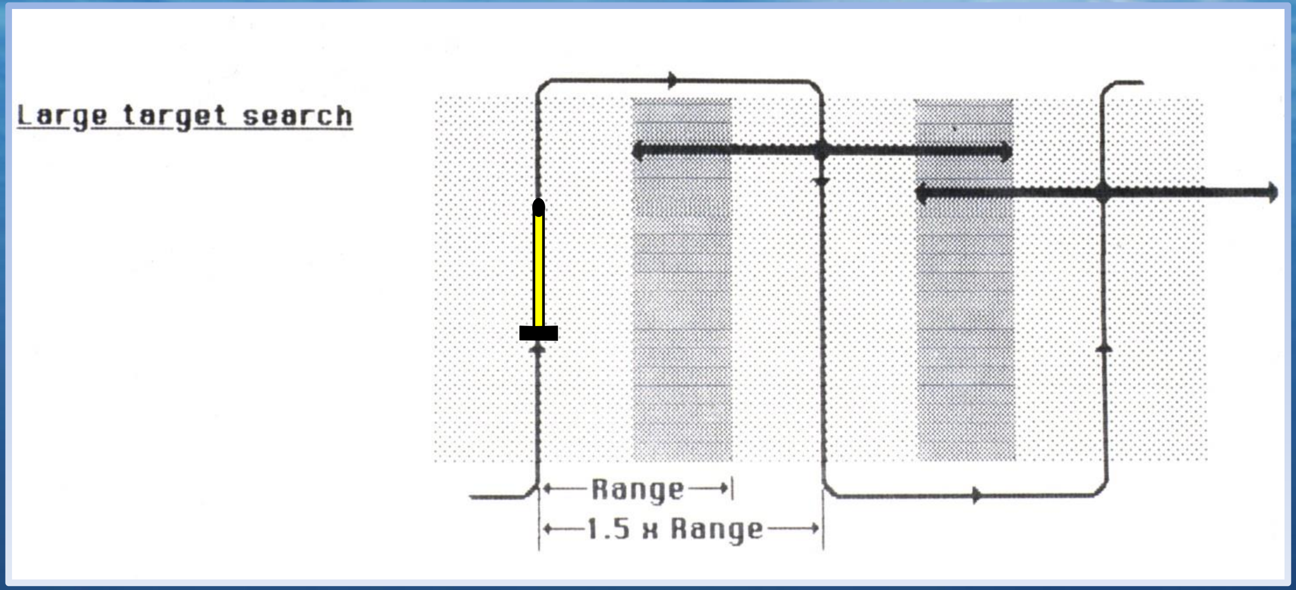


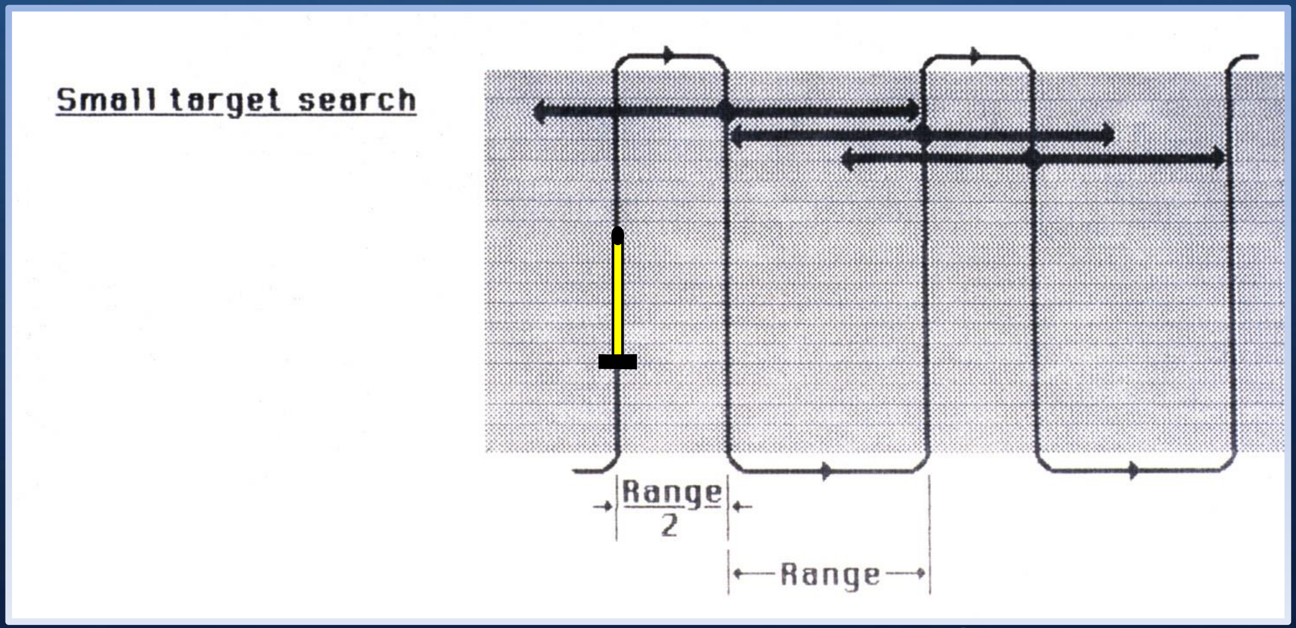
Depressors



IV. Field Operations

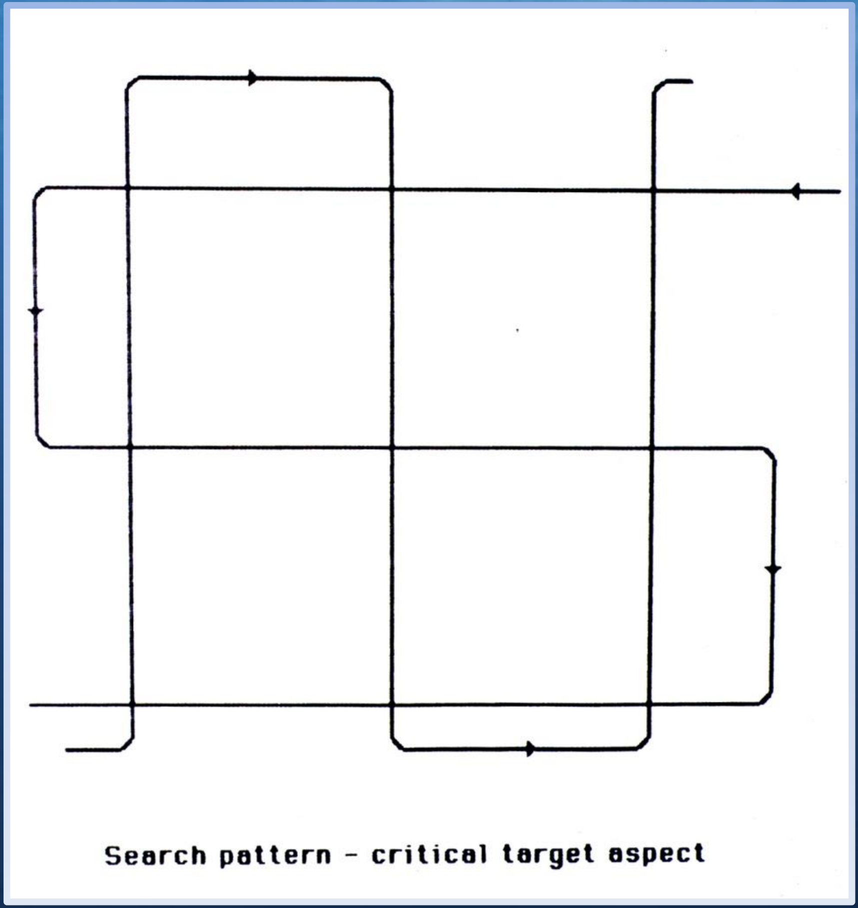
Survey Patterns

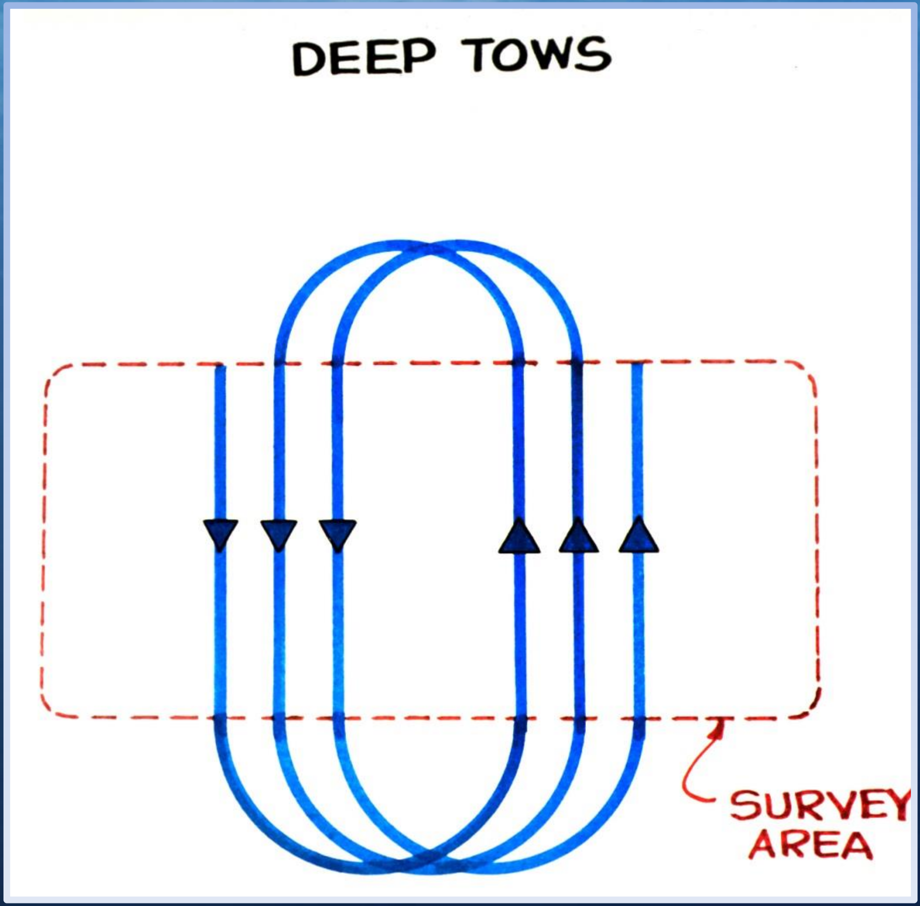




IV. Field Operations

Survey Patterns





IV. Field Operations

Target Detection Factors

Target Reflectivity

Target Aspect

Contrast with Backscatter Back Ground

Shadowing

Nadir Region

Number of Pings on Target

Operator Experience

IV. Field Operations

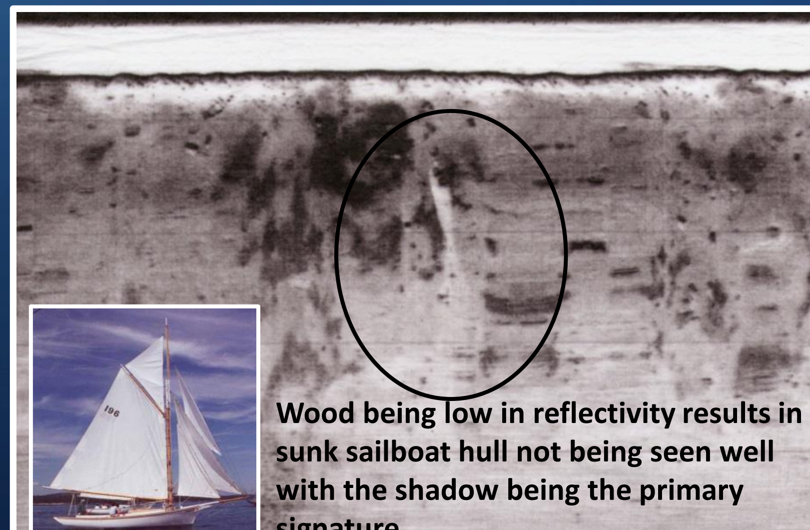
Target Reflectivity

REFLECTION

	SOUND VELOCITY m/sec.	ACOUSTIC IMPEDANCE MKS rayls Poc x 10	REFLECTION COEFFICIENT R,%
AIR	331	0.000428	99.90
CORK	500	0.12	73.00
CASTOR OIL	1540	1.45	00.09
WATER (FRESH)	1481	1.48	00.04
WATER (SEA)	1500	1.54	----
RUBBER (RHO-C)	1550	1.55	00.001
PINE	3500	1.57	00.009
OAK	4000	2.90	9.40
ICE	3200	2.95	10.00
CONCRETE	3100	8.00	46.00
GLASS	5600	12.90	62.00
ALUMINUM	6300	17.00	70.00
STEEL	6100	47.00	88.00

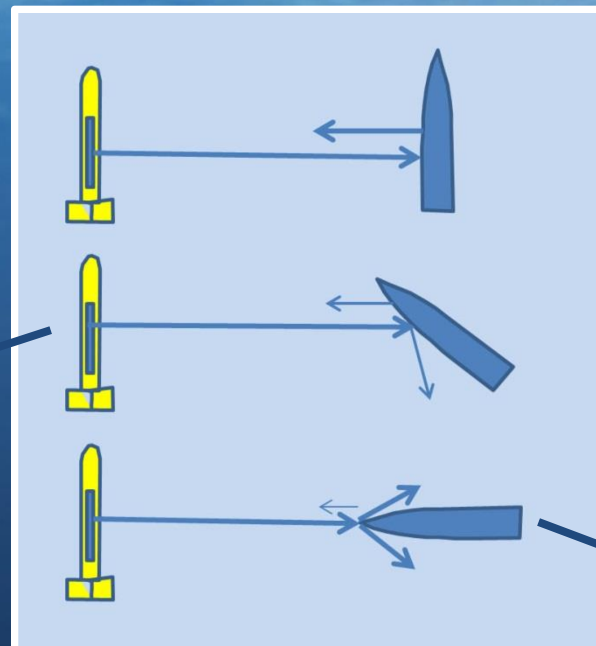
$$M = \frac{pc\ material}{pc\ water}$$

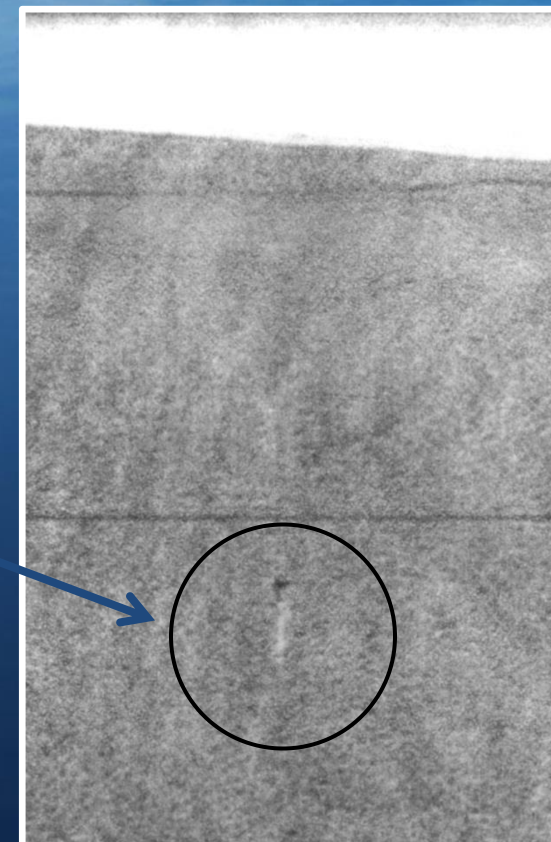
THE IMPEDANCE RATIO FOR THE REFLECTOR MATERIAL AND WATER IS THE SIGNIFICANT QUANTITY IN DETERMINING REFLECTION (ACOUSTICAL OCEANORGRPHY, CLAY & MEDWIN, 1977).



IV. Field Operations

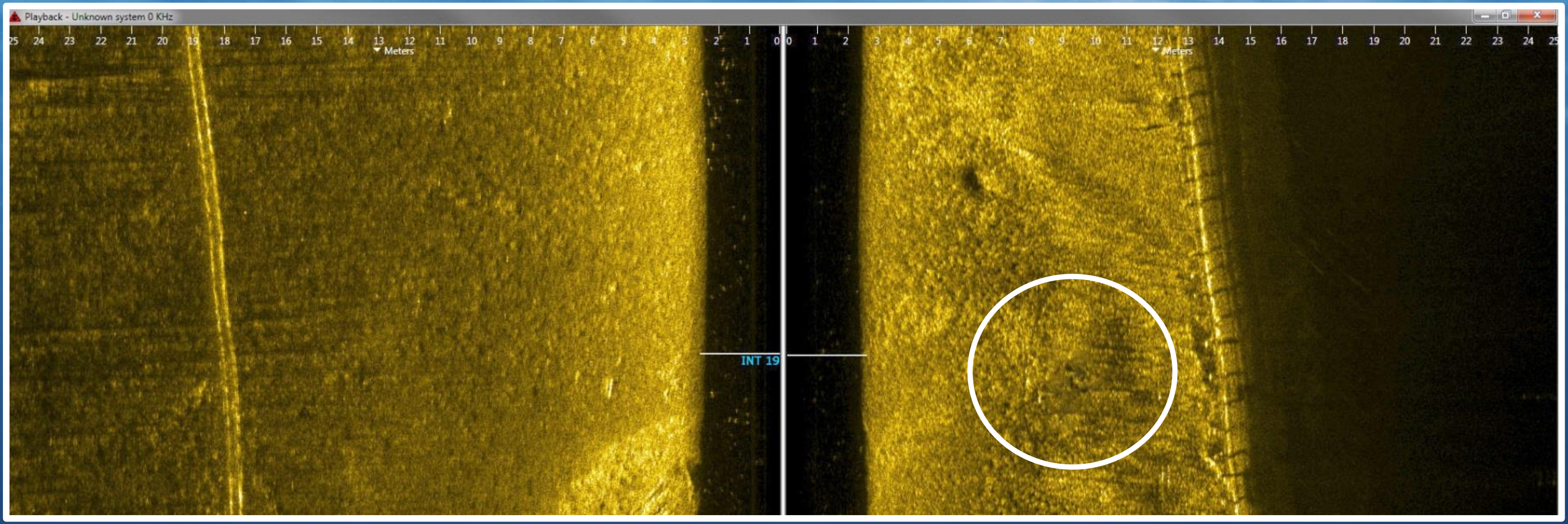
Aspect Critical Targets

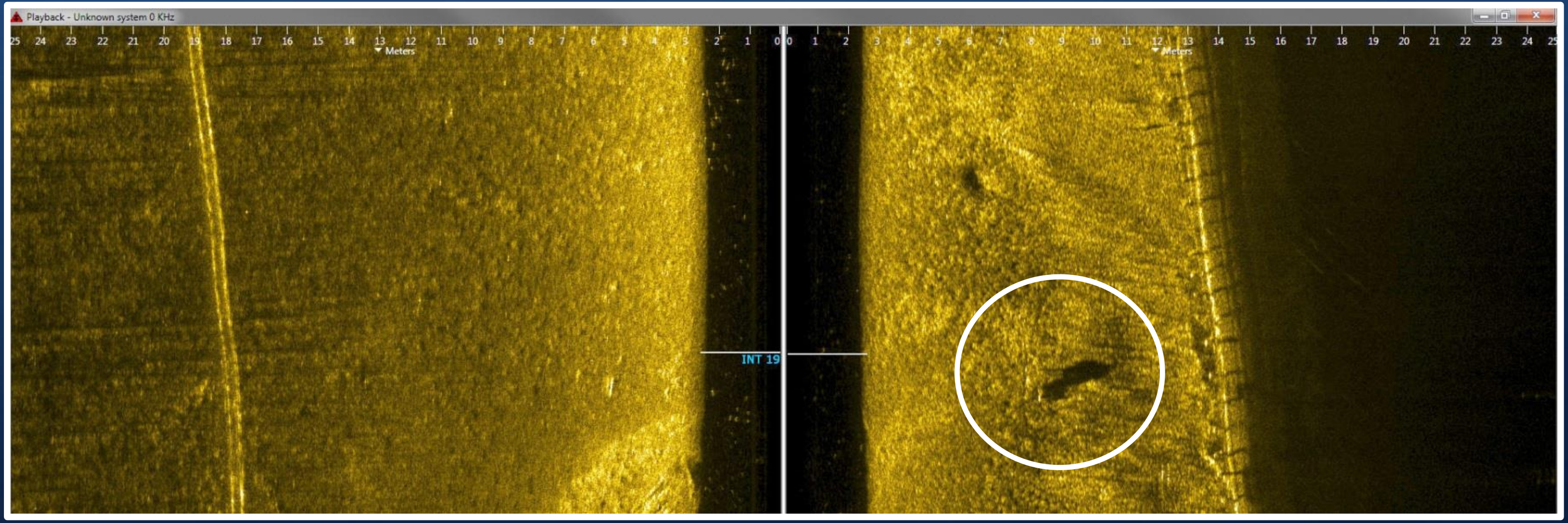




IV. Field Operations

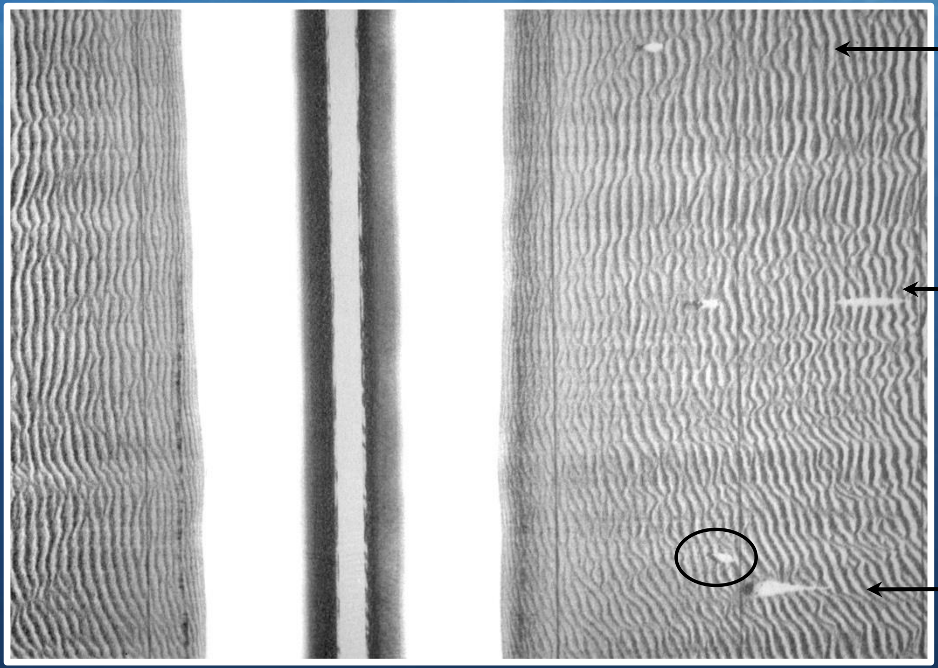
Anechoic Targets & Acoustic Shadows

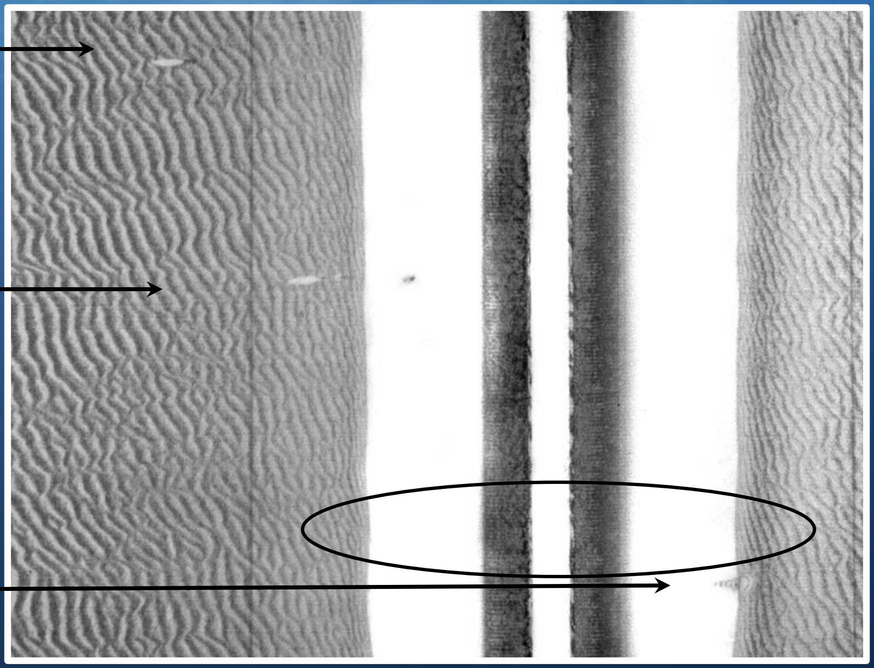




IV. Field Operations

Nadir & Small Targets

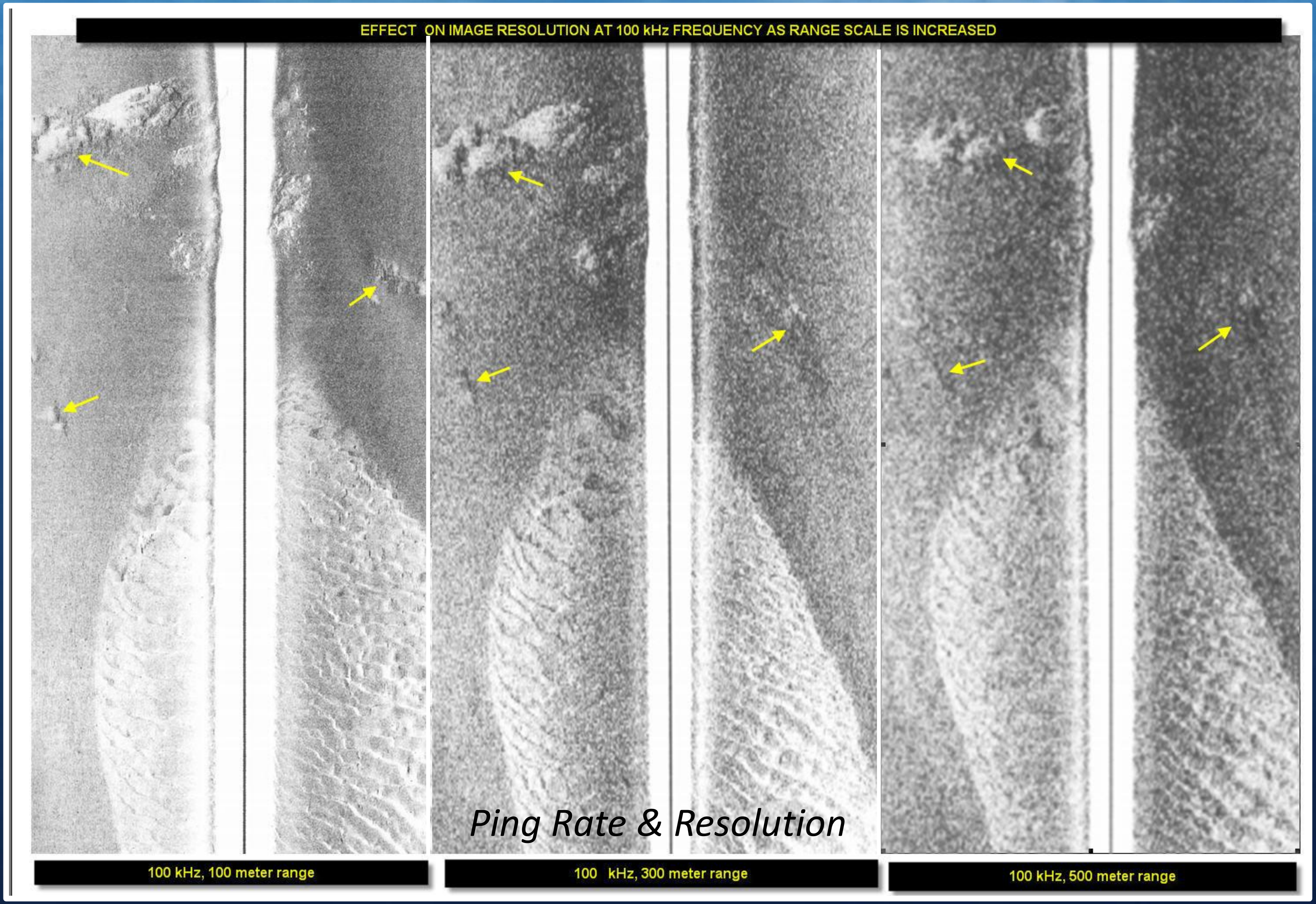

1.5 m Steel Cylinder is Detected


1.5 m Steel Cylinder in Nadir is not Detected

IV. Field Operations

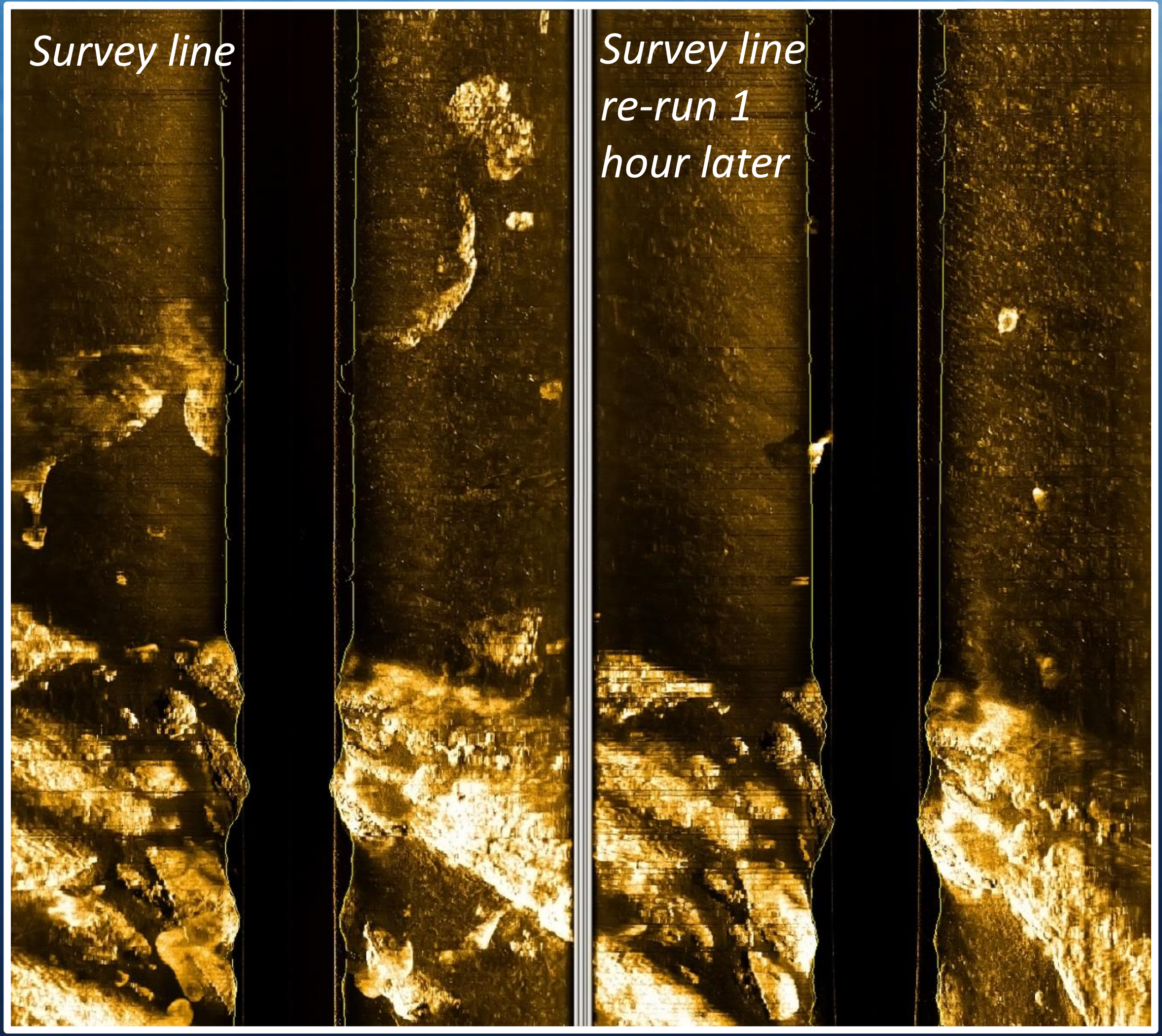
Range / Resolution Tradeoff

- Shorter Range Scale's have higher ping rates thus higher resolution



IV. Field Operations

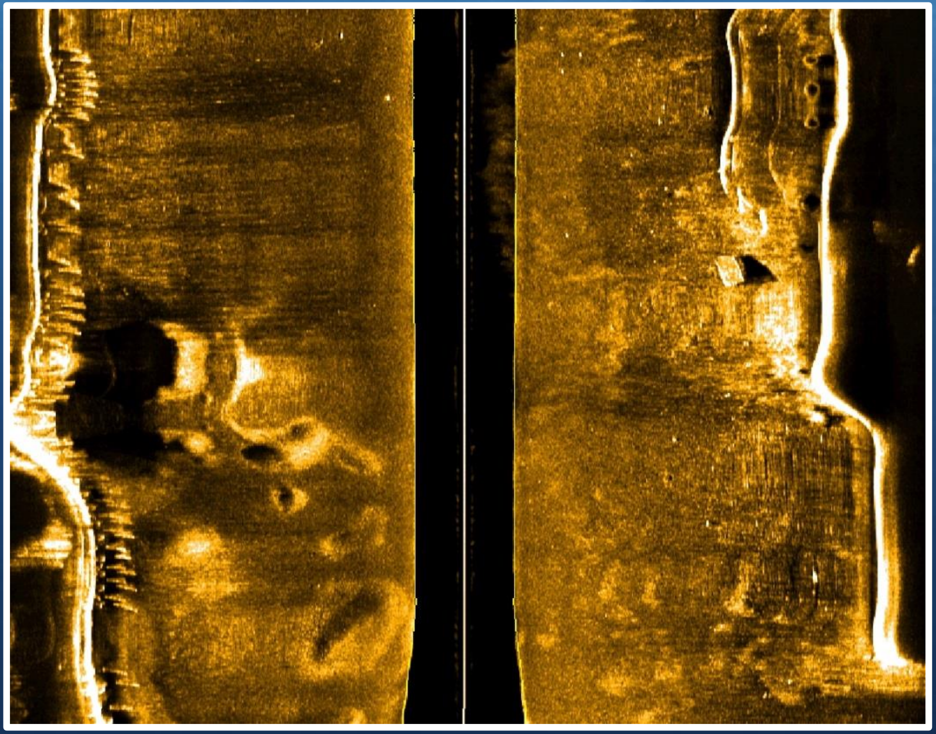
Repeatability

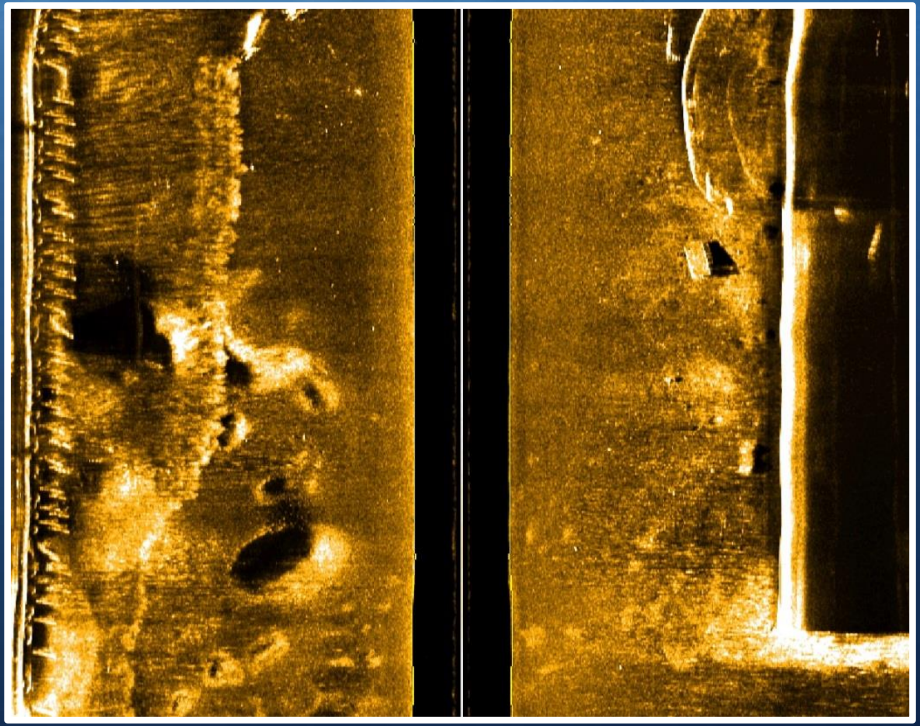


The very important practice of getting 2 looks minimum of a suspected target or feature. An anomalous target will show up only once, where as a real target on the seafloor is repeatable and it will consistently show up in multiple passes.

IV. Field Operations

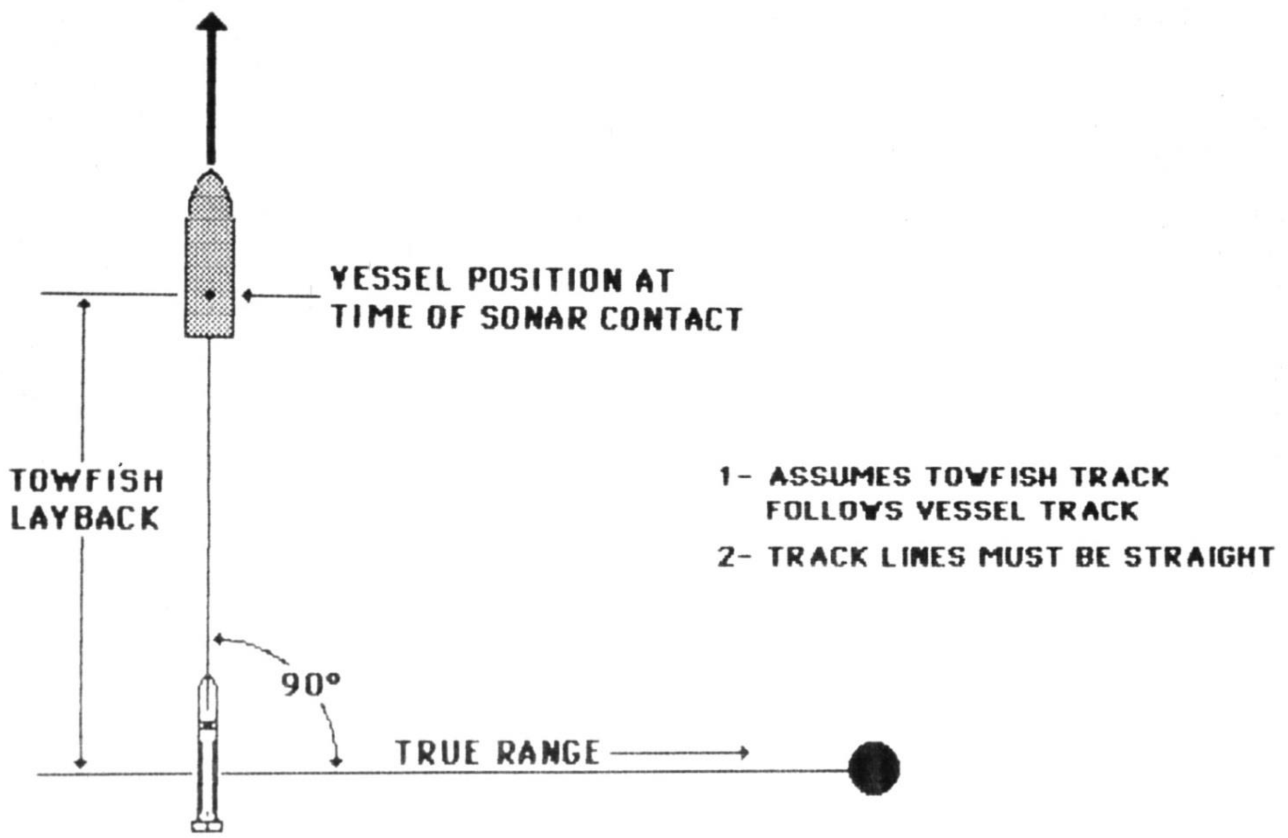
Only Good Data is Straight Line Survey Data





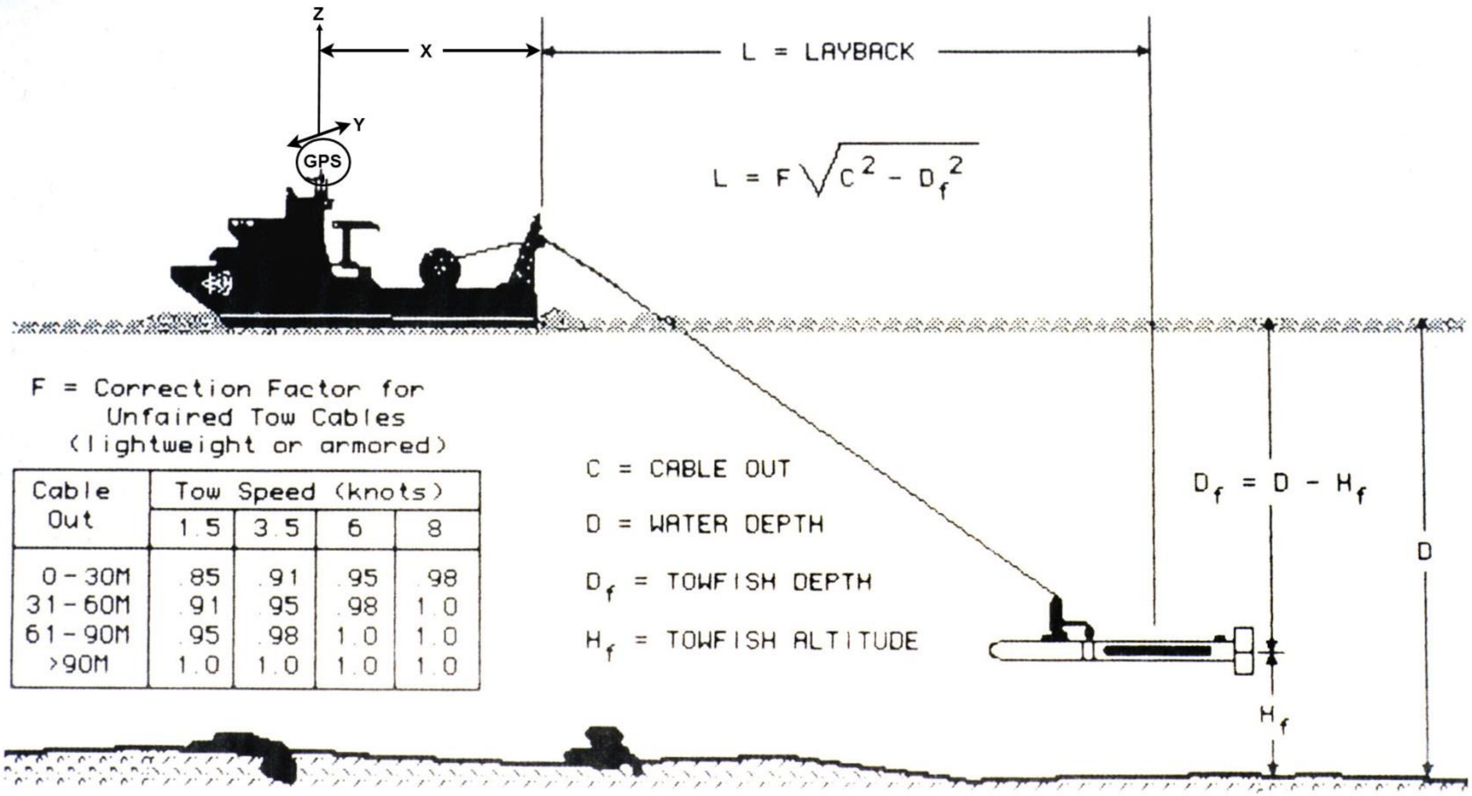
IV. Field Operations

Target Positioning by Layback



IV. Field Operations

Towfish Layback and Position



$$L = F\sqrt{C^2 - D_f^2}$$

F = Correction Factor for Unfaired Tow Cables (lightweight or armored)

Cable Out	Tow Speed (knots)			
	1.5	3.5	6	8
0 - 30M	.85	.91	.95	.98
31 - 60M	.91	.95	.98	1.0
61 - 90M	.95	.98	1.0	1.0
>90M	1.0	1.0	1.0	1.0

C = CABLE OUT

D = WATER DEPTH

D_f = TOWFISH DEPTH

H_f = TOWFISH ALTITUDE

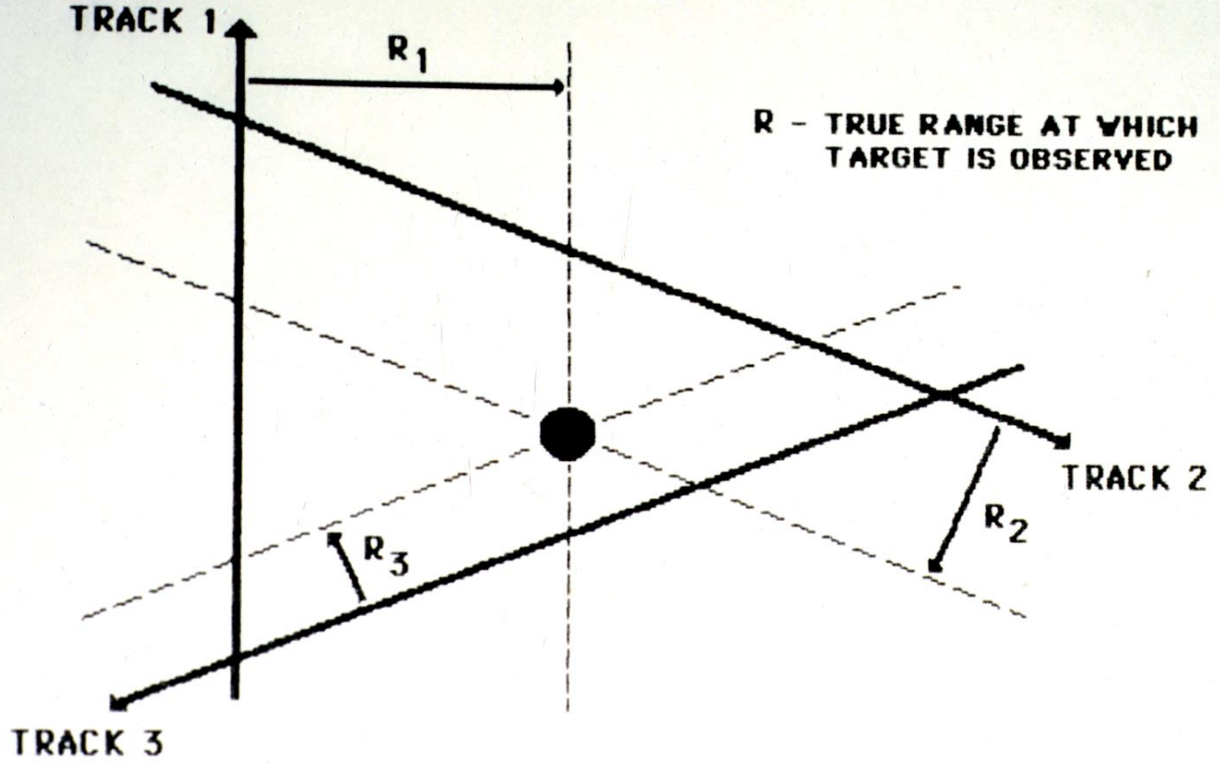
$D_f = D - H_f$

FIGURE 4-3. Approximate Cable Layback (Pythagorean Approximation Method)

Pressure Sensor provides Towfish Depth & Cable Counters provides Cable Out

IV. Field Operations

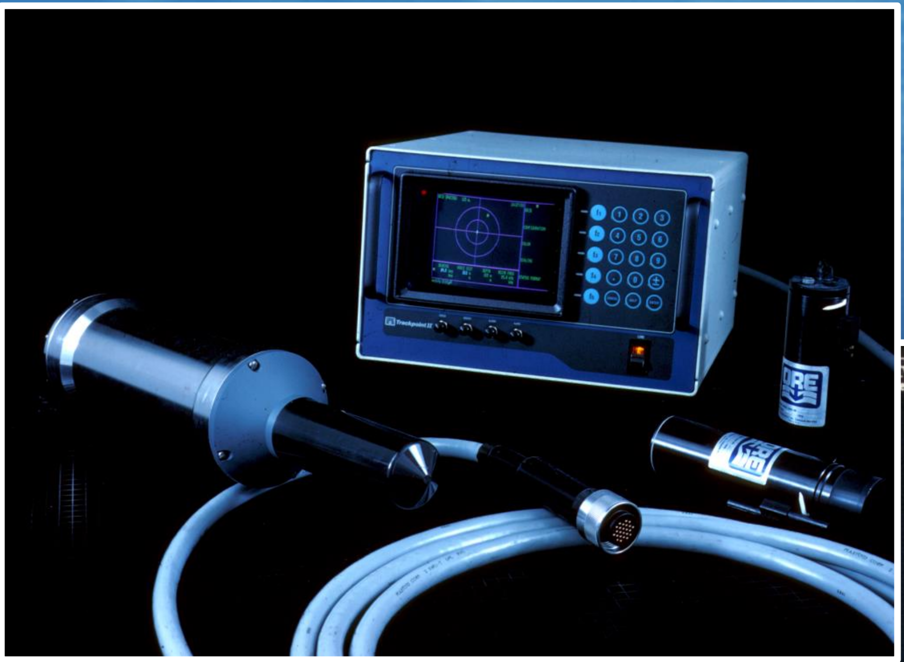
Target Position by Triangulation

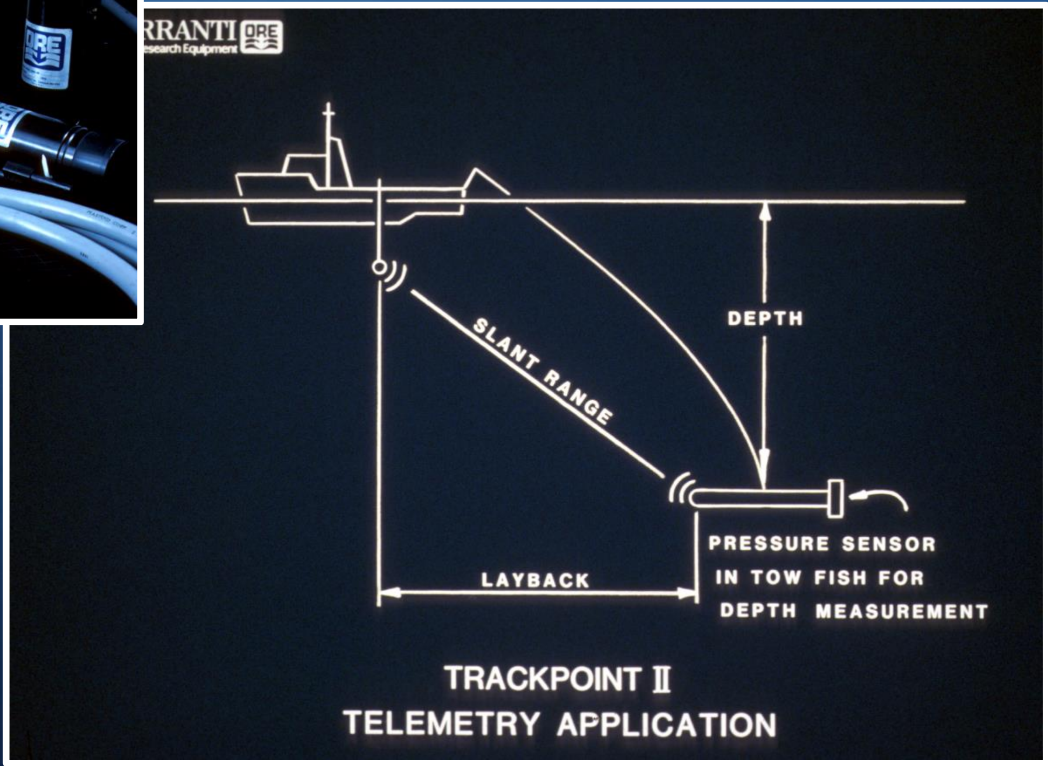


TARGET POSITION
-TRIANGULATION METHOD-

IV. Field Operations

USBL Acoustic Positioning System

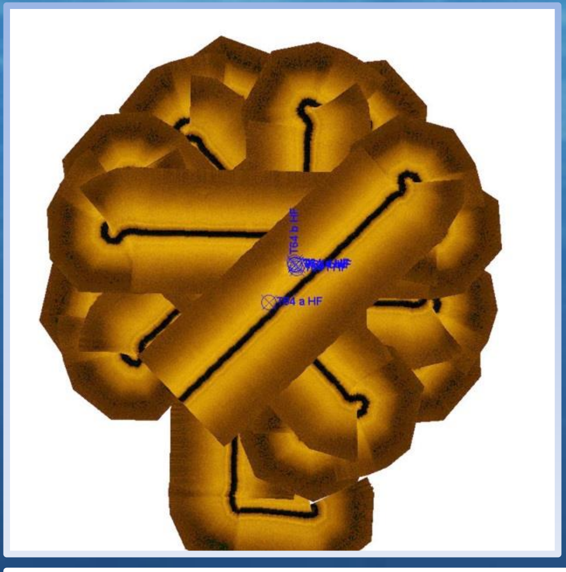


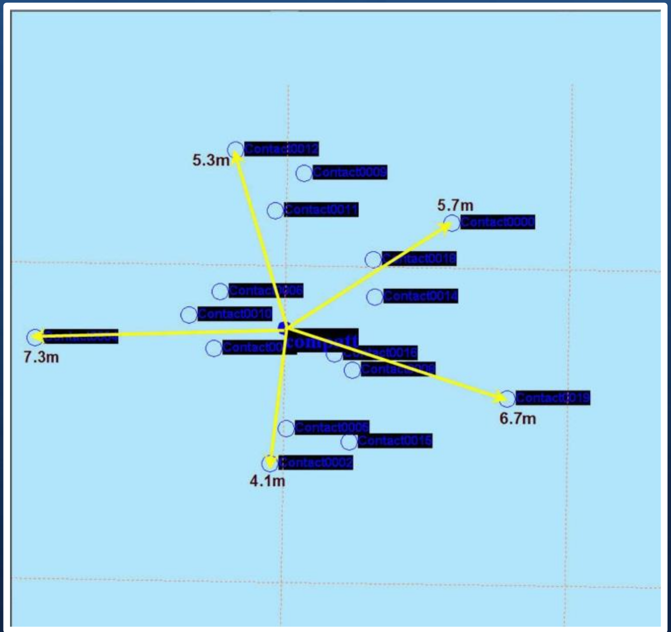


IV. Field Operations

Getting to a Target

- *Do Multiple passes at Different Headings*
- *Average Target Locations*
- *Drop a Sonar Reference Target & Surface Buoy*
- *Make a Sonar Pass to Calculate Range and Bearing between Target & Reference Target*
- *Move Reference Target with Buoy Line as needed*





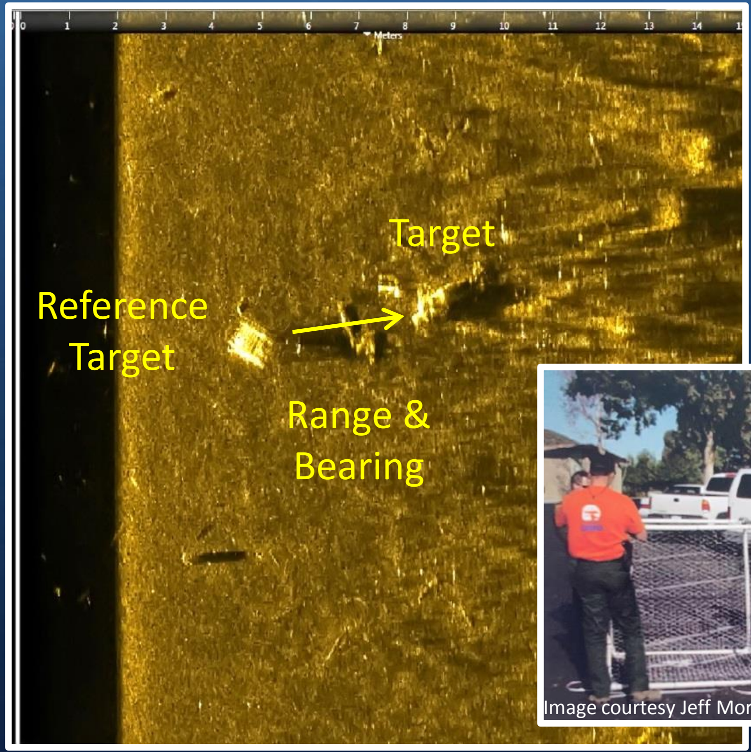


Image courtesy Jeff Morgan, San Bernardino Sheriffs Dept

IV. Field Operations

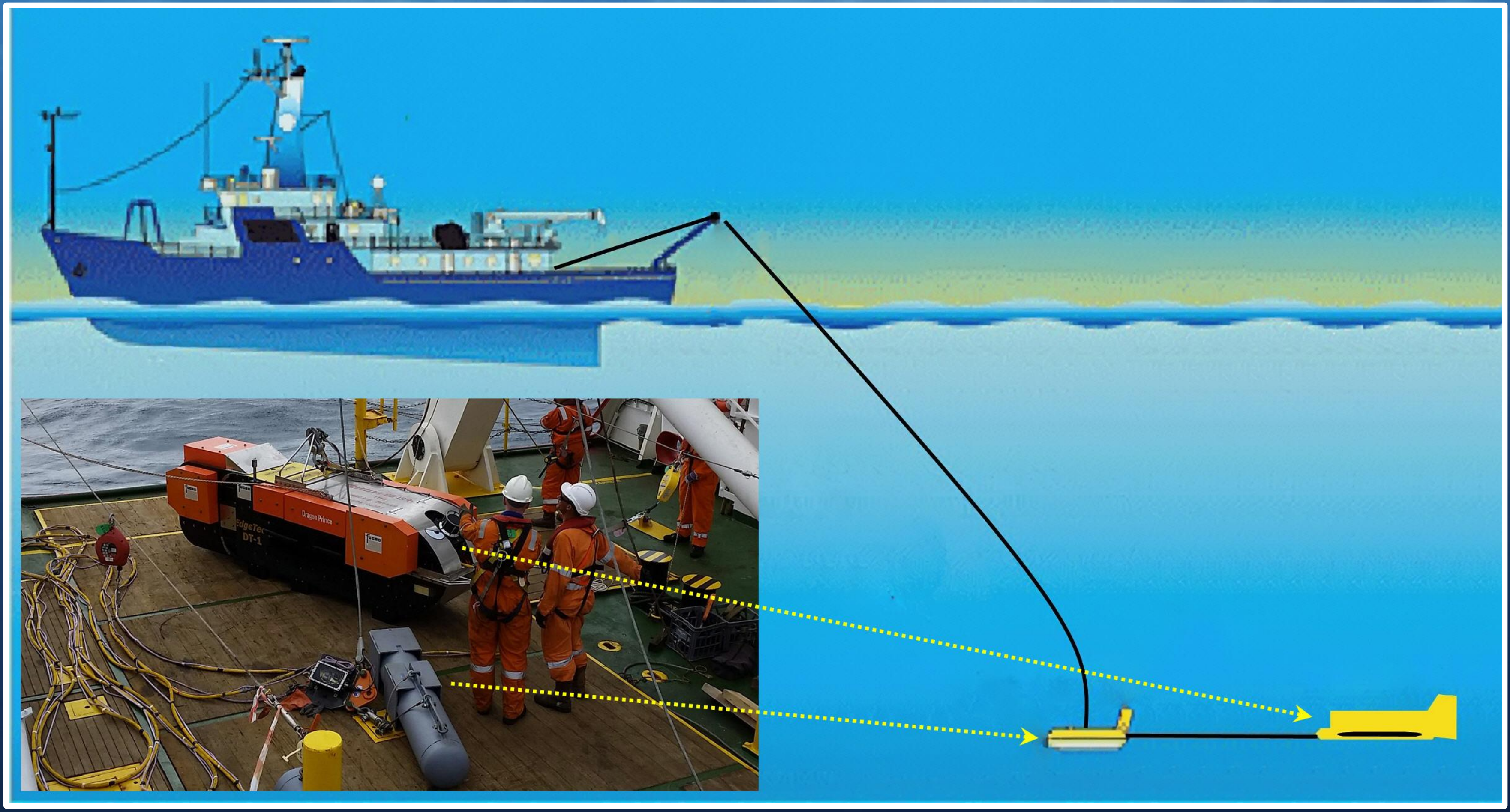
Deep Tow Winch with 10,000 meters of tow cable

Deep Tows – A Dying Breed

6000 meter Rated Deep Tow with INS, DVL, & Acoustic Positioning

IV. Field Operations

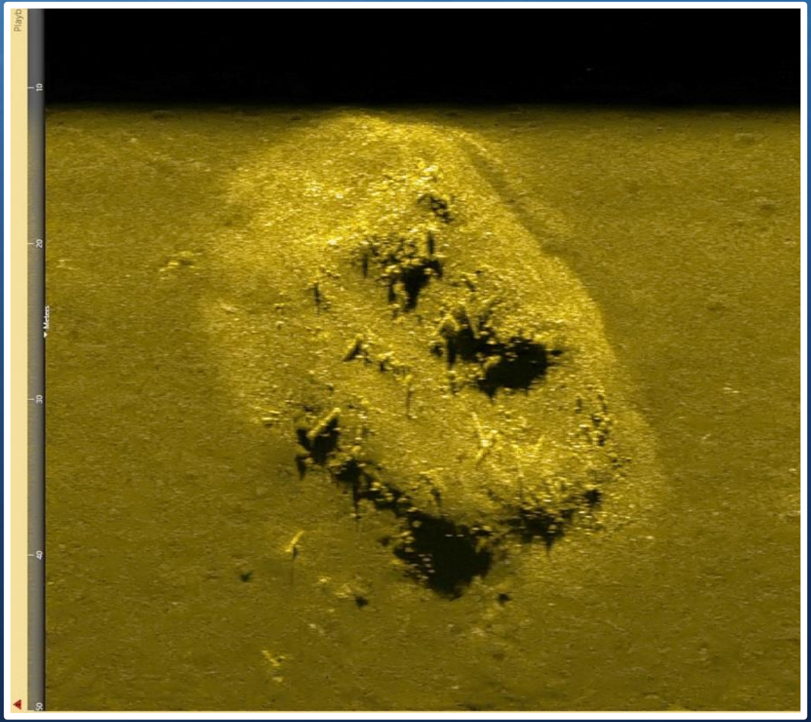
Deep 2 Part Tows



V. Applications & Cool Images

V. Applications

Search - Shipwrecks



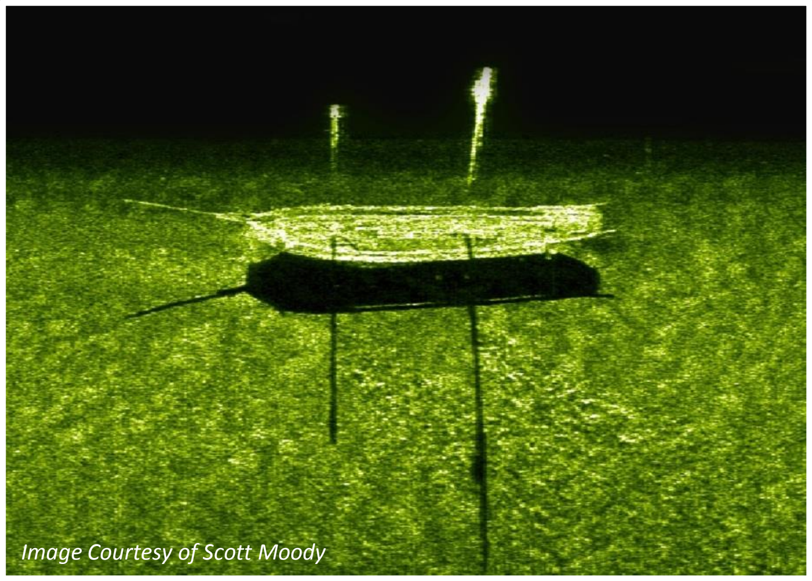
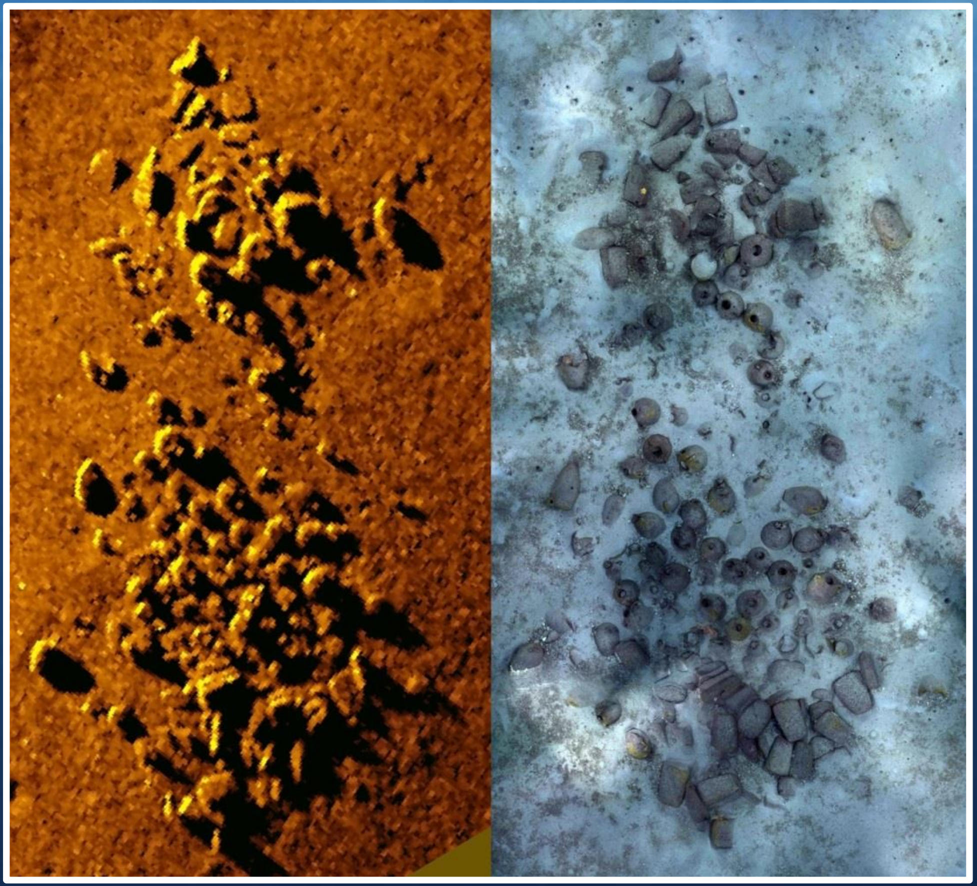
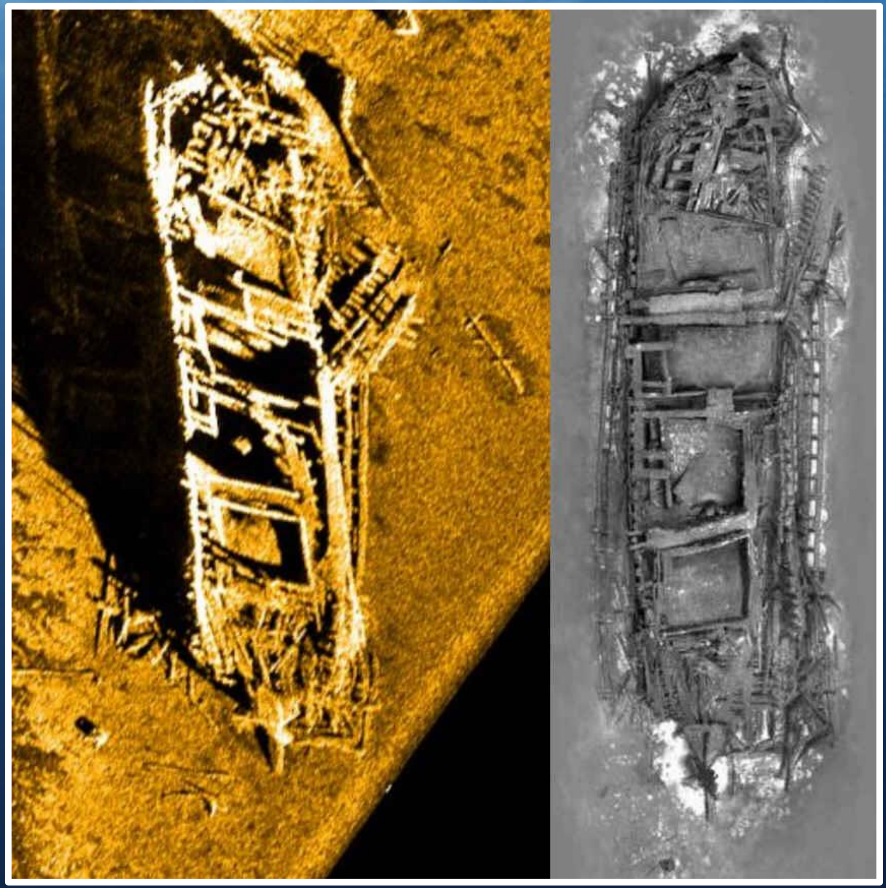


Image Courtesy of Scott Moody

V. Applications

Shipwreck Comparison Of SSS Image to Camera Image

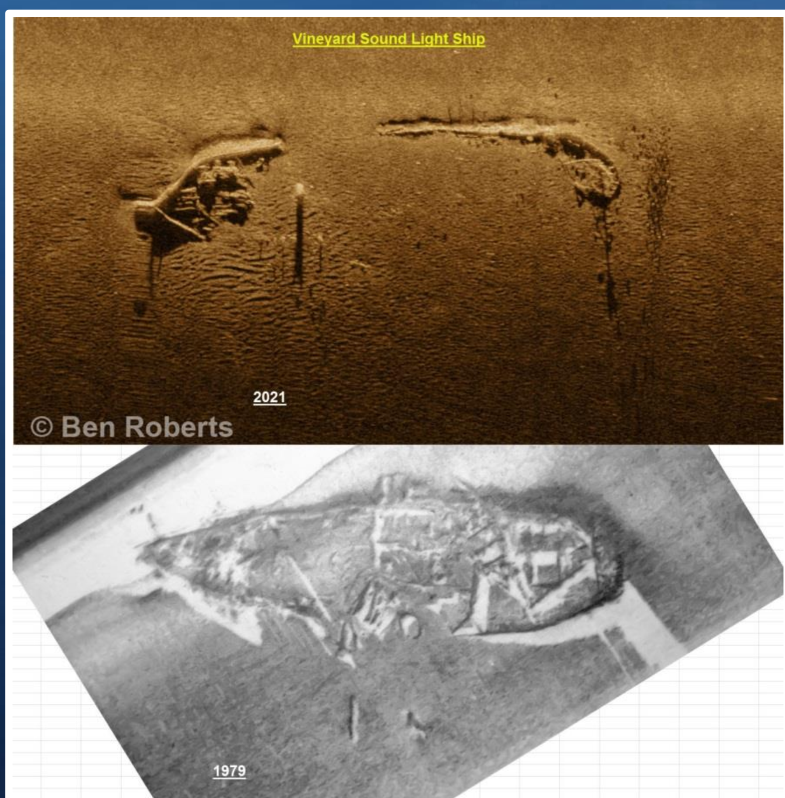


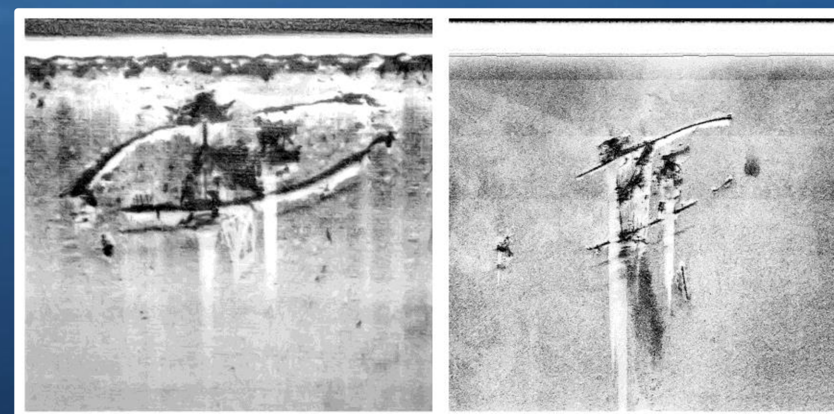


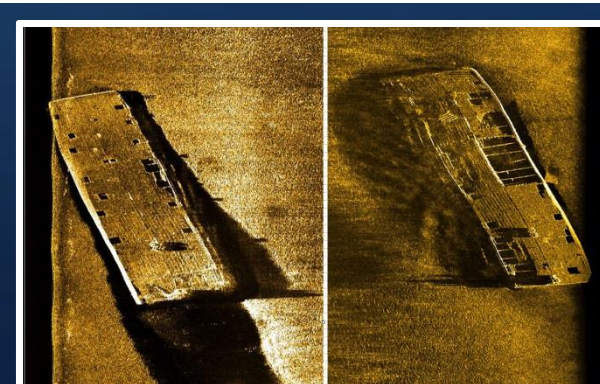
V. Applications

Search - Shipwrecks

An ongoing philosophy of the underwater archeological community is that the best preservation and protection of cultural resoures/shipwrecks is to leave them "In-Situ". This argument has been used for years as a reason to restrict shipwreck salvor's or divers from recovering artifacts. Unfortunately Mother Nature has her own ideas on shipwrecks and has decided to ignored the "In-Situ" policy and continues to deteriorate shipwrecks and cultural resources.







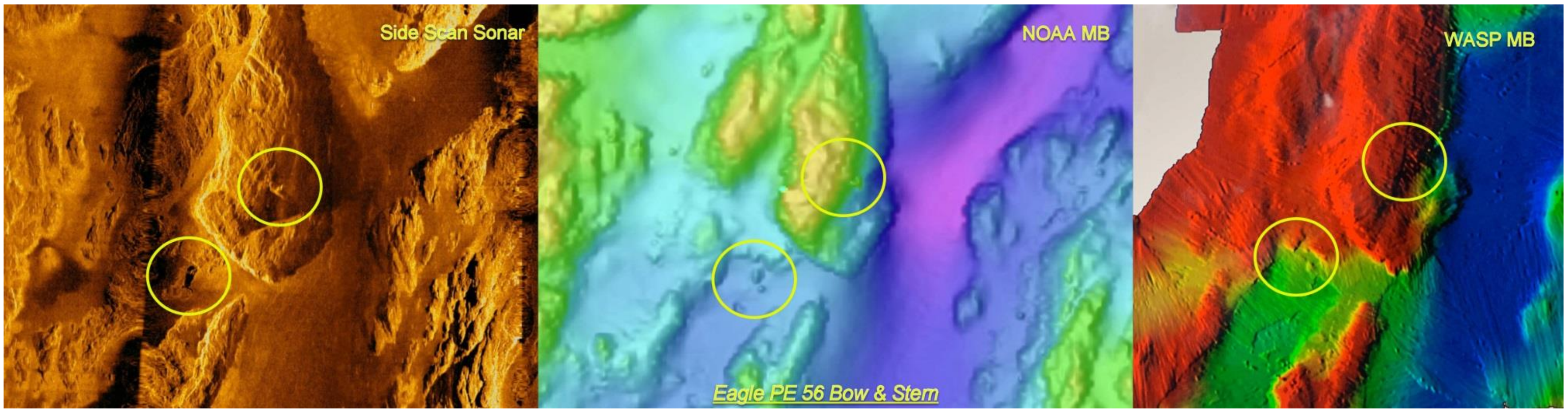
V. Applications

Search - Shipwrecks

Question: are Multi-Beam systems good for shipwreck search. Answer: YES and NO

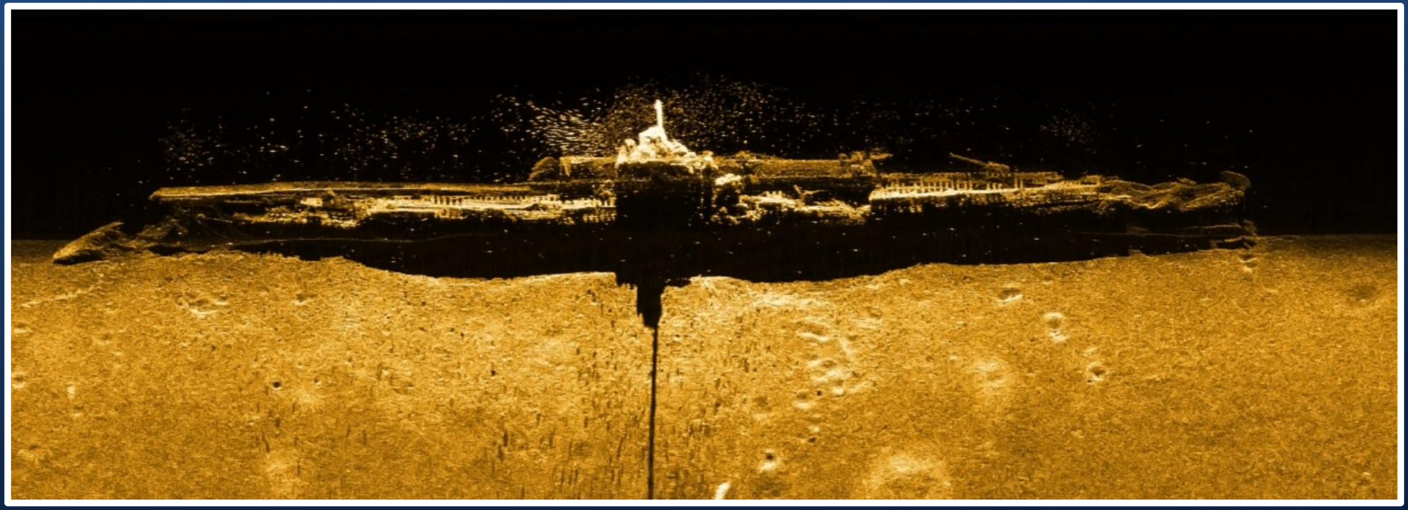
Though a MB system produces both point cloud and backscatter data, the resolution and acoustic shadowing ability is less especially in a cluttered seafloor. They work well in shallow benign seafloors but are not efficient in deep or geologically cluttered seafloors.

The following example, shows how the WW II shipwreck would surely be overlooked as a shipwreck in the MB data.



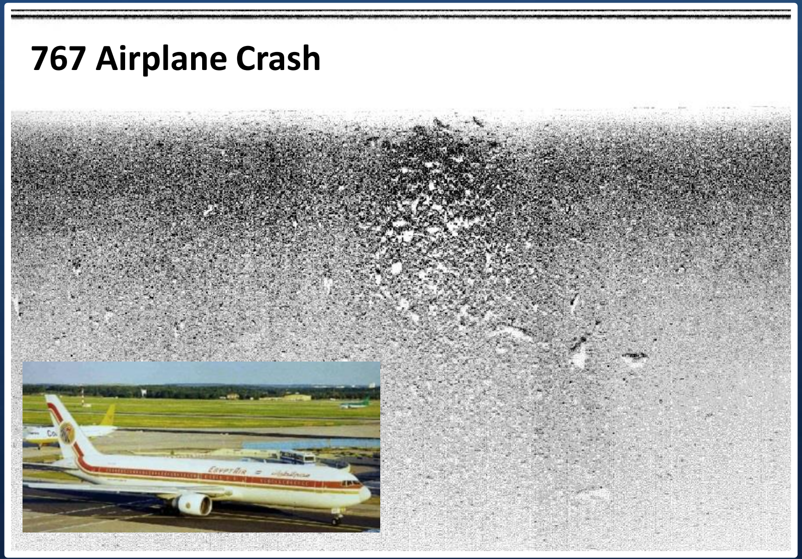
V. Applications

Search - Submarines



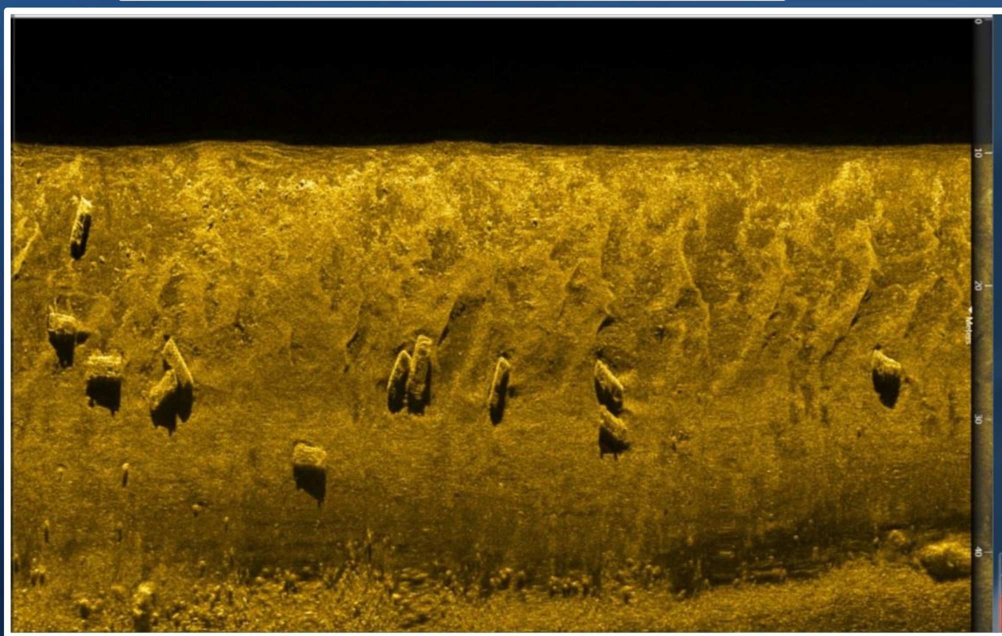
V. Applications

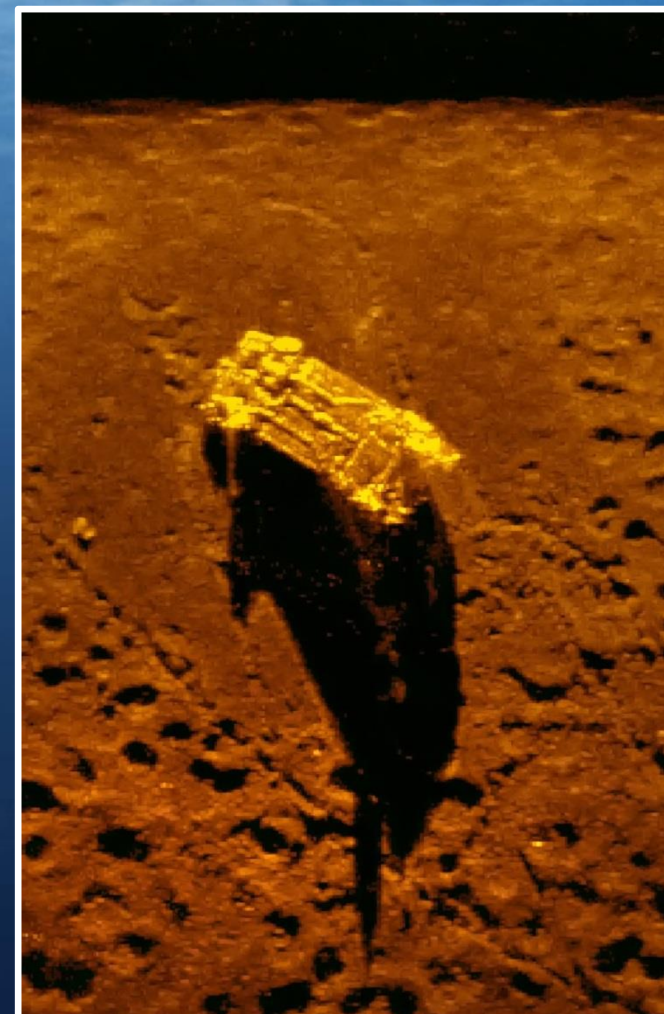
Search - Aircraft



V. Applications

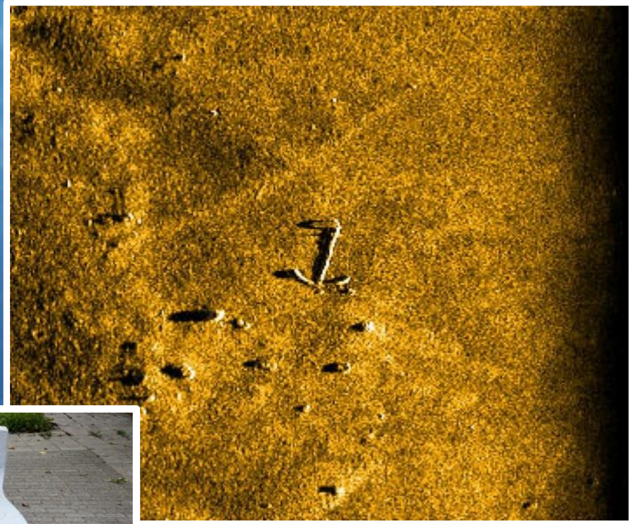
Search - Automobiles

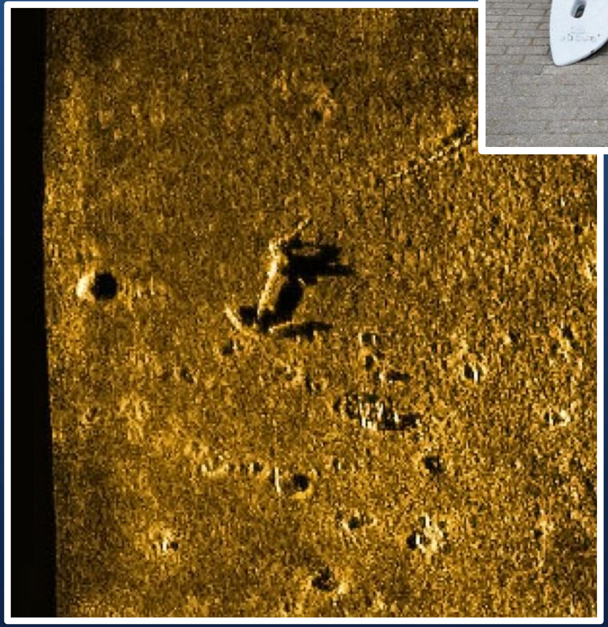


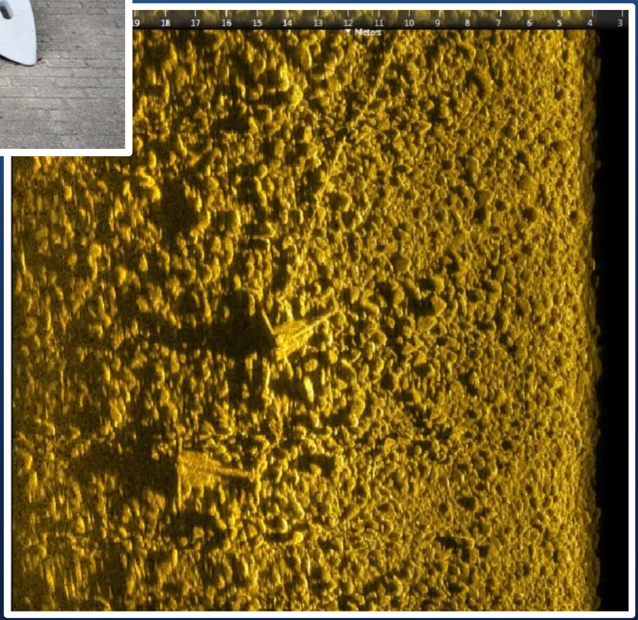


V. Applications

Search - Anchors

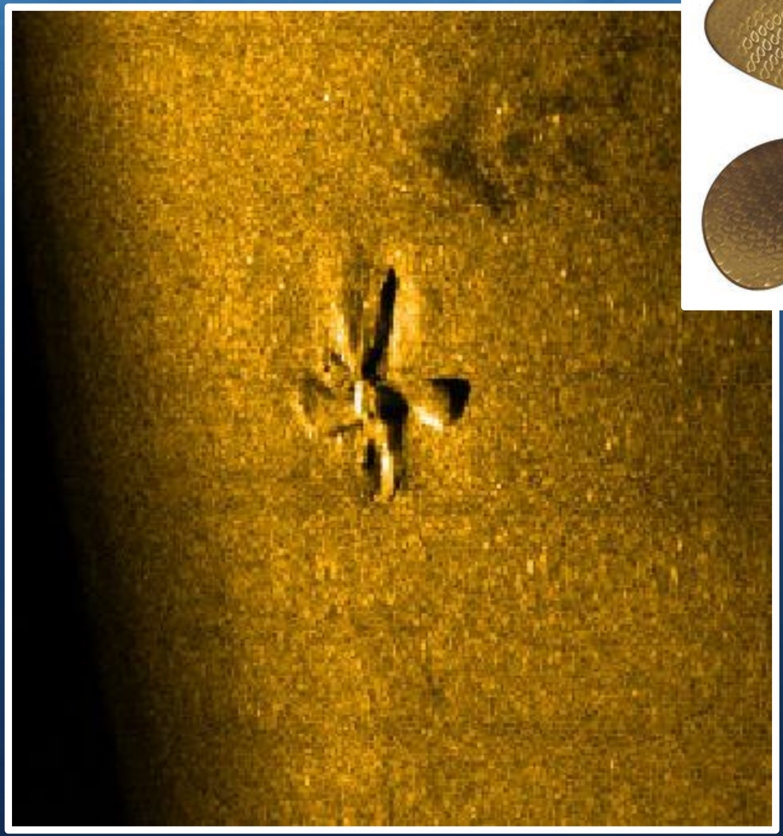


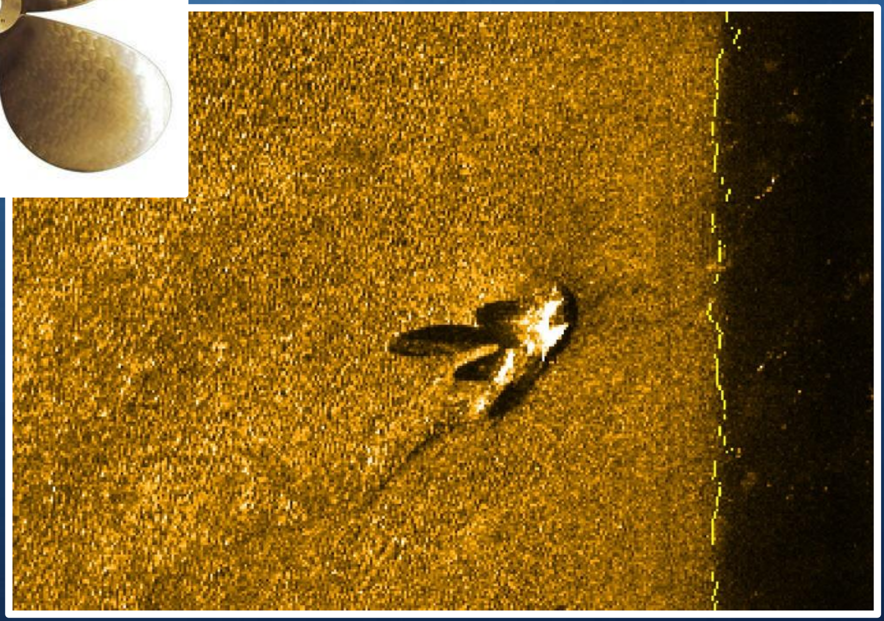




V. Applications

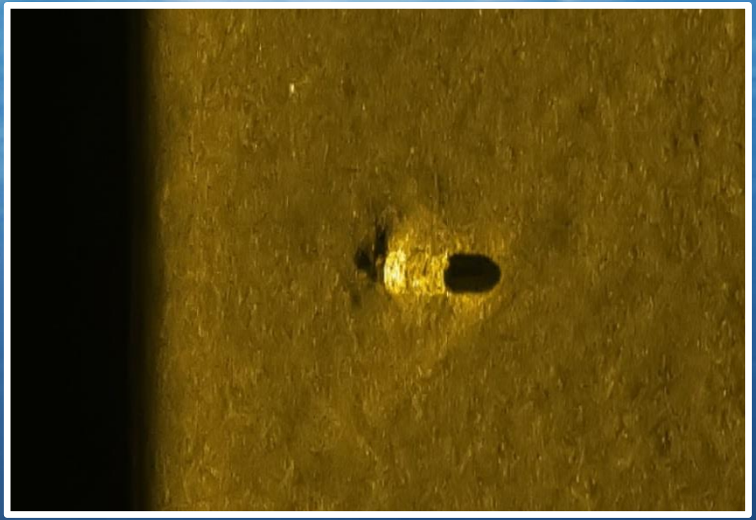
Search – Lost Propellers





V. Applications

Search – Barrels / Hazardous Waste



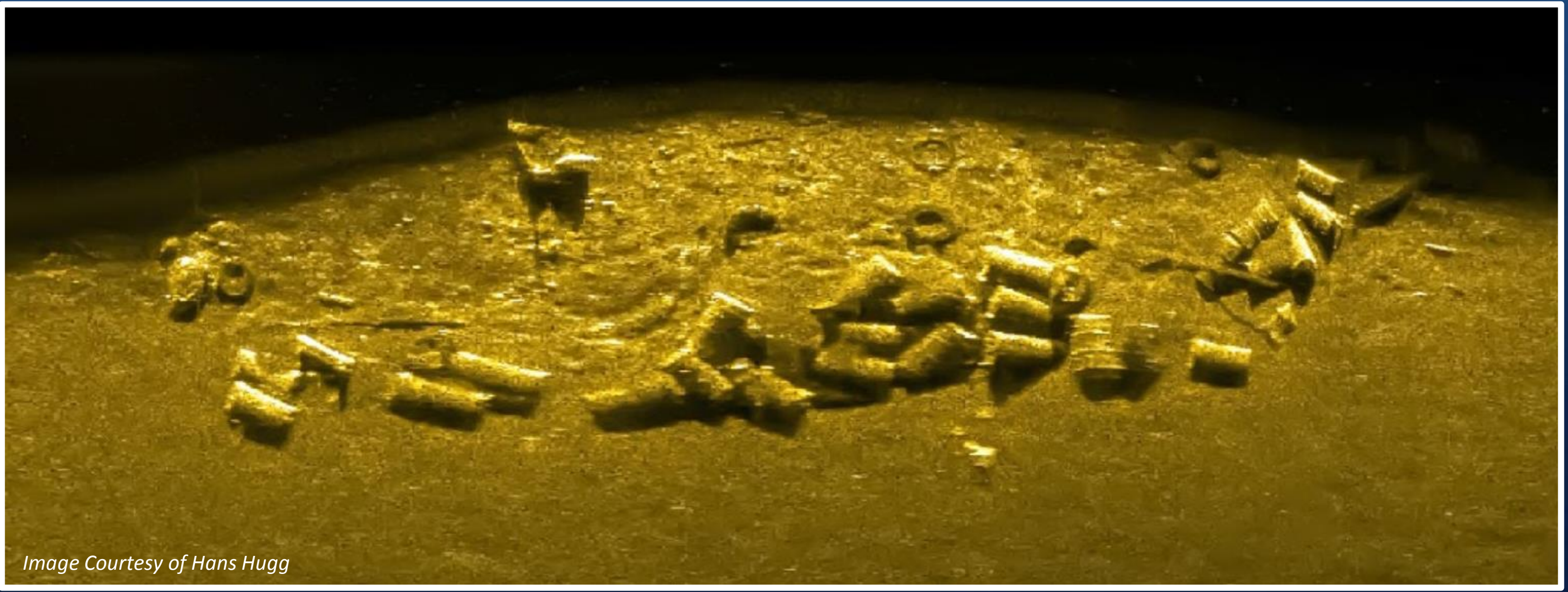
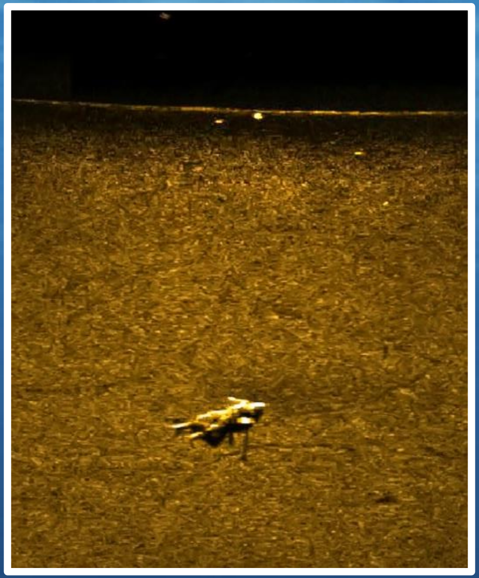
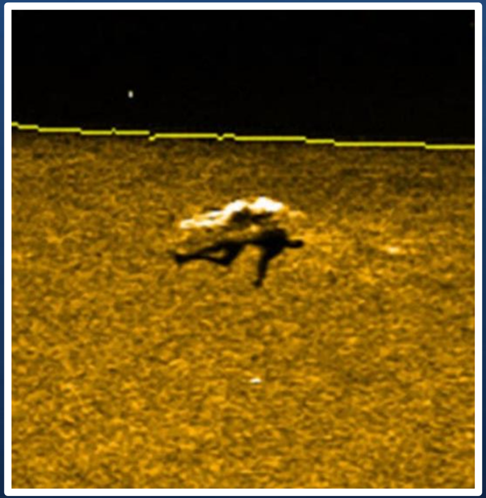


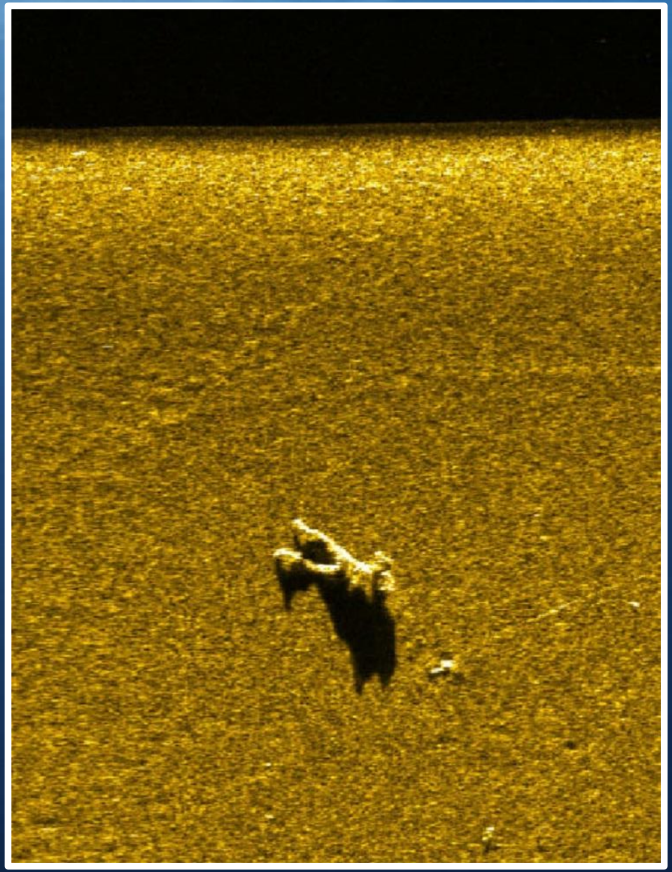
Image Courtesy of Hans Hugg

V. Applications

Search – Drowning Victims

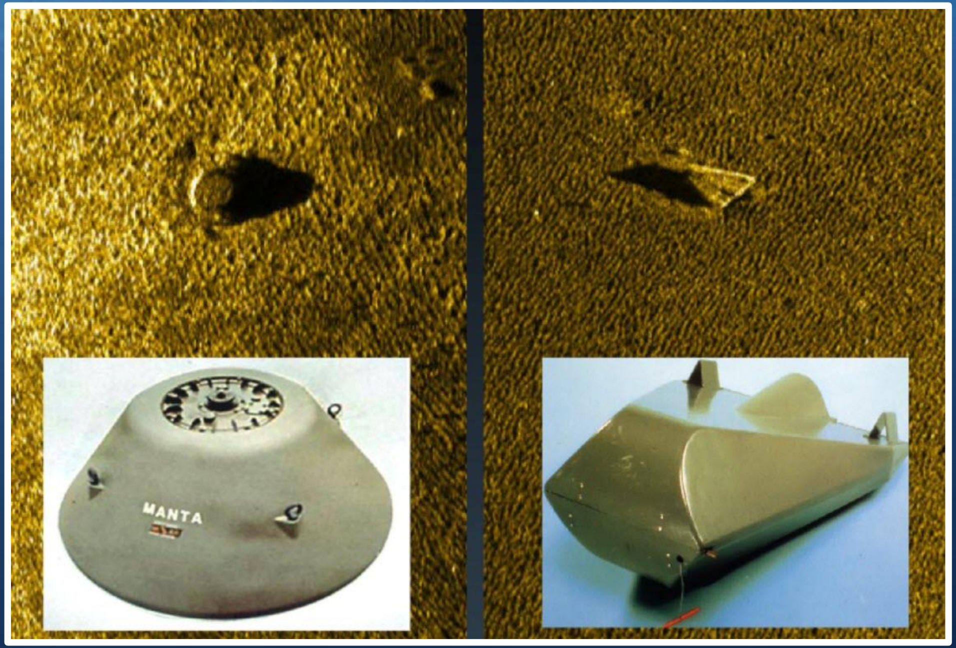






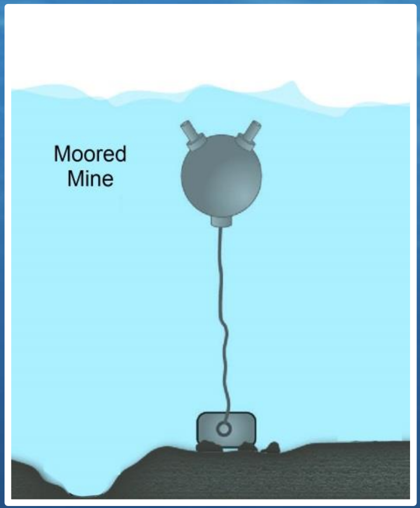
V. Applications

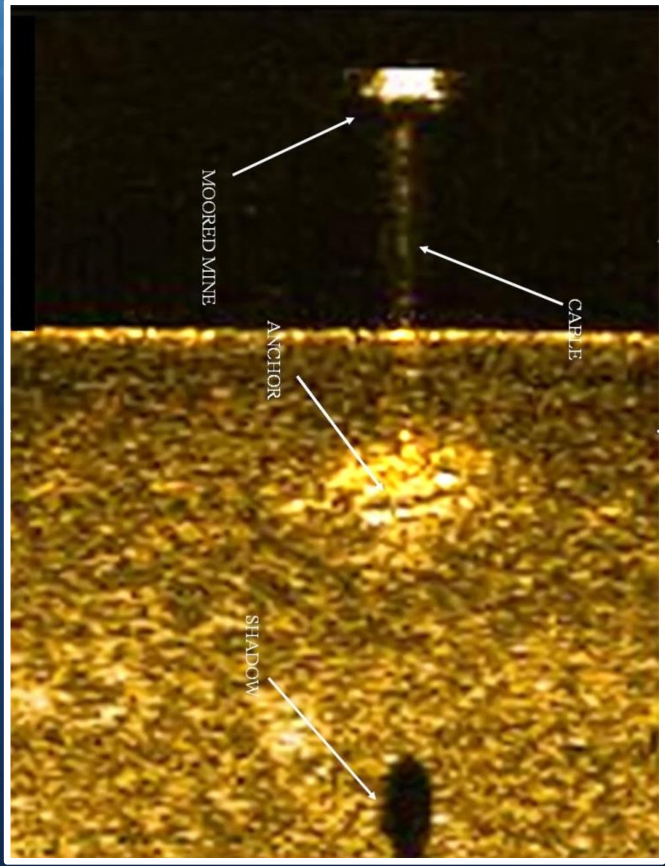
Search – Naval Ground Mines

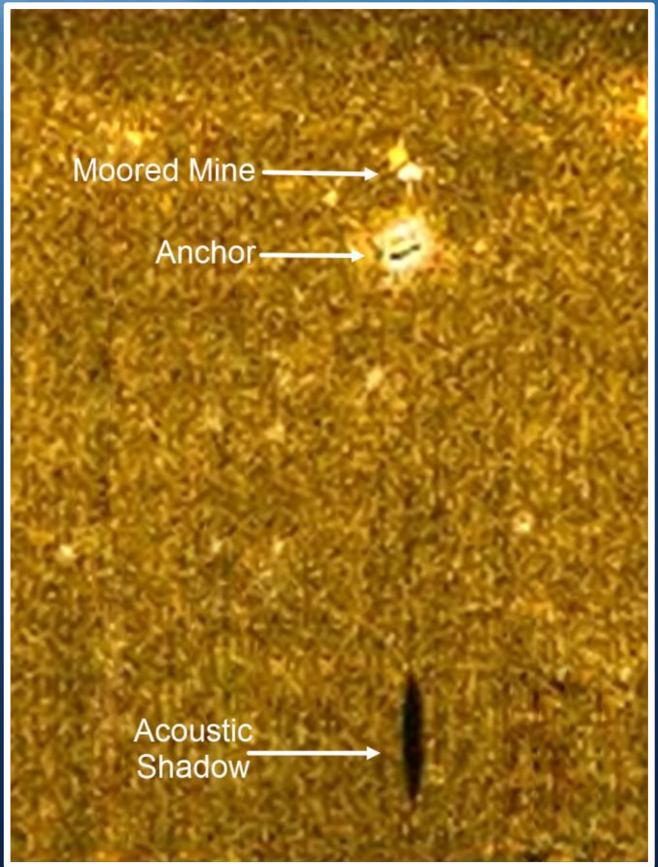


V. Applications

Search – Naval Moored Mines

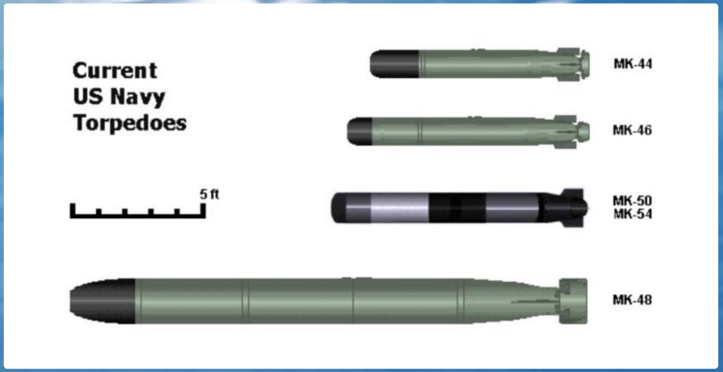


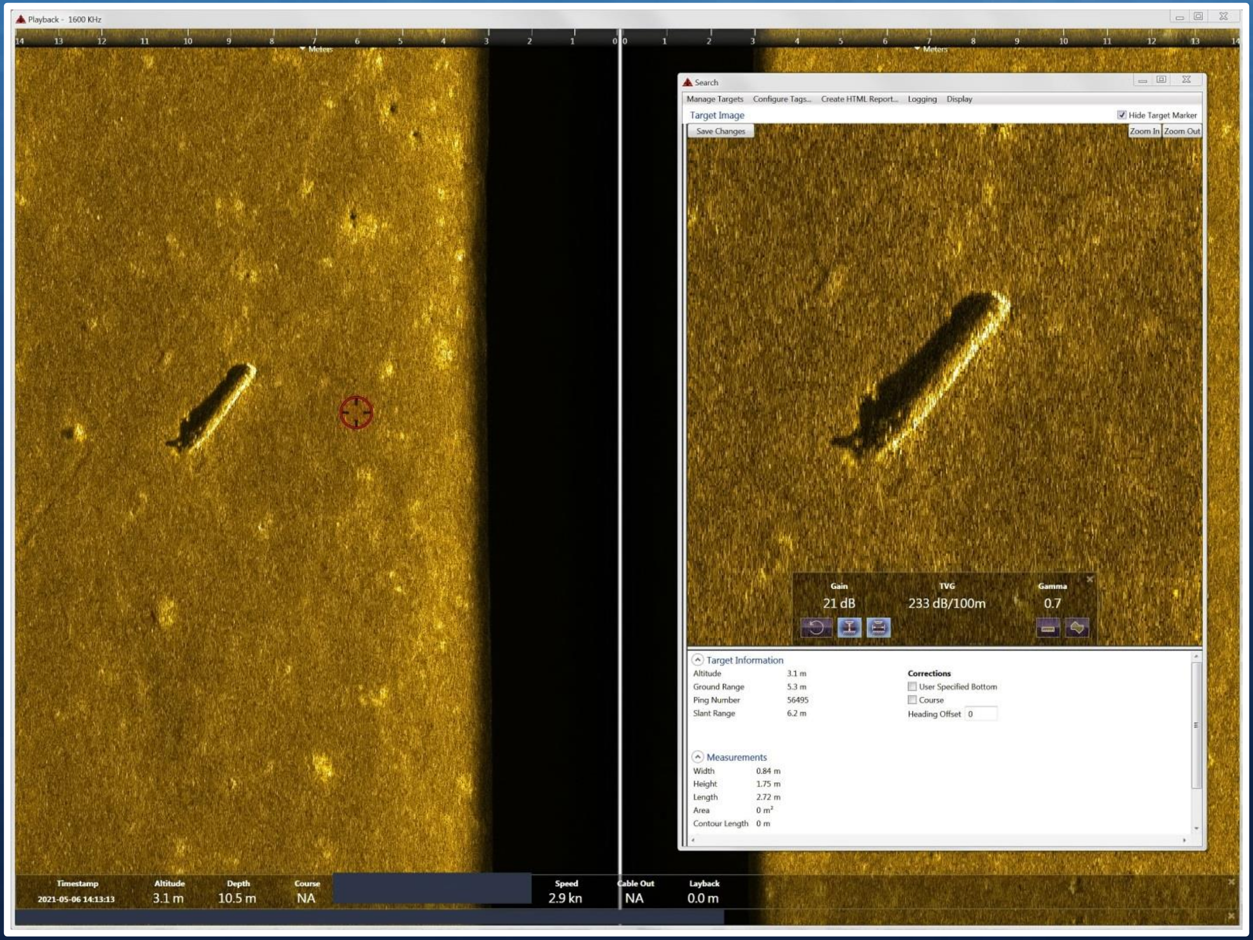




V. Applications

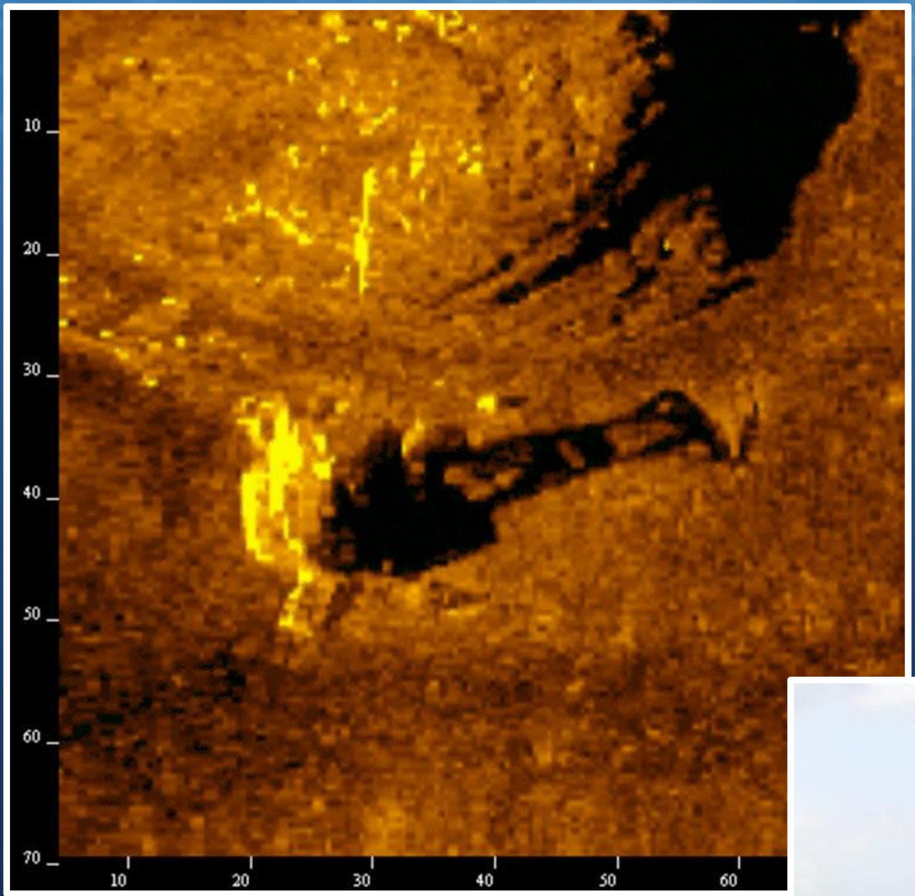
Search -Torpedoes

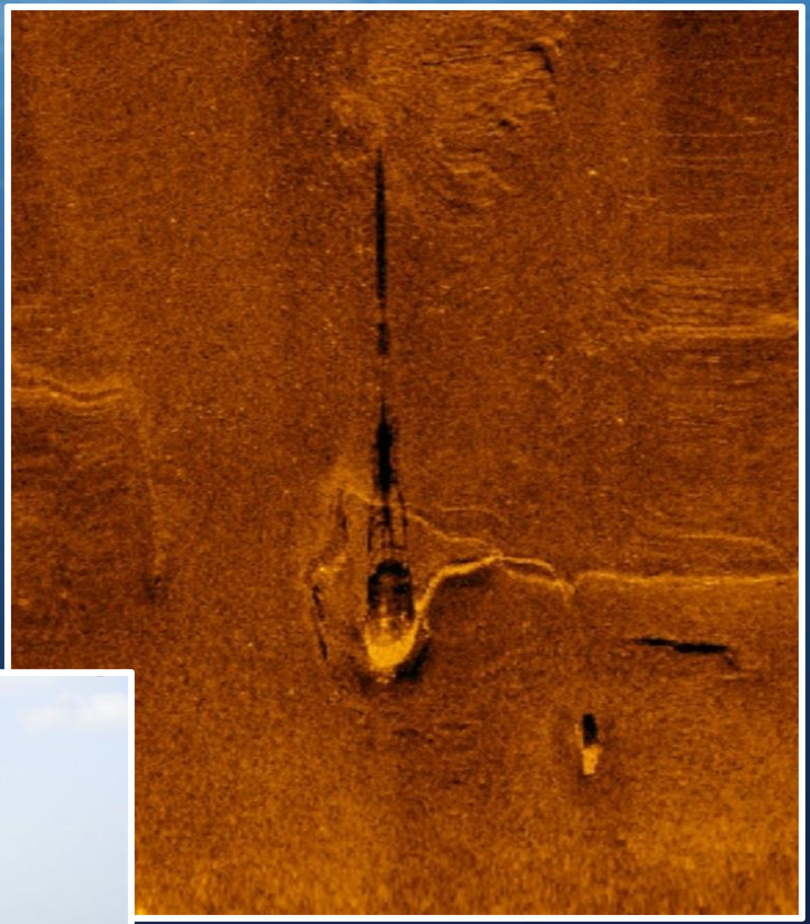




V. Applications

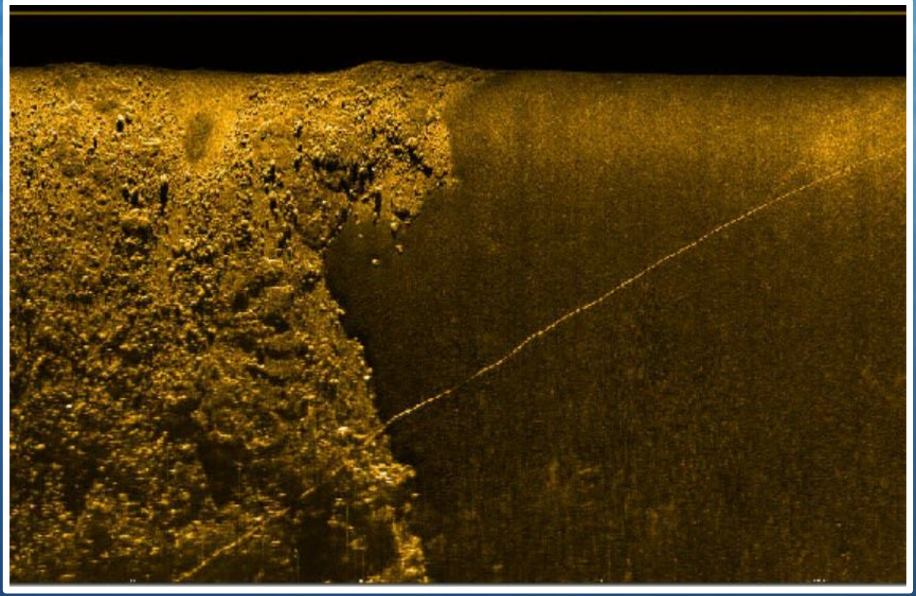
Search – Lost Buoys

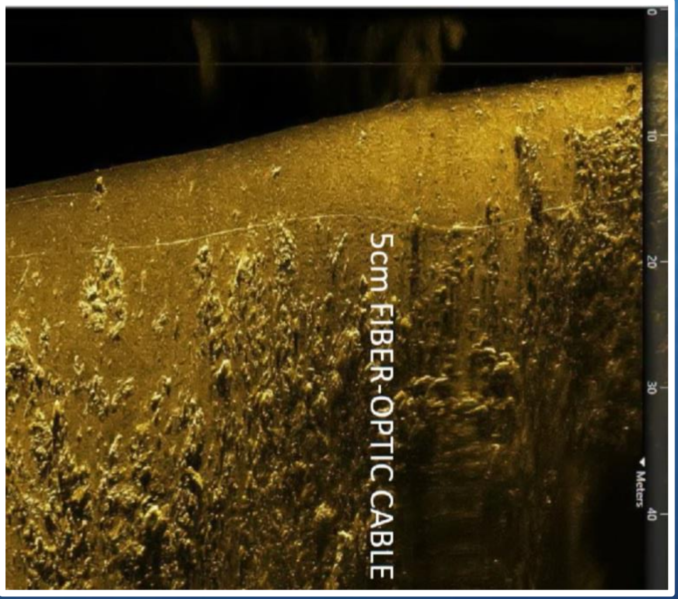


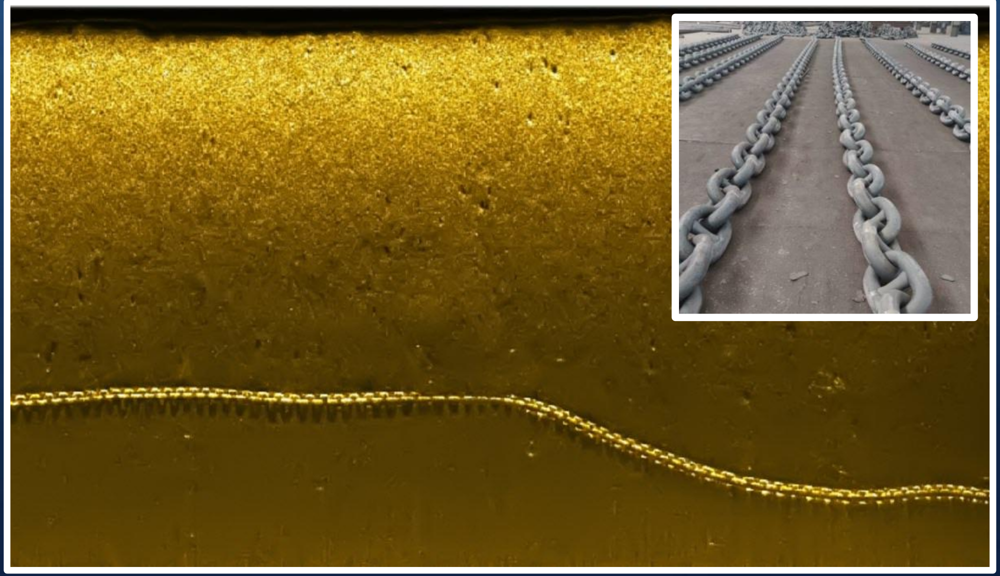


V. Applications

Search – Chain & Cables







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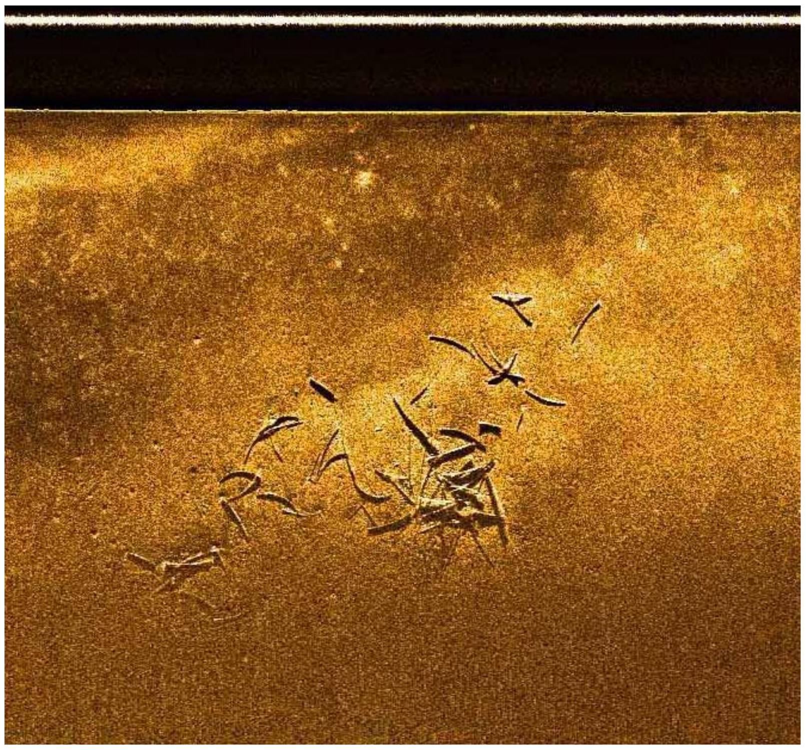
V. Applications

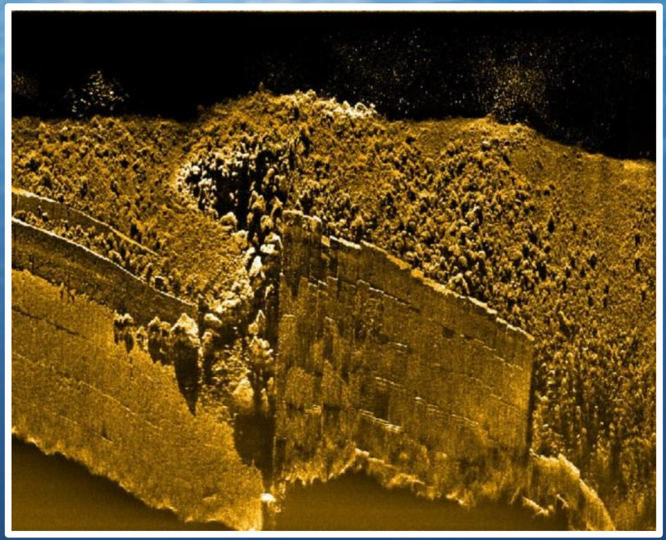
Search – Logging

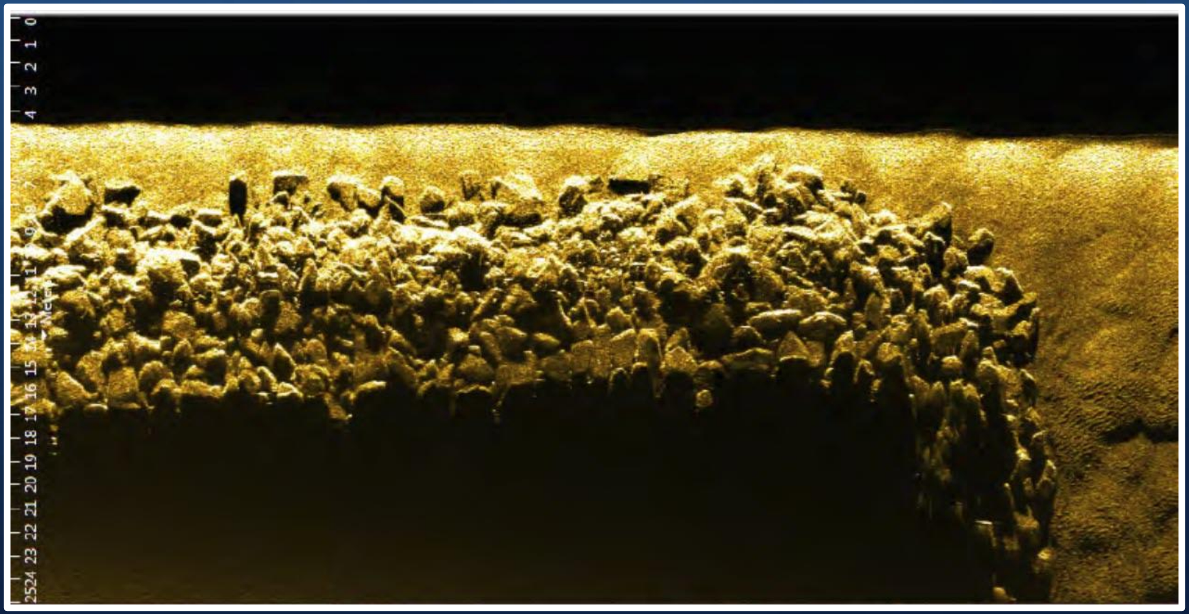


There is treasure in those old sunk logs. One log can be worth several thousand dollars in value.

V. Applications

Structure Surveys - Breakwalls





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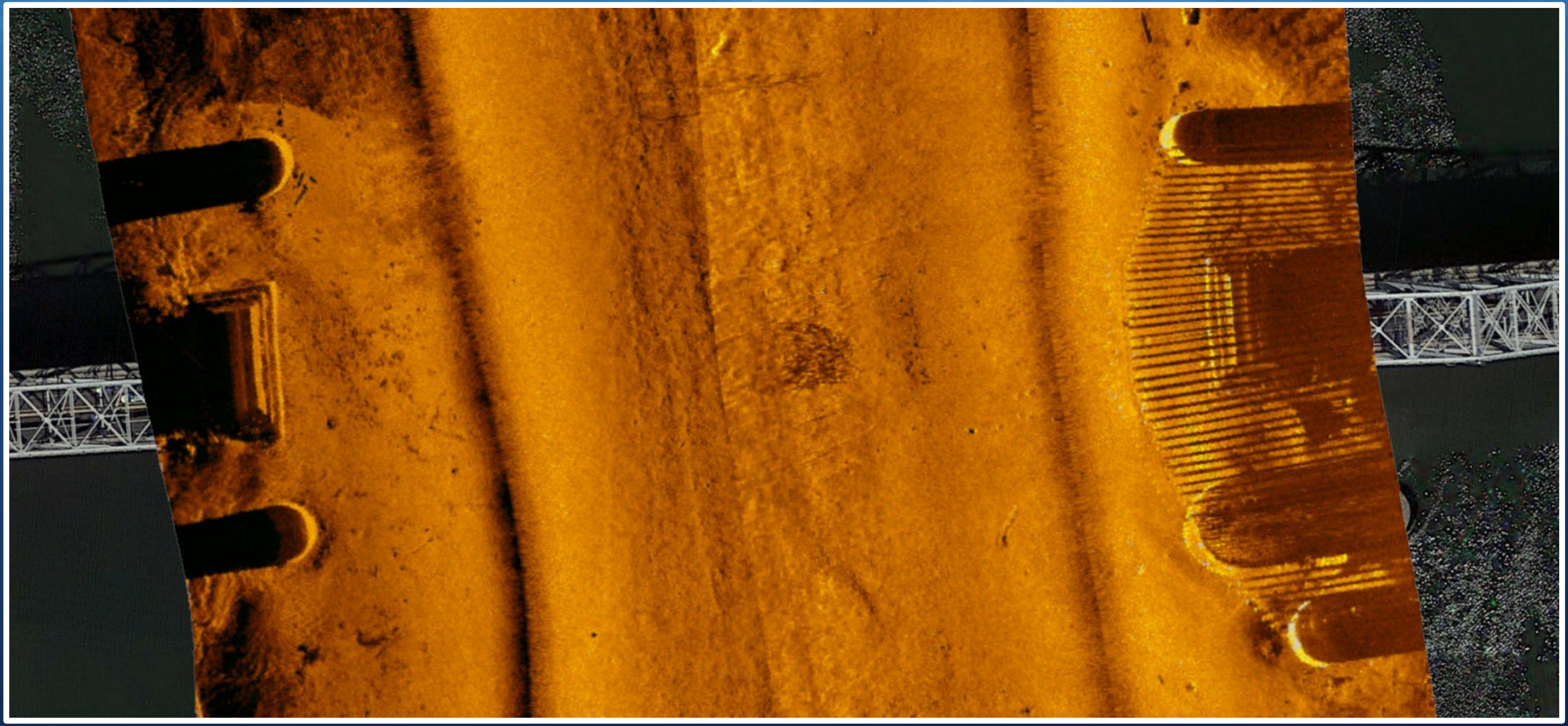
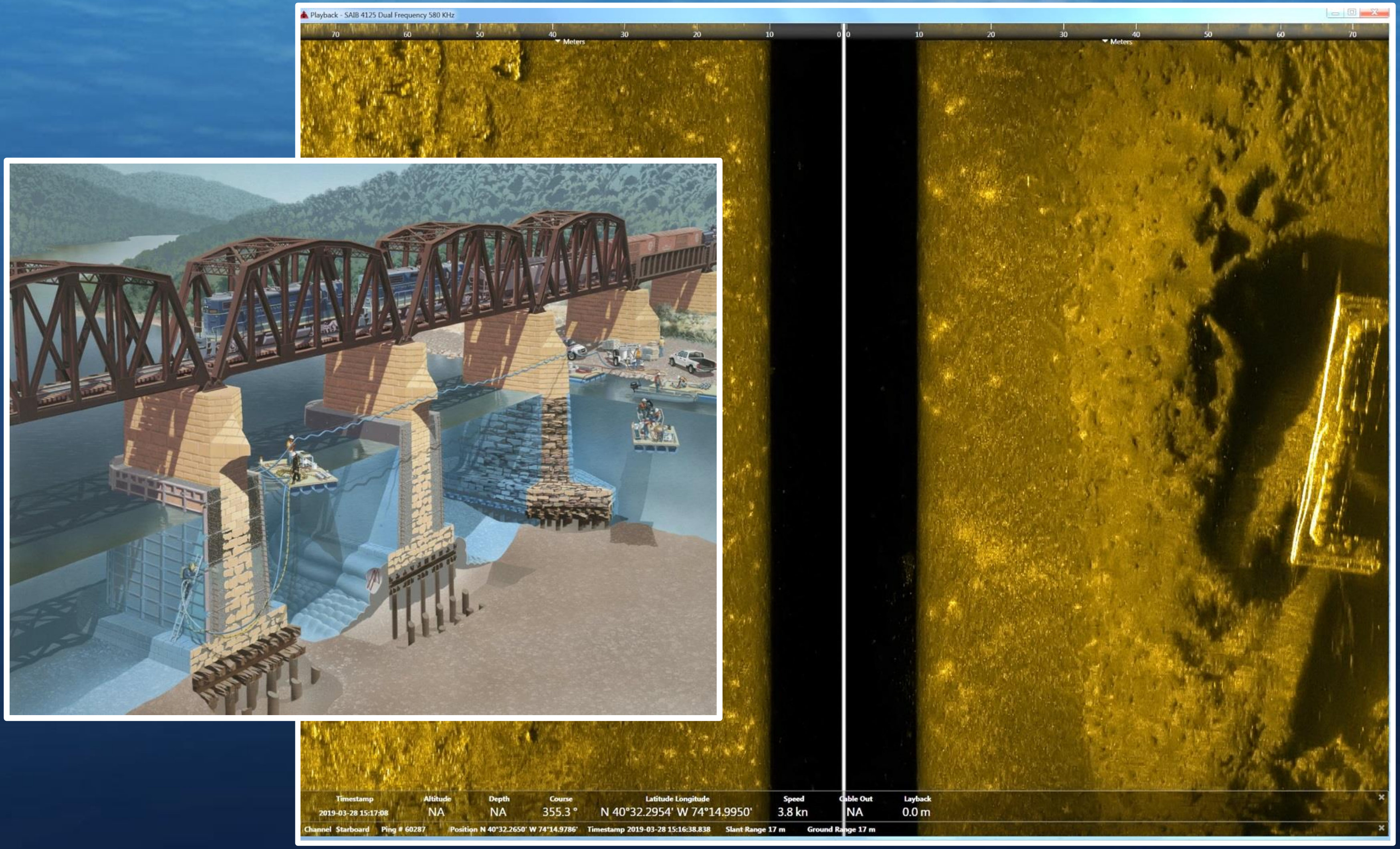
V. Applications

Structure Surveys – Bridge Footings



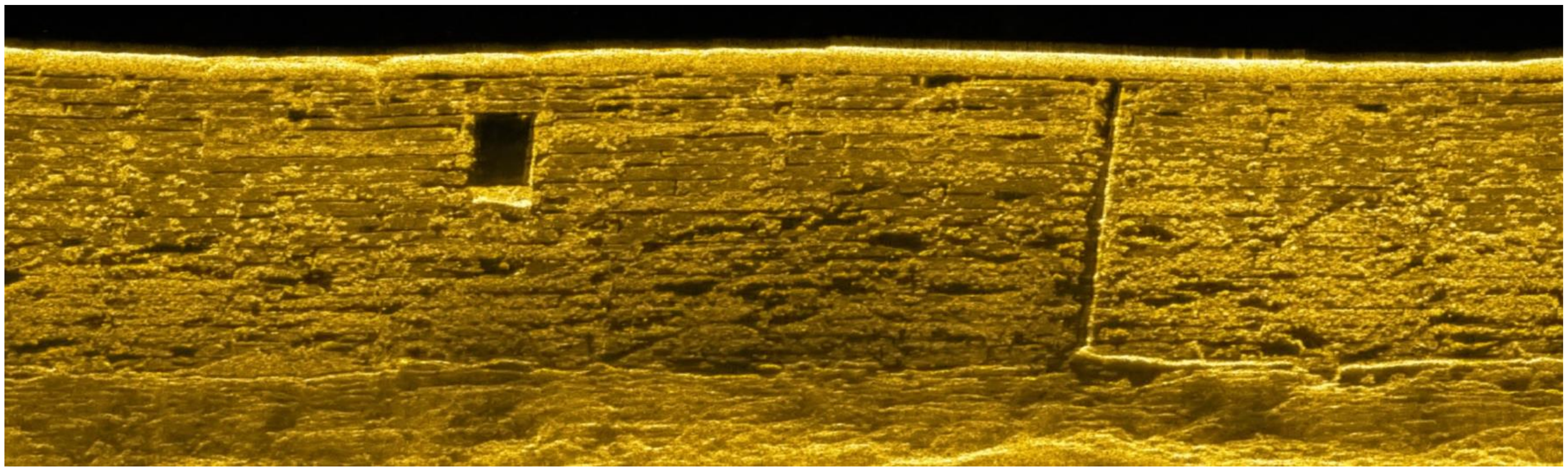
V. Applications

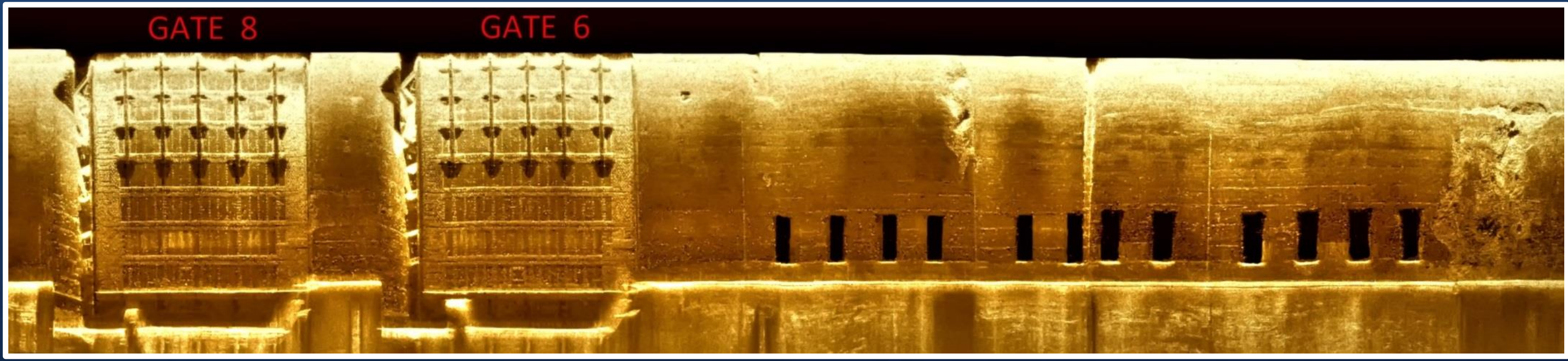
Structure Surveys – Bridge Footing Scour Detection



V. Applications

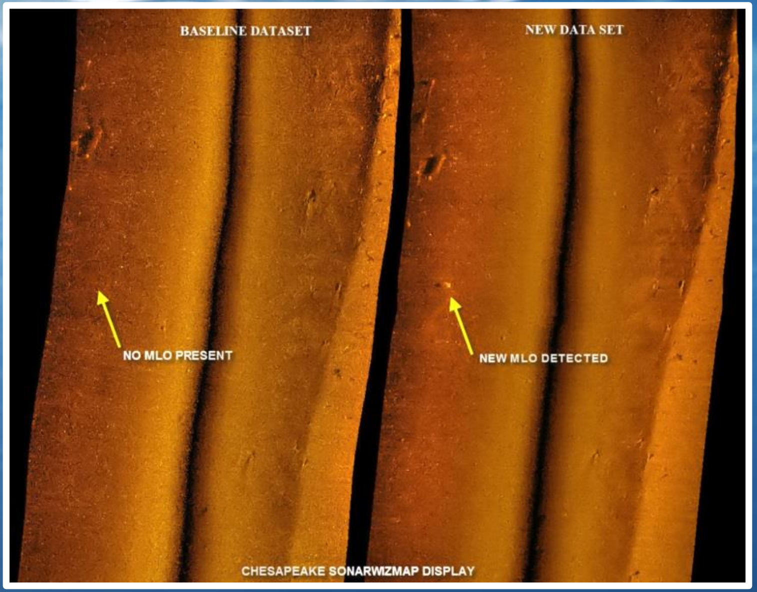
Structure Surveys – Vertical Dock & Pier Walls

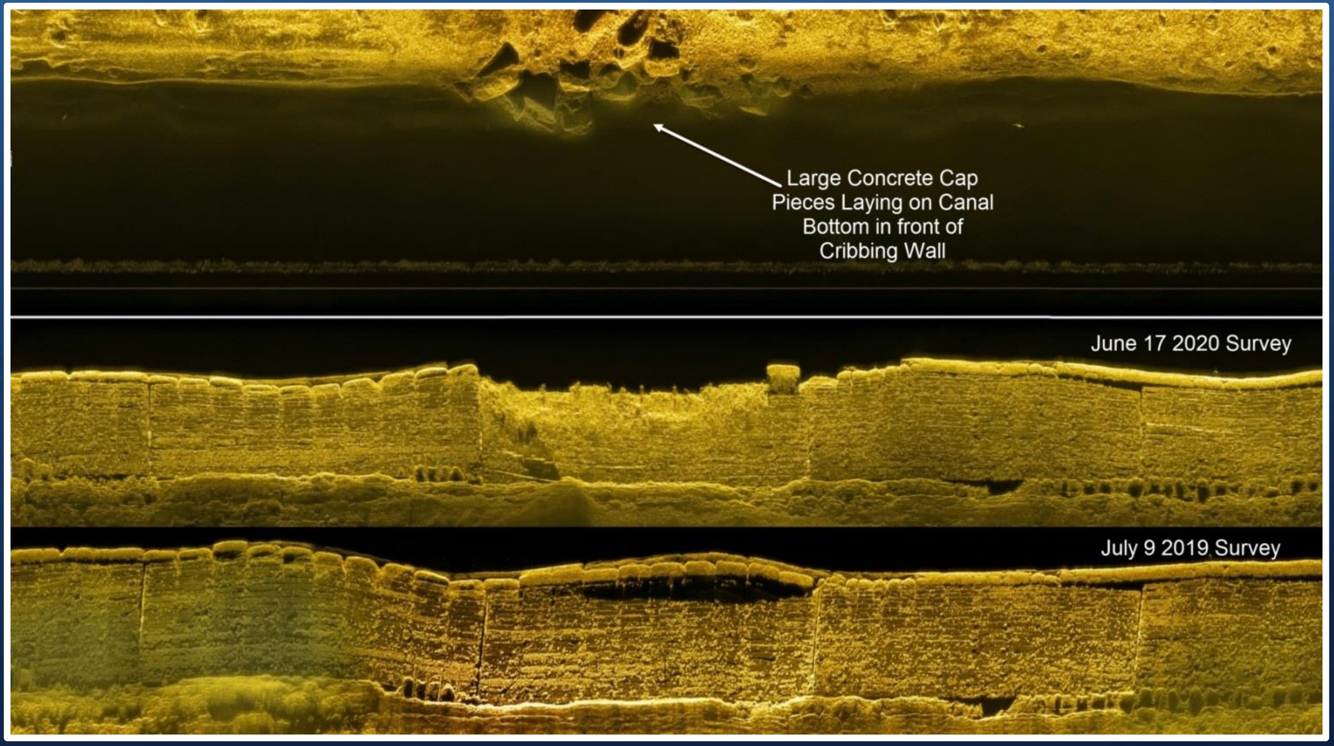




V. Applications

CHANGE DETECTION: comparing an earlier base line survey with future surveys allows easy detection of changes over time

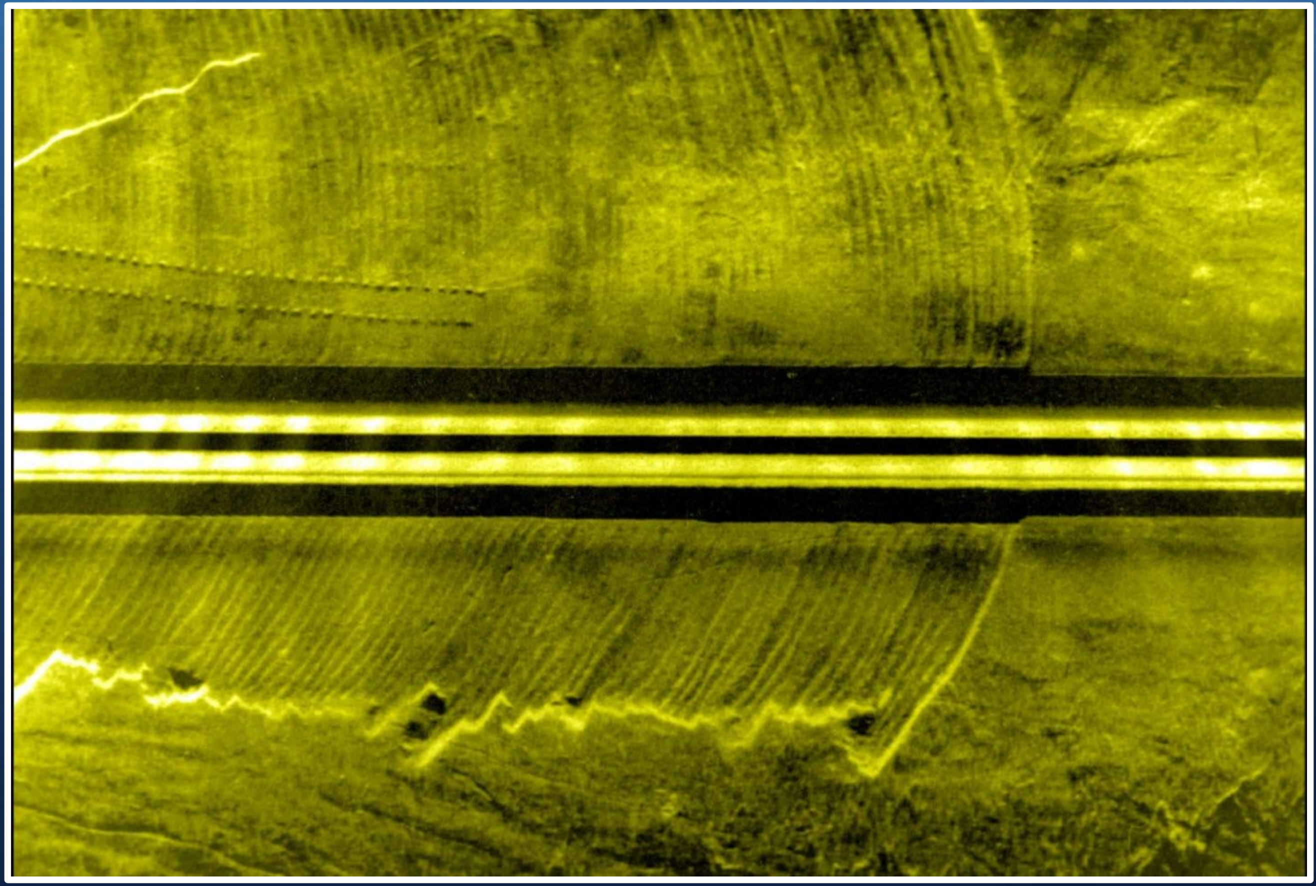




Change Detection: comparing base line survey of pier wall 1 year later clearly shows deterioration

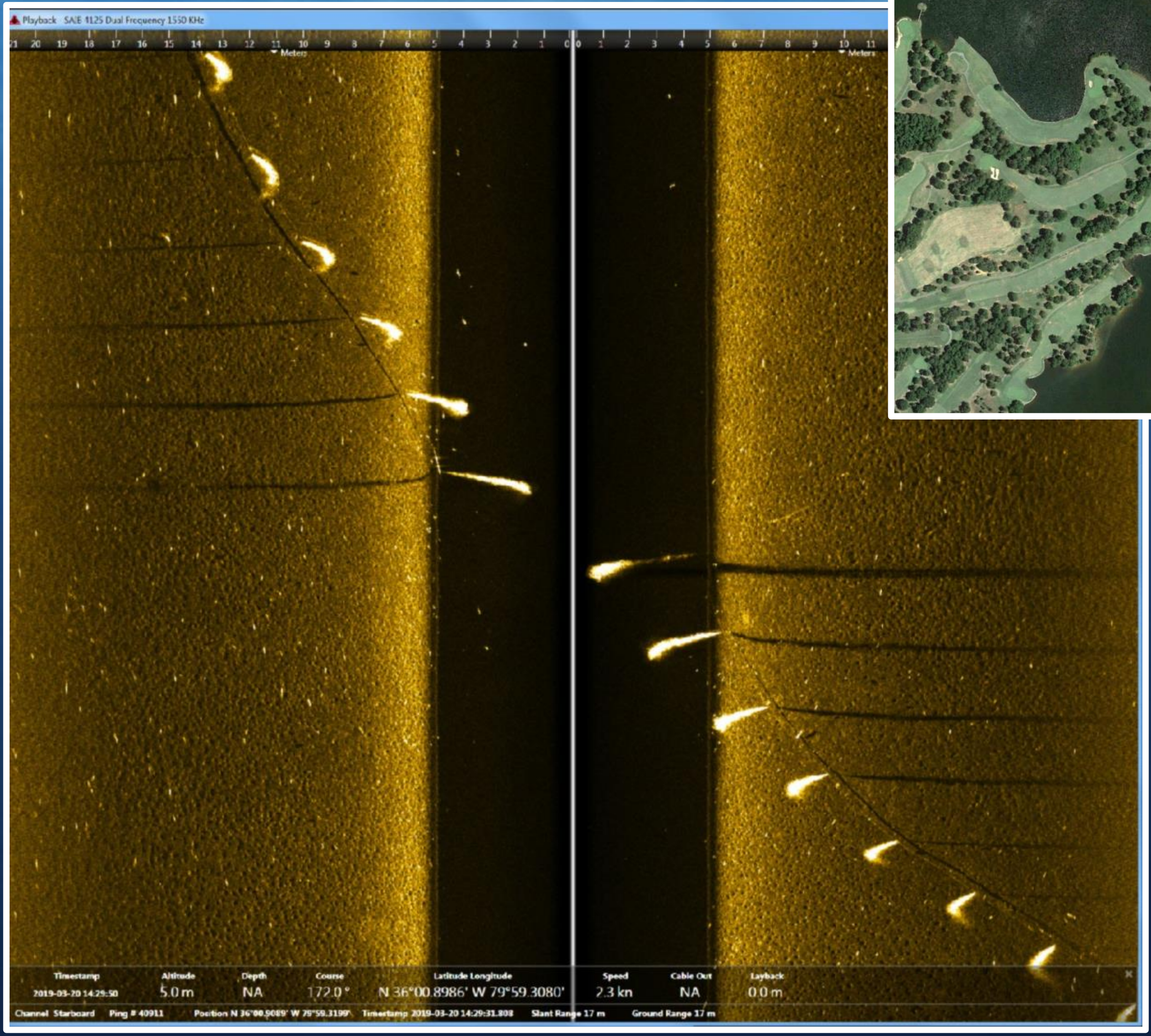
V. Applications

Dredge Monitoring



V. Applications

Mapping – Aeration System



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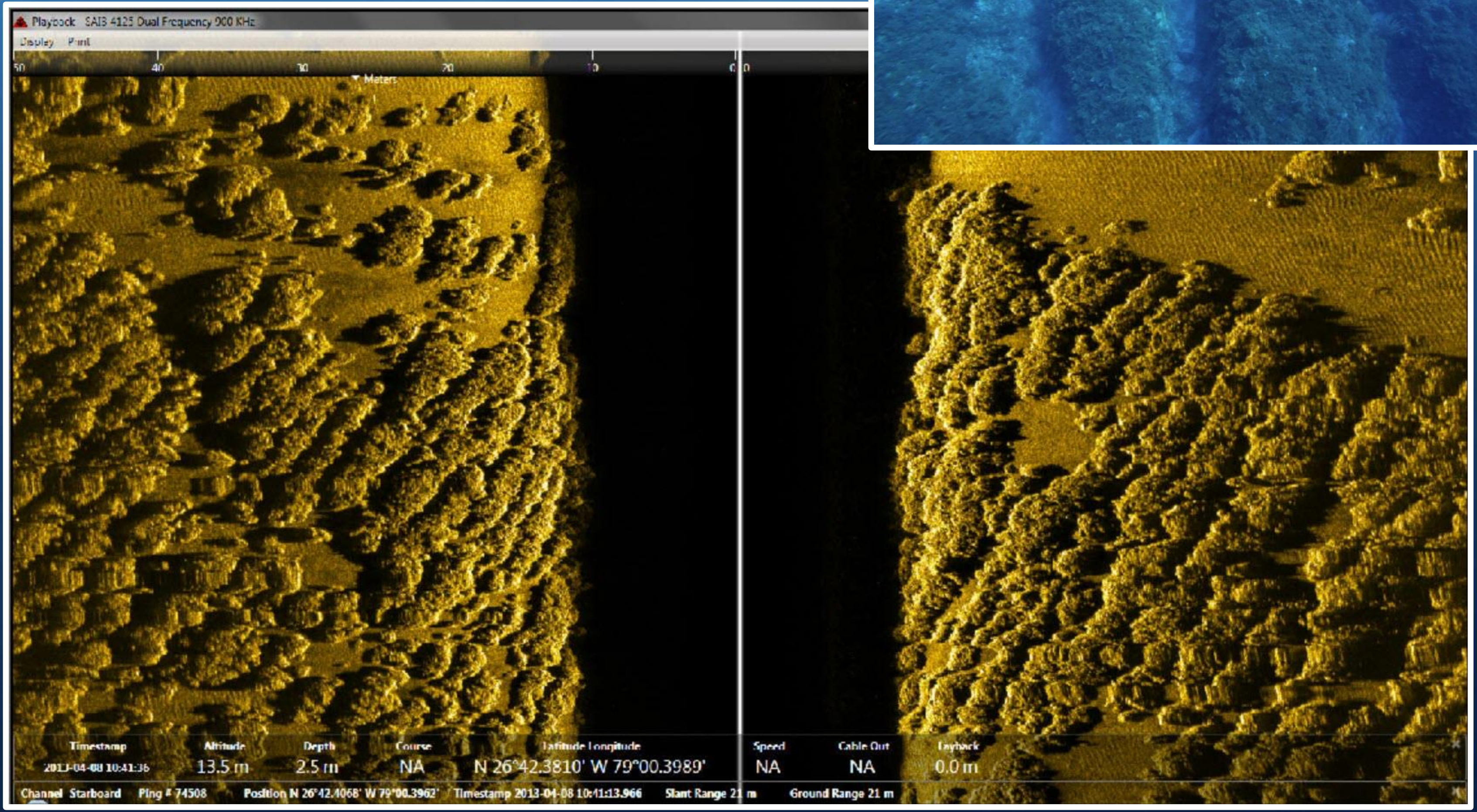
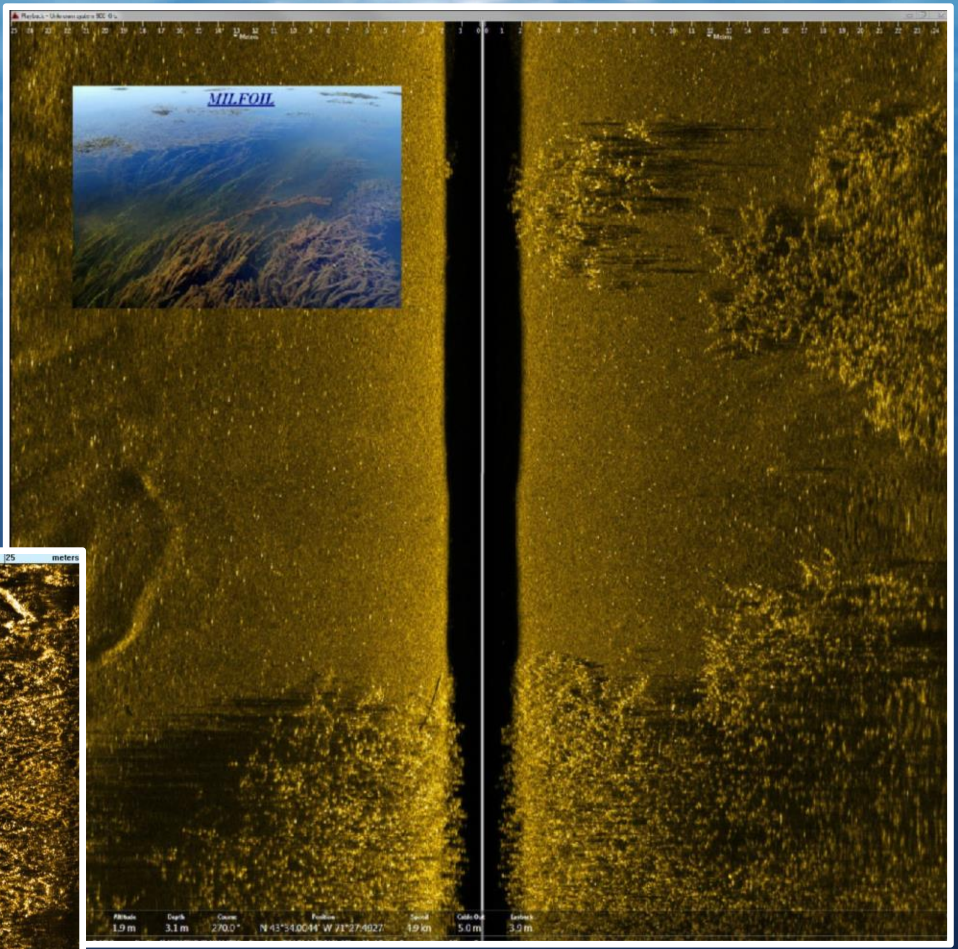
V. Applications

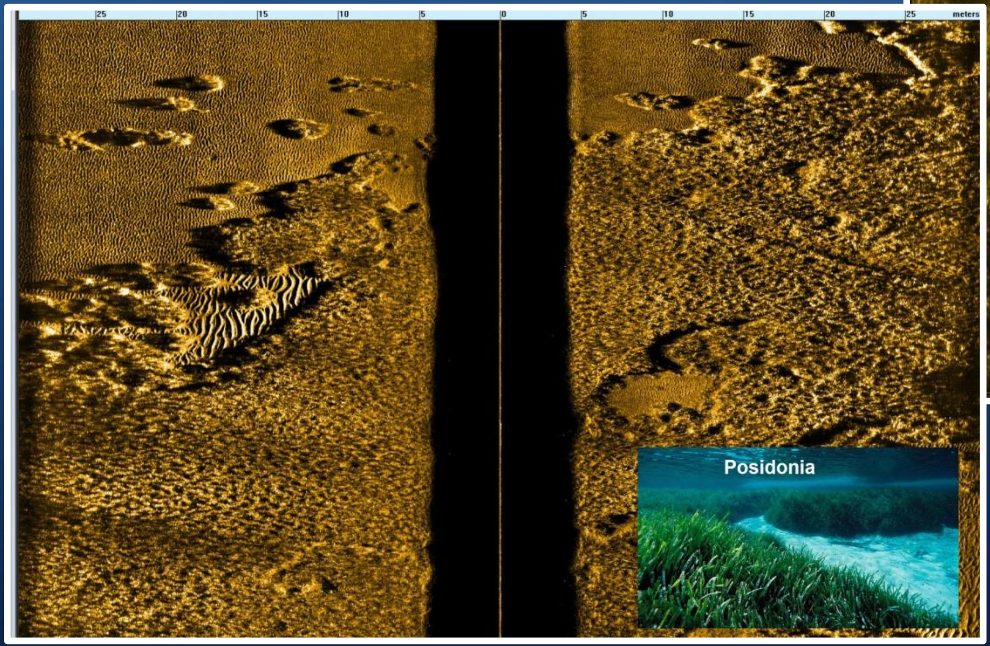
Mapping – Coral Reefs



V. Applications

Mapping – Vegetation





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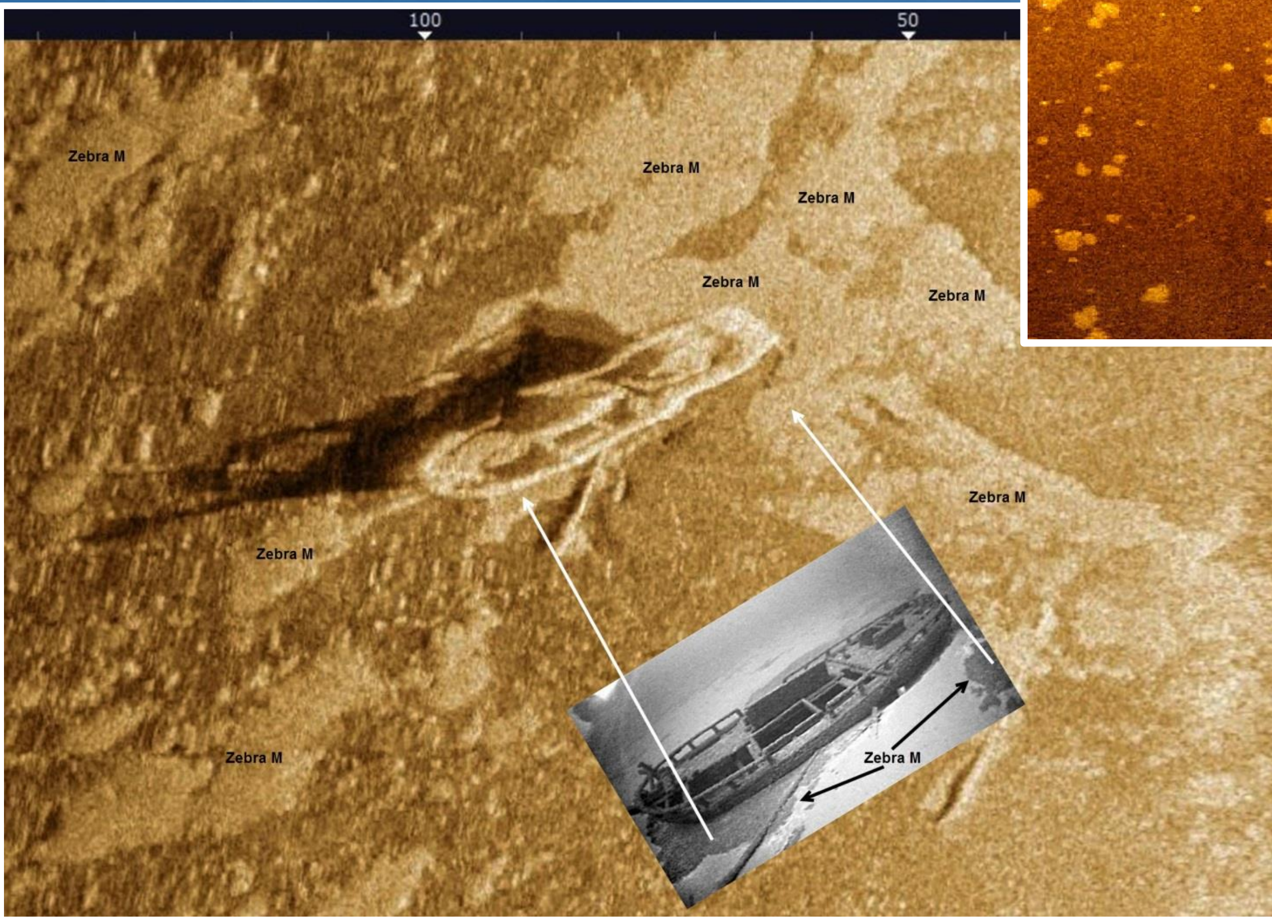
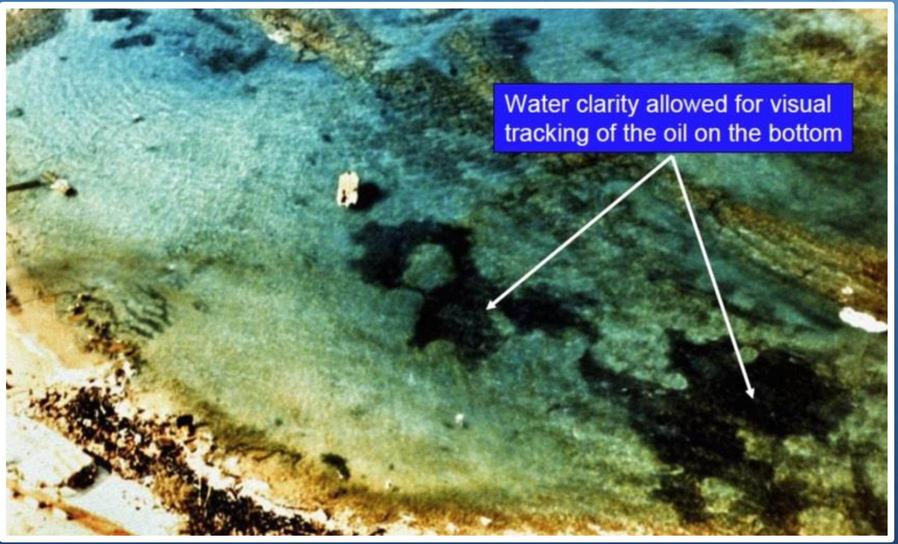
V. Applications

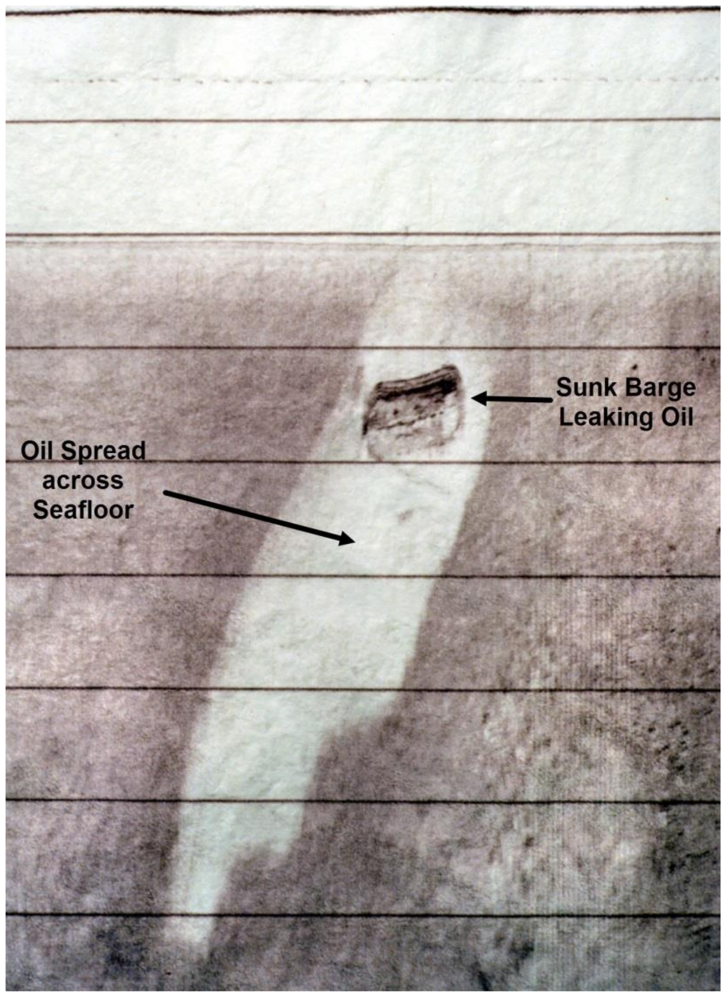
Mapping – Zebra & Quagga Mussels
Invasive Species



V. Applications

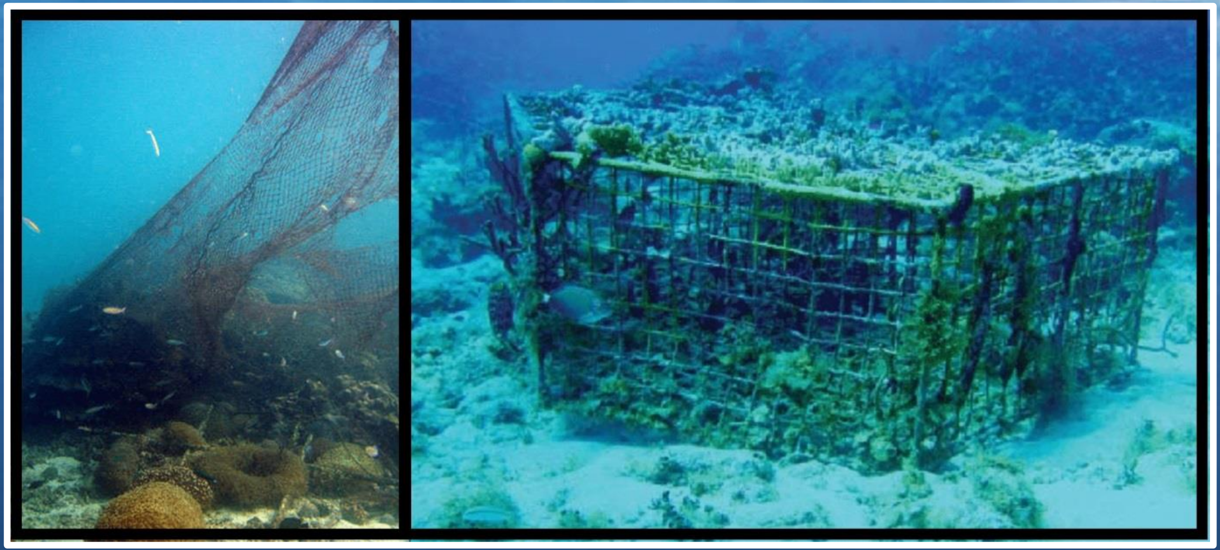
Mapping – Oil Spills

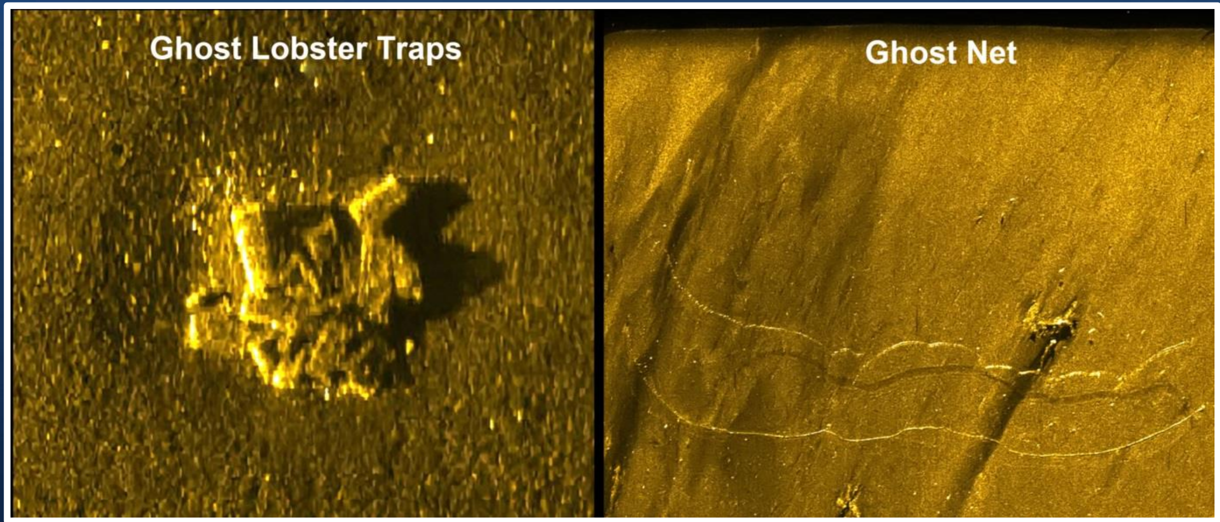




V. Applications

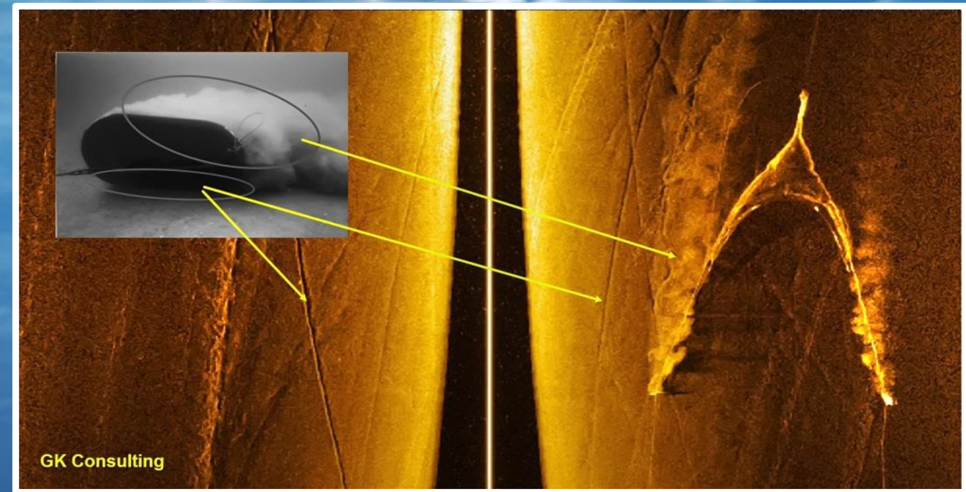
Ghost Gear:
Traps & Nets



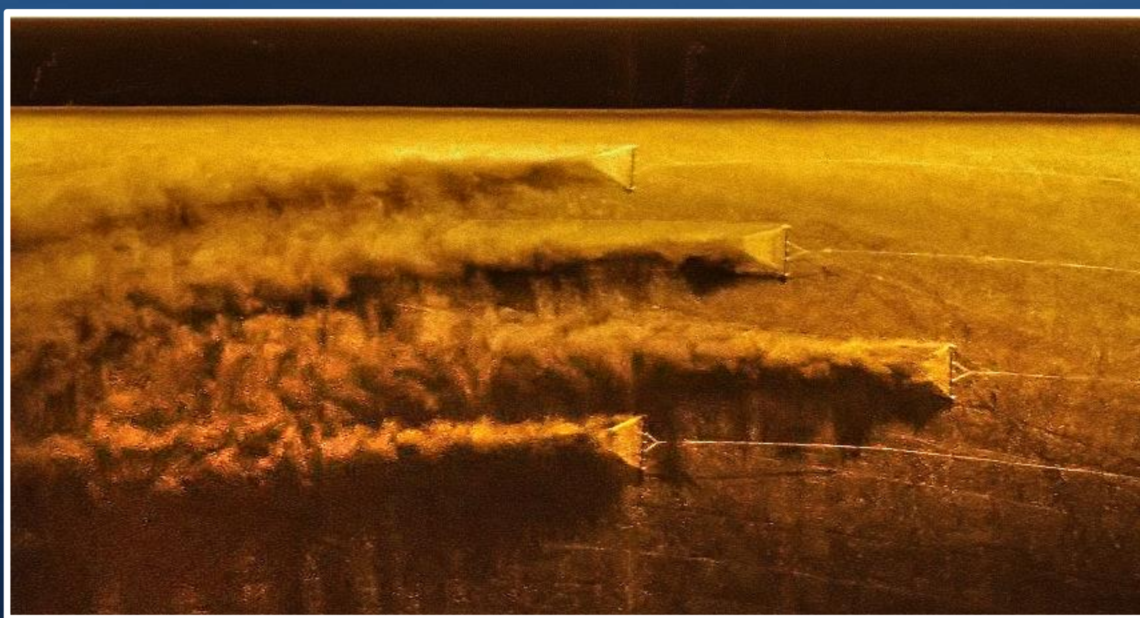


V. Applications

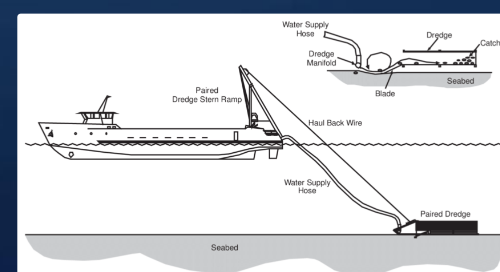
Monitoring Fishing Trawls



Trawl Net and Otter Boards

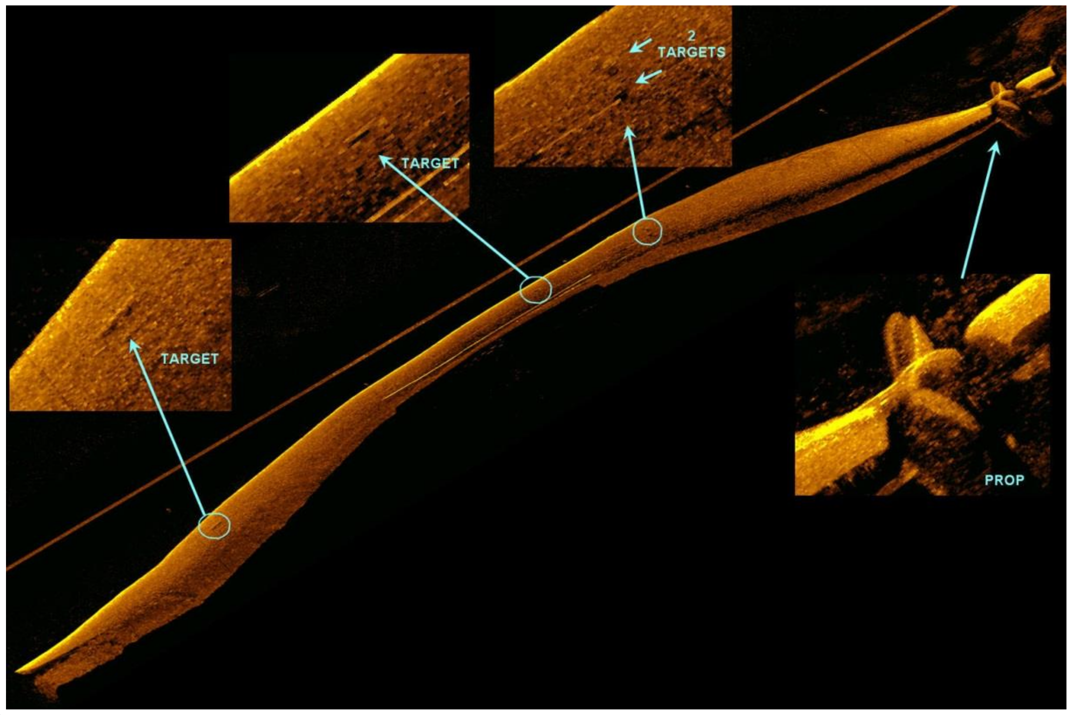


Hydraulic Dredges



V. Applications

Hull Inspection



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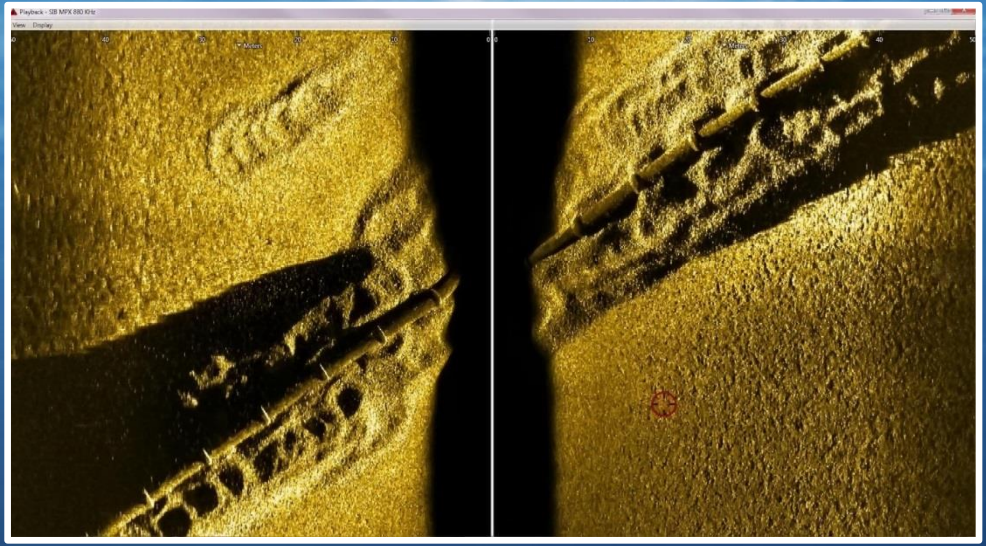
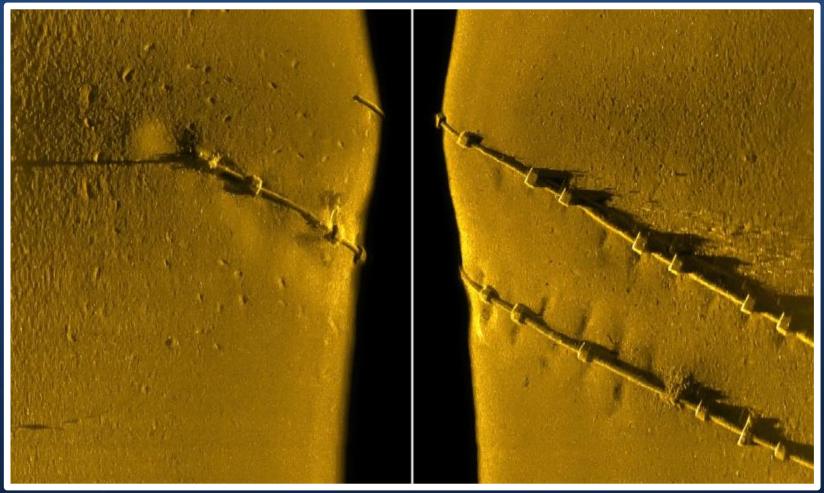
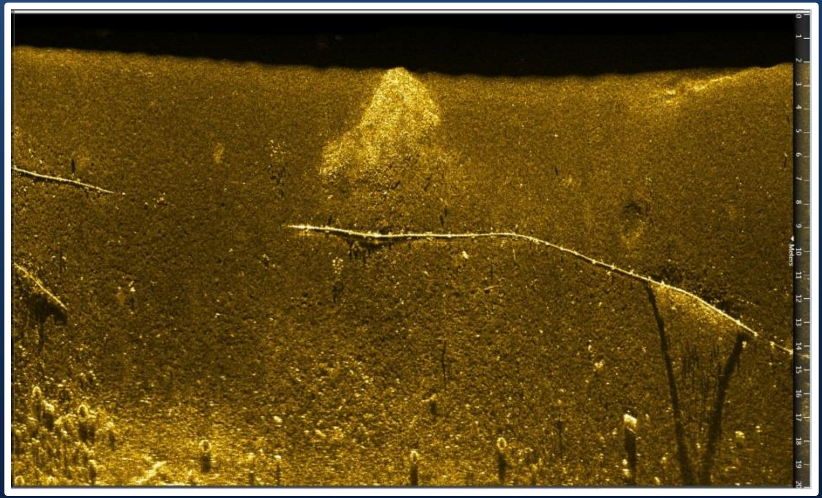
V. Applications

Pipeline Surveys

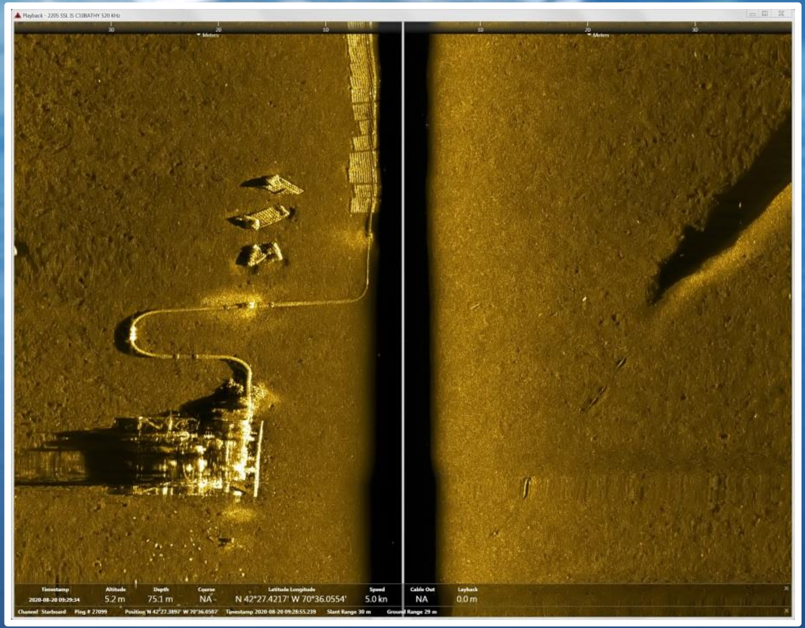


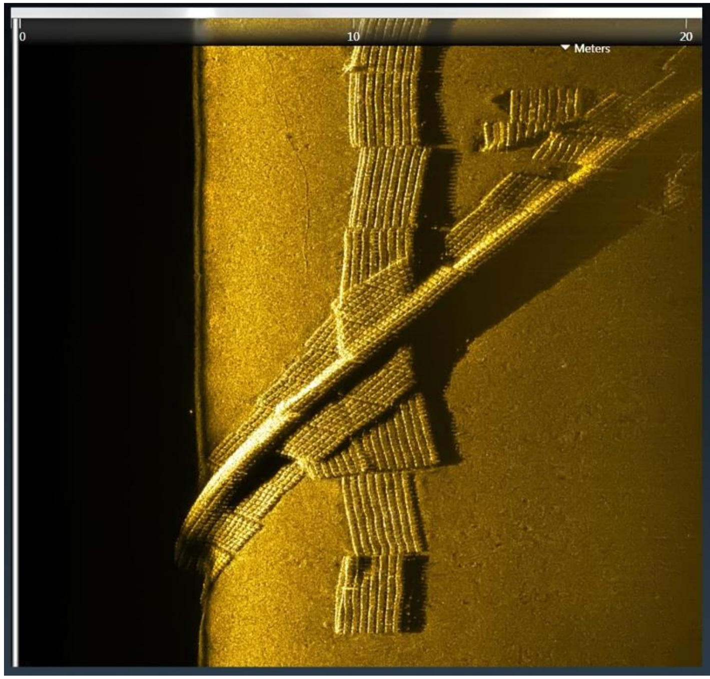




V. Applications

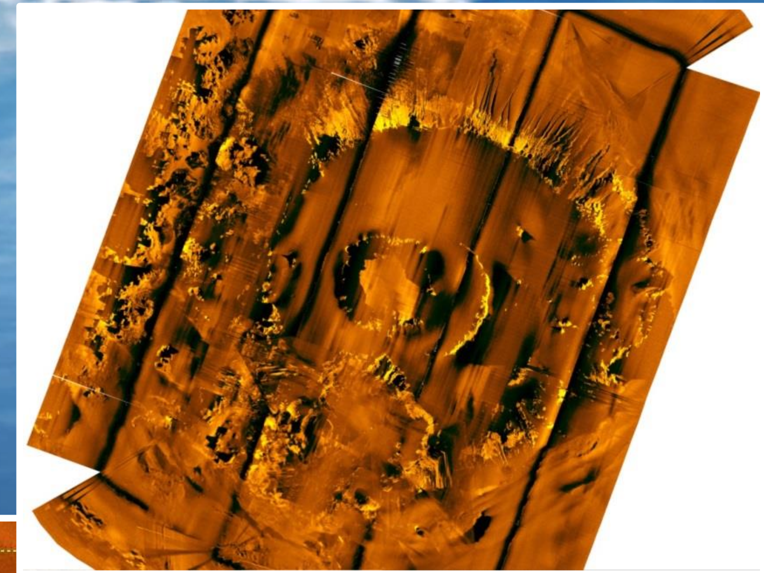
Pipeline Protective
Concrete Matts

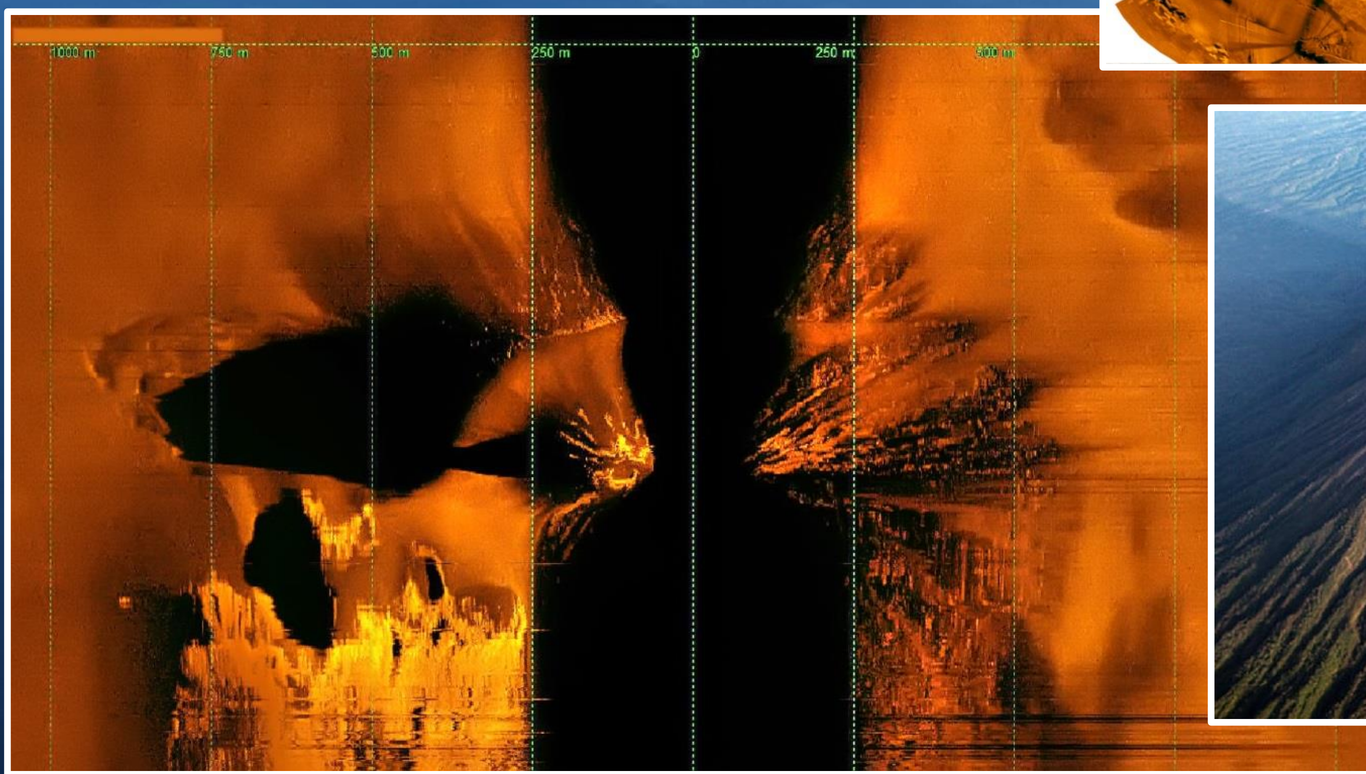




V. Applications

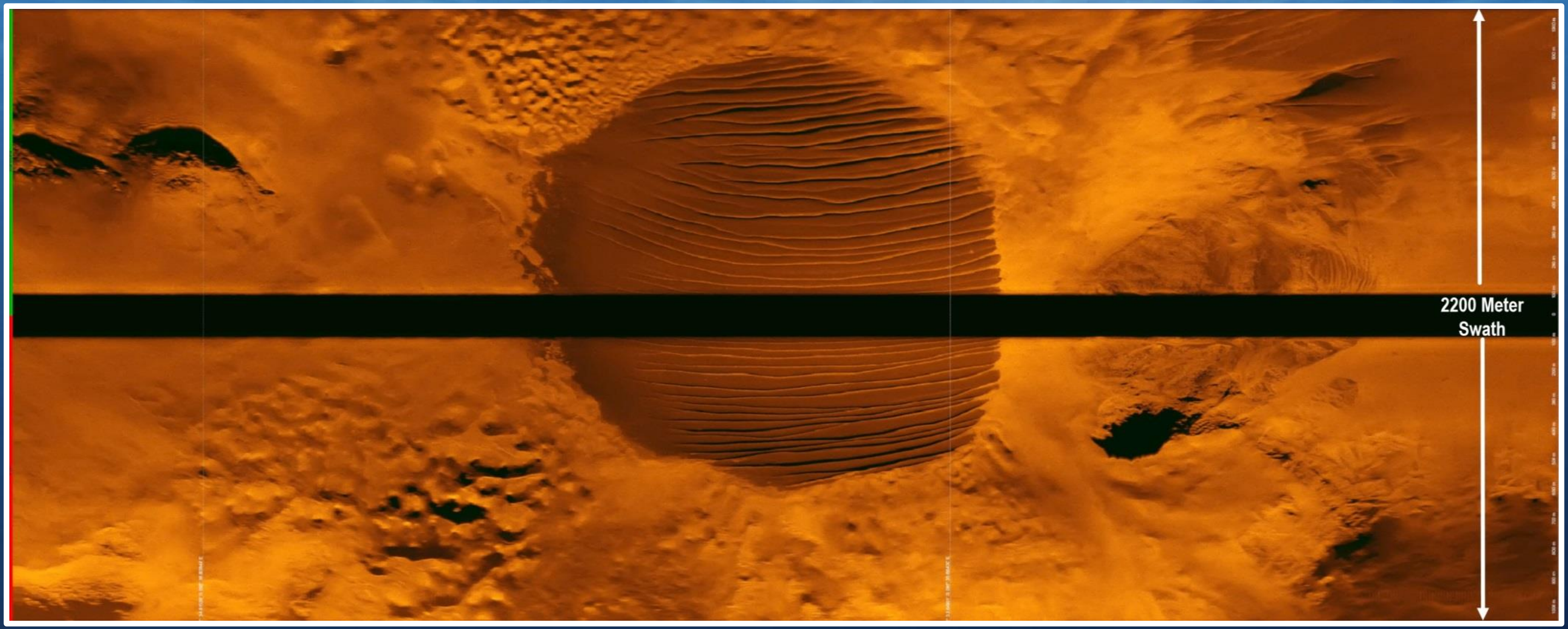
Geology - Volcanoes





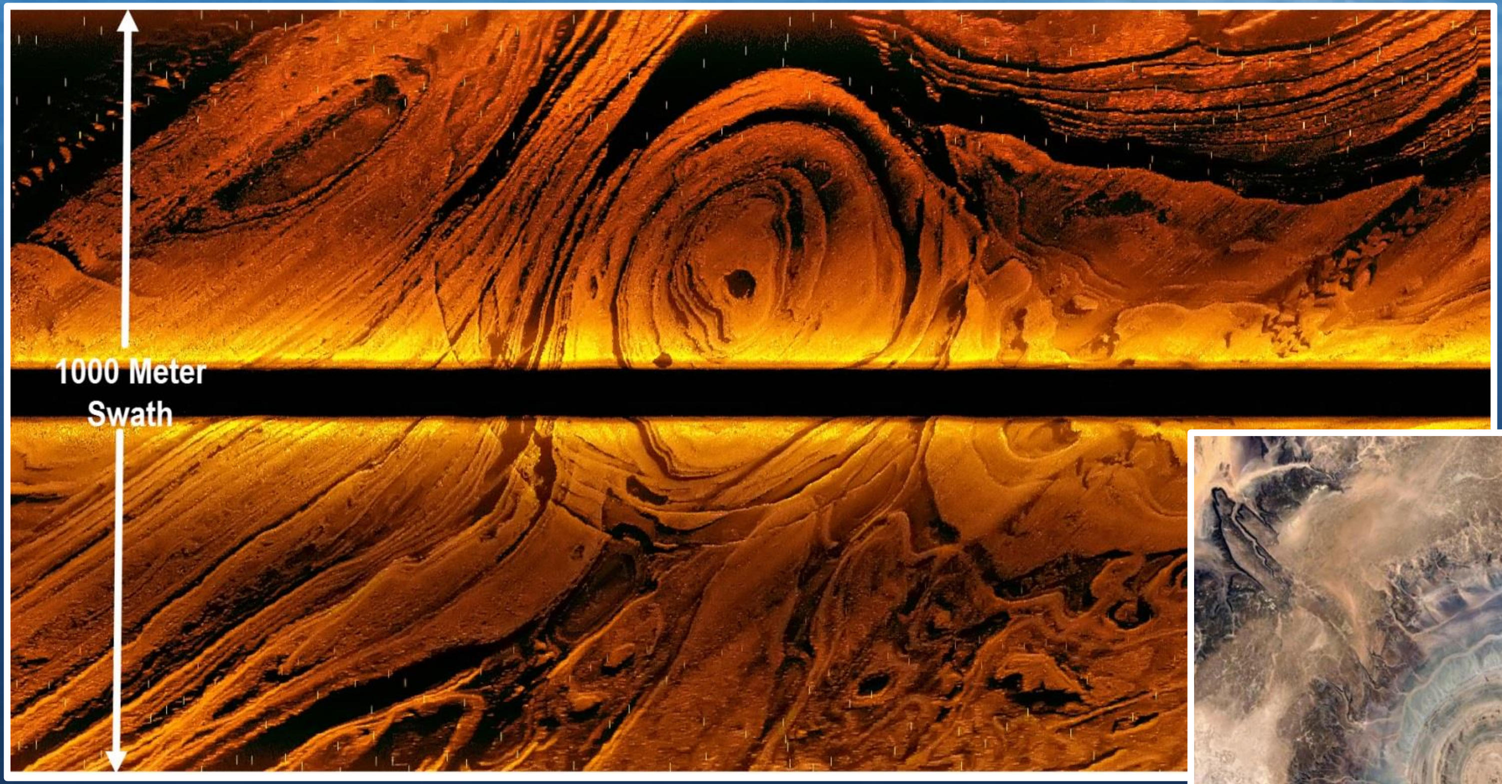
V. Applications

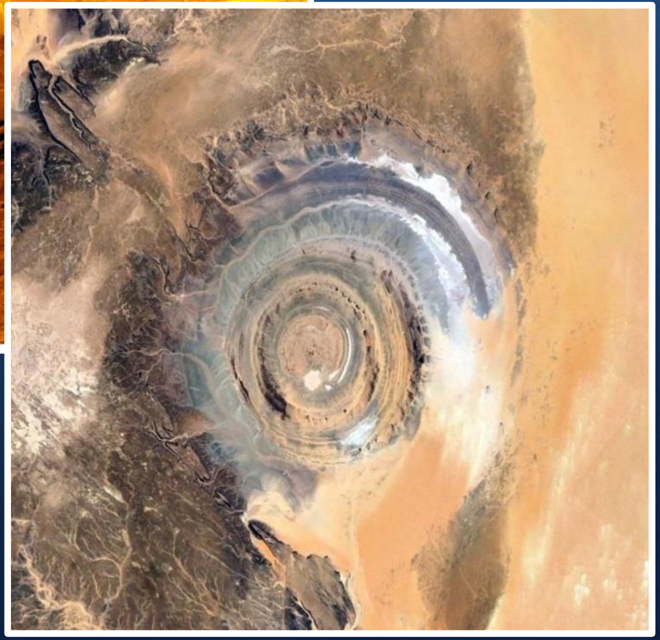
Geology – Cool Feature



V. Applications

Geology – Cool Feature

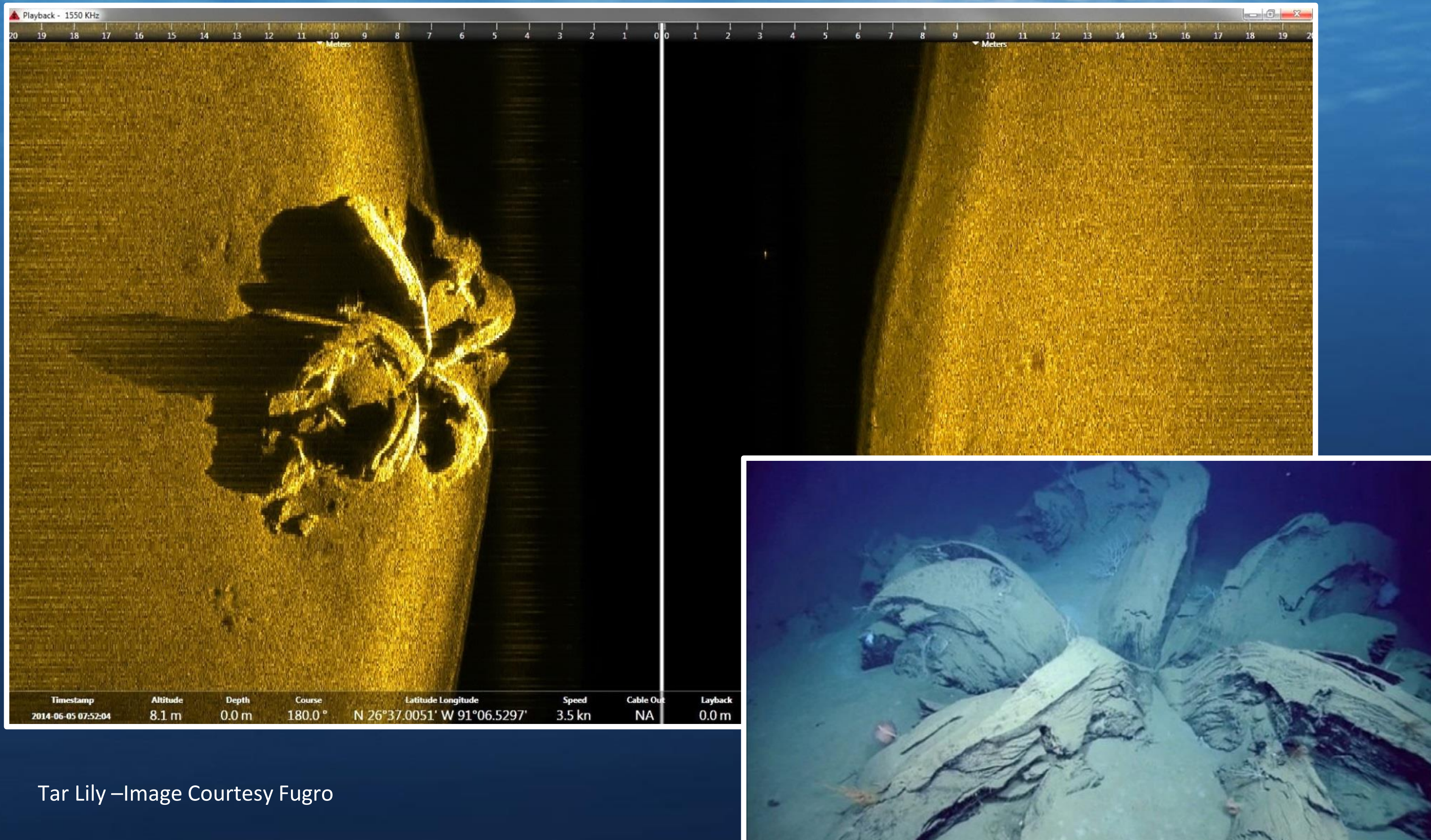




Symmetrical uplift (circular anticline) that has been laid bare by erosion ?

V. Applications

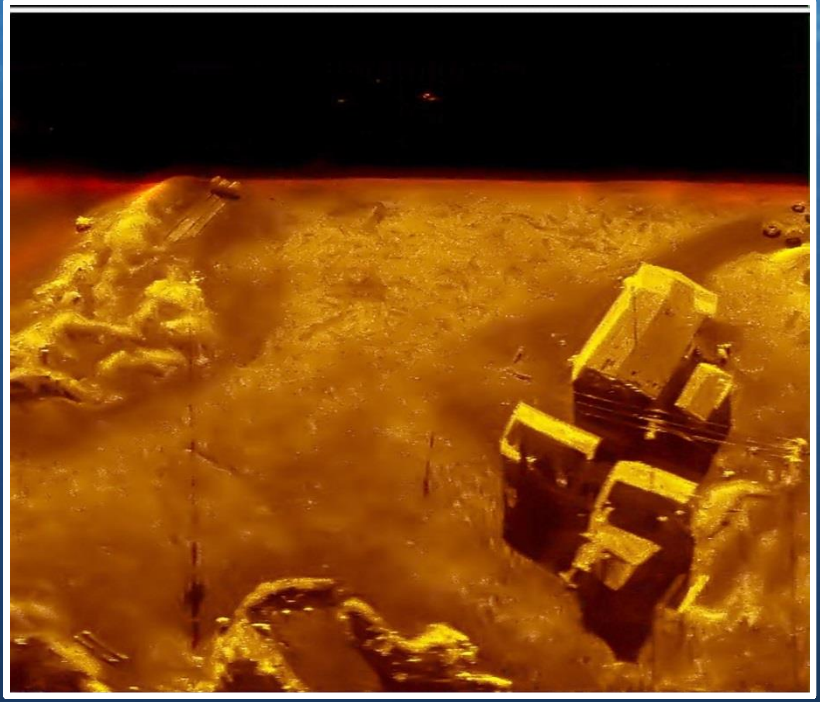
Geology – Cool Feature

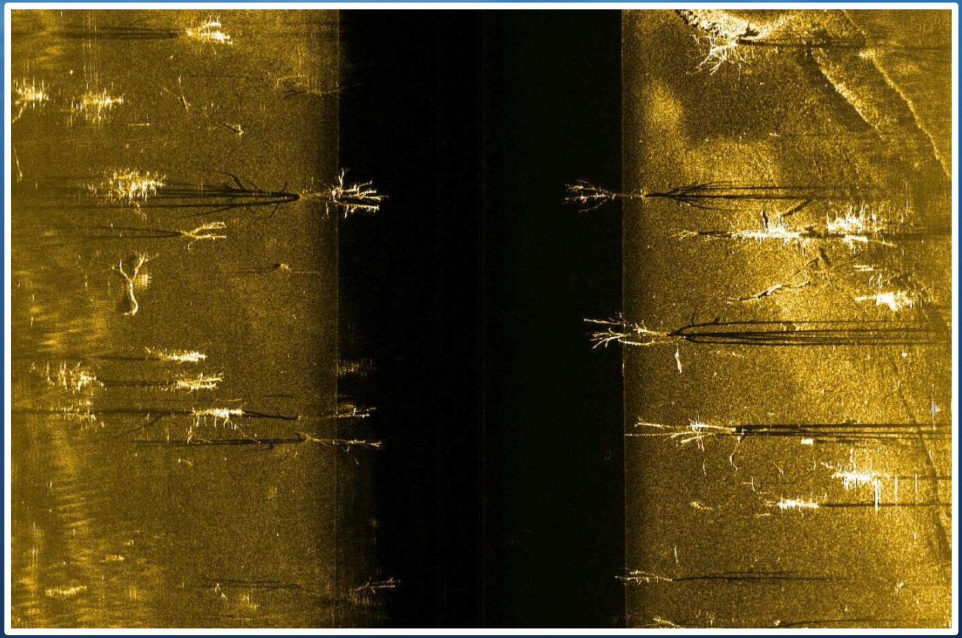


Tar Lily –Image Courtesy Fugro

V. Applications

Structures – Cool Features

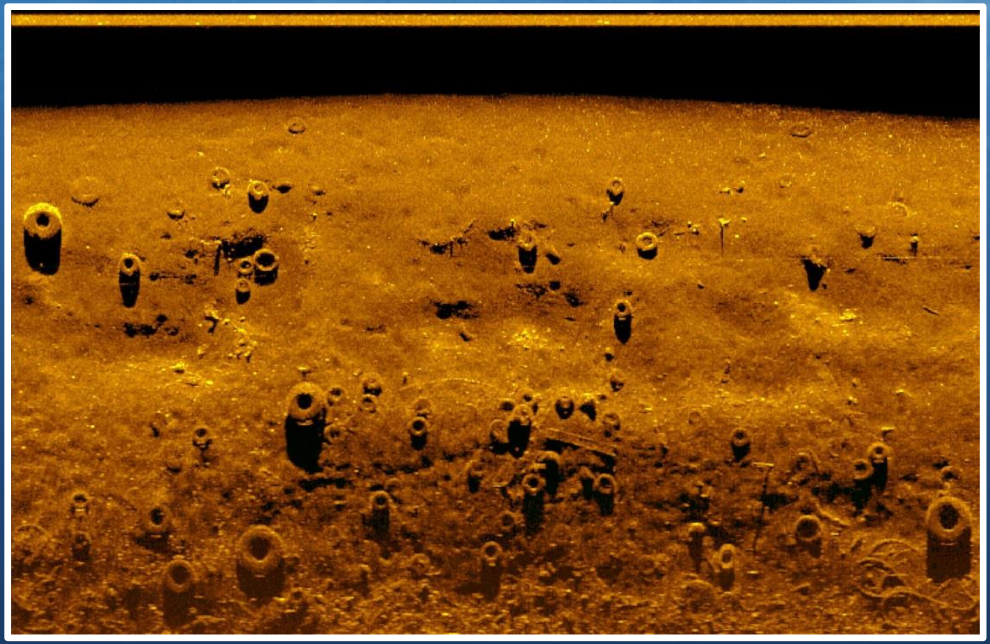


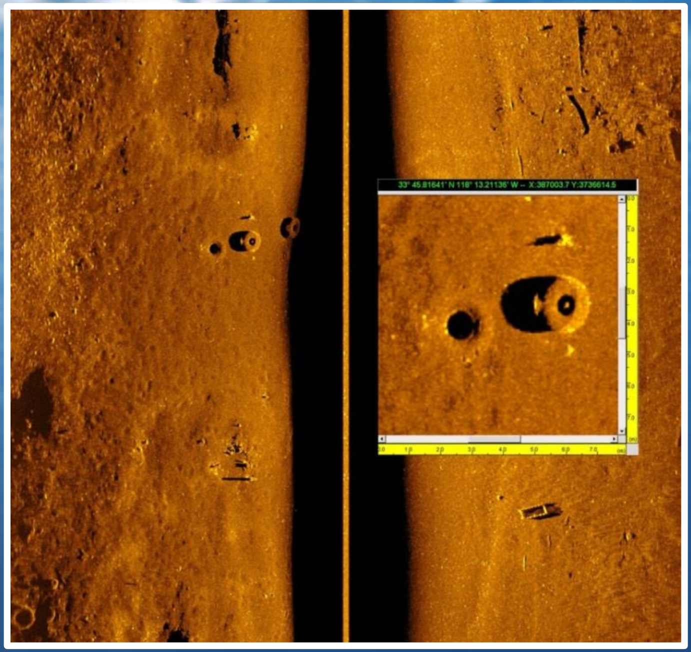


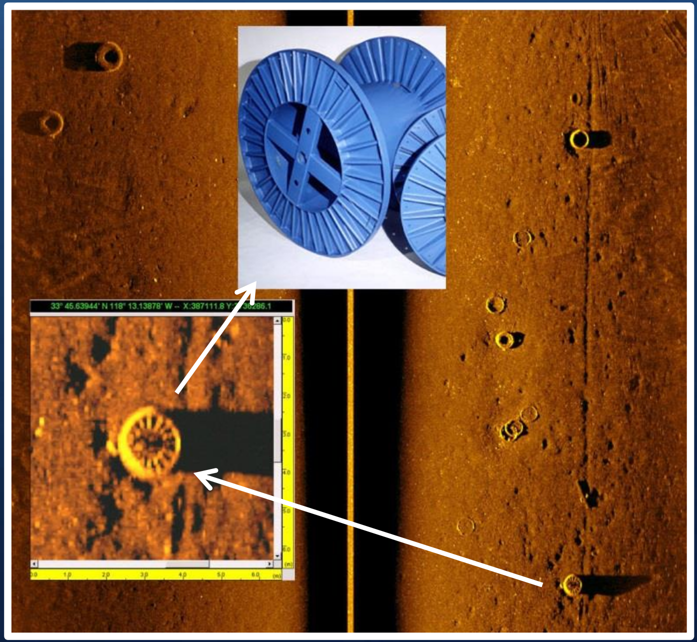
Man-Made Lake with Buildings and Trees still standing

V. Applications

Tires

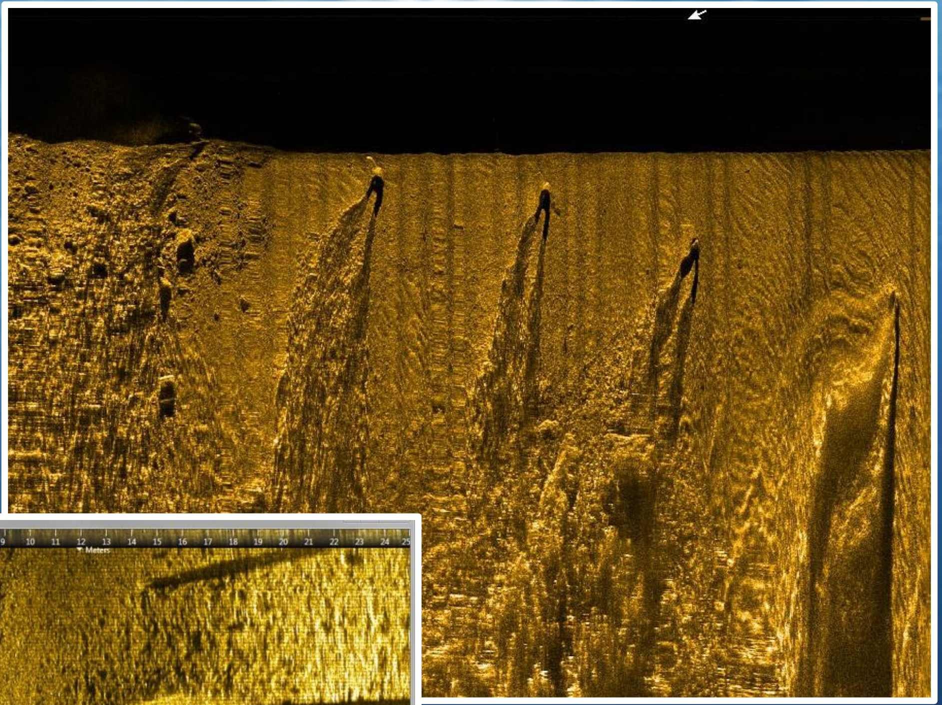


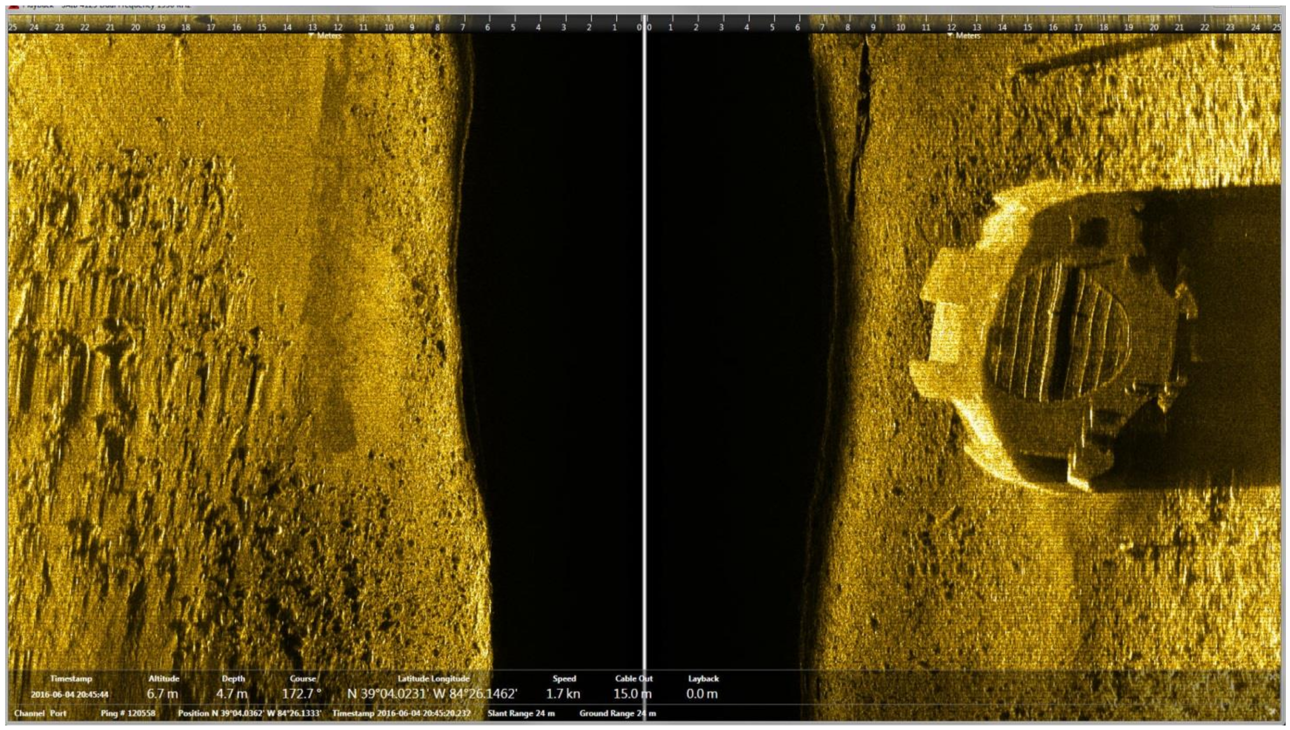




V. Applications

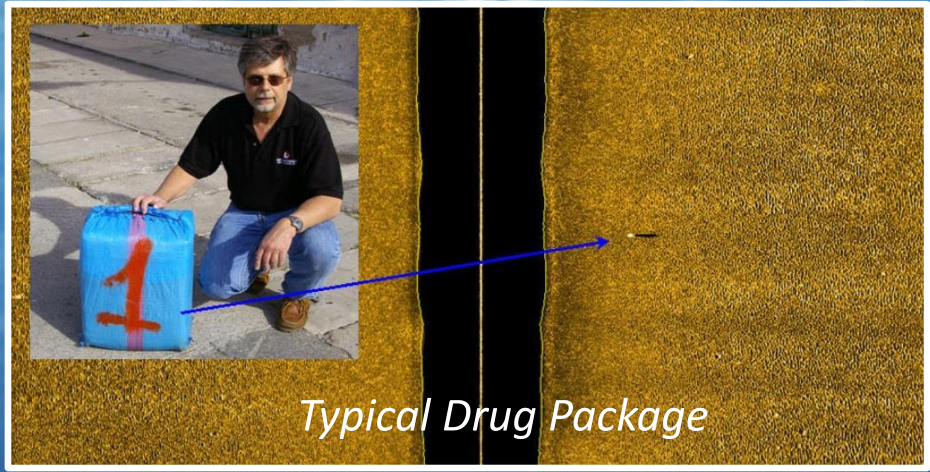
Water Intakes & Exhaust Diffusers





V. Applications

Jettisoned Drug Package Location

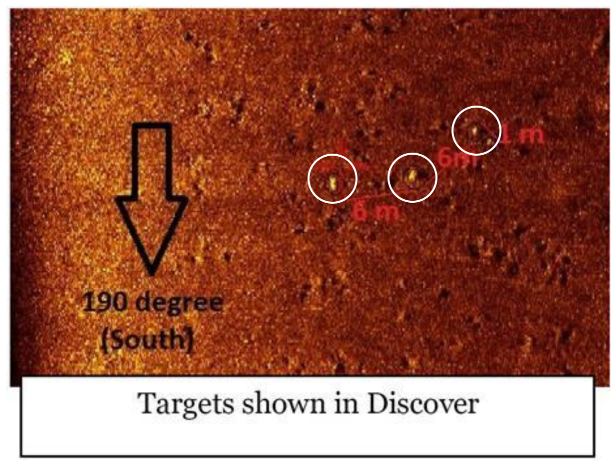


Typical Drug Package

Saudi Arabia Coast Guard Drug Bust

***4** Jettisoned bags of drugs thrown overboard into sea and located with EdgeTech 4125 Side Scan Sonar*

Traffickers boat with a dozen gas tanks.

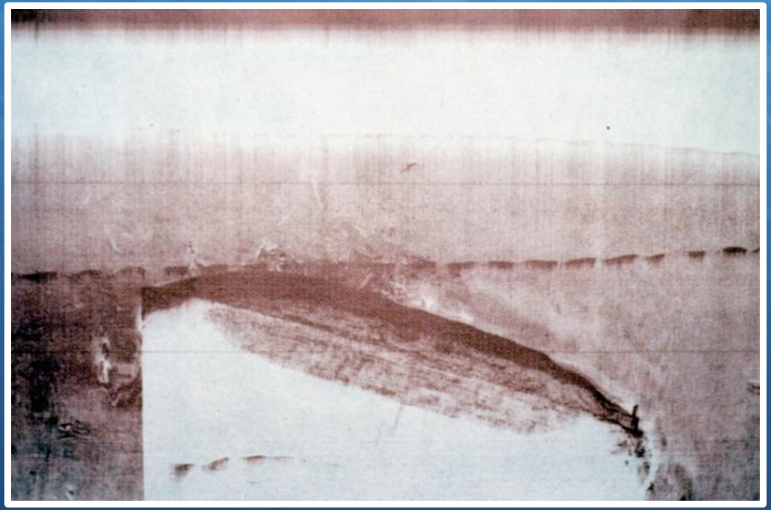


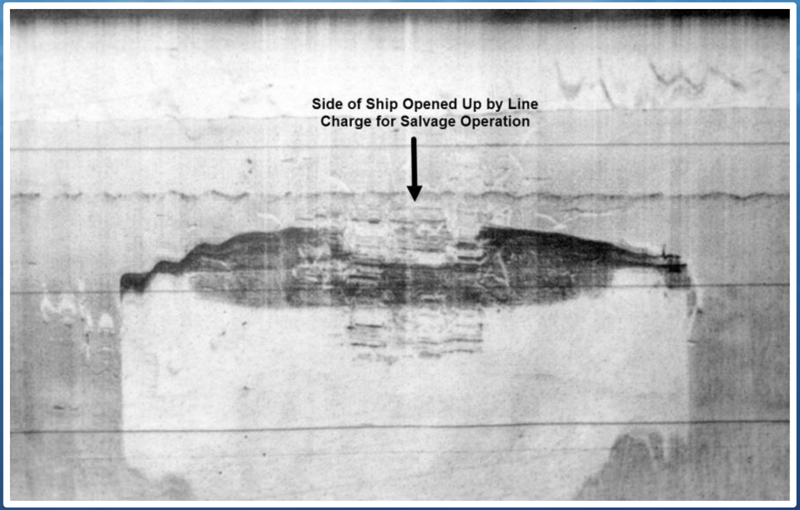
Targets shown in Discover

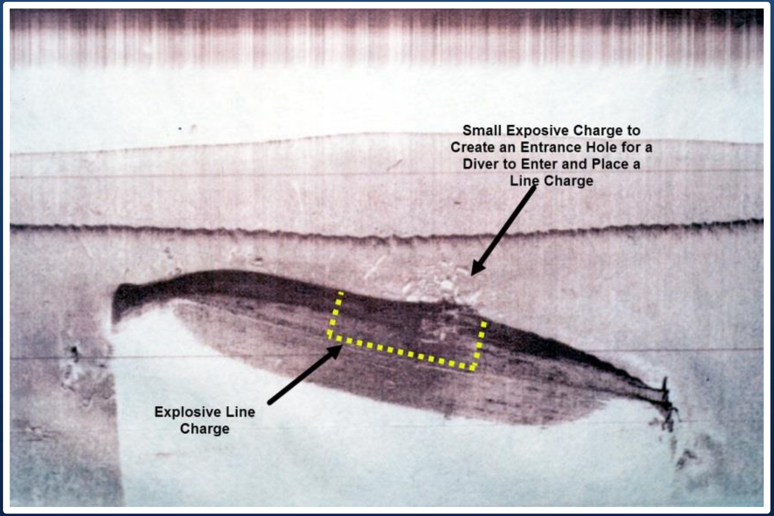
2 of the 4 recovered bags

V. Applications

Side Scan Sonar Eyes to Monitor Explosive Results as Salvors Rig Explosives to Create Entry into a Shipwreck

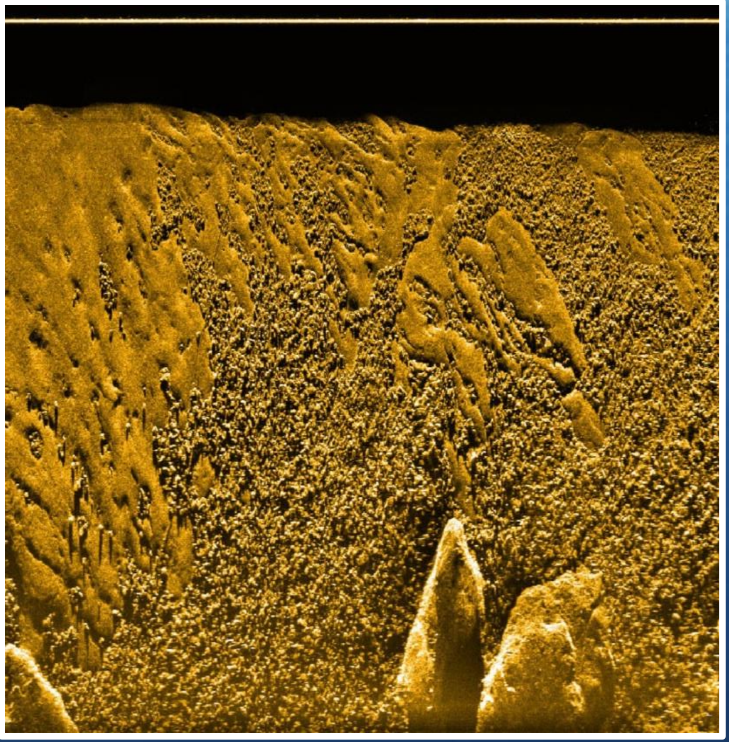


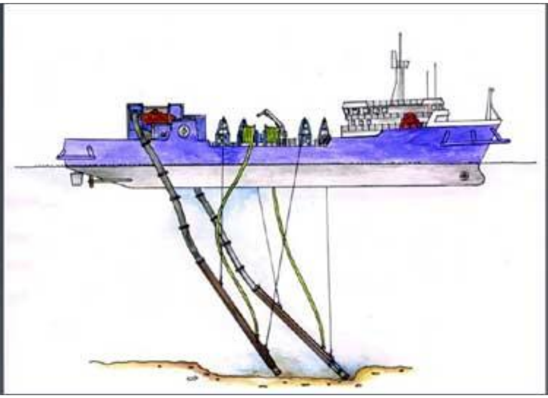




V. Applications

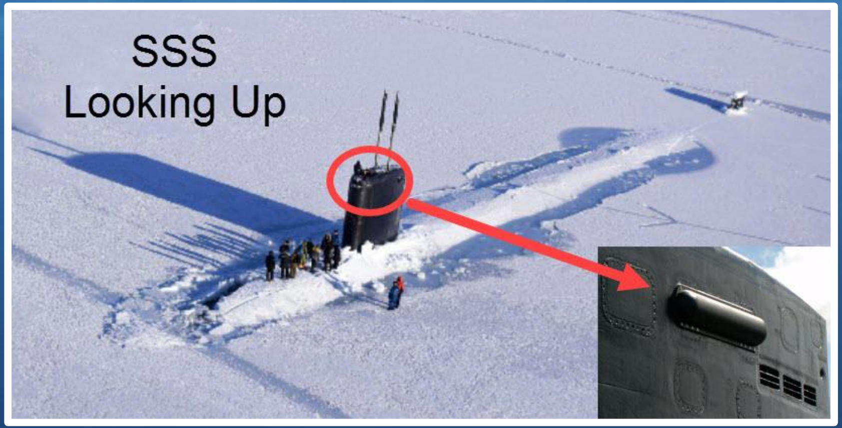
Diamond Mining – AUV's equipped with SSS map alluvial gravel deposit locations so dredge ships can vacuum up the diamond bearing gravel.

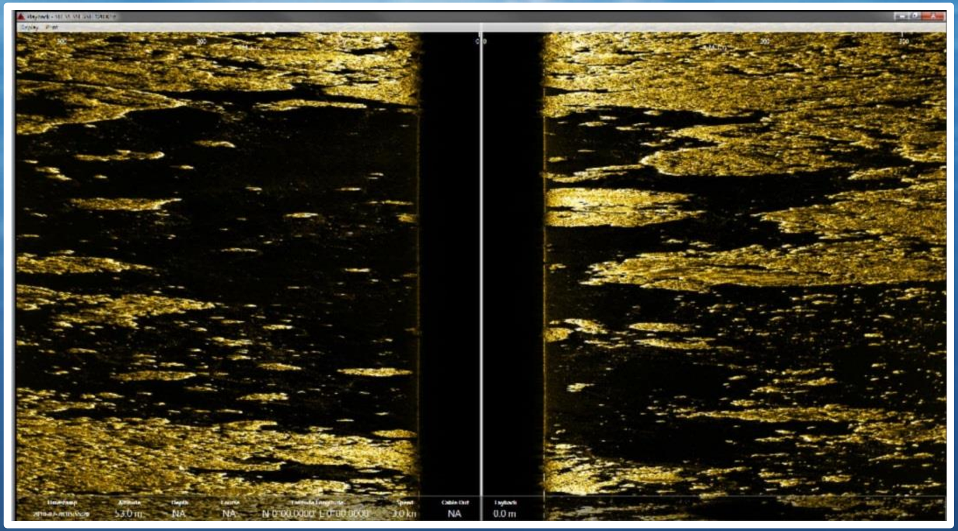




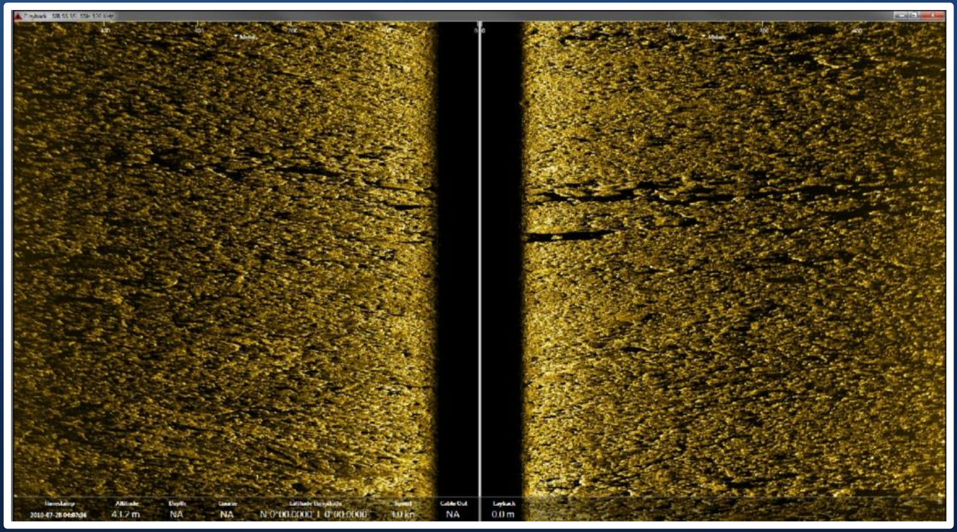
V. Applications

Under Ice Imaging





Under Arctic Ice SSS Images



Submarines that Navigate beneath Arctic Ice have SSS mounted on the Sail, pointed up to map the ice sheet underside for various needs.