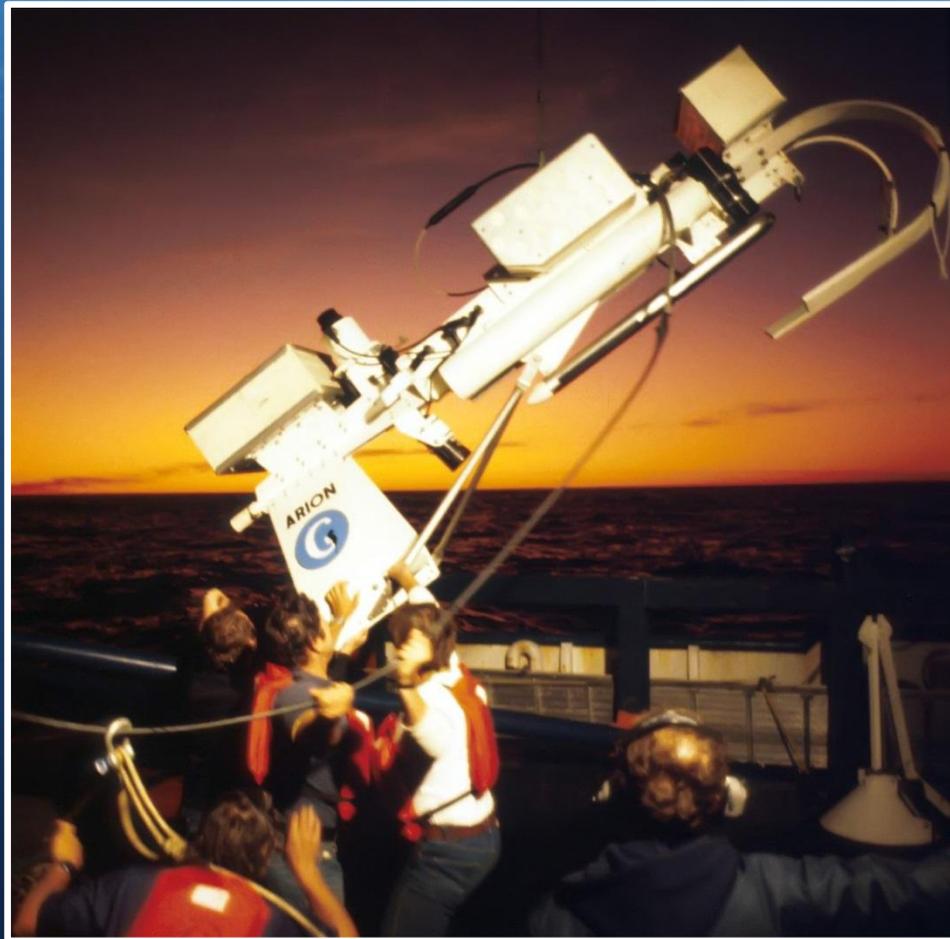


FUNDAMENTALS of SIDE SCAN SONAR

Rev 3A

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

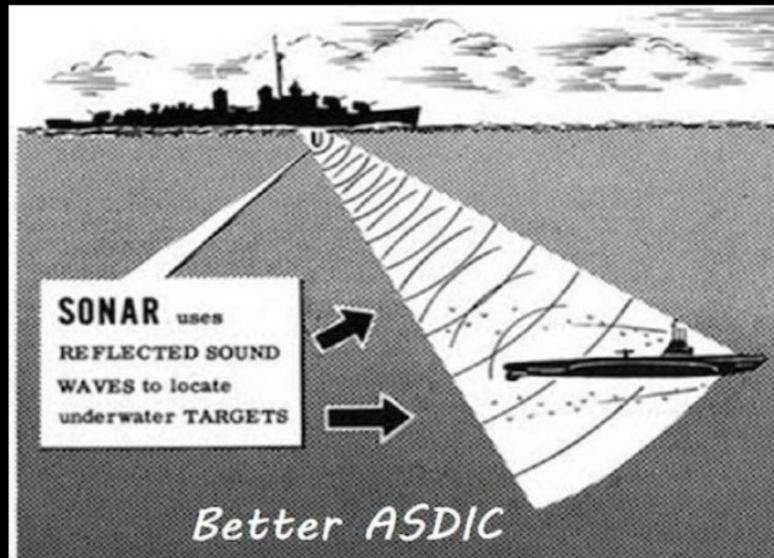
The Roots of SSS go back to early 1900's when ASDIC Sonar was developed for locating enemy submarines.

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

Who invented ASDIC?



A Canadian physicist named Robert William Boyle, took on to working on the active sound detection project along with an A. B. Wood in 1916.



I. SSS History

First SSS Concept – Dr Hans Kietz Filed German Patent
February 11, 1955

Oct. 24, 1961 H. KIETZ 3,005,973
SUBMARINE LOCATING SYSTEM
Filed Feb. 11, 1955 2 Sheets-Sheet 1

FIG. 1

FIG. 2

FIG. 4

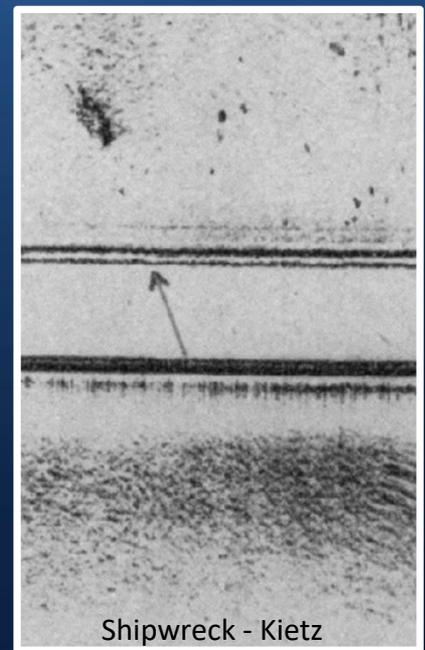
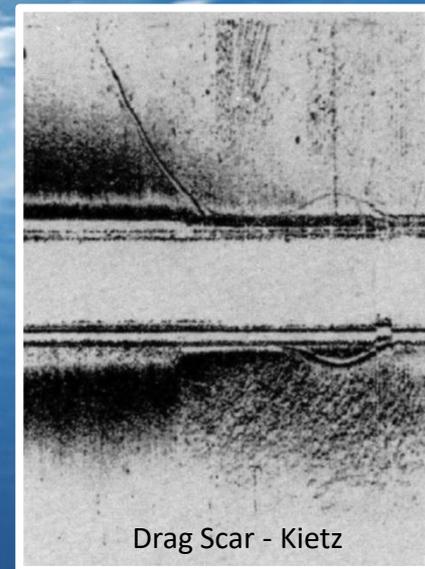
INVENTOR.
HANS KIETZ
BY
Ezekiel Wolf, Wolf & Greenfield
ATTORNEYS

Oct. 24, 1961 H. KIETZ 3,005,973
SUBMARINE LOCATING SYSTEM
Filed Feb. 11, 1955 2 Sheets-Sheet 2

FIG. 3

FIG. 5

INVENTOR.
HANS KIETZ
BY
Ezekiel Wolf, Wolf & Greenfield
ATTORNEYS



I. SSS History



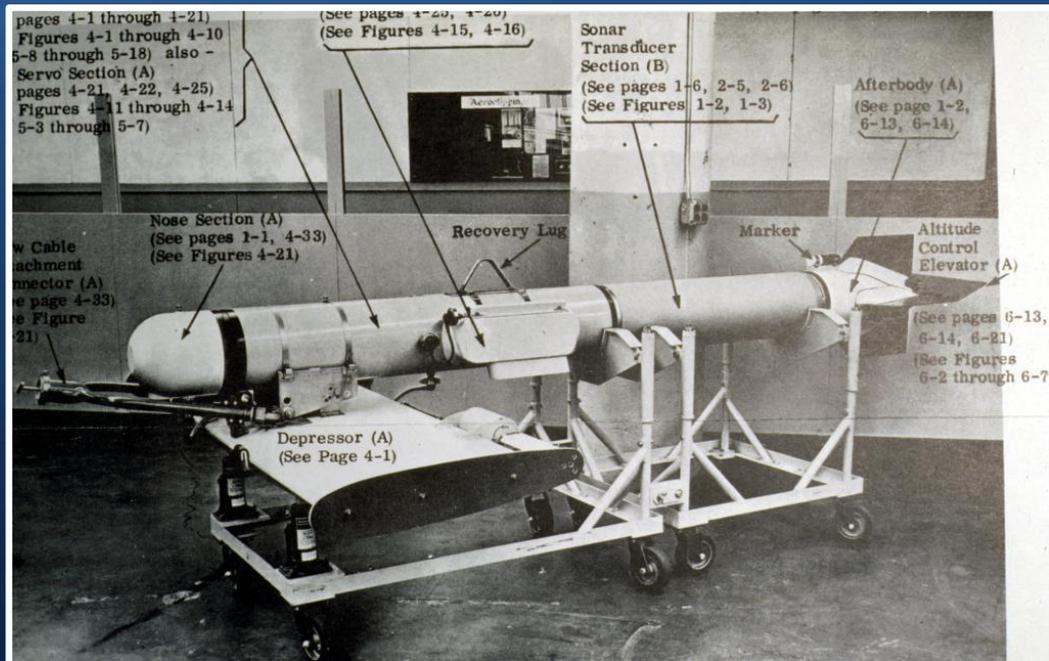
Figure 1a - Sonar Console - C Mk-1

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

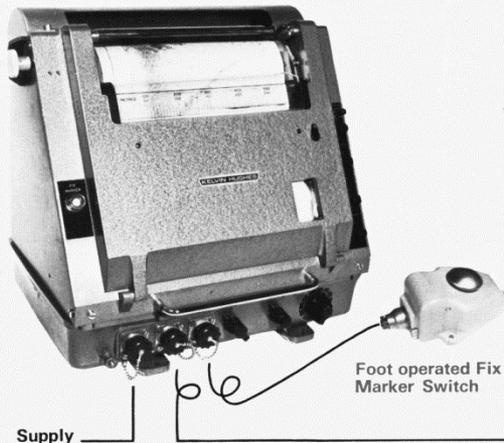
EG&G in USA
1965

I. SSS History

Kelvin Hughes in UK 1960

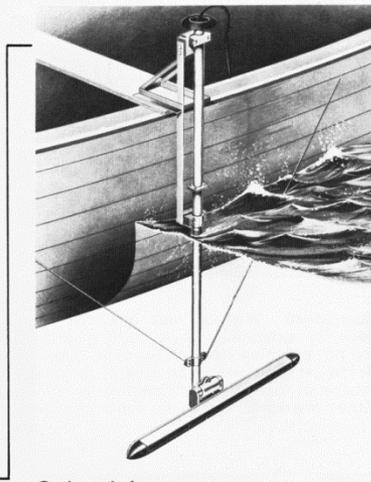
KELVIN HUGHES SIDE SCAN SONAR MS 47

Recorder



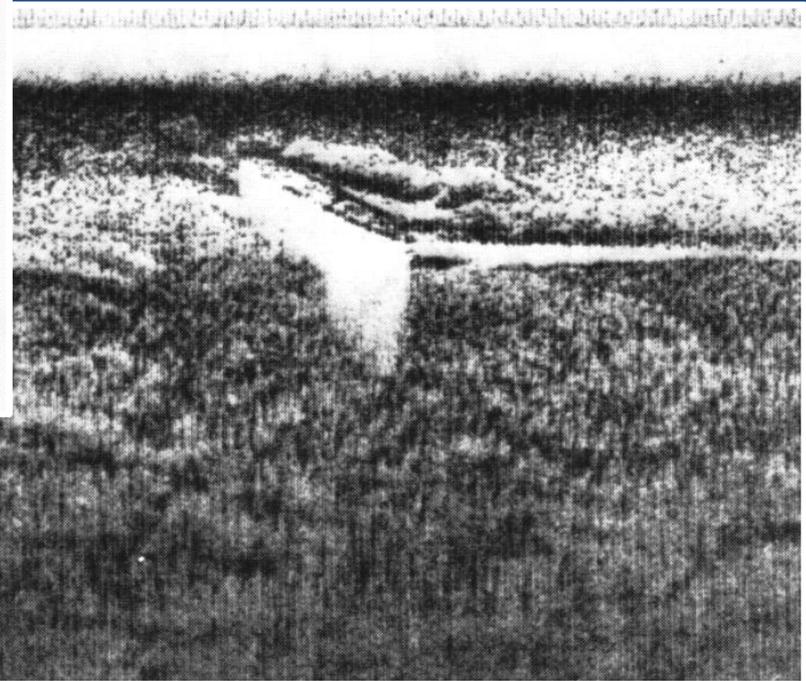
Foot operated Fix
Marker Switch

Supply



Outboard rig
The depth of immersion of the transducer,
and its angle of tilt, are adjustable

MS47 MK.2 Side Scan Sonar incorporating a typical outboard rig. (Alternatively a towed body can be supplied to special order).



48 kHz @ 550 m Range

I. SSS History

Marty Klein with the first
EG&G Side Scan System



EG&G -Boston MA
(AKA EdgeTech)

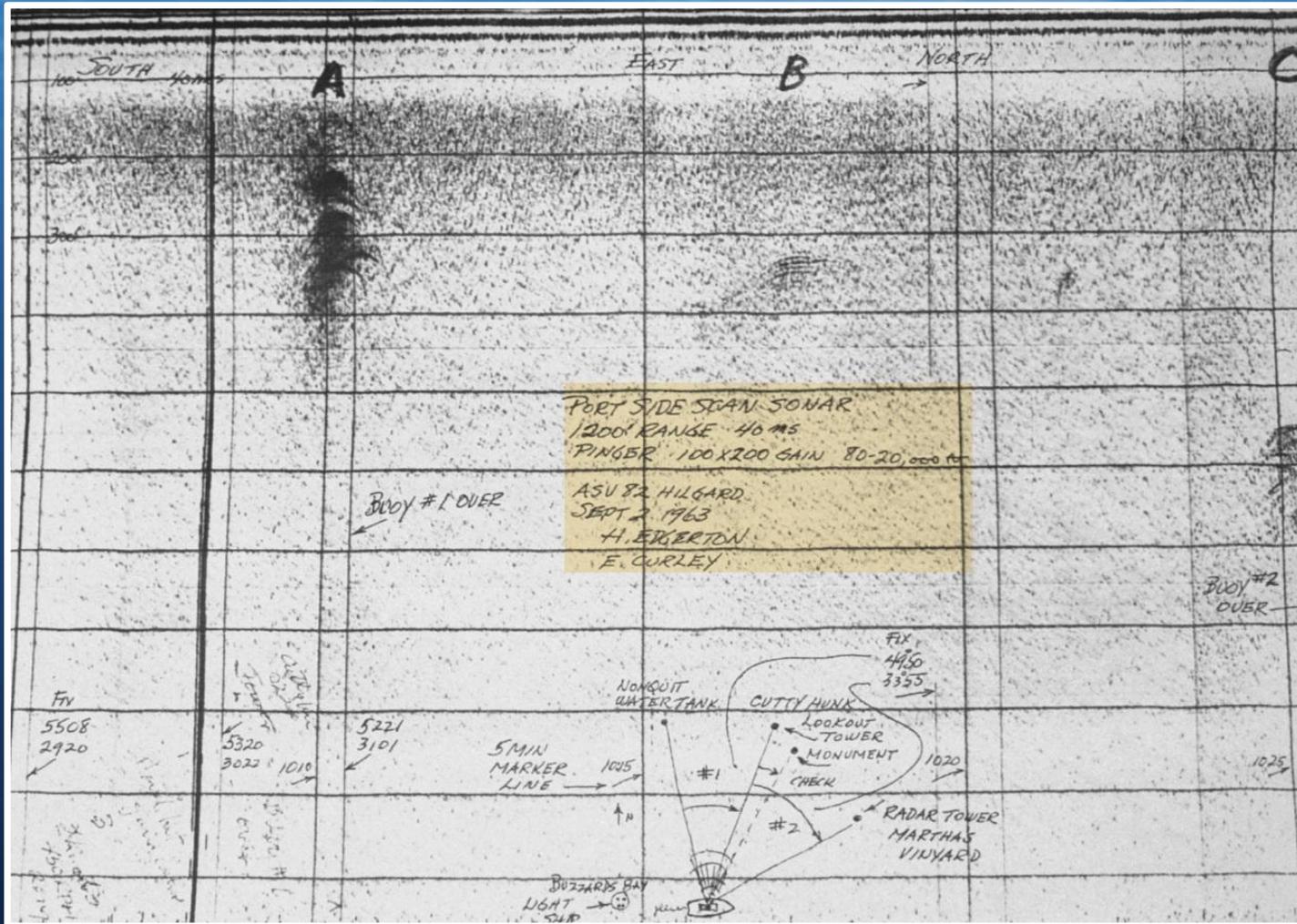


Doc Edgerton Introduced in 1967
105 kHz @ 500 m Range

I. SSS History

EG&G

“Doc” Edgerton 1st SSS Image 1963



I. SSS History

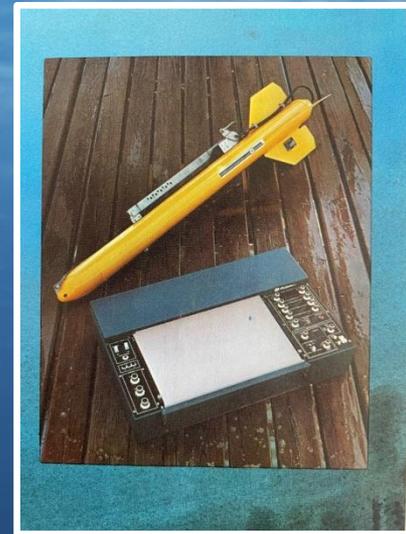
Commercial SSS Development 1970's & 1980's



EG&G (EdgeTech)



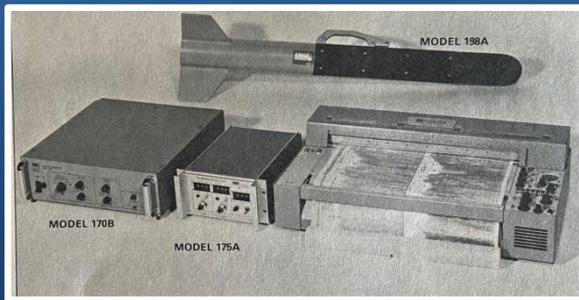
UDI



EDO Western



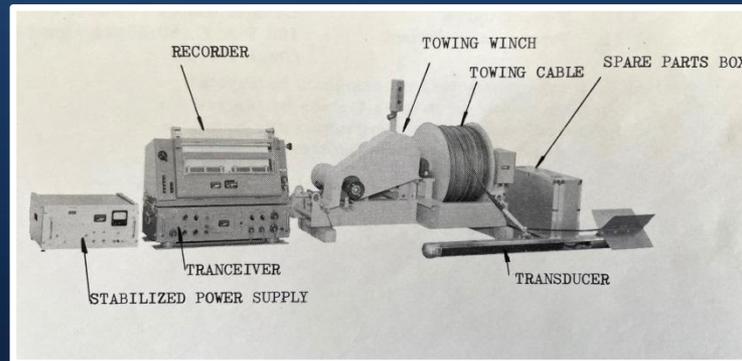
Furuno



O.R.E.



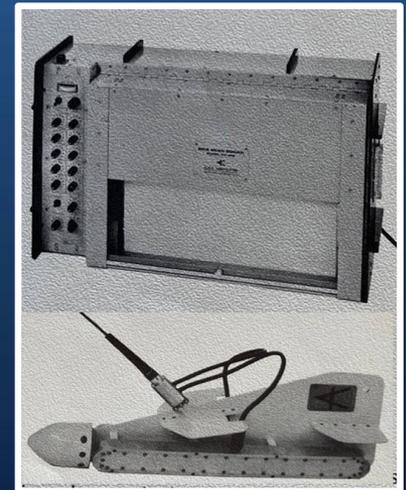
Datasonics



Nippon Electric Corp.



Wesmar



Klein

Also Electrospace

I. SSS History

Today's Commercial SSS Manufacturers



1979 Klein 531T System

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

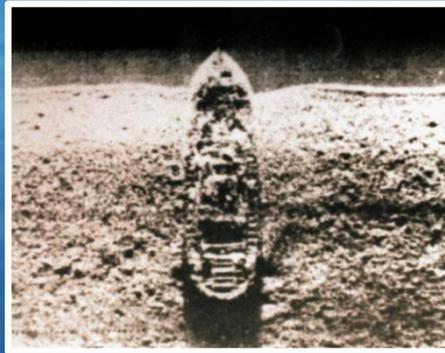
I. SSS History

Military SSS Development

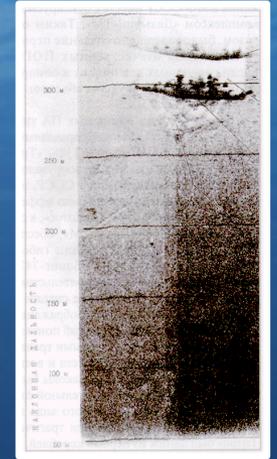
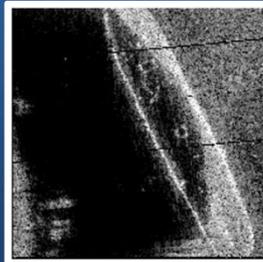
1970's & 1980's



Thompson DUBM-41 SSS - French Navy



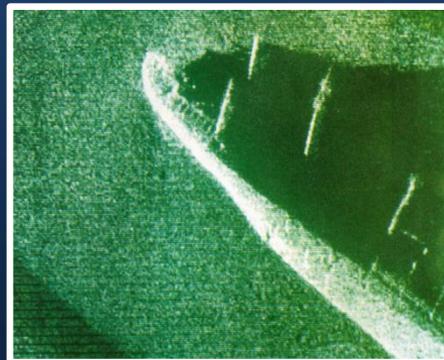
MDA AN-SQS 511 Canadian Navy



Soviet Era SSS



Westinghouse SSS - US Navy

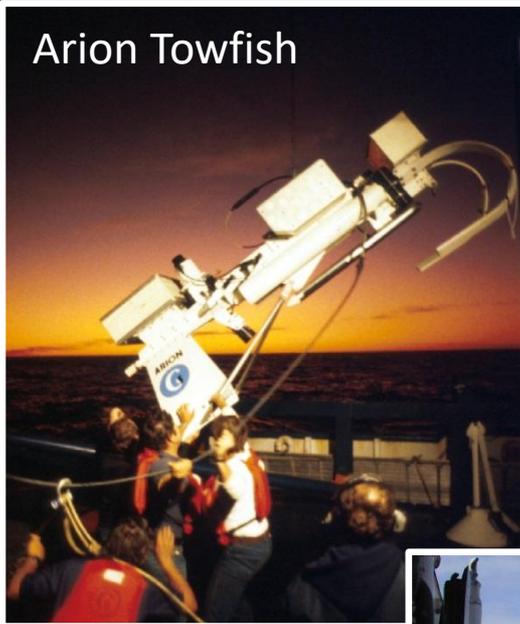


I. SSS History

Unique SSS Development

1970's & 1980's

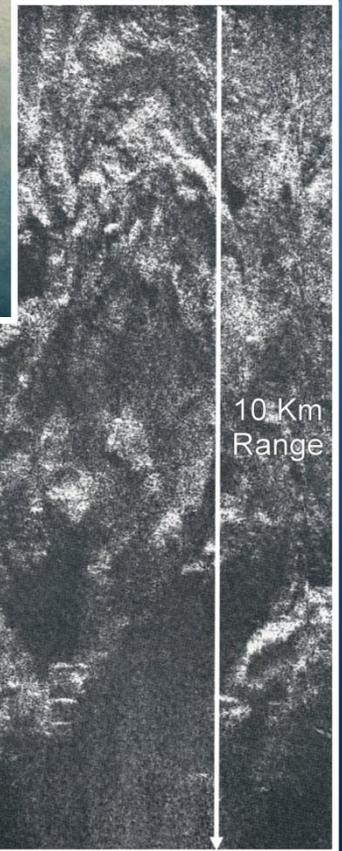
Arion Towfish



Gloria Mk1



Ocean Explorer



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

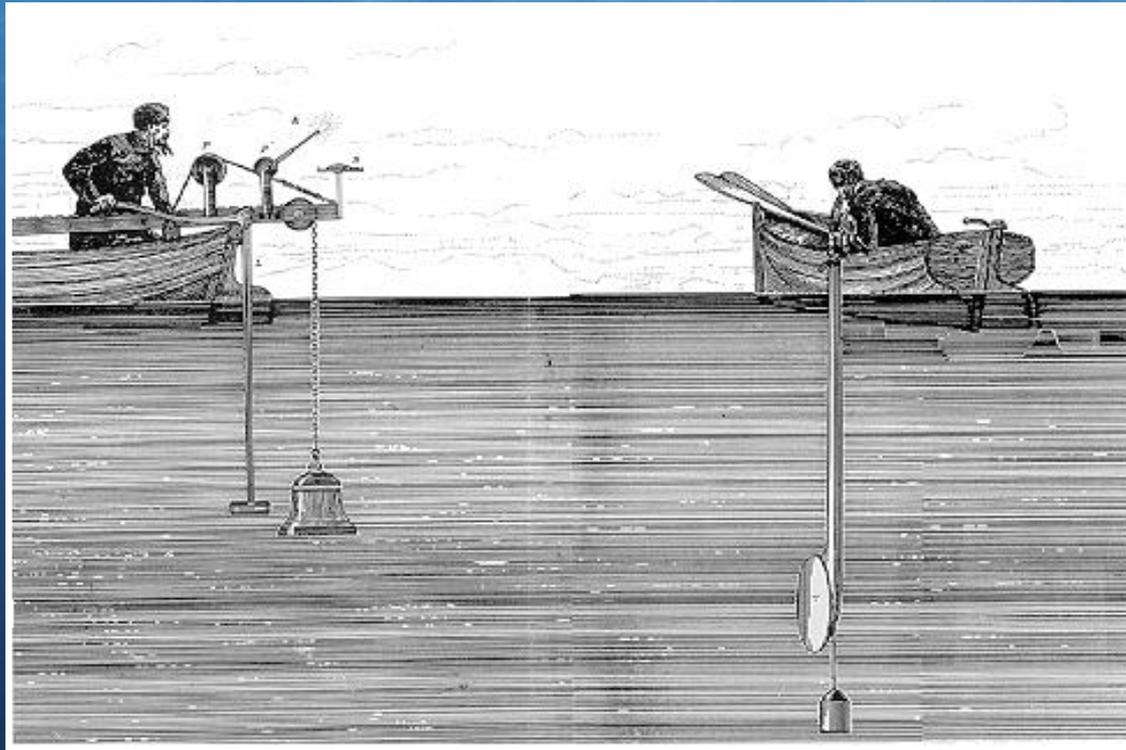
The first consumer SSS was introduced by Humminbird in 2005 and today there are at least a half dozen



Humminbird
Garmin
Lowrance
RayMarine
Simrad
Furuno

II. SSS Principles

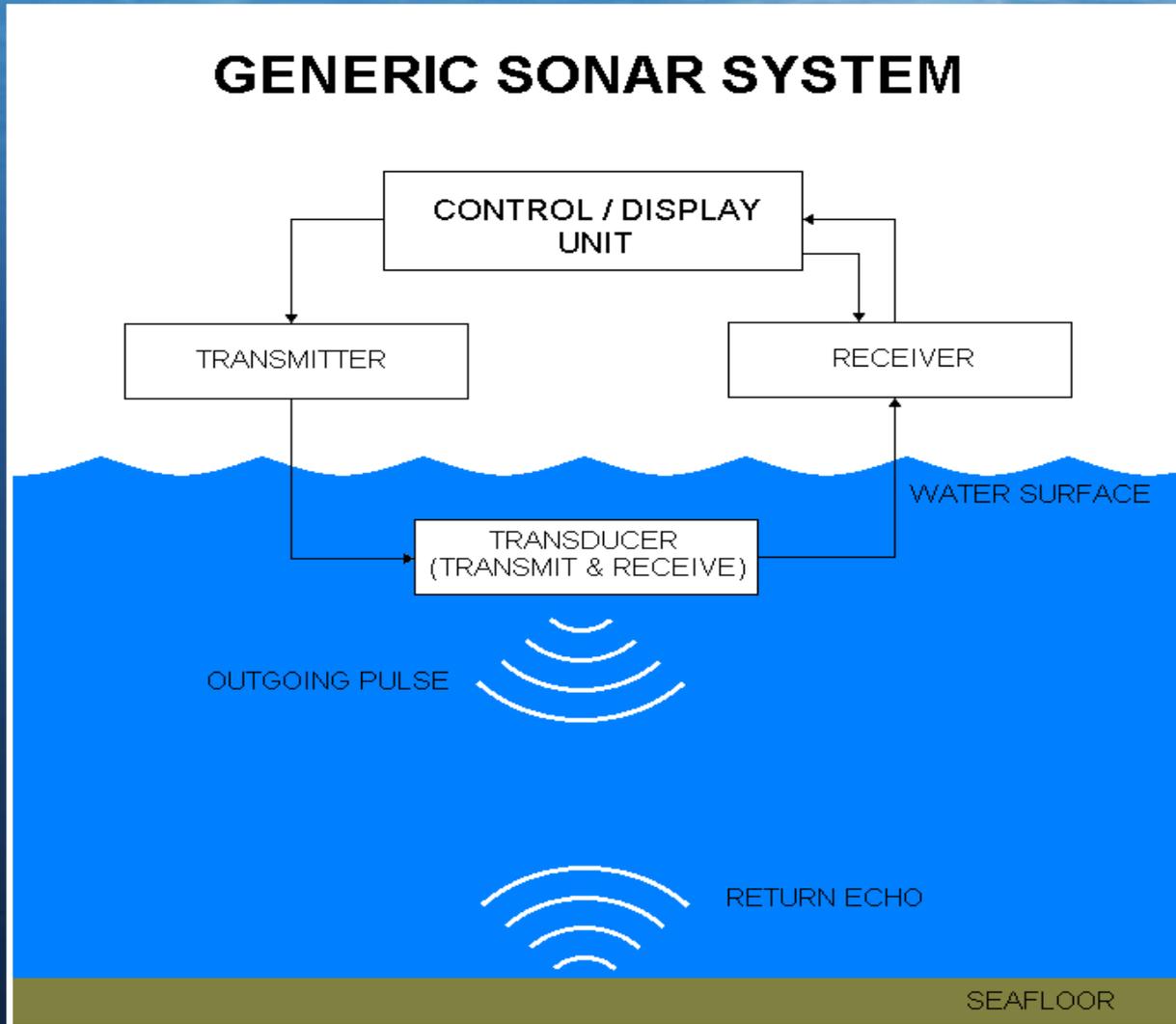
Speed of Sound



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



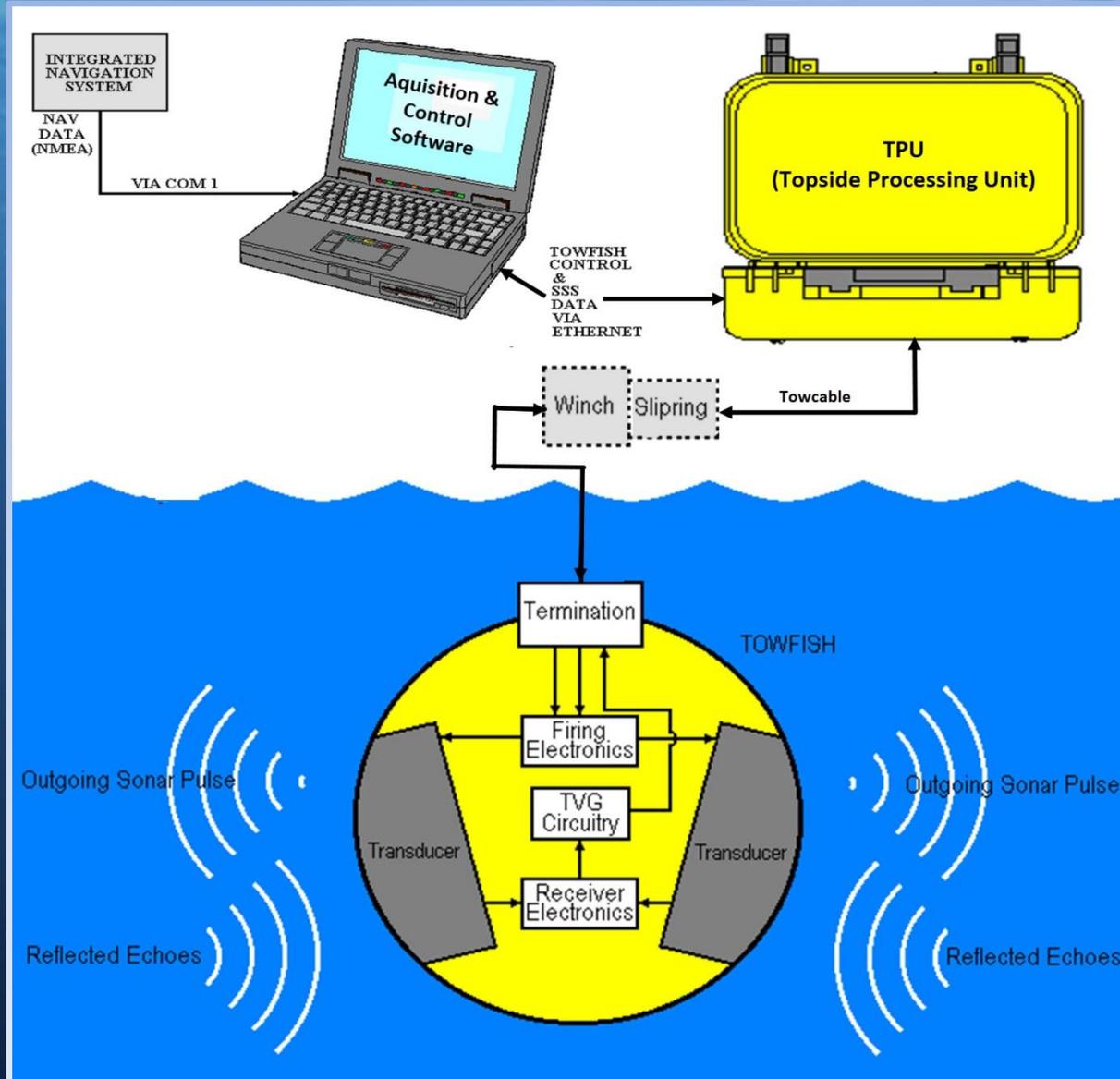
II. SSS Principles

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

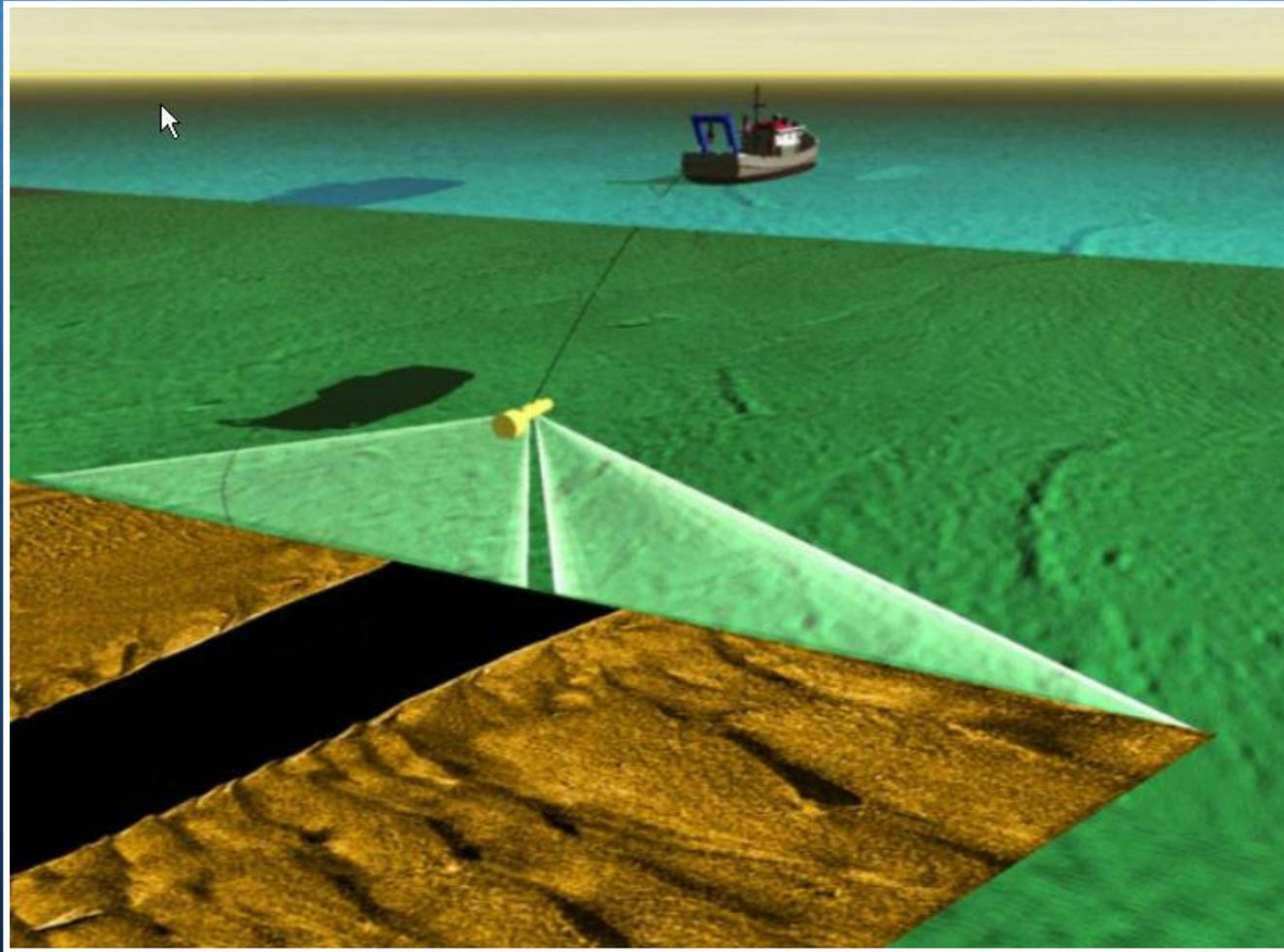
SSS System



EdgeTech 4200 Side Scan Sonar System

II. SSS Principles

SSS Image Creation



Drawing Courtesy of Vince Capone

II. SSS Principles

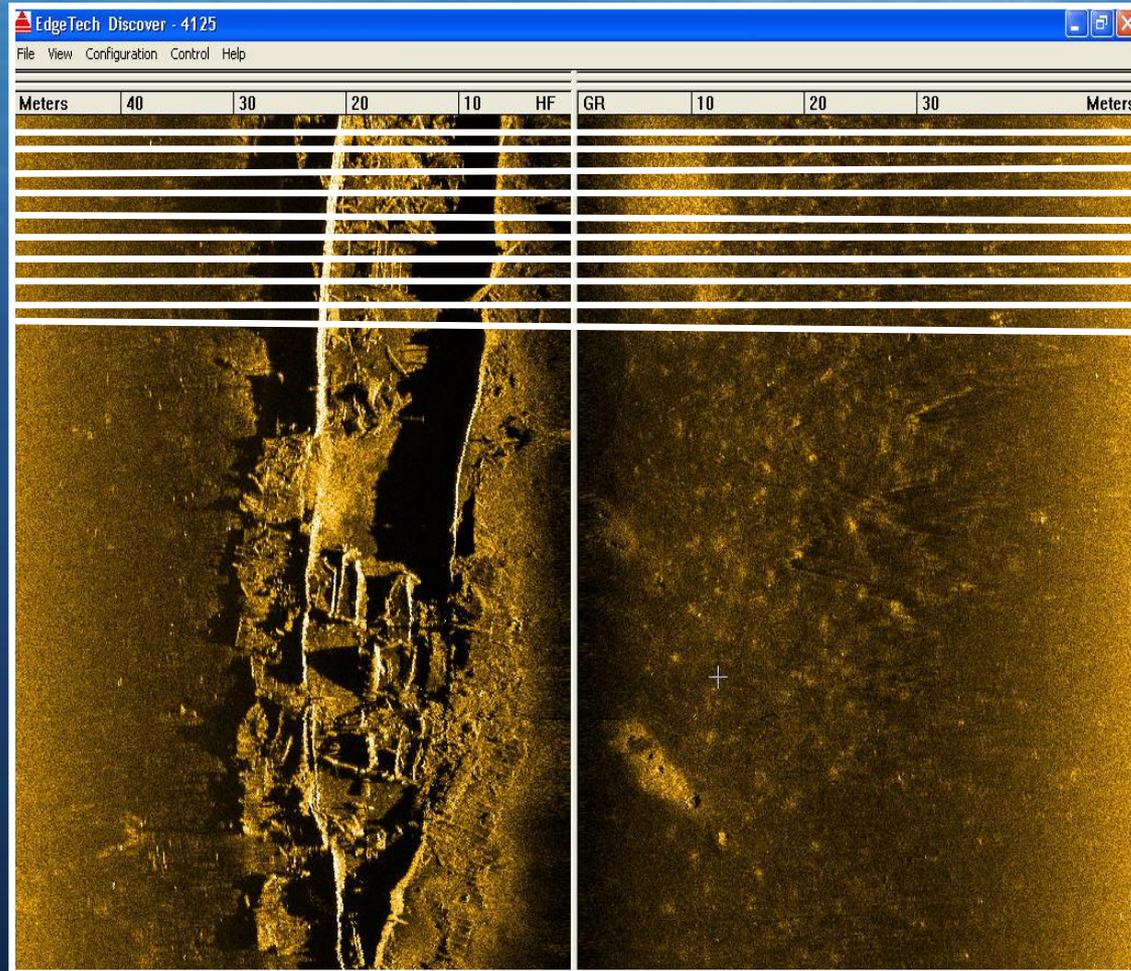
Line Scanning Imaging Technique



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

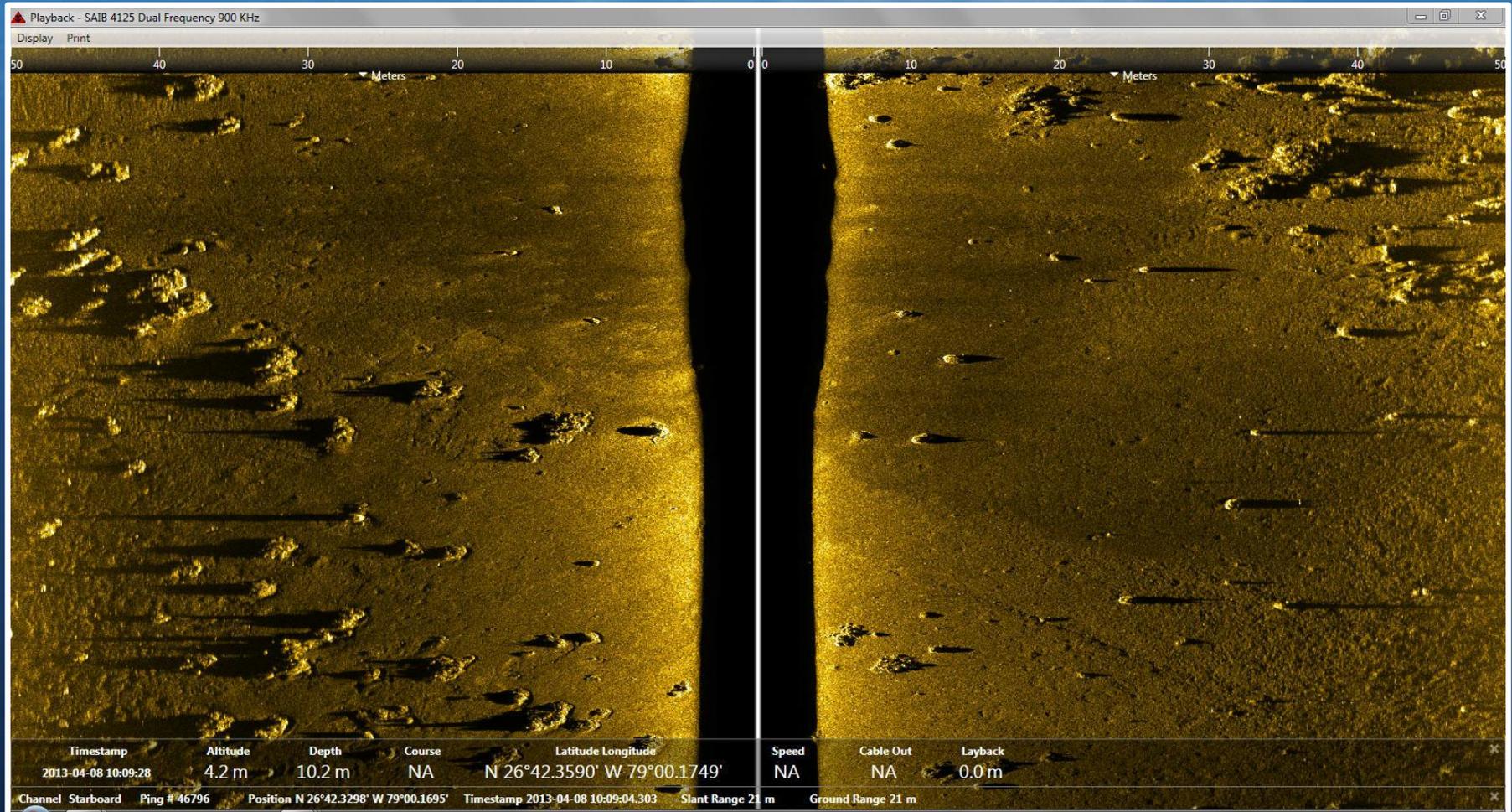
Line Scanning Imaging Technique



II. SSS Principles

Line Scan SSS Image

Acoustic Slices Mapped in Order Create Seafloor Image



II. SSS Principles

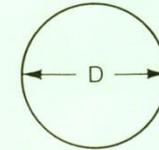
Transducer Concepts: Beam Directivity



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:

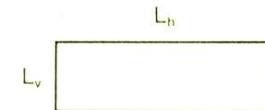


Some simplified approximations for the beamwidth (BW)

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

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.



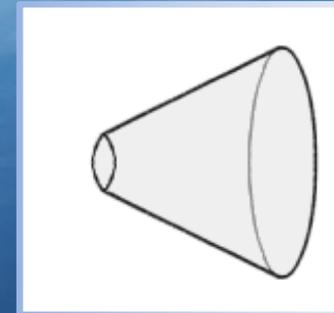
L_h, L_v = Active dimensions of the face [inches]

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

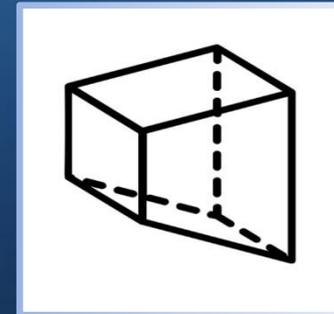
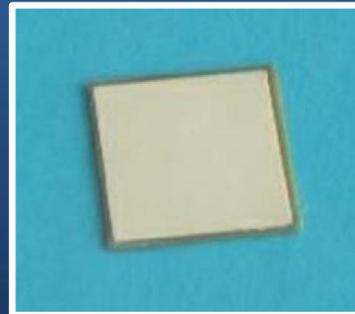
II. SSS Principles

Transducer Concepts: SSS Transducer Beam Shapes

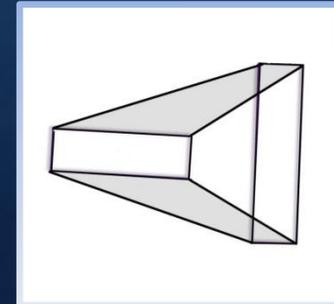
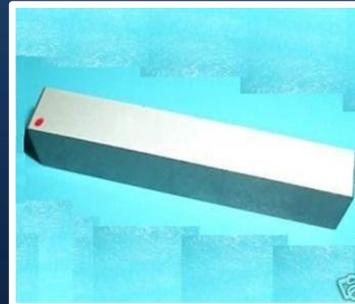
DISK



SQUARE PLATE

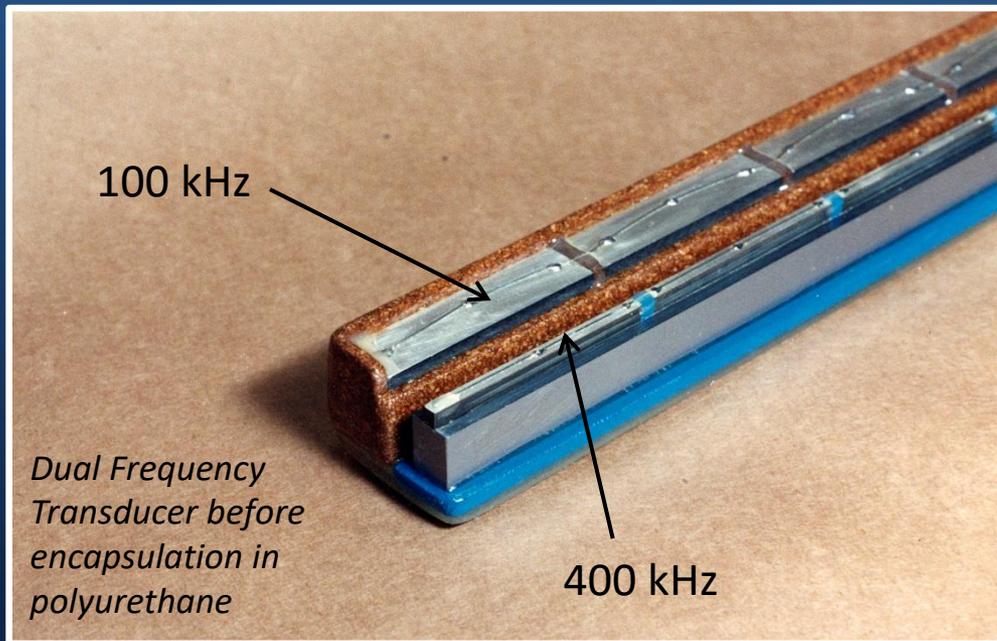
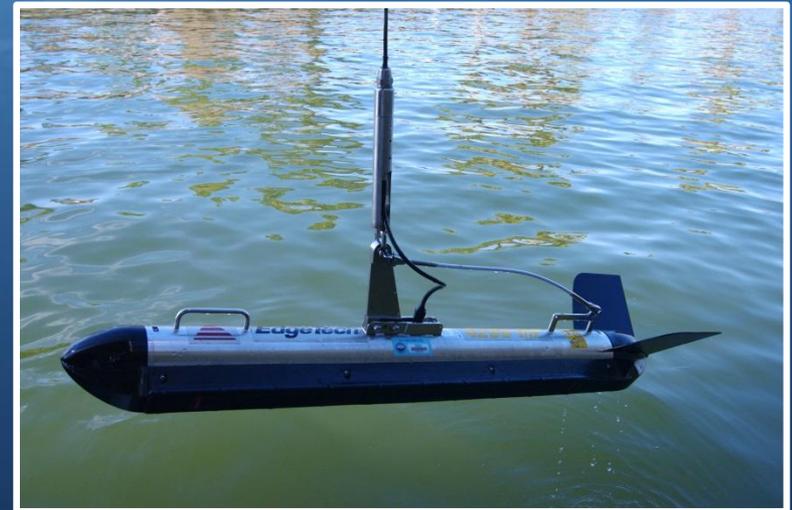
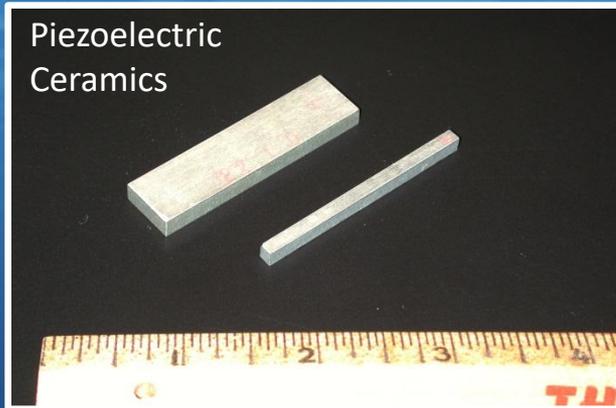


RECTANGULAR PLATE



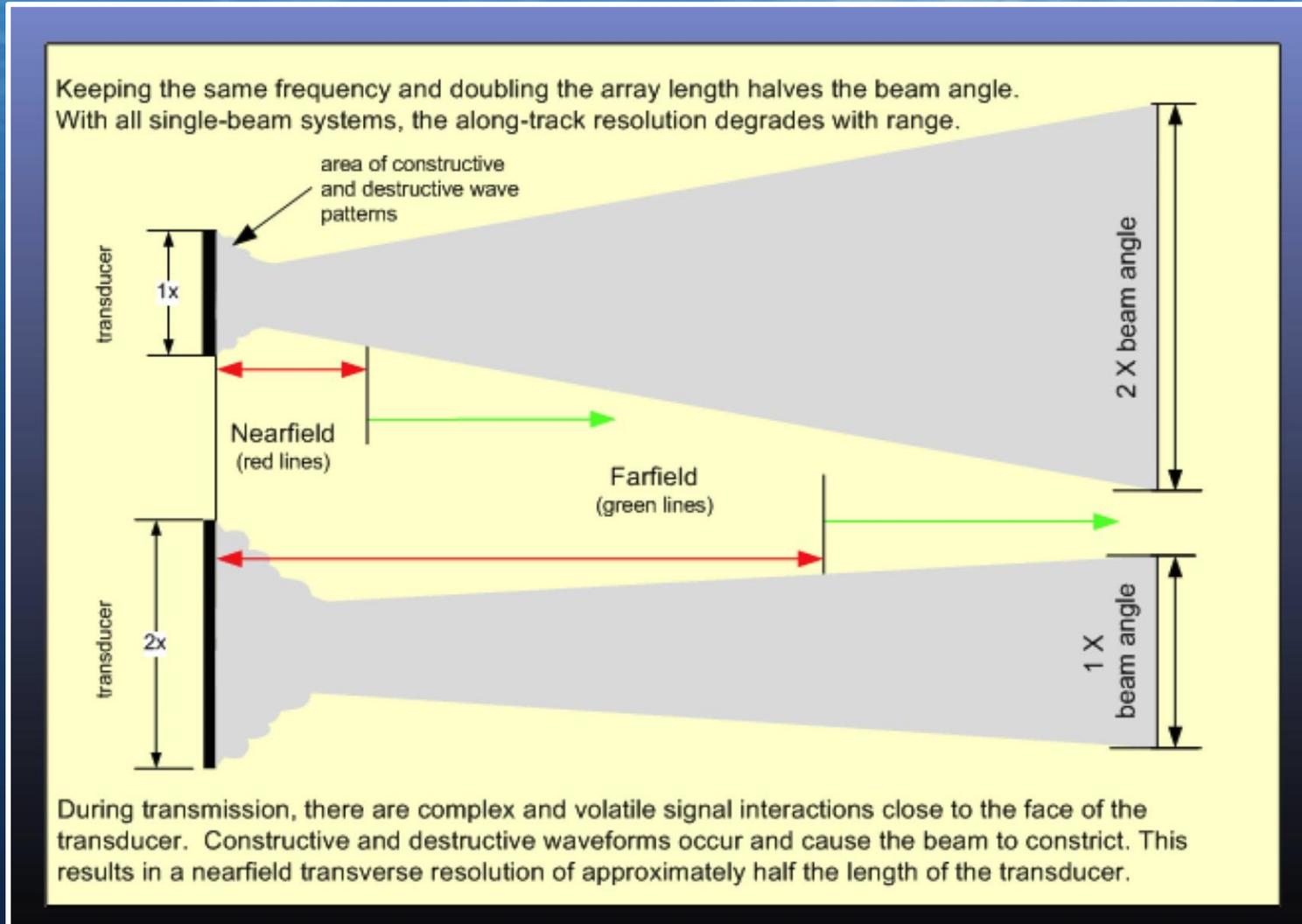
II. SSS Principles

Transducer Concepts: SSS Transducer Construction



II. SSS Principles

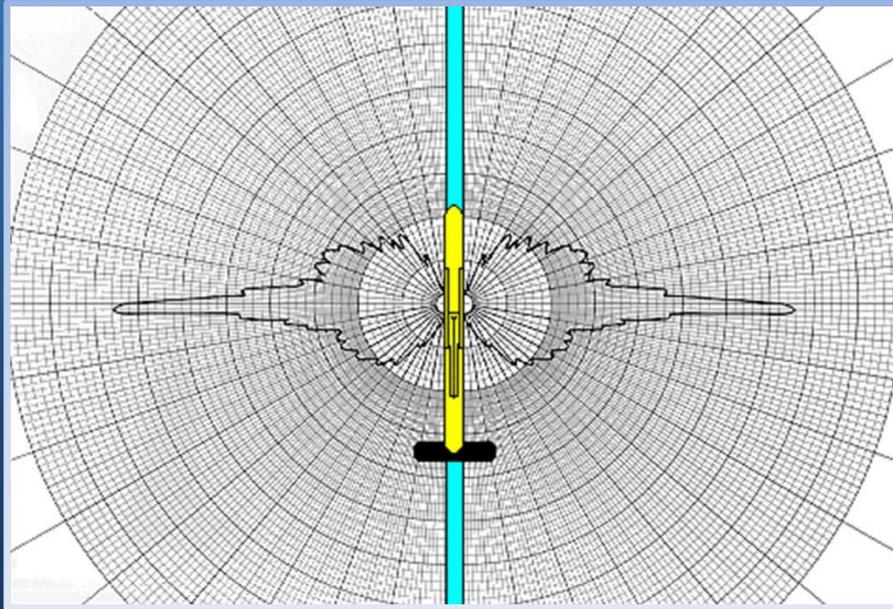
Transducer Concepts: Beam Width vs Array Length



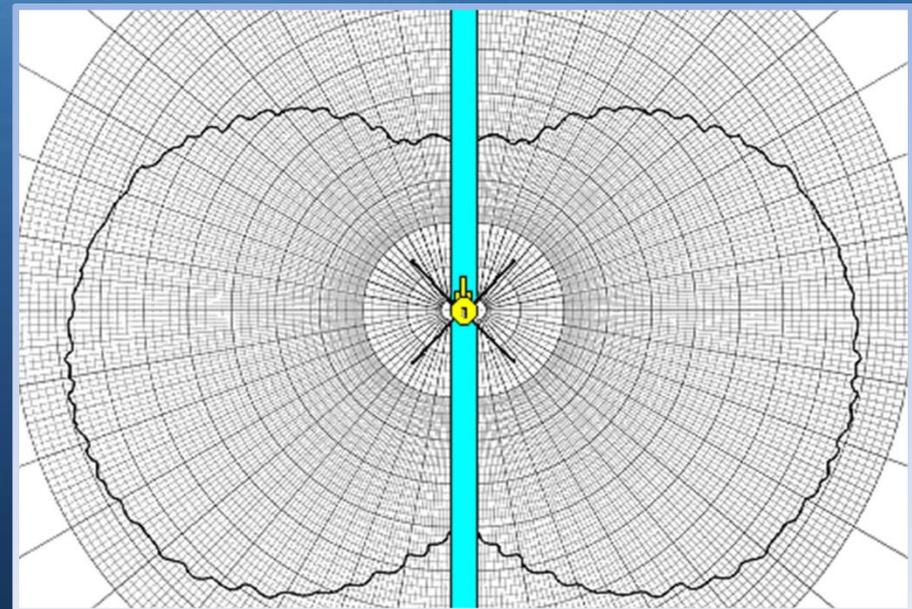
Drawing courtesy M.W. Atherton, Echoes and Images

II. SSS Principles

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



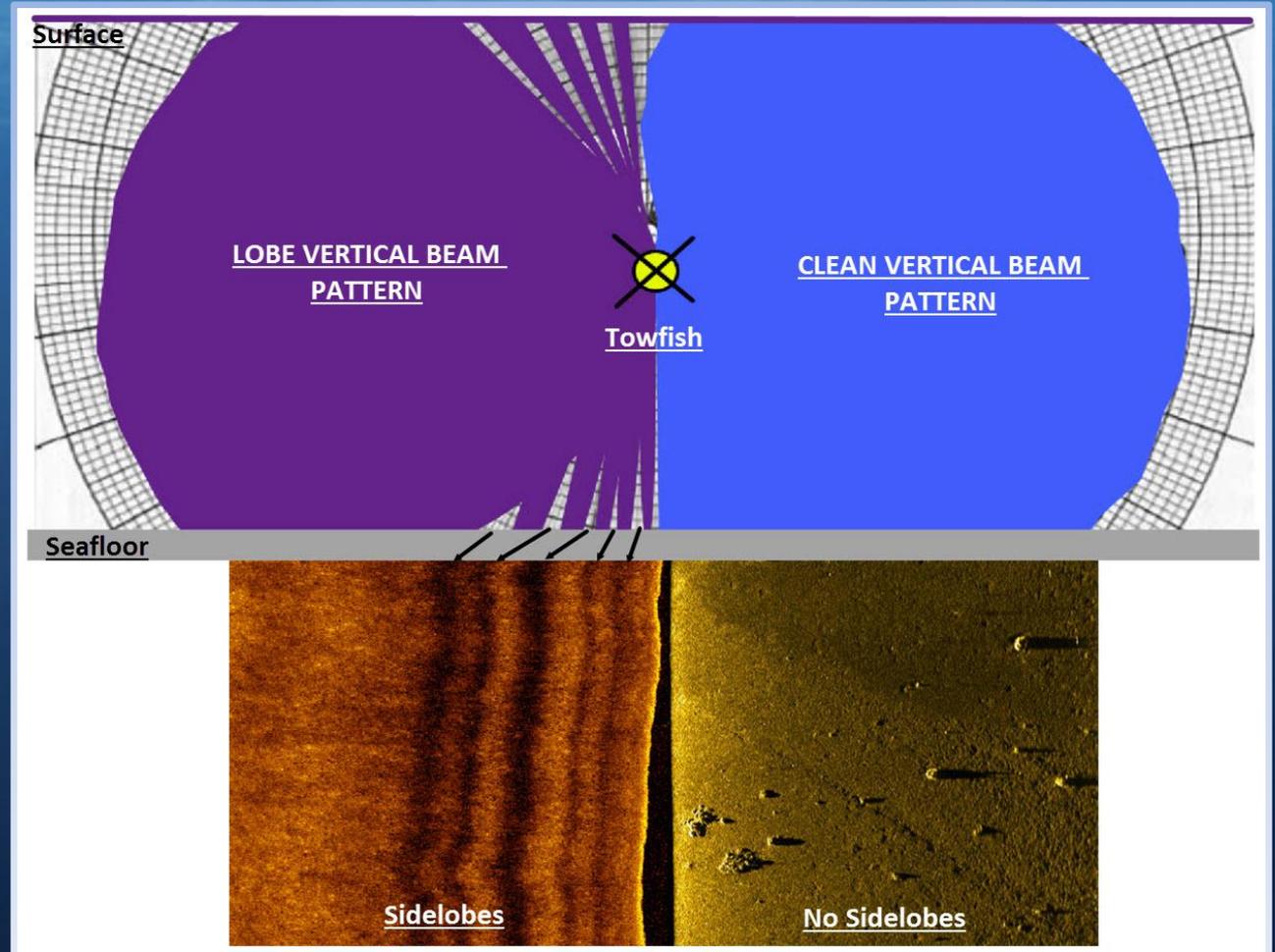
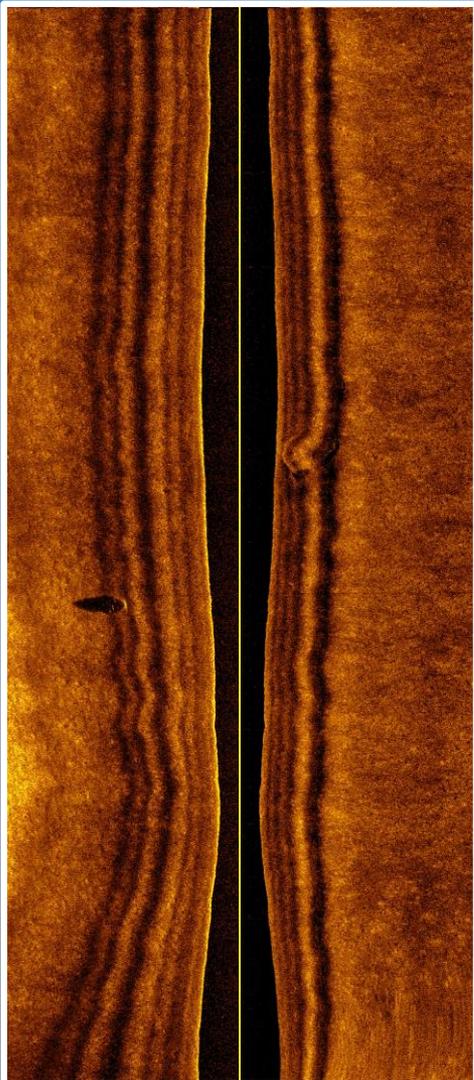
Horizontal Beam is
the same for both
Transmit & Receive
Mode



Vertical Beam is the
same for both
Transmit & Receive
Mode

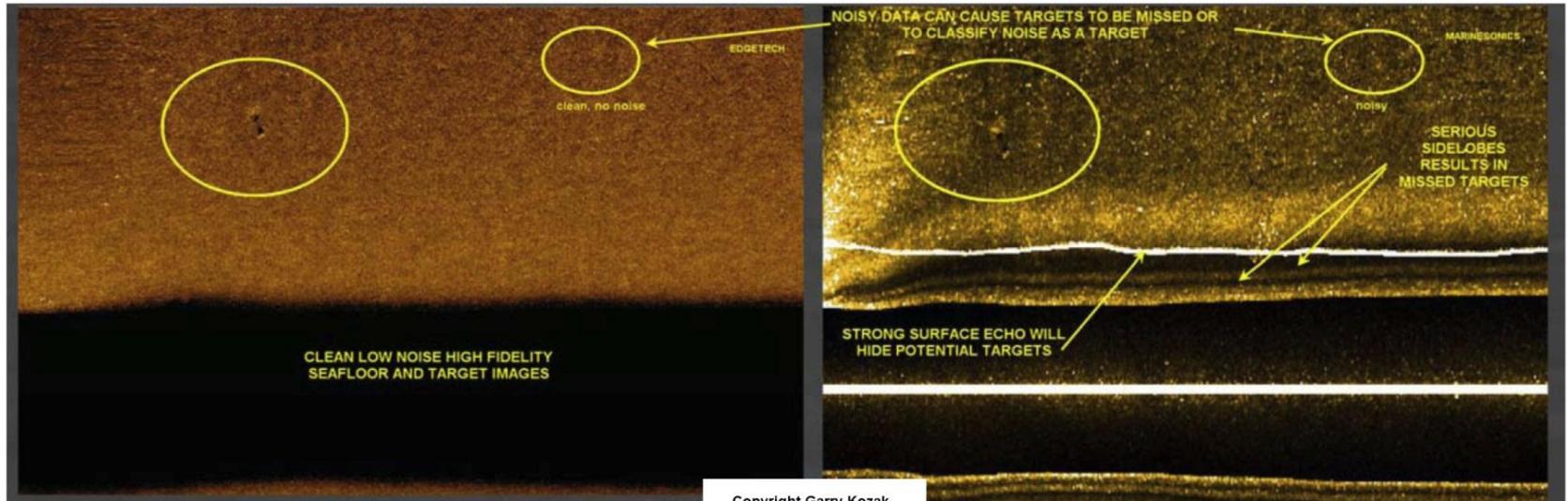
II. SSS Principles

Vertical Beam Sidelobe Artifacts

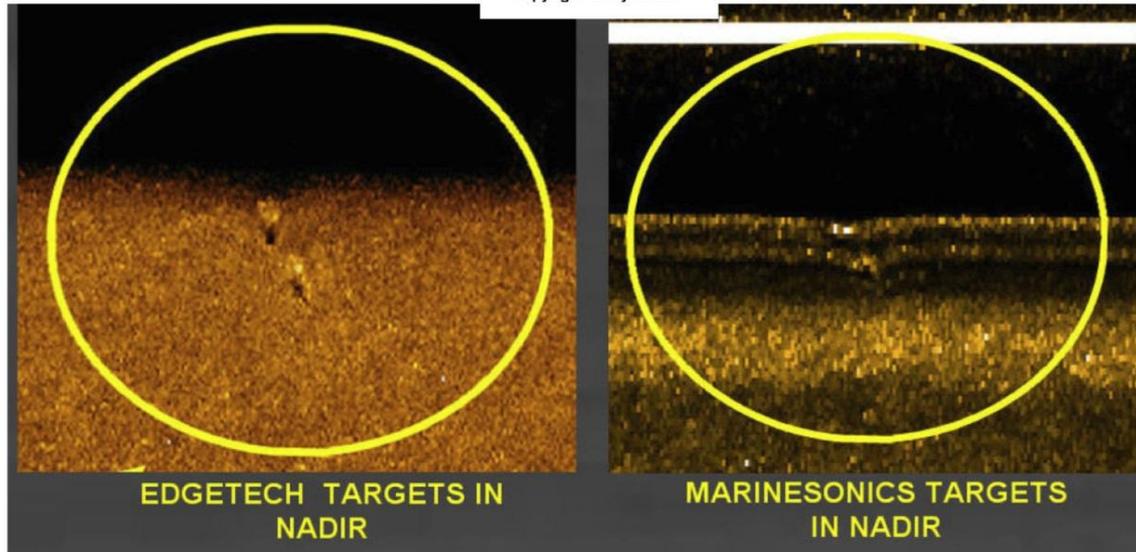


II. SSS Principles

Vertical Sidelobe Impact on Target Detection



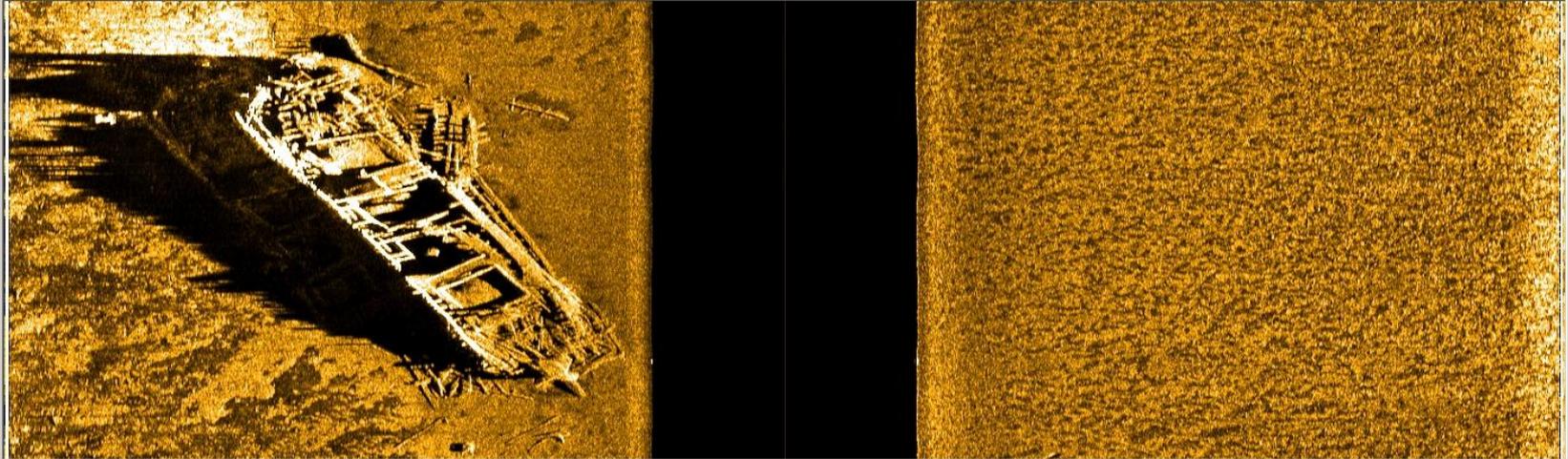
Copyright Garry Kozak



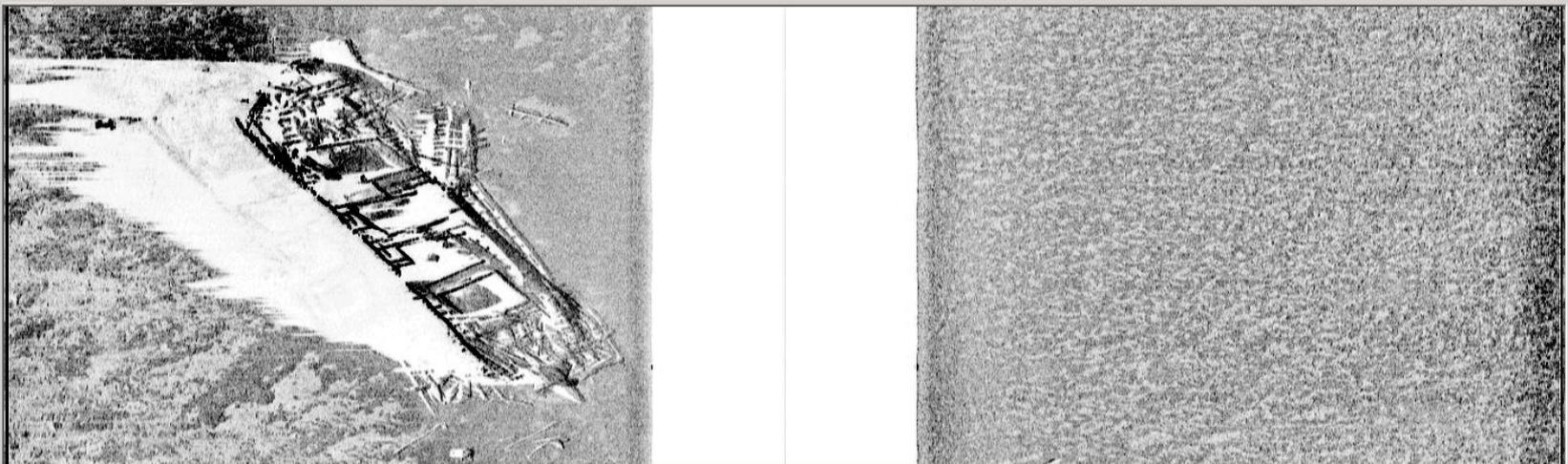
II. SSS Principles

SSS Image Display Color

BRONZE INVERTED



GRAY SCALE



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

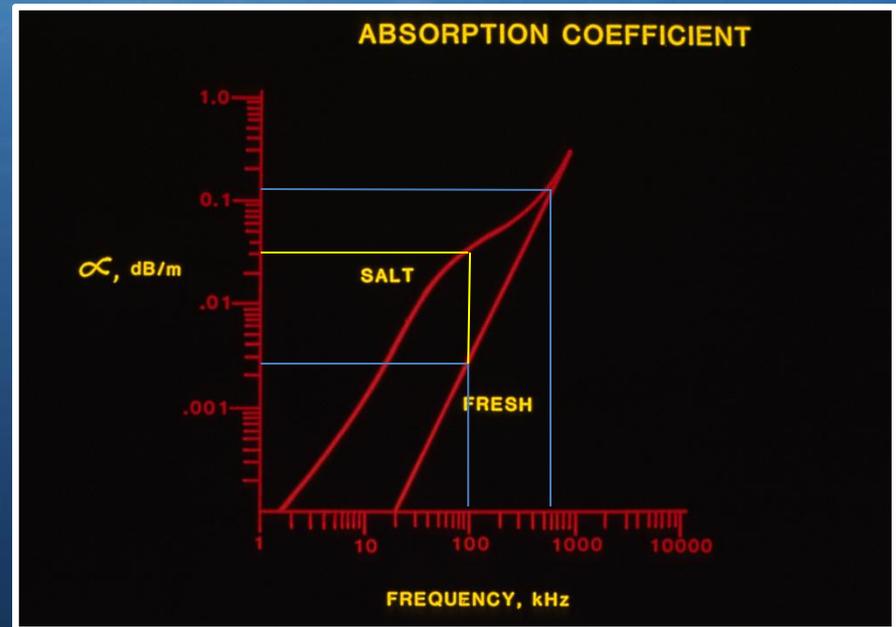
II. SSS Principles

SSS Ping Rate

<u>Sonar Range Scale (Meters)</u>	<u>Pings per Second</u>
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

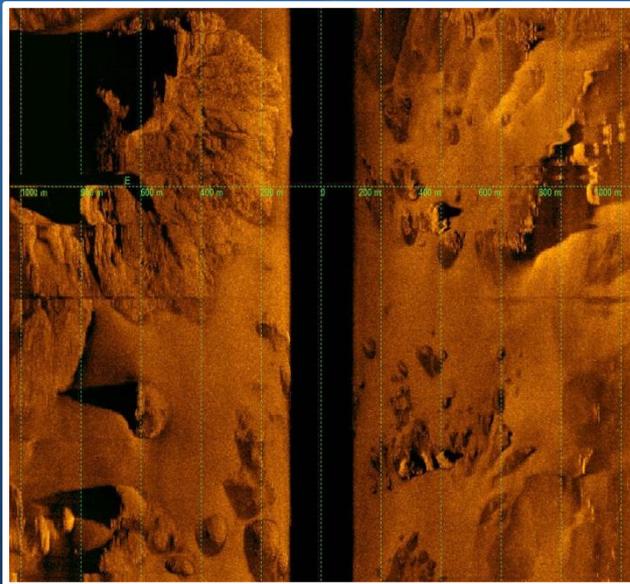
Sonar Operational Maximum Range

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

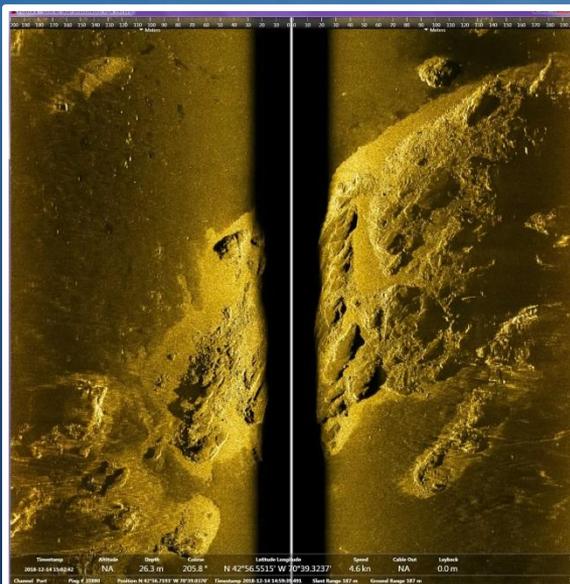
Sonar Operational Maximum Range

EdgeTech 75 kHz



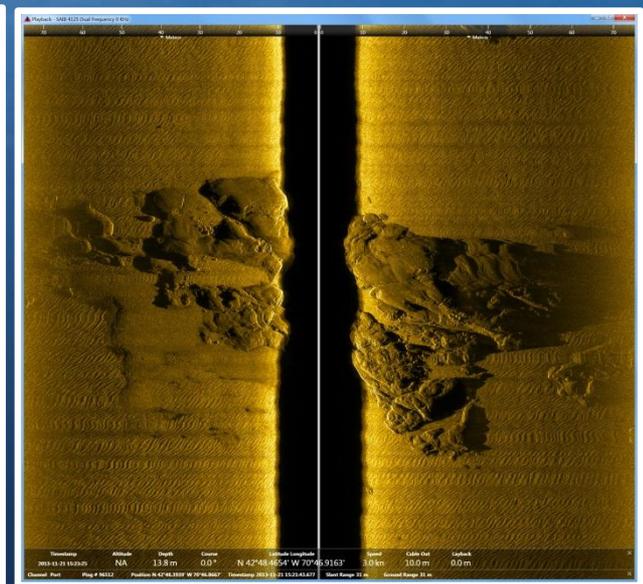
2200 Meters

EdgeTech 400 kHz



400 Meters

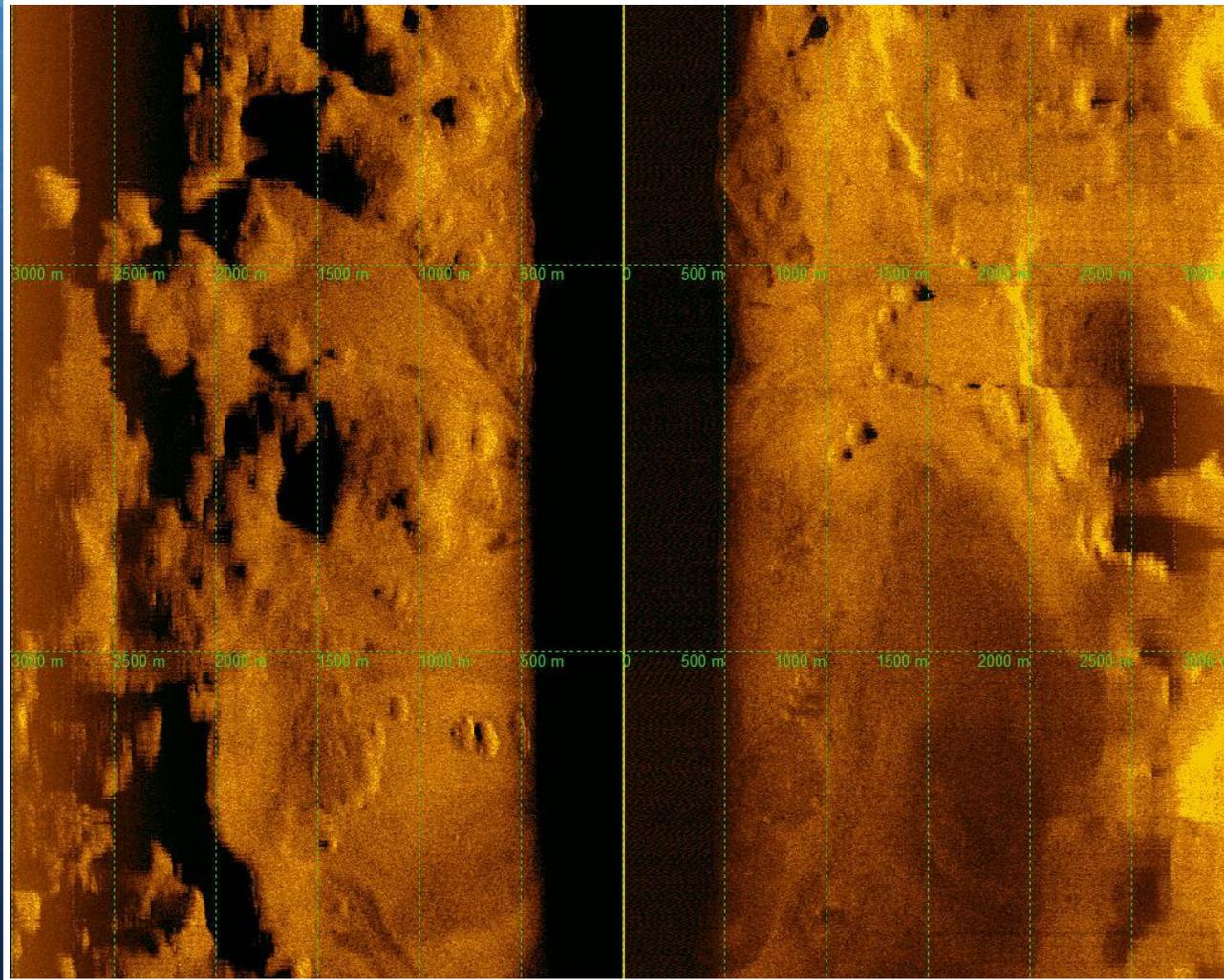
EdgeTech 900 kHz



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	-----	0.53 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 -----	0.53 m
580 kHz -----	0.45 m
850 kHz -----	0.30 m
1600 kHz-----	0.15 m

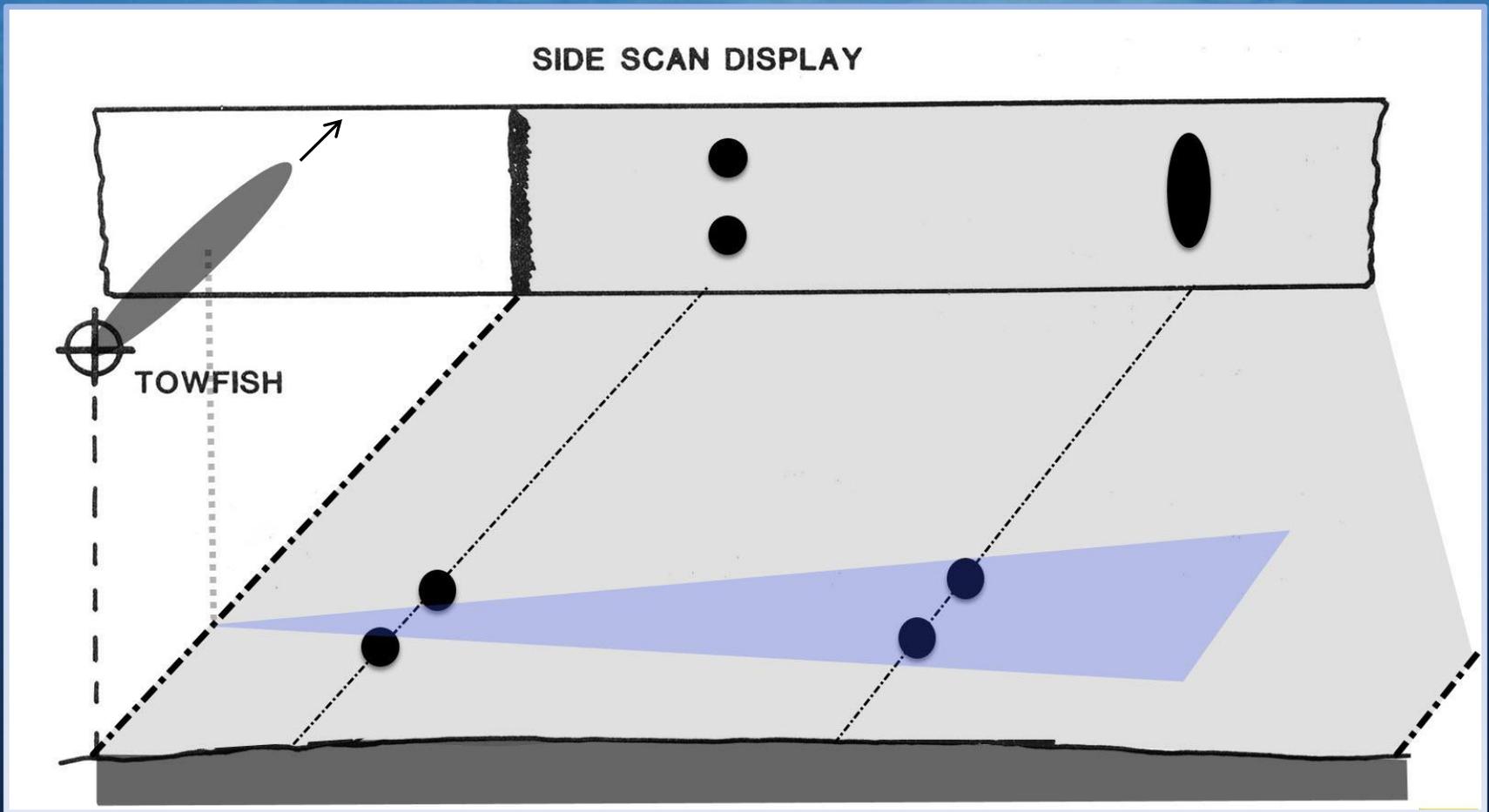
Far Field @ 100 Meter Range

Angle/57 x Range = Beam Width

75 kHz: 1.3 degree -----	2.28 m
120 kHz: 0.7 degree -----	1.23 m
230 kHz: 0.44 degree -----	0.77 m
410 kHz: 0.30 degree -----	0.53 m
580 kHz: 0.26 degree -----	0.46 m
850 kHz: 0.23 degree -----	0.40 m
1600 kHz: 0.20 degree -----	0.35 m

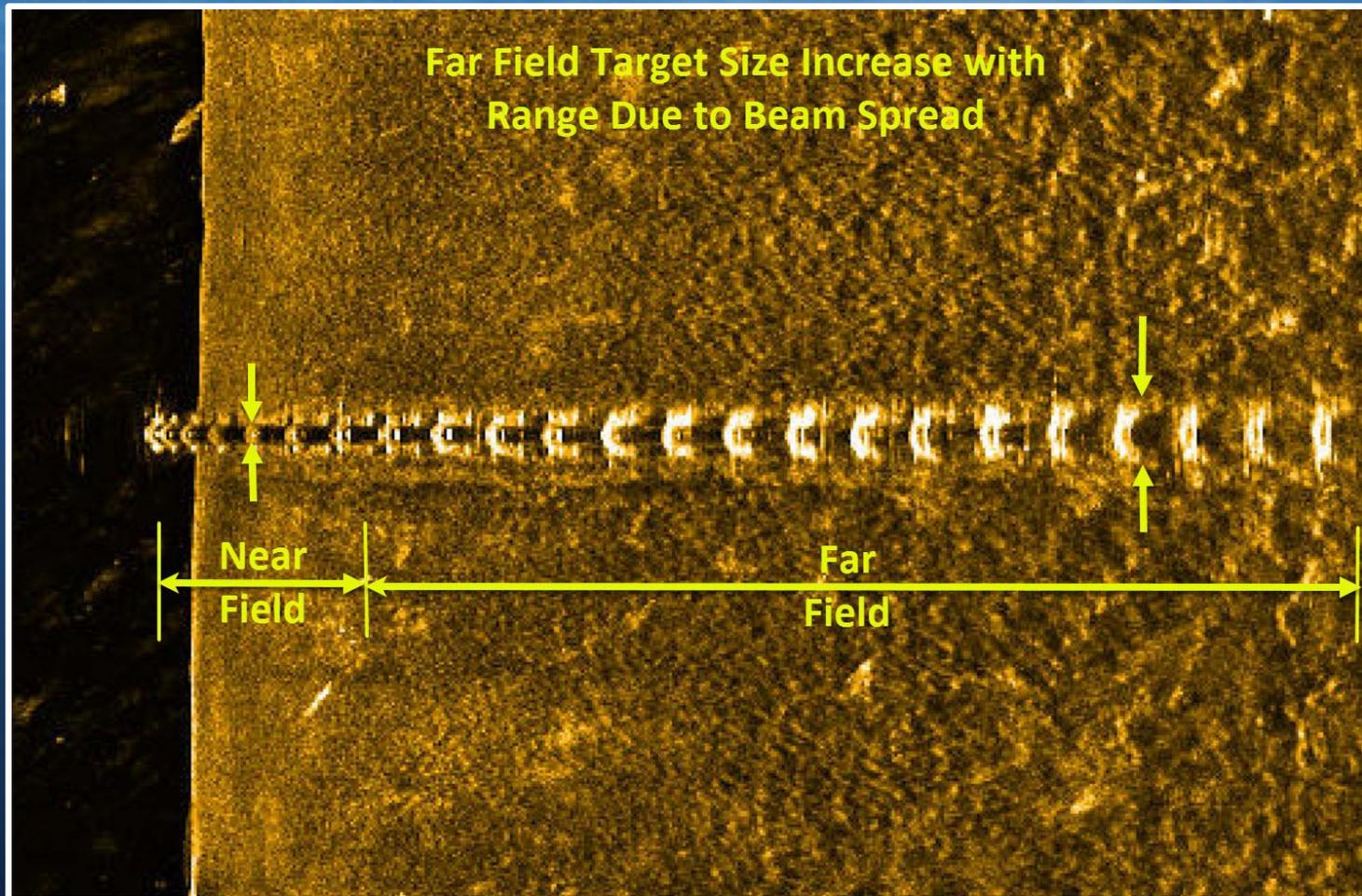
II. SSS Principles

Along Track Resolution



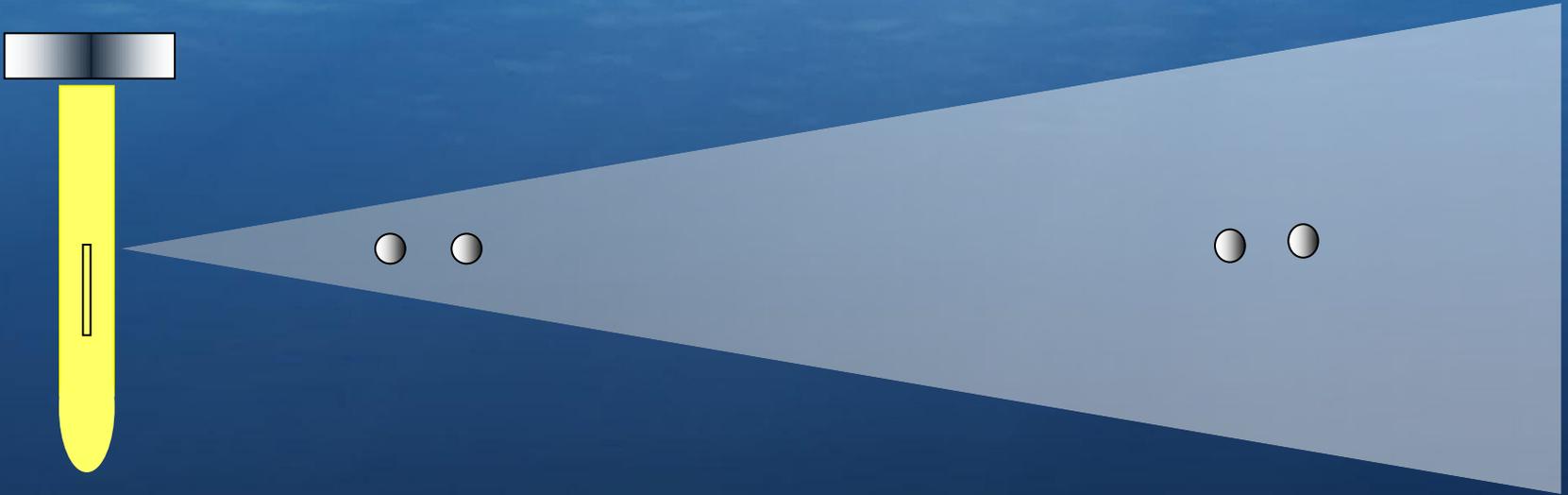
II. SSS Principles

Along Track Resolution



II. SSS Principles

Across Track (Range) Resolution

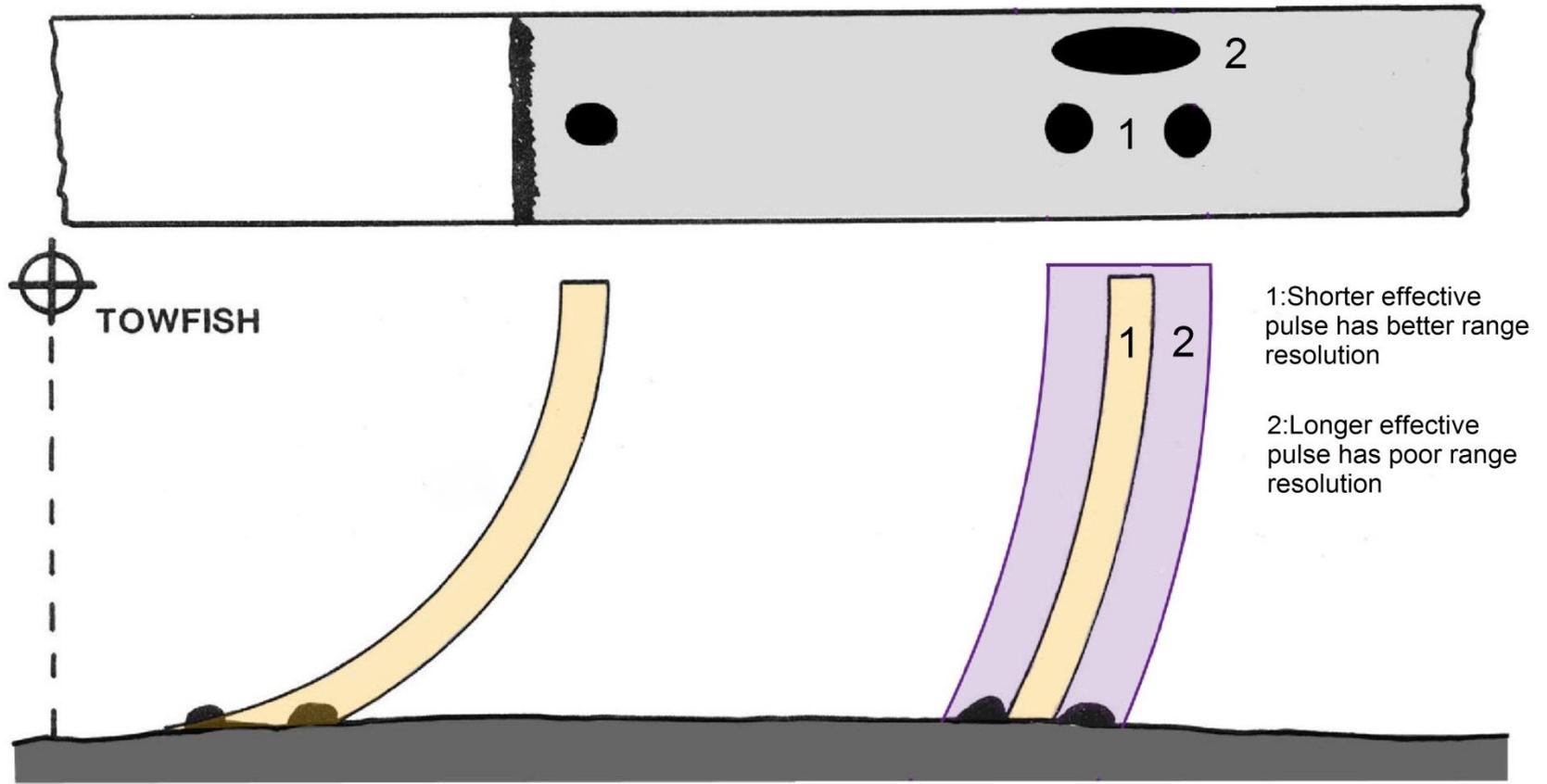


Shorter Transmit Pulses or Wider Chirp Bandwidth Result in Higher Range Resolution

II. SSS Principles

Across Track Resolution

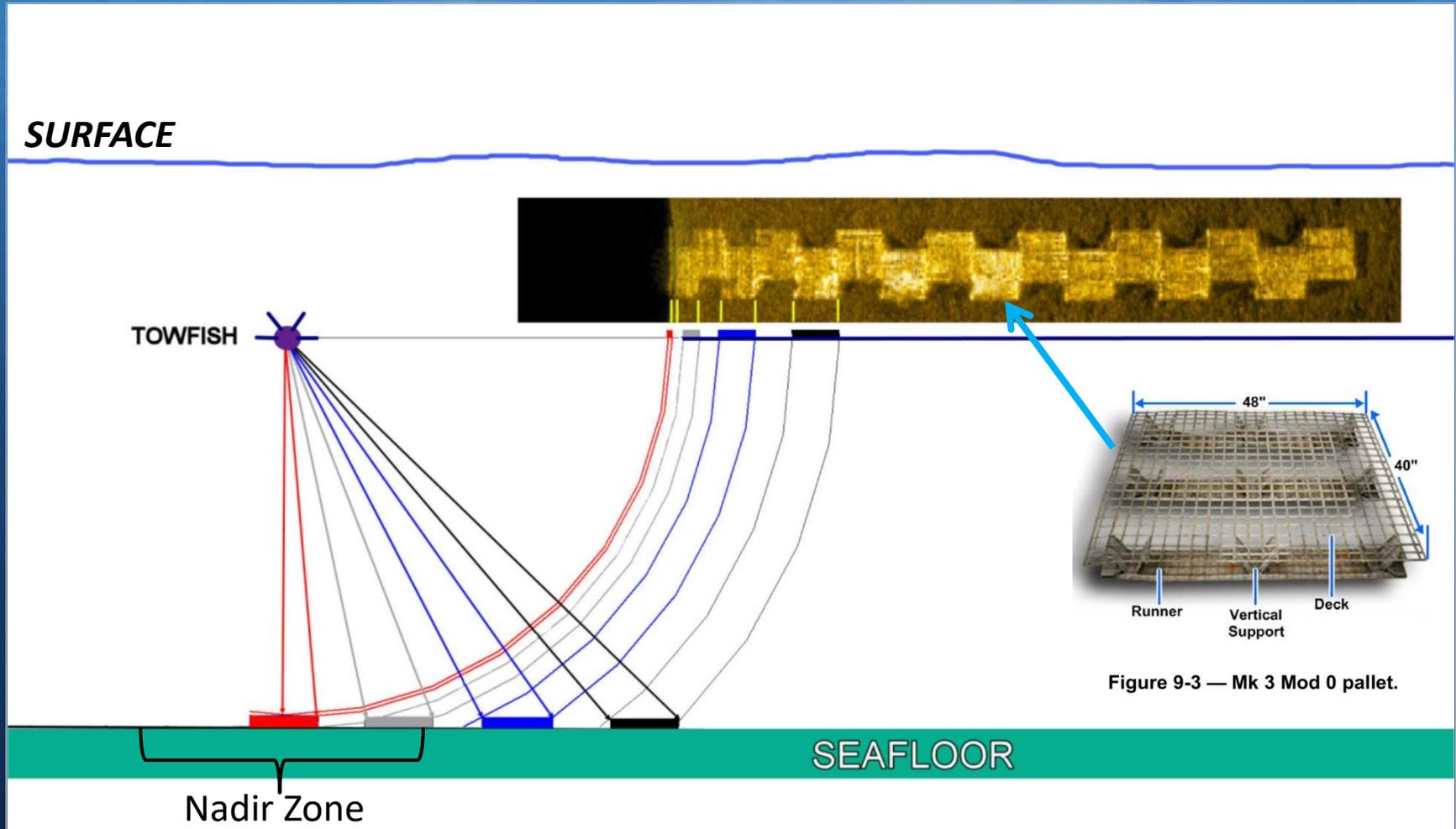
SIDE SCAN DISPLAY



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

II. SSS Principles

Nadir Compression



II. SSS Principles

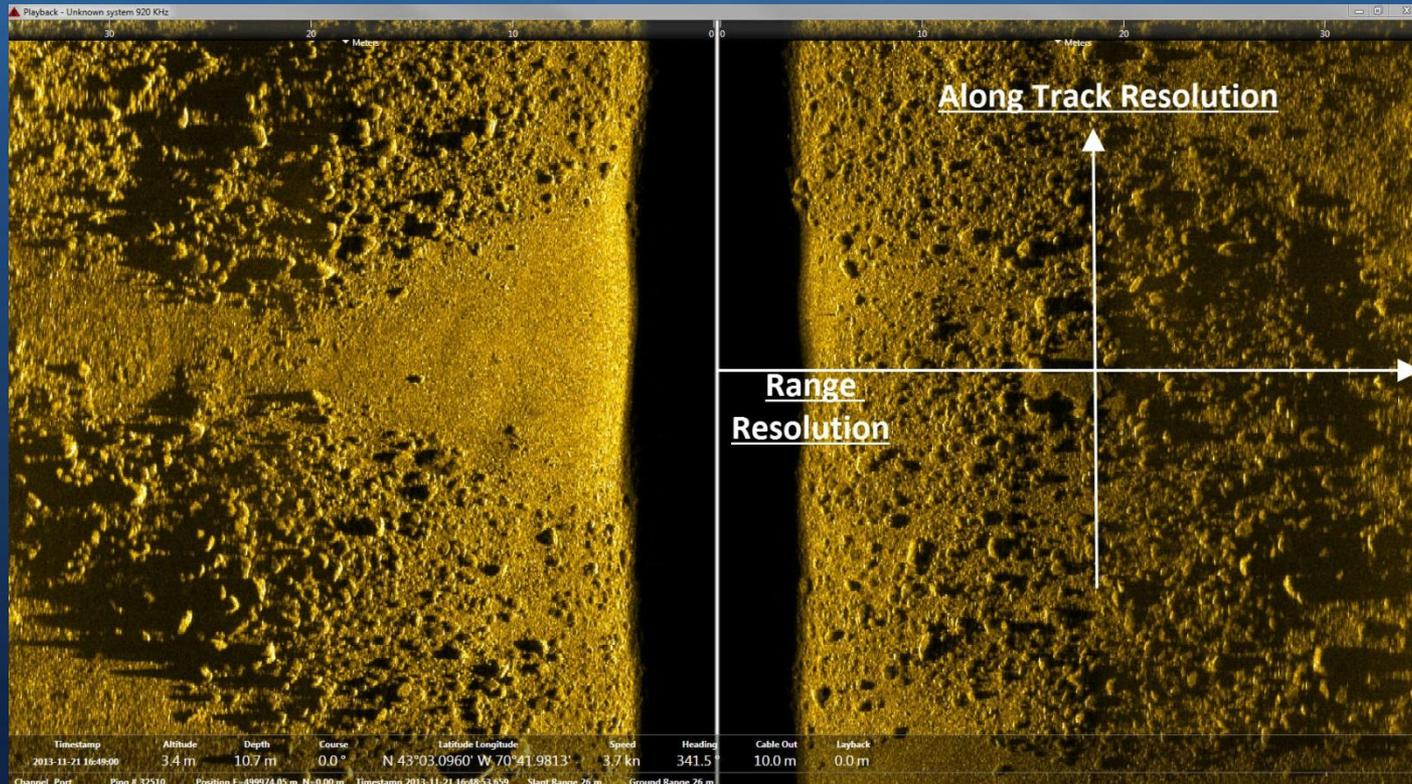
Across Track Resolution

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...

Simplified Formula

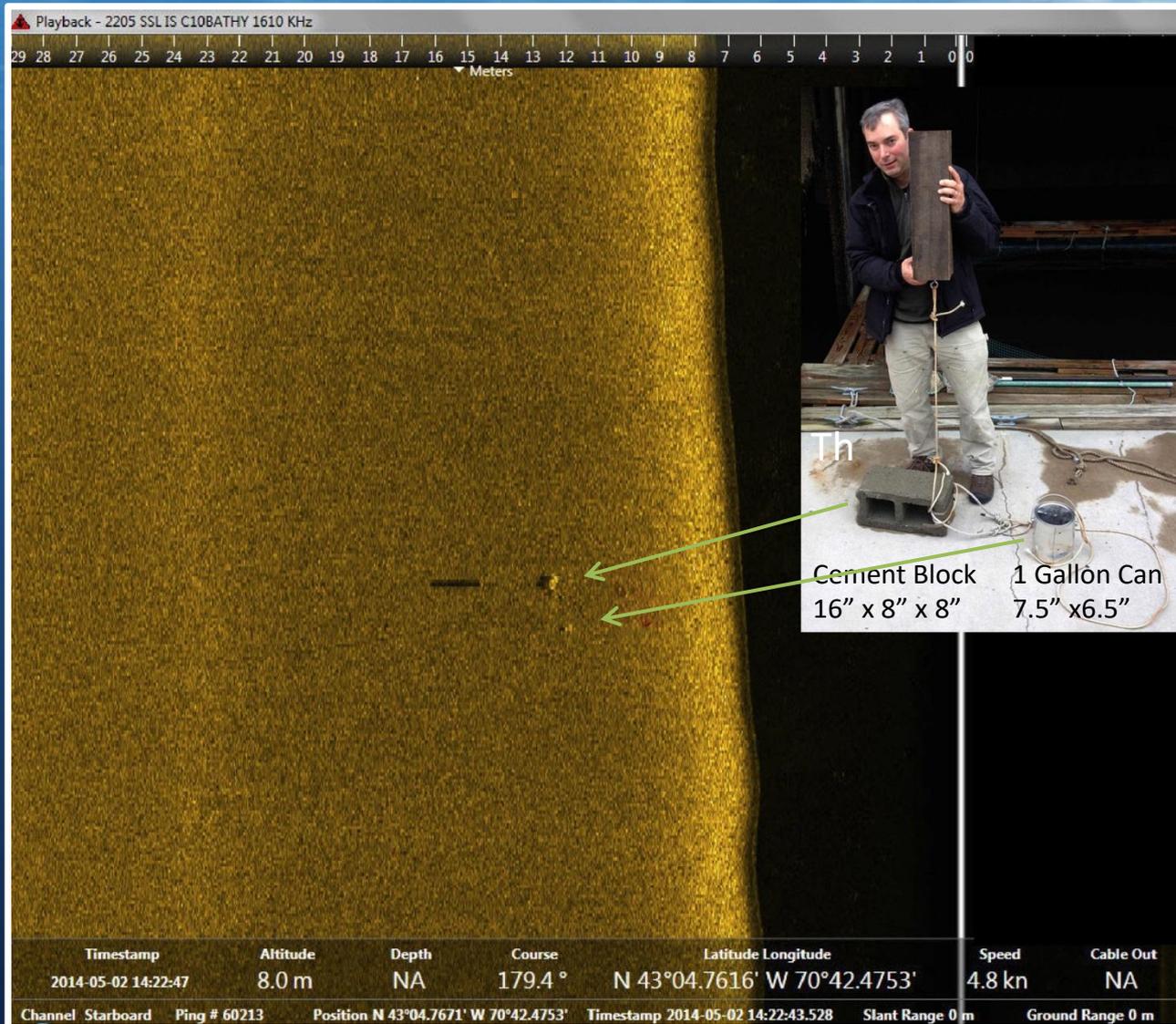
Pings on Target per Meter = Ping Rate (Pings/Second:Set by Range Scale) / Tow Speed (M/second)

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



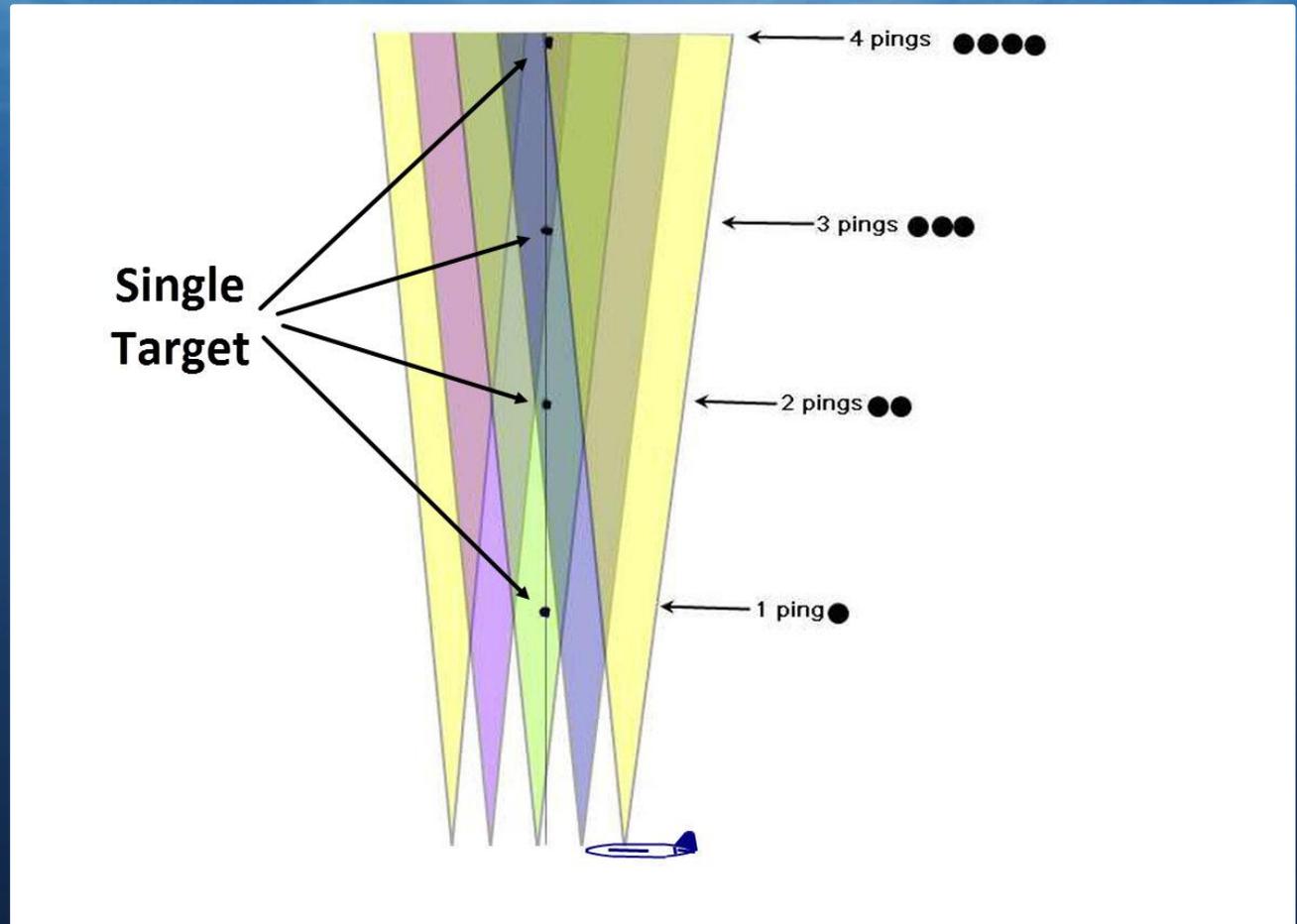
Target Detection

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

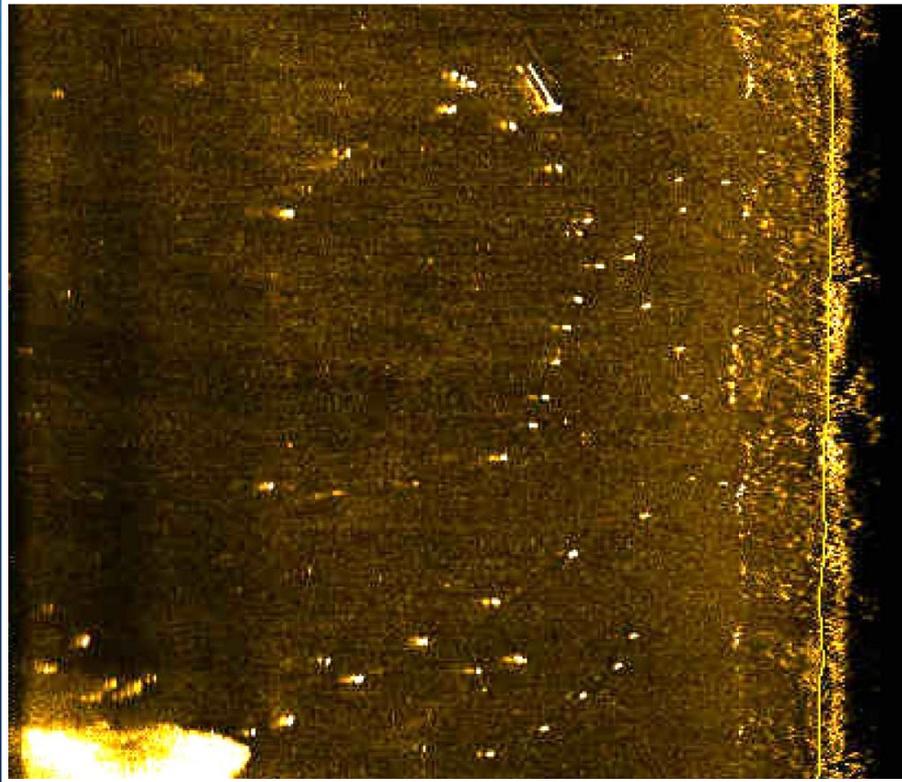
Target Detection

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

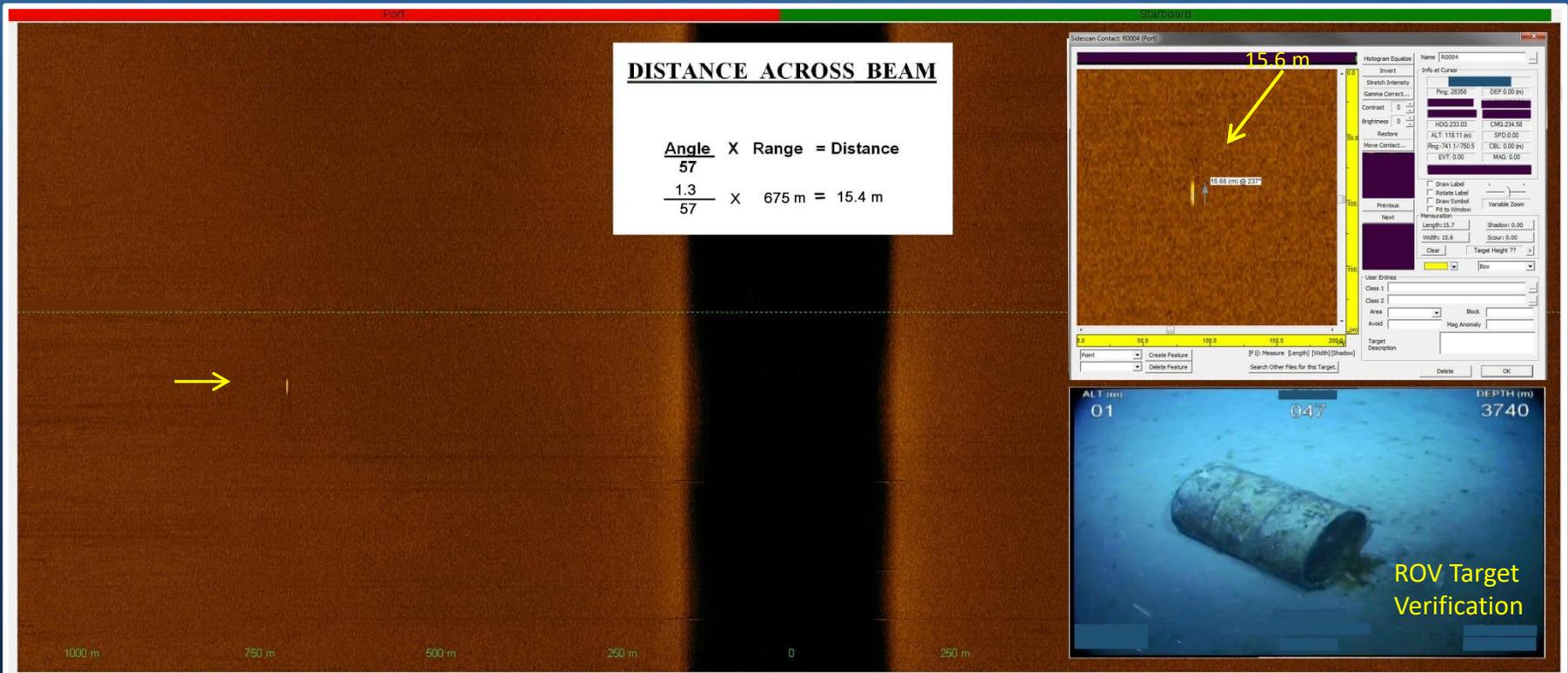
II. SSS Principles

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 θ of 1.3 degrees @ 675 m range agrees with what size the target should appear on the sonar display.

DISTANCE ACROSS BEAM

$$\frac{\text{Angle}}{57} \times \text{Range} = \text{Distance}$$
$$\frac{1.3}{57} \times 675 \text{ m} = 15.4 \text{ m}$$



II. SSS Principles

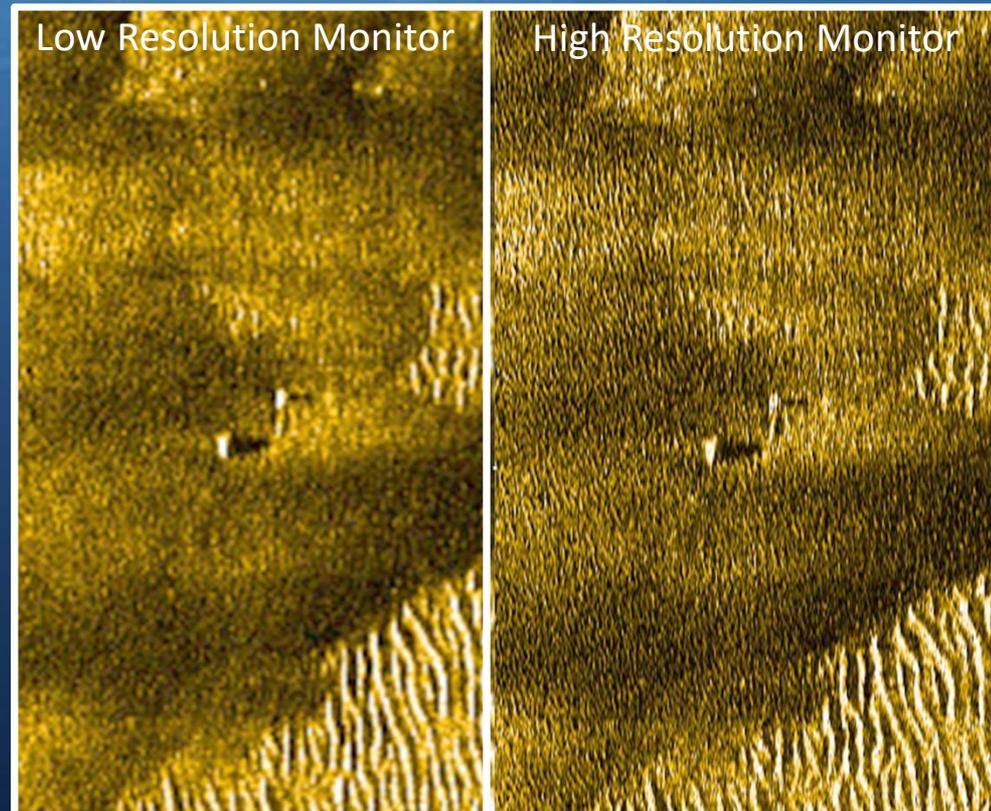
Target Detection & Sonar Display Resolution

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 $10000 \text{ cm}/640=15.6 \text{ cm}$
- Therefore the full SSS resolution of 1.5 cm will not be displayed with a display resolution of 15.6 cm/pixel

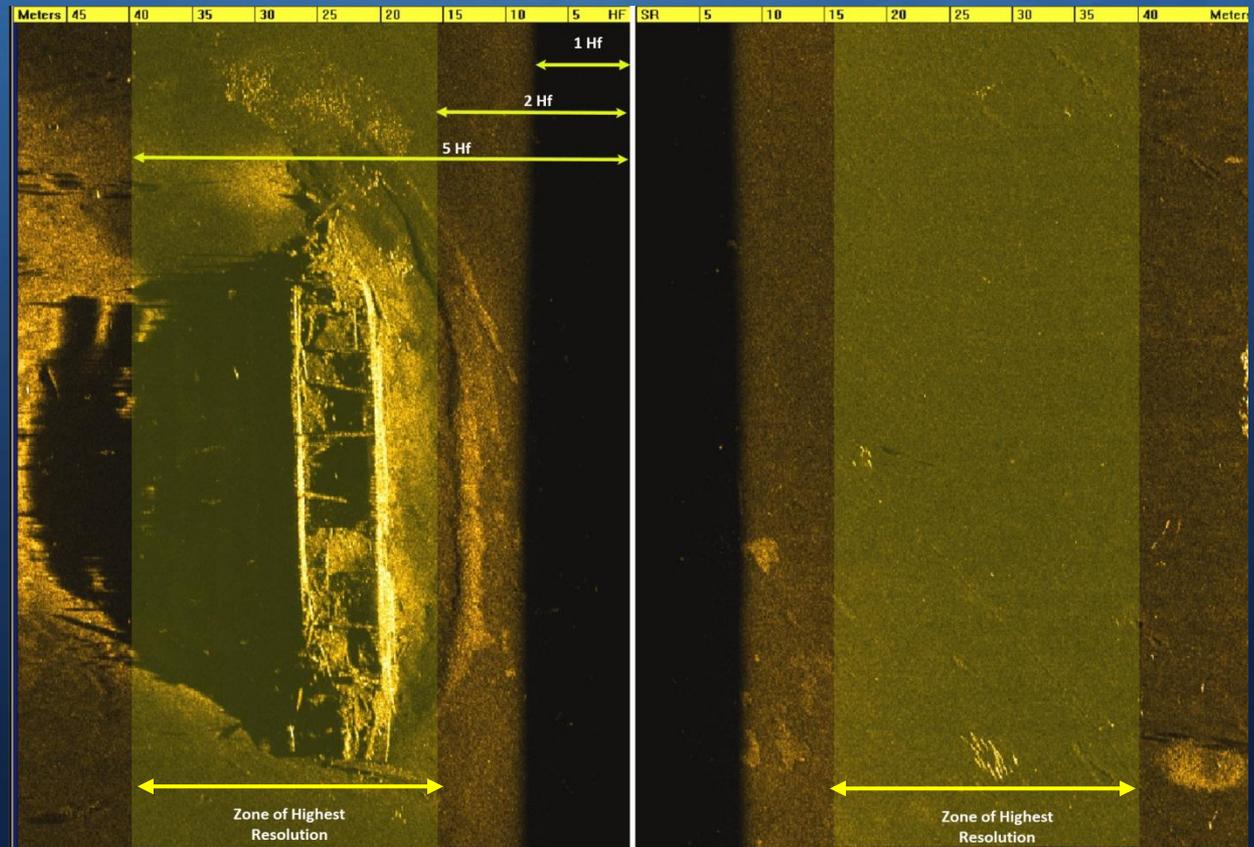
To maximize SSS resolution when viewing data, a large monitor (ie 30 "+) and a minimum of 4k display resolution should be used.



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 (H_f) and is bounded in range defined by $2H_f$ to $5H_f$ 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

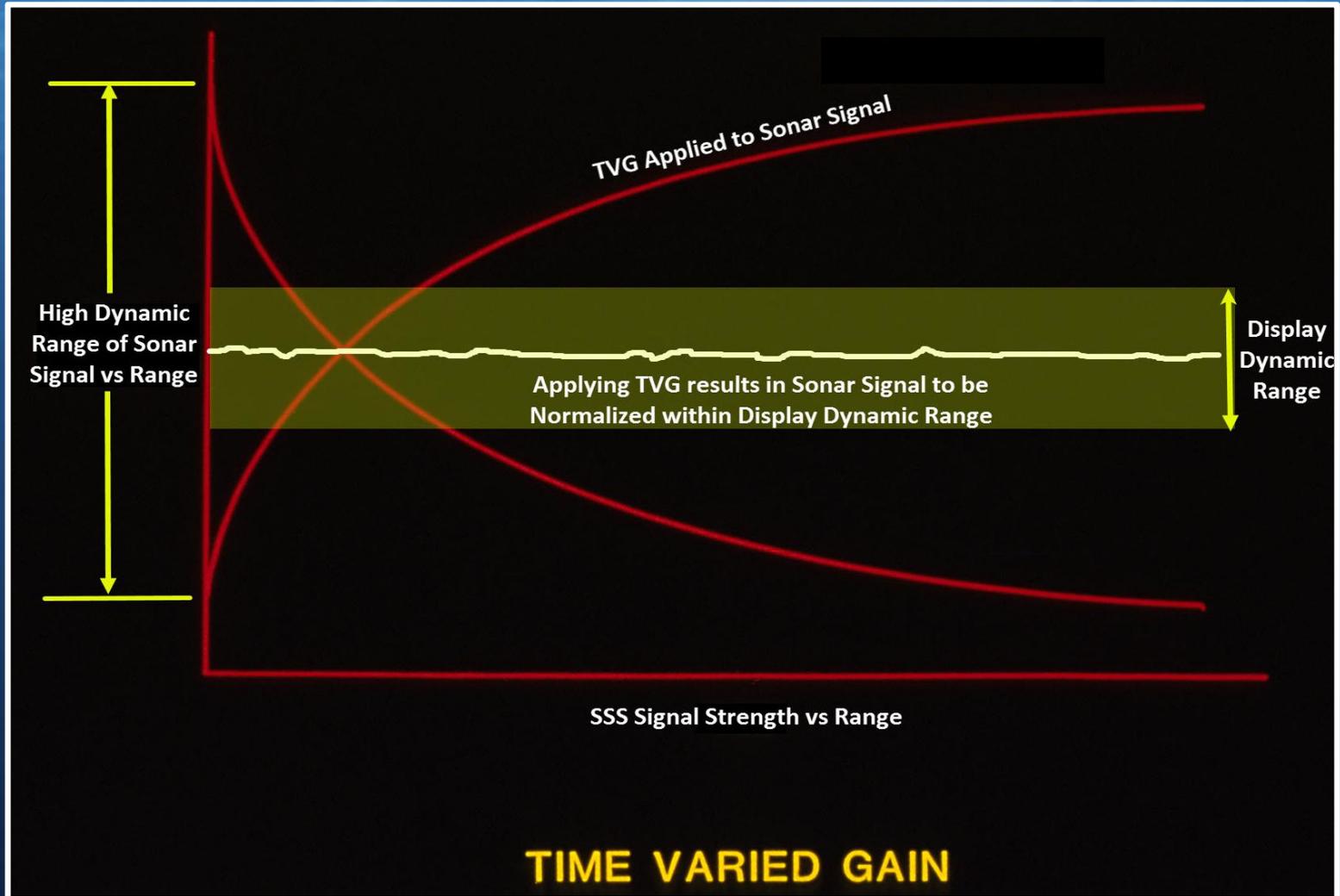
Frequency & Resolution



II. SSS Principles

Time Variable Gain (TVG)

The Magic Sauce to High Fidelity SSS Images

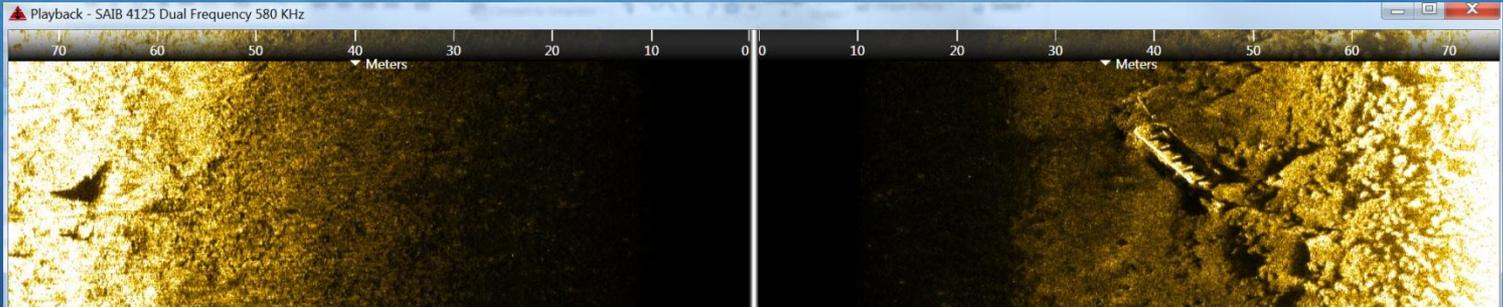


II. SSS Principles

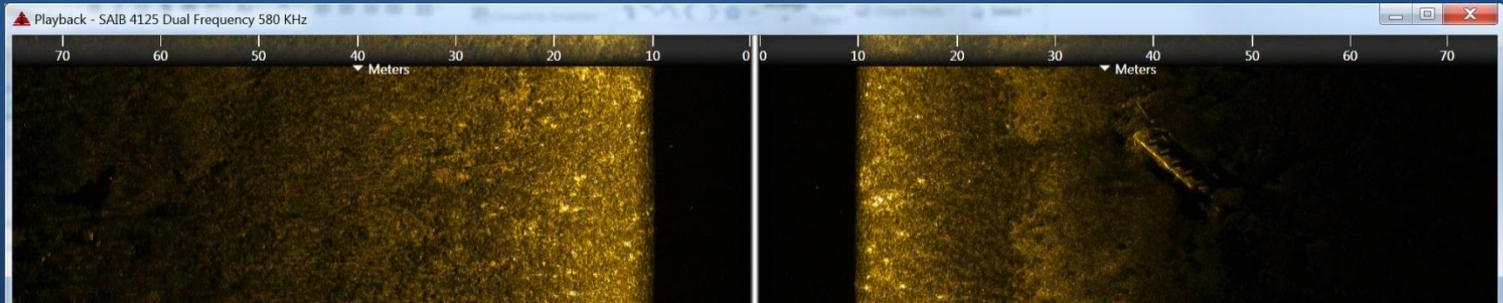
Time Variable Gain (TVG)

The Magic to High Fidelity SSS Images

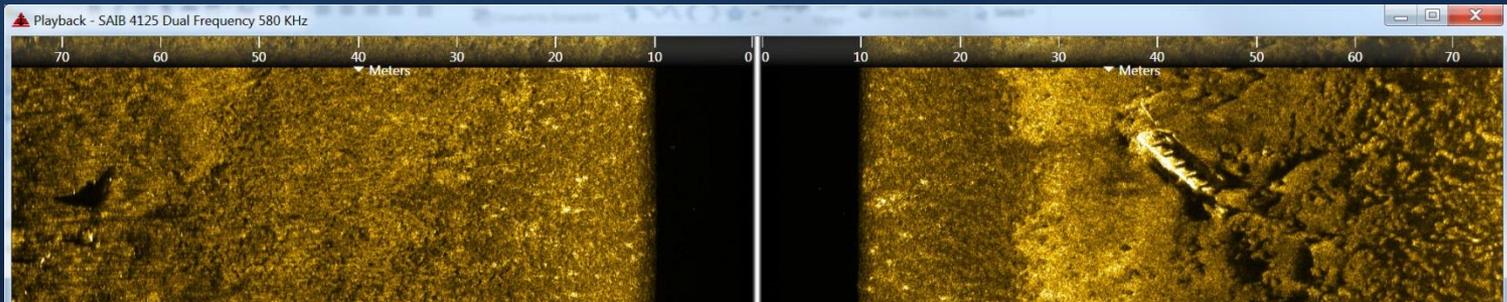
Poor TVG
Near Gain



Poor TVG
Far Gain

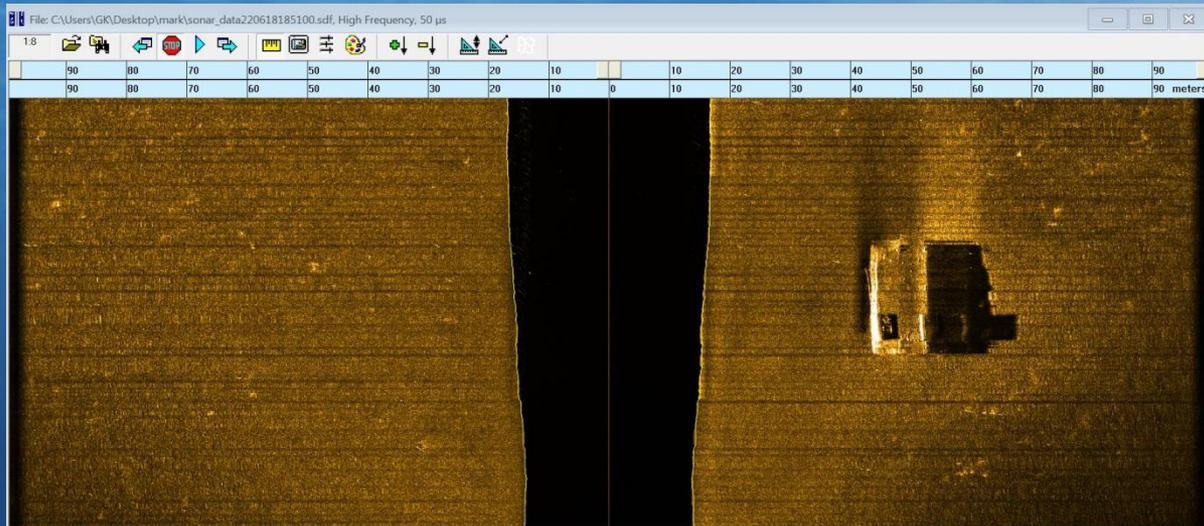


Good TVG
Gain &
Properly
Normalized
Data

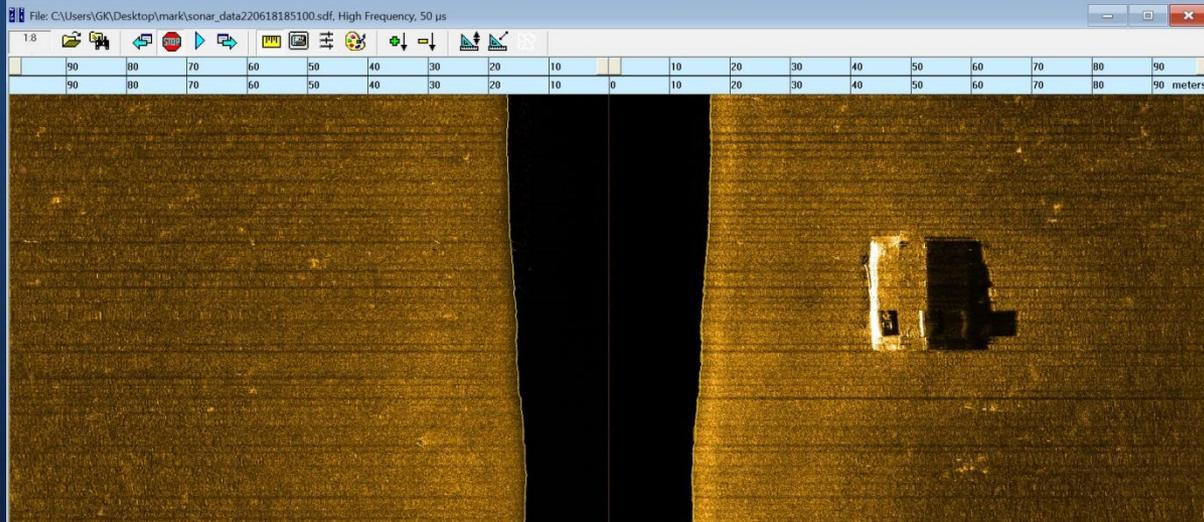


II. SSS Principles

Auto TVG Artifacts vs Manual TVG



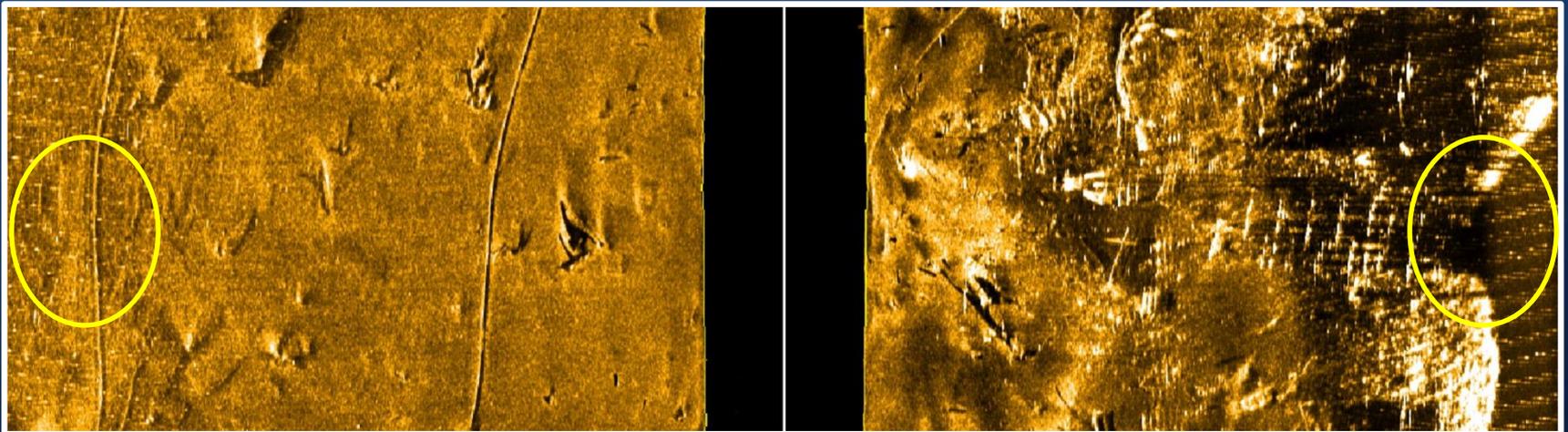
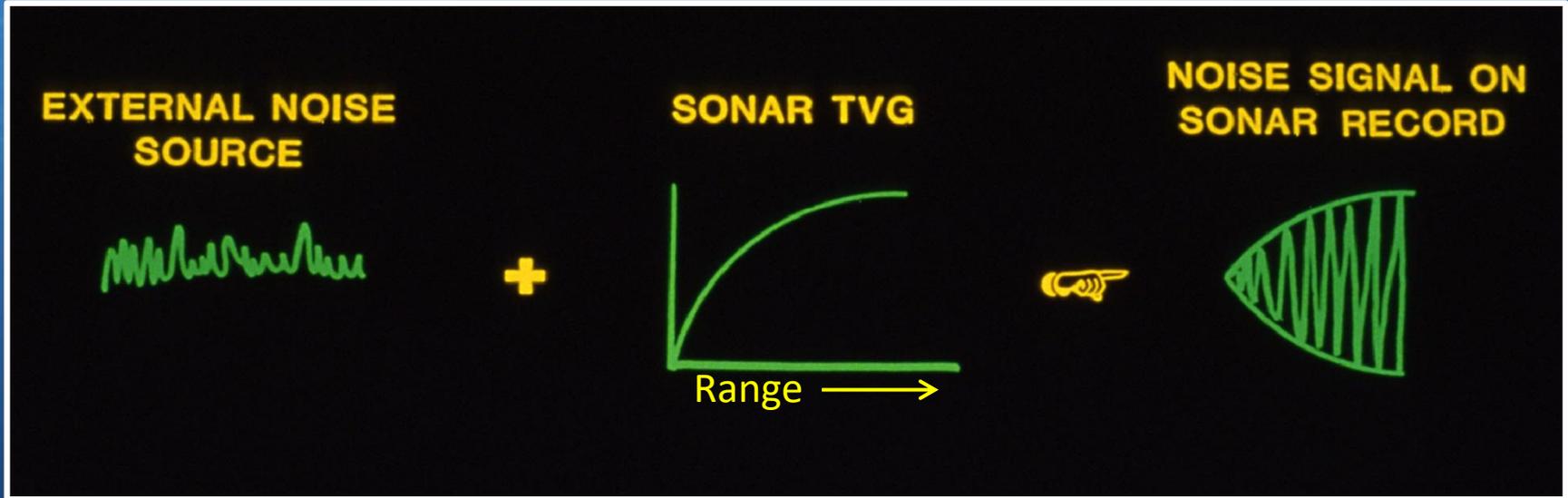
Auto TVG



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).

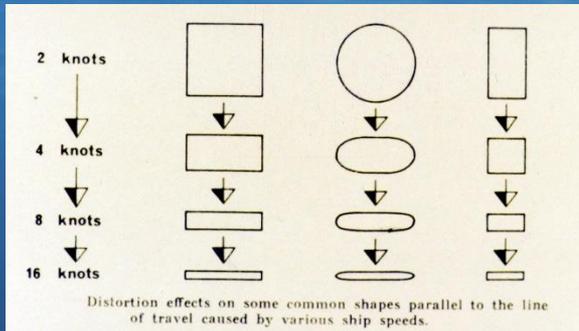
The along track direction has a scale distortion that results from a combination of sonar ping rate, tow speed and the sonar display resolution.

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

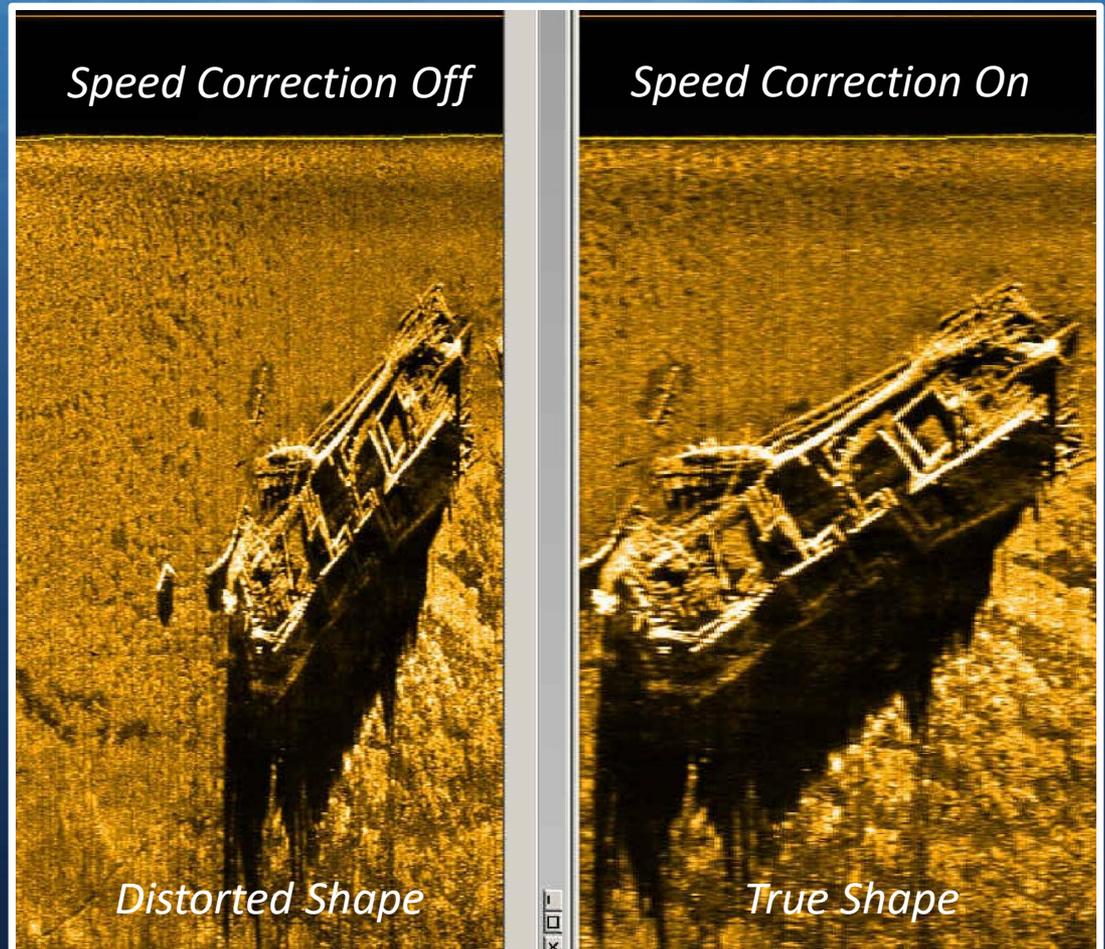
Modern SSS systems today can correct for these 2 scale distortions by using both the tow speed, sonar ping rate, display resolution and towfish altitude to show a 1:1 scale corrected feature. Simply put the features are displayed in true shape with no distortion.

II. SSS Principles

Speed Correction



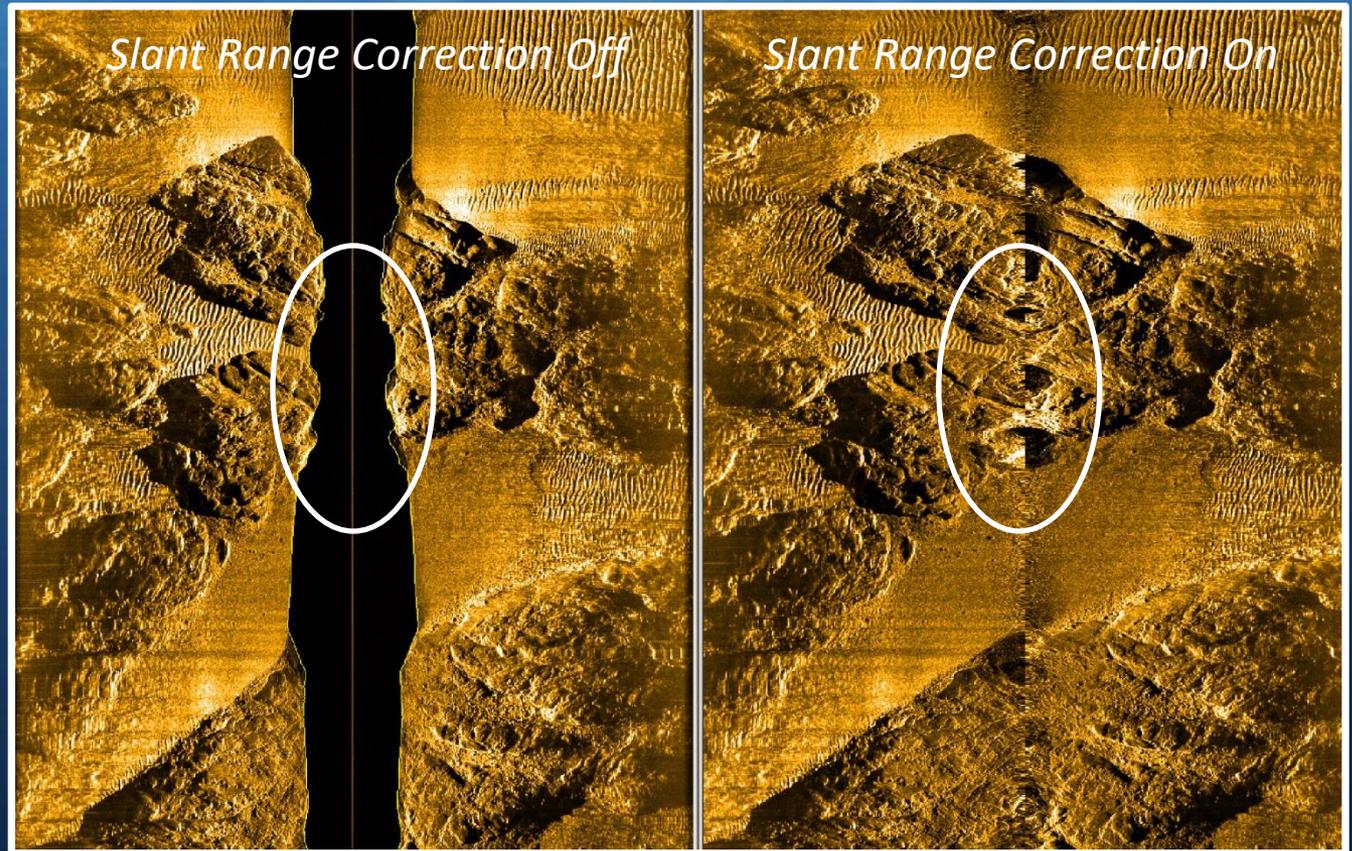
On a set range scale (ping rate) as a pass is made by a target at faster speeds, the target is pinged less, resulting in it being compressed in the along track direction. When speed correction is active it will correct the along track scale to remove this distortion.



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

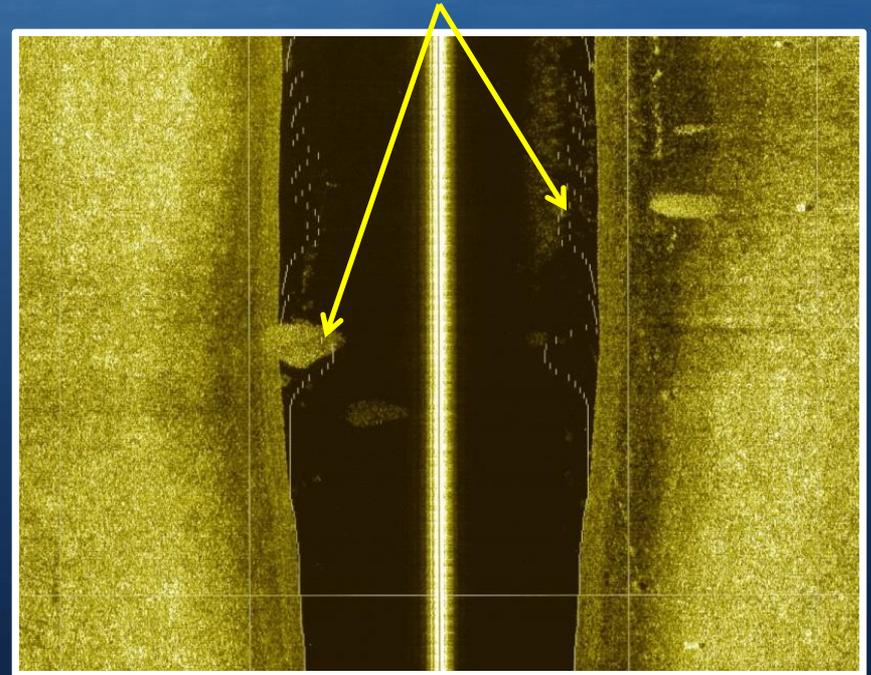
Altitude Tracking

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

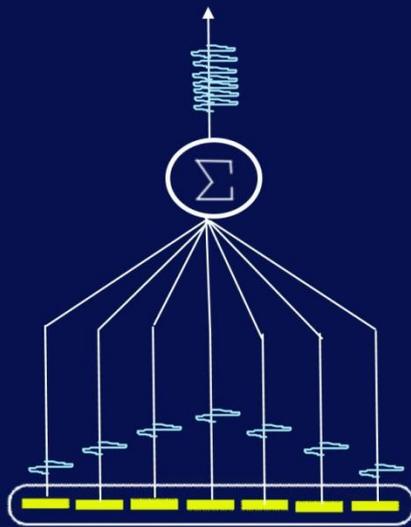
Other Side Scan Sonar Types

- 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

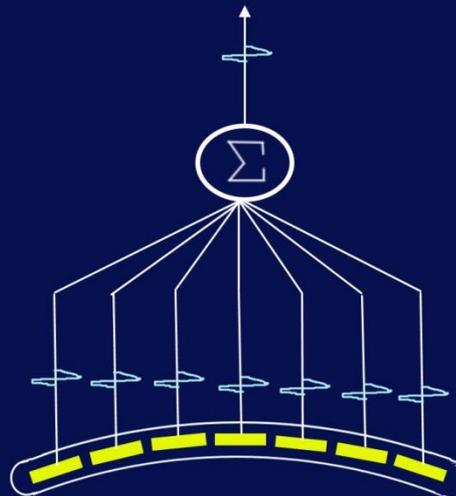
Other Side Scan Sonar Types

Focused Side Scan Sonar



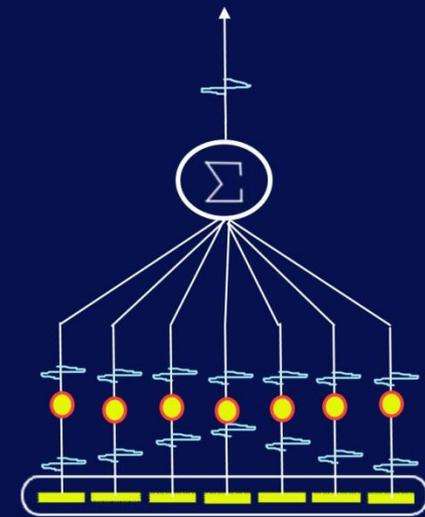
Spherical Echo Wave Front

Standard Line Array Not Focused



Spherical Echo Wave Front

Mechanical Focused Array



Spherical Echo Wave Front

Electronically Focused Array



II. SSS Principles

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

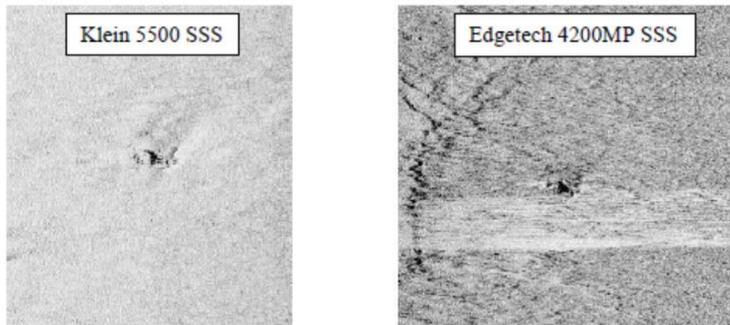
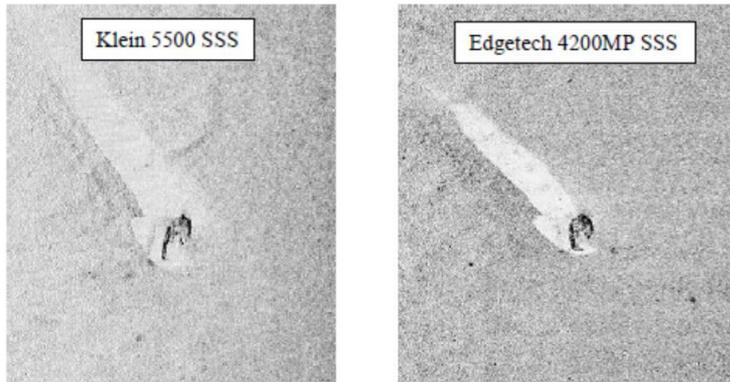


Image comparison 2 – 8 meter small boat wreck comparison



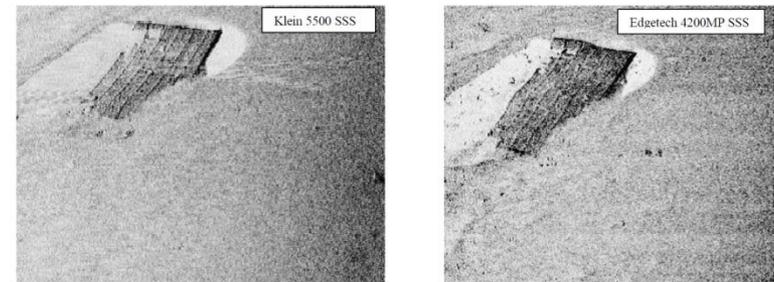
Other Side Scan Sonar Types

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



Multi-Beam vs Multi-Ping Data @ 8 knots

II. SSS Principles

Other Side Scan Sonar Types

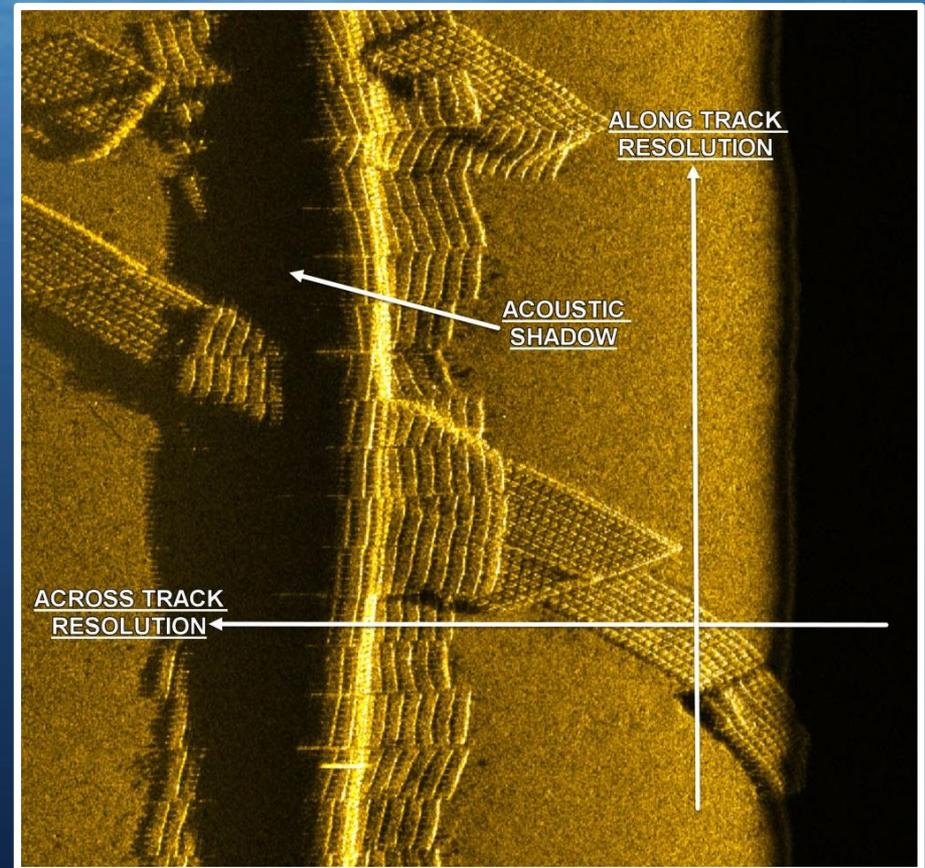
Synthetic Aperture Side Scan Sonar

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

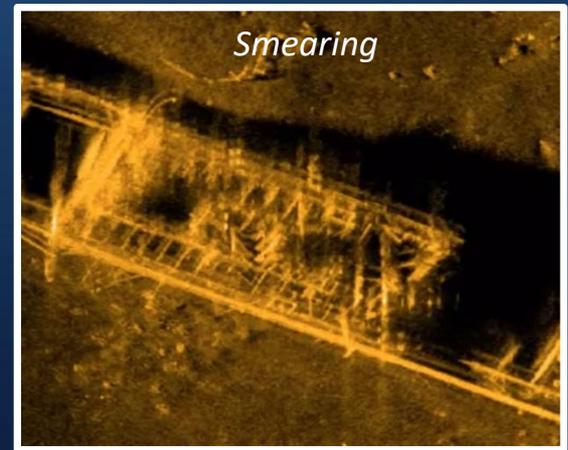
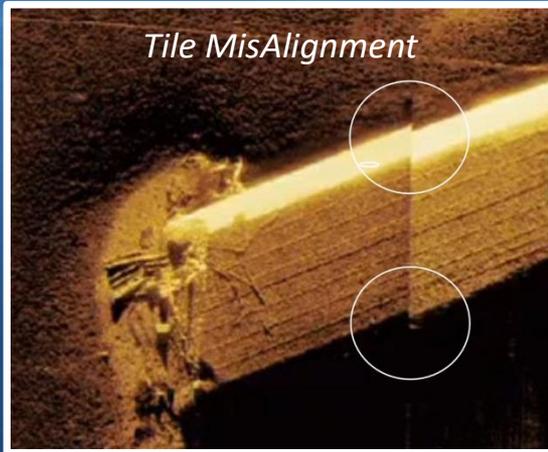
- Data is geo-referenced processed image files(Tiles) and not raw sonar data
- SAS Tile Misalignment
- Tiles vary in gain and gamma correction
- Image smearing
- Poor nadir 1st bottom return compared to RAS (Real Aperature Sonar)
- Acoustic shadow softening
- Data volumes are very large compared to RAS
- 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

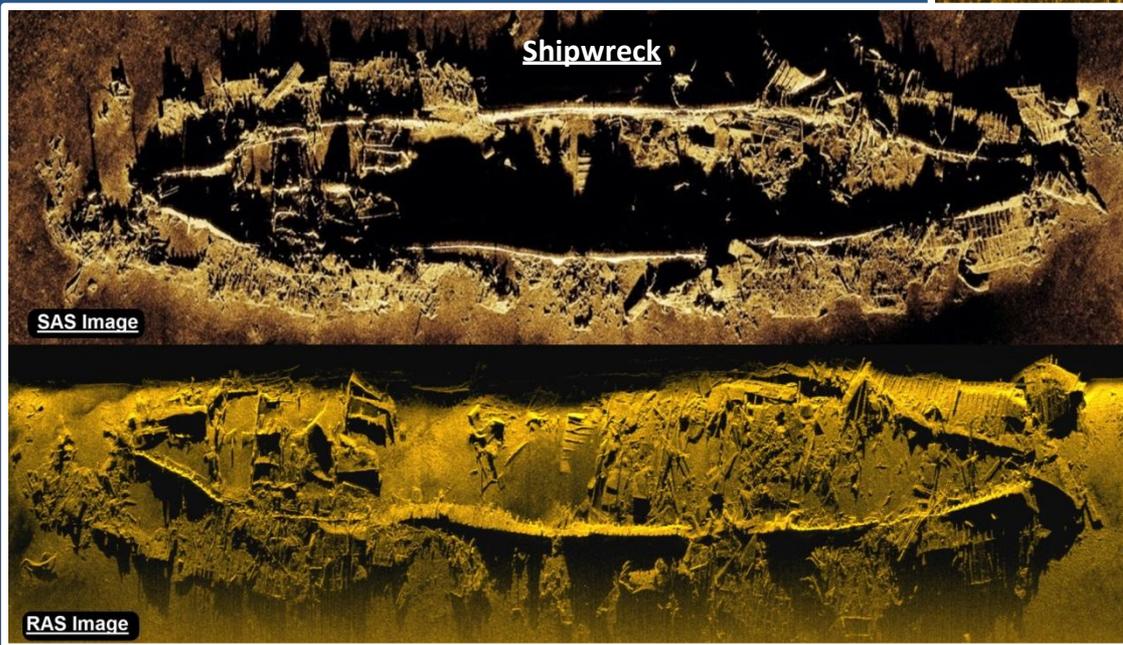
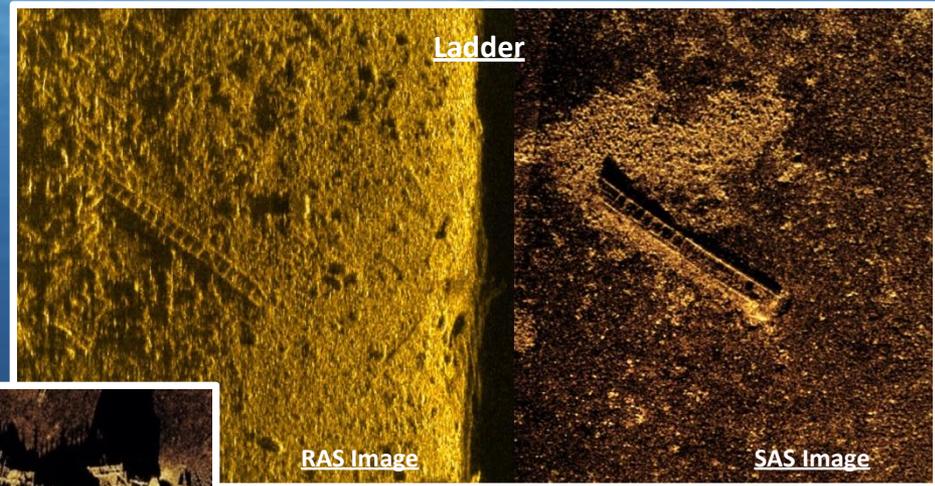


II. SSS Principles

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 😊



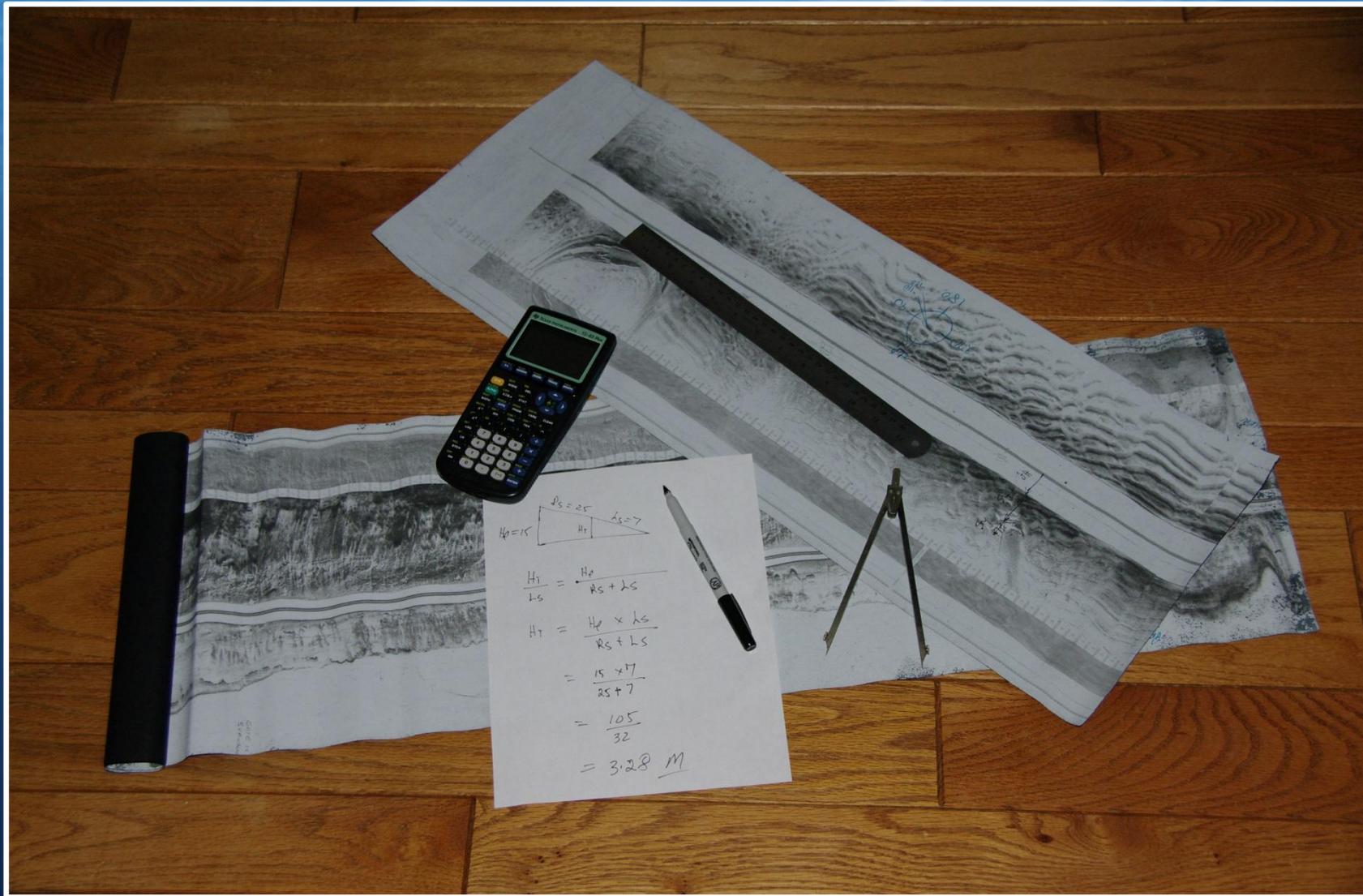
← This @ \$9000

OR

This @ \$900 →

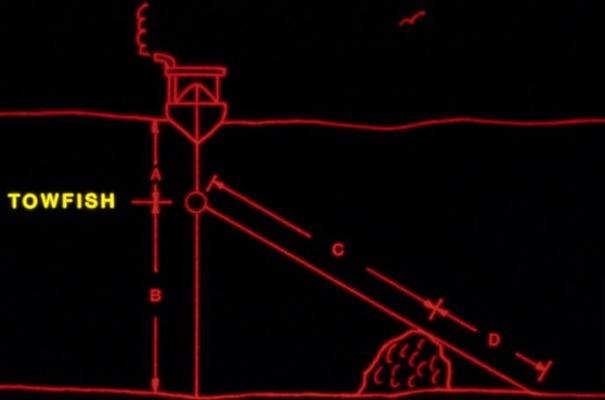


III. SSS Data Interpretation



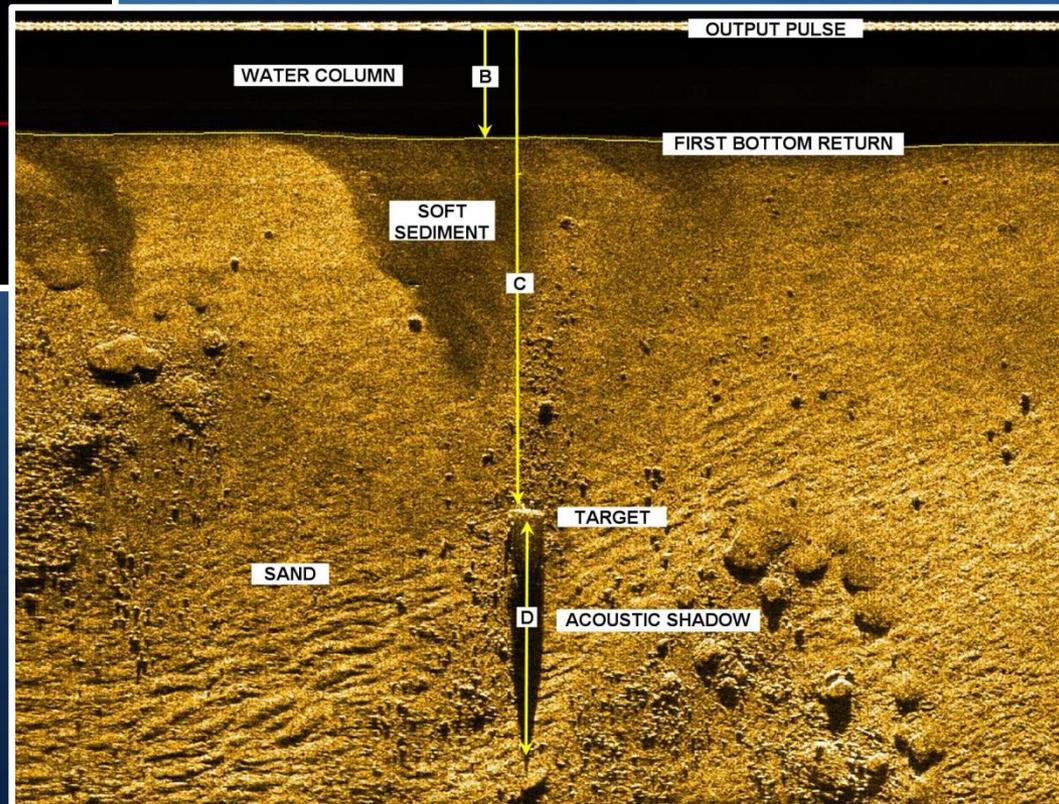
III. SSS Data Interpretation

SIDE SCAN SONAR GEOMETRY



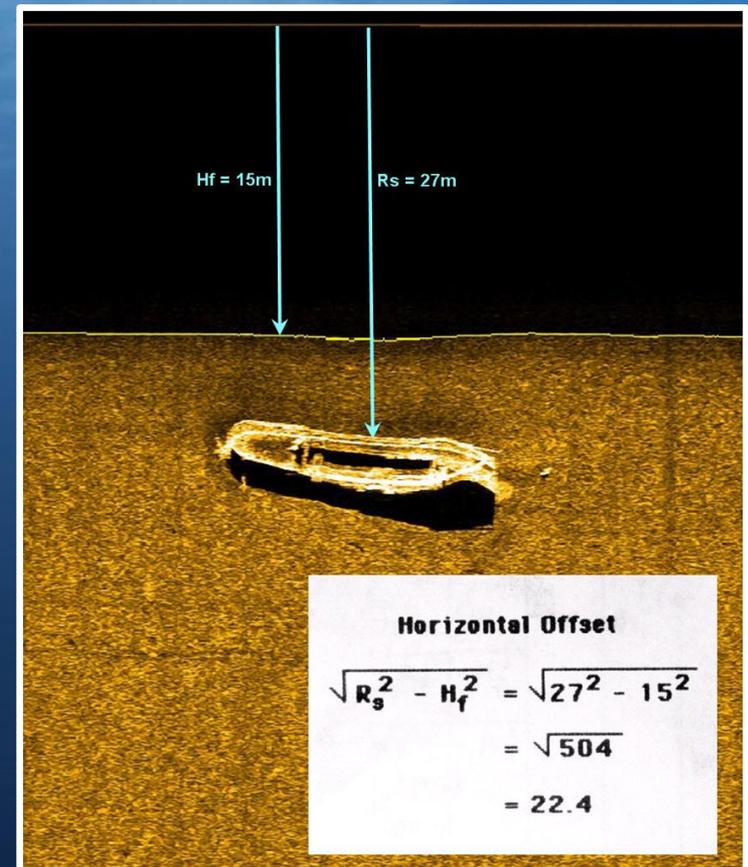
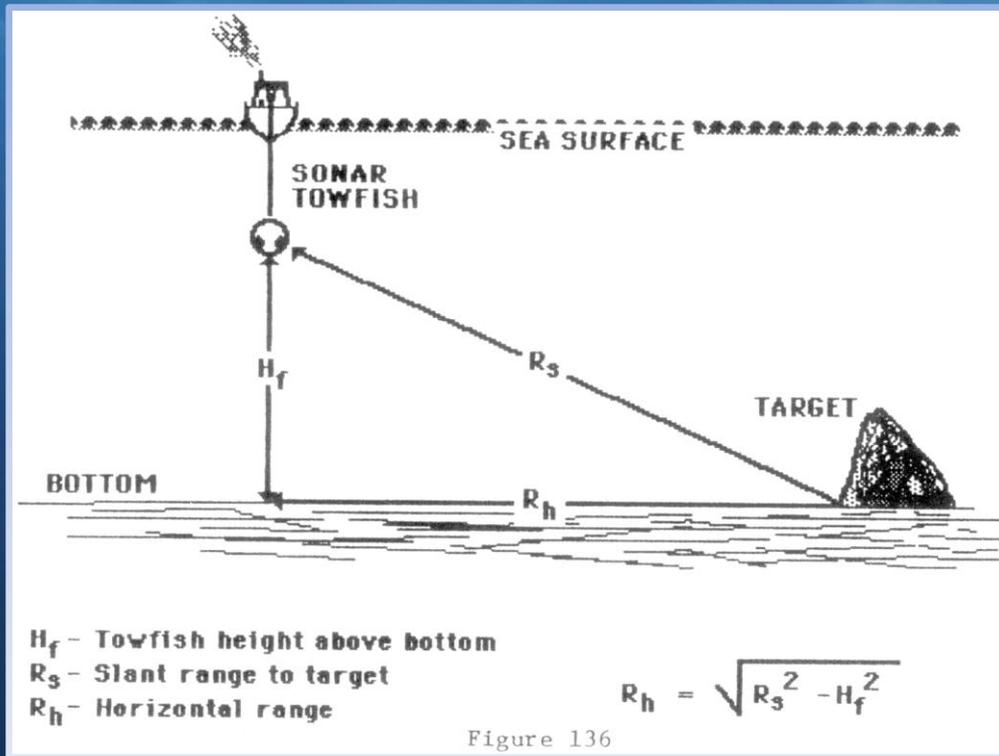
- A--TOWFISH DEPTH BELOW SURFACE
- B--TOWFISH ALTITUDE ABOVE BOTTOM
- C--SLANT RANGE TO TARGET
- D--ACOUSTIC SHADOW LENGTH

SSS Image Geometry



III. SSS Data Interpretation

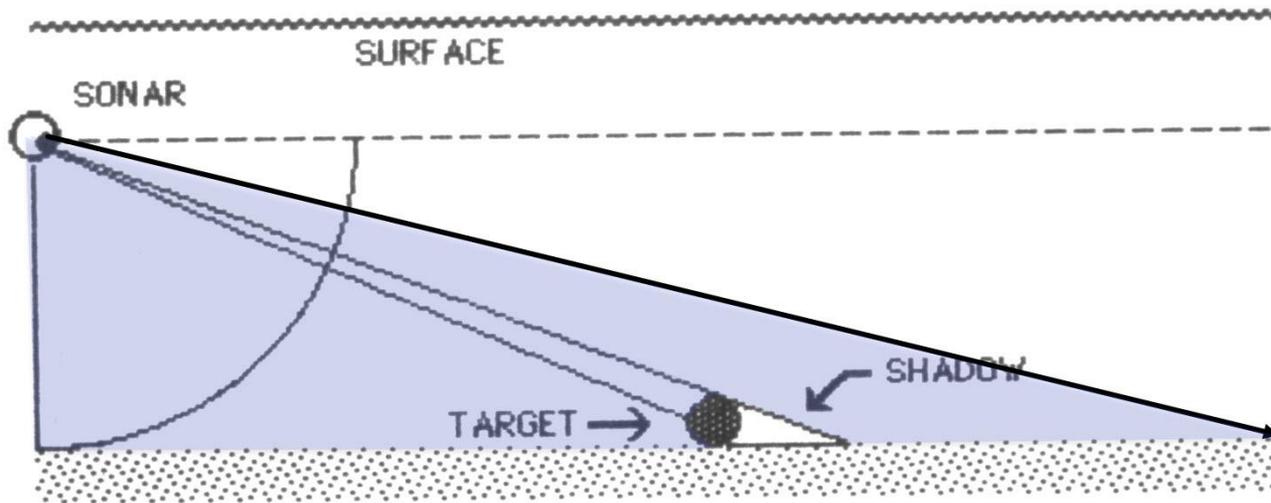
Slant vs Horizontal Range



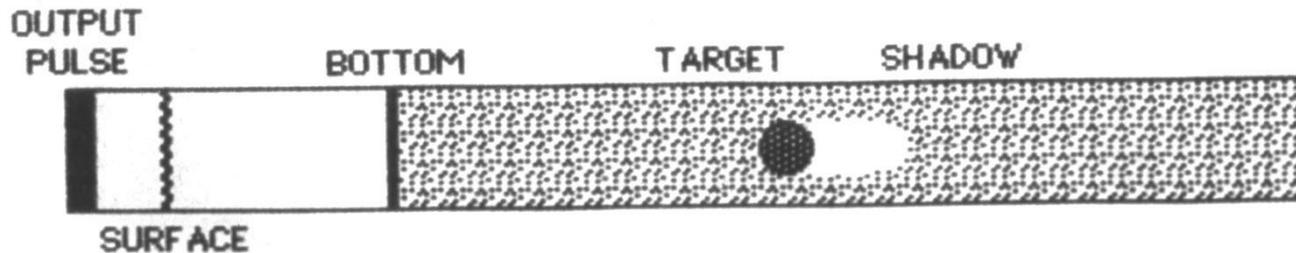
III. SSS Data Interpretation

Acoustic Shadows

TARGET ON THE BOTTOM



SONAR RECORD



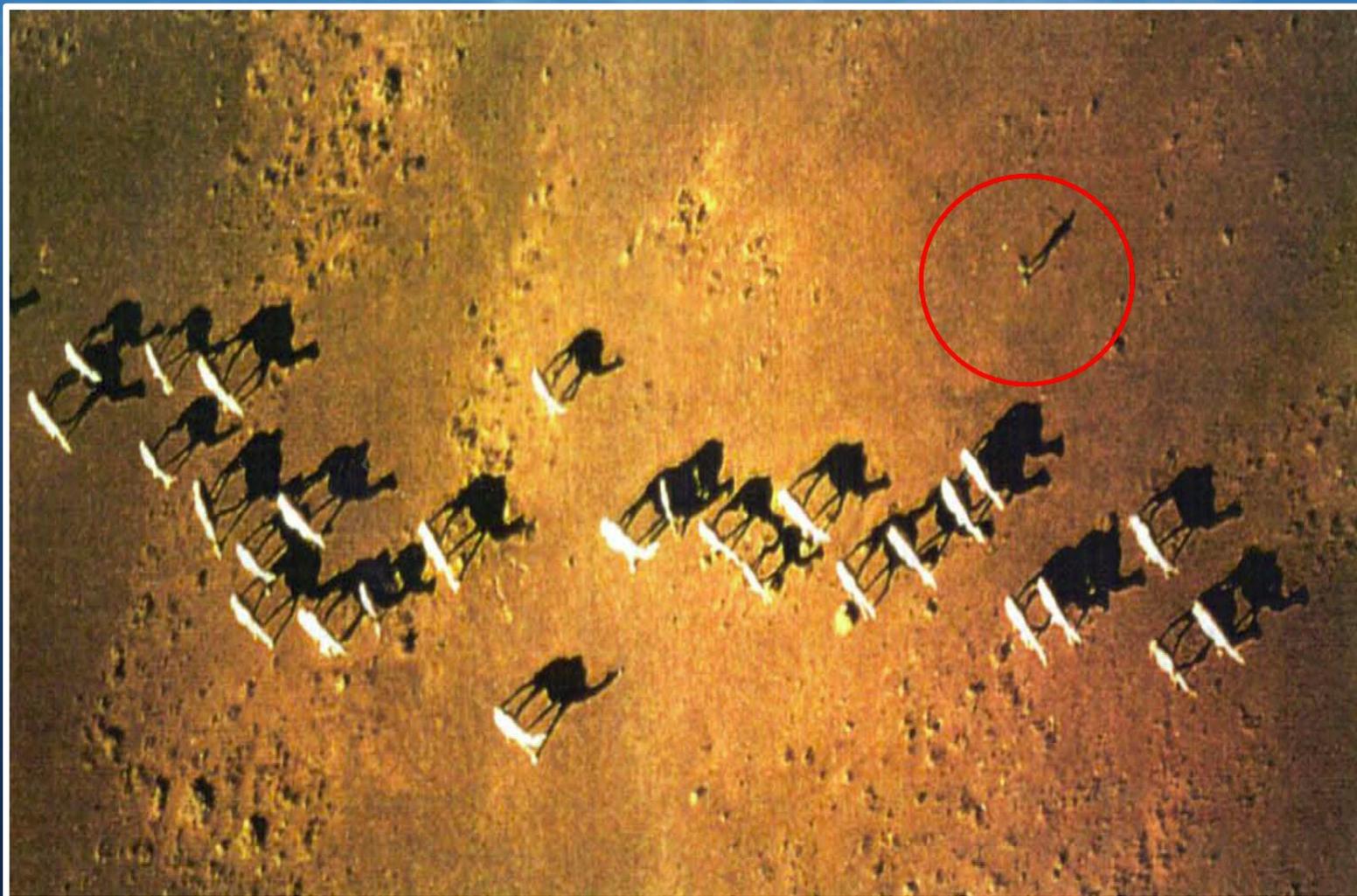
III. SSS Data Interpretation

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



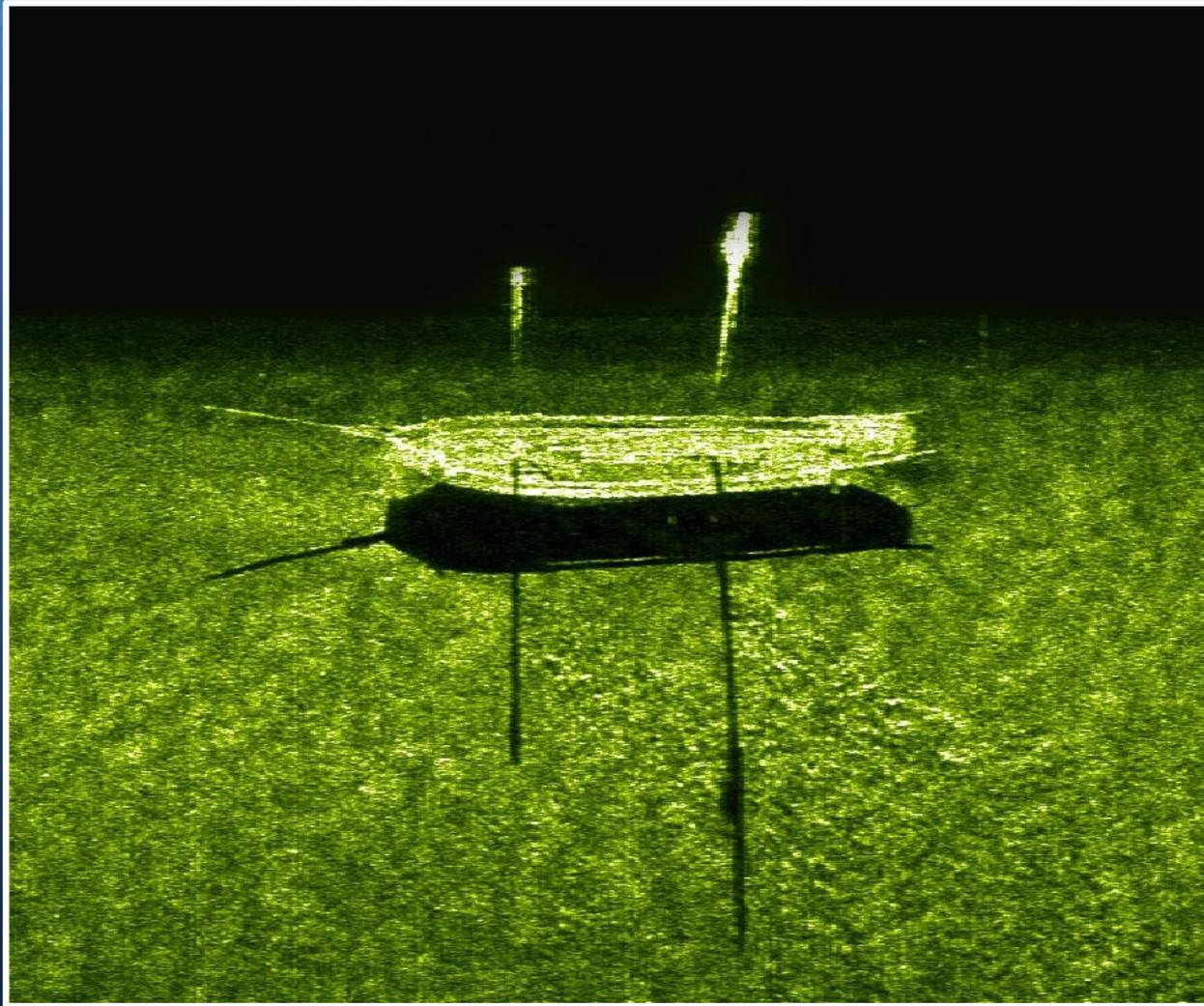
III. SSS Data Interpretation

Shadows – They Are Really Important to Assist in Target Classification



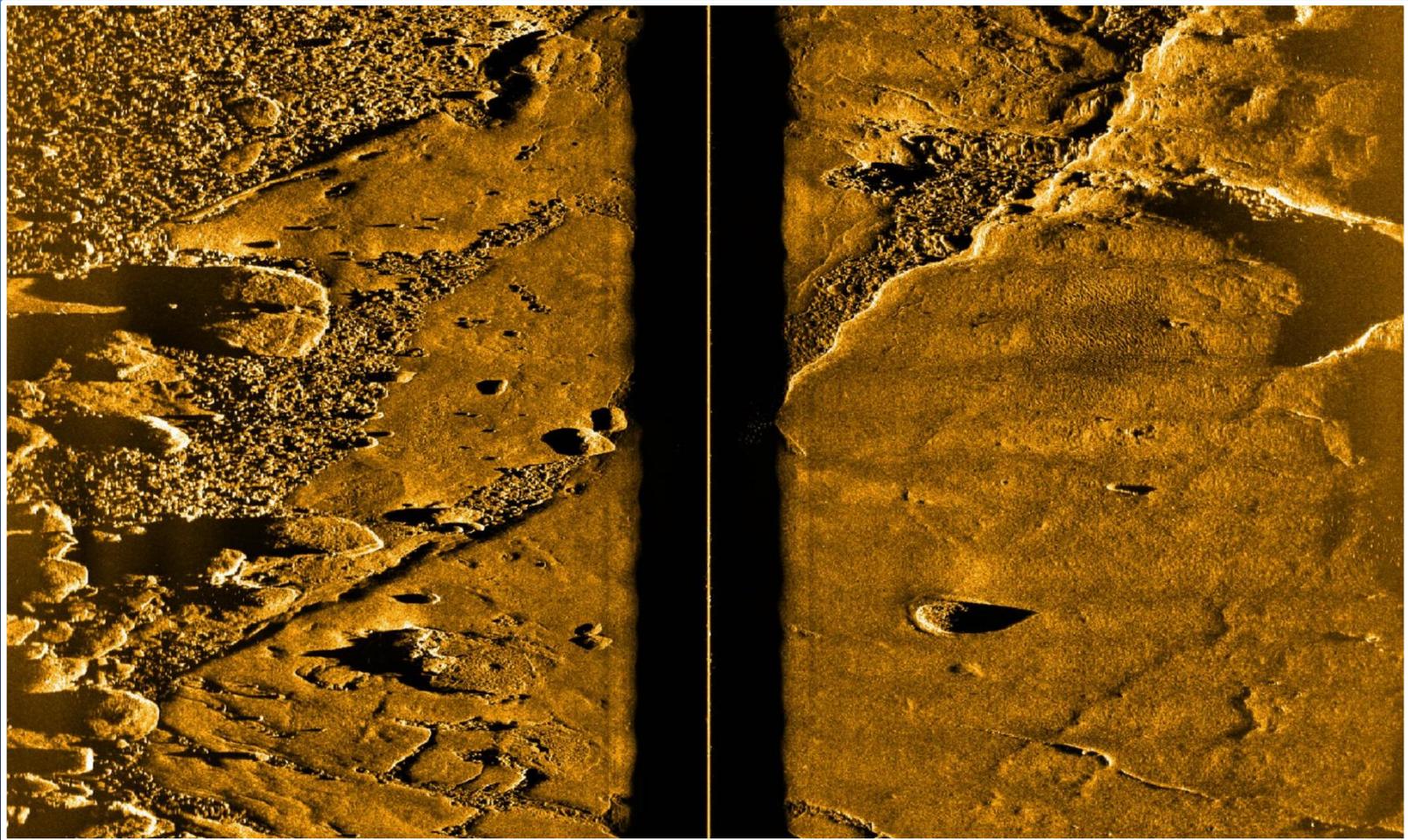
III. SSS Data Interpretation

Acoustic Shadows



III. SSS Data Interpretation

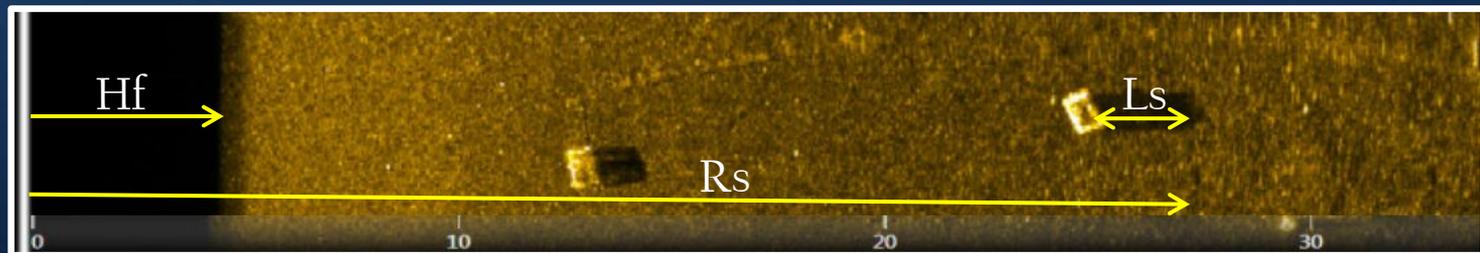
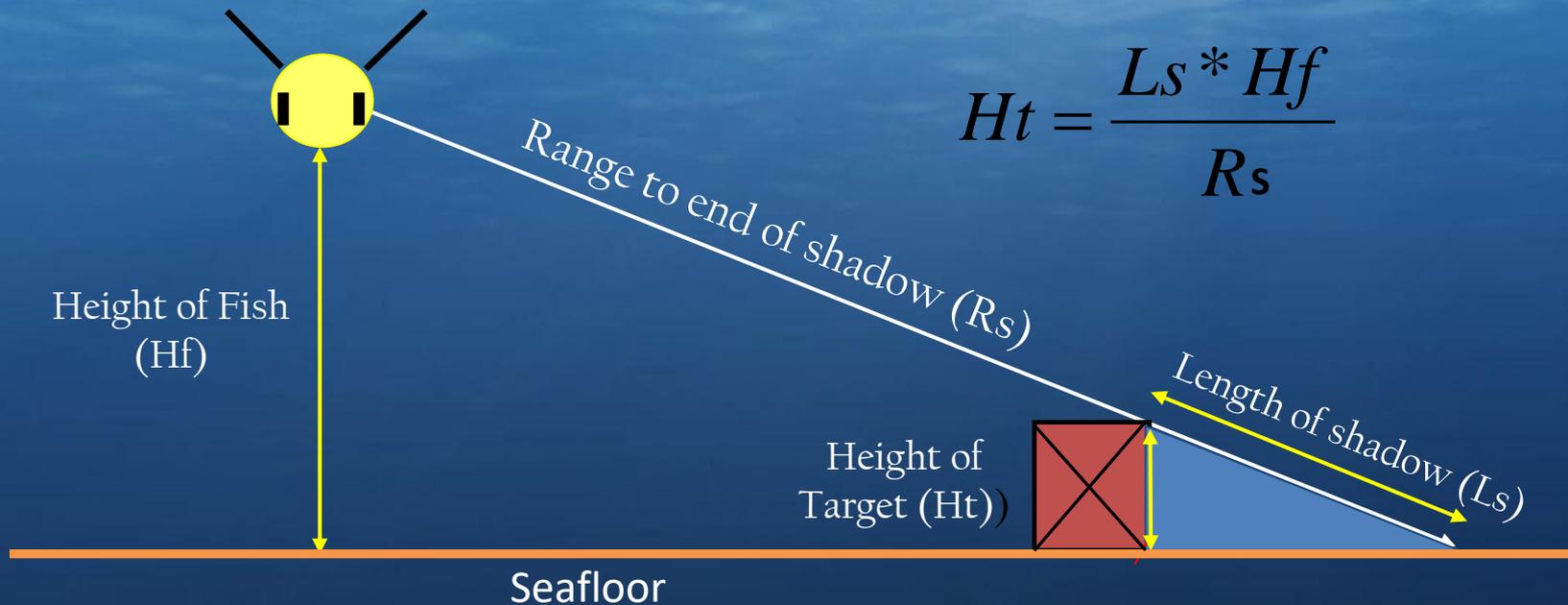
Acoustic Shadows



Boulders & Rocks on Geologic out cropping with Gravel in Depressions

III. SSS Data Interpretation

Target Height Calculation Using Acoustic Shadow



III. SSS Data Interpretation

Target Measurement

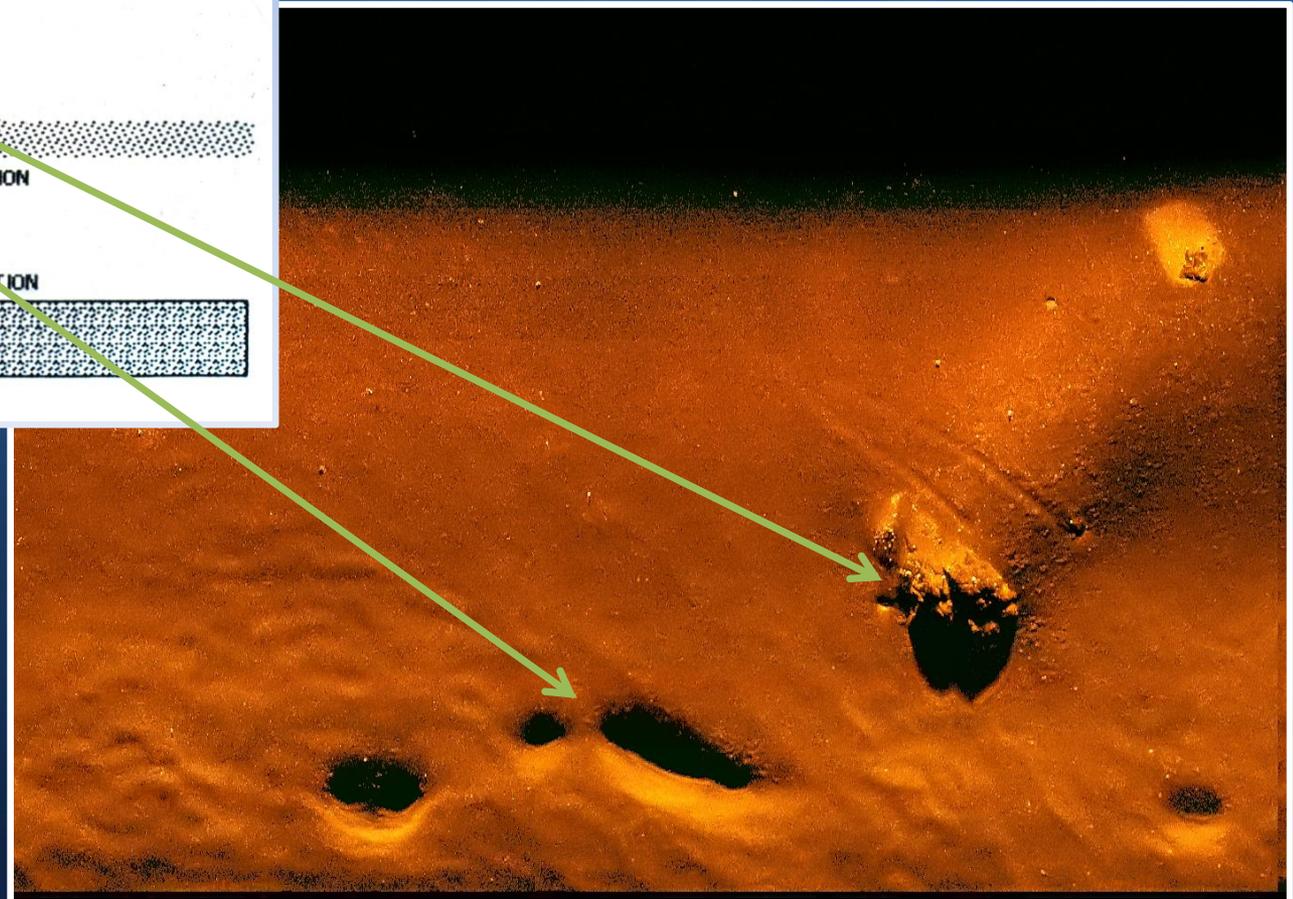
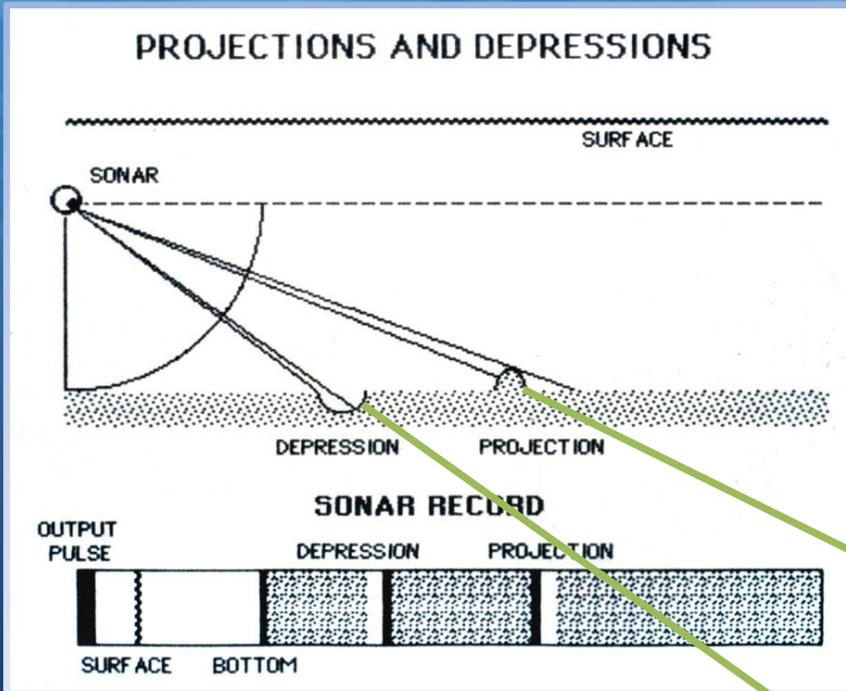
The screenshot displays the 'Target Logger' software interface. On the left is a 'Target Catalog' with thumbnails for Target-0205, Target-0204, Target-0203, and Target-0201. The main window shows 'Target-0211' selected, with a corresponding sonar image and a table of measurement data. Below the image are tabs for 'Target', 'TVG Gamma', 'Color Palette', and 'Navigation Offsets'. The 'TVG Gamma' tab is active, showing a table with columns A, B, and C, and a formula: $TVG(\text{range}) = A \times \text{Log}(\text{range}) + B \times \text{range} + C$. The 'Gamma' value is set to 0.80.

Tag	None
Ping	51802
Position	24°33.47149'N 081°44.12995'W
Altitude	5.40 m
Course	230.25
Heading	238.69
Slant Range	18.31 m
Ground Range	17.50 m
Length	4.56 m
Width	1.52 m
Height	0.85 m
Description	

Target	TVG Gamma	Color Palette	Navigation Offsets
TVG	A	B	C
	38	-2	40
$TVG(\text{range}) = A \times \text{Log}(\text{range}) + B \times \text{range} + C$			
Gamma	0.80		

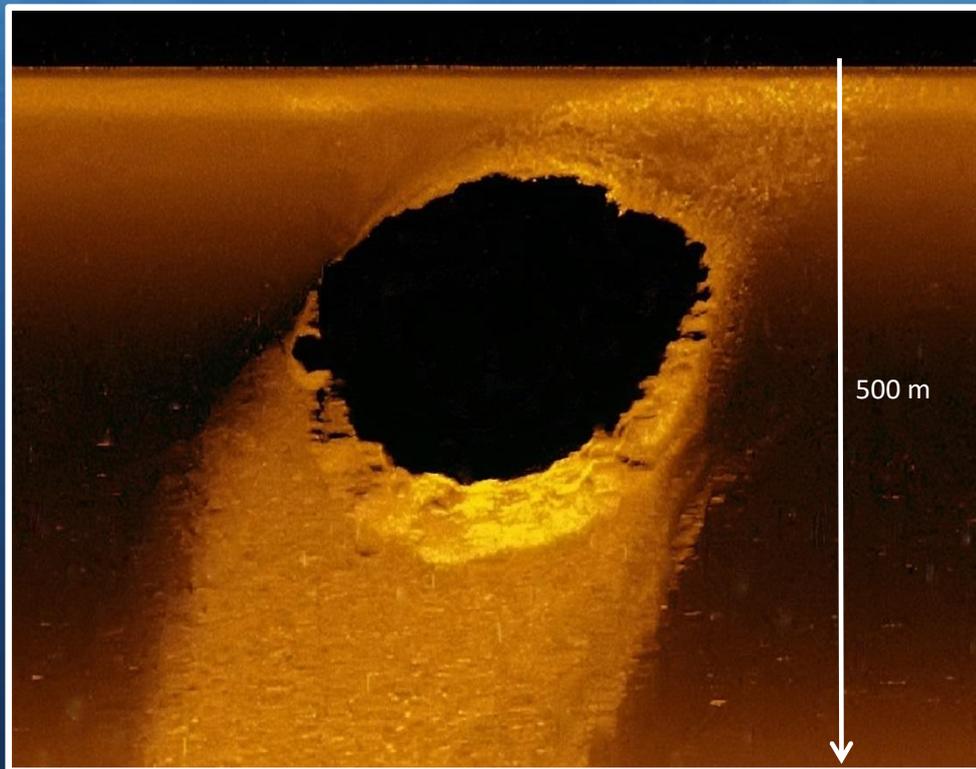
III. SSS Data Interpretation

Acoustic Shadows in Front of Target
-Depressions

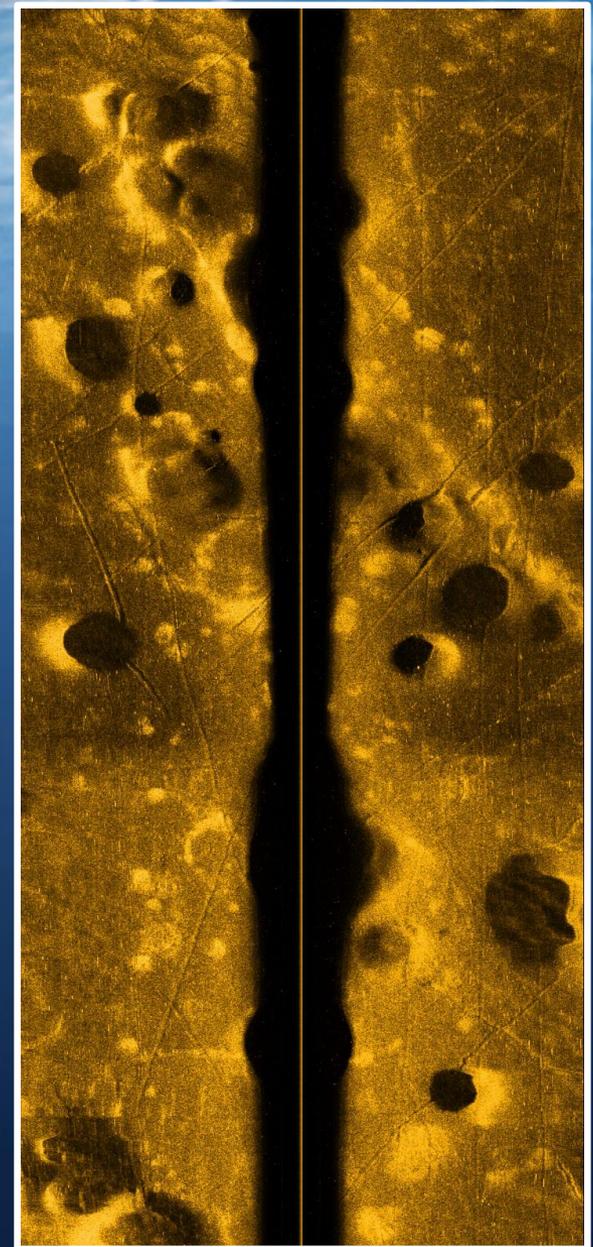


III. SSS Data Interpretation

Acoustic Shadows in Front of Target

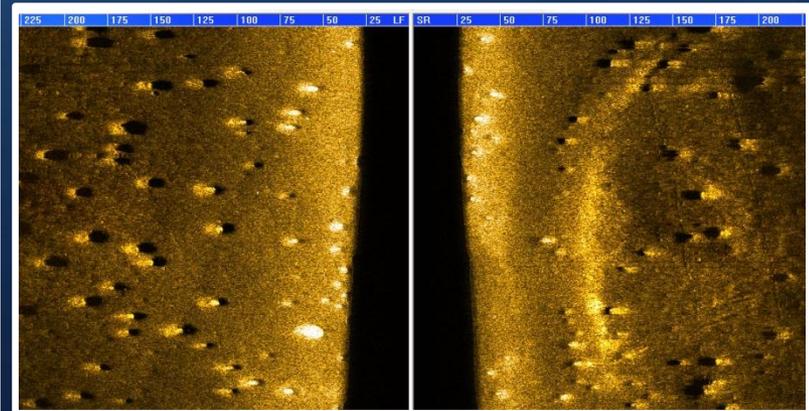
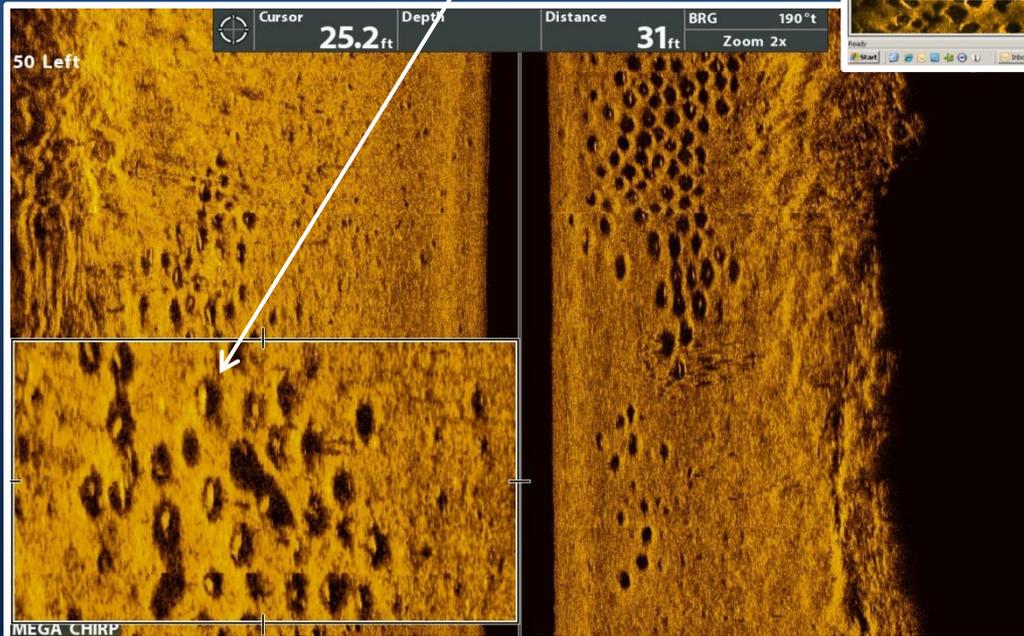
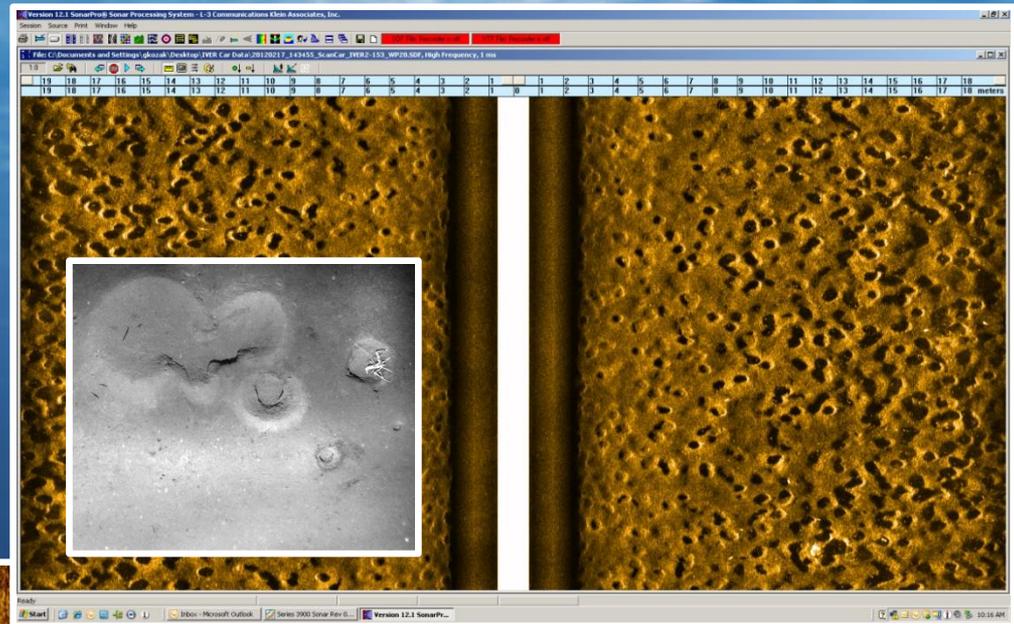


Gas Blowout Craters



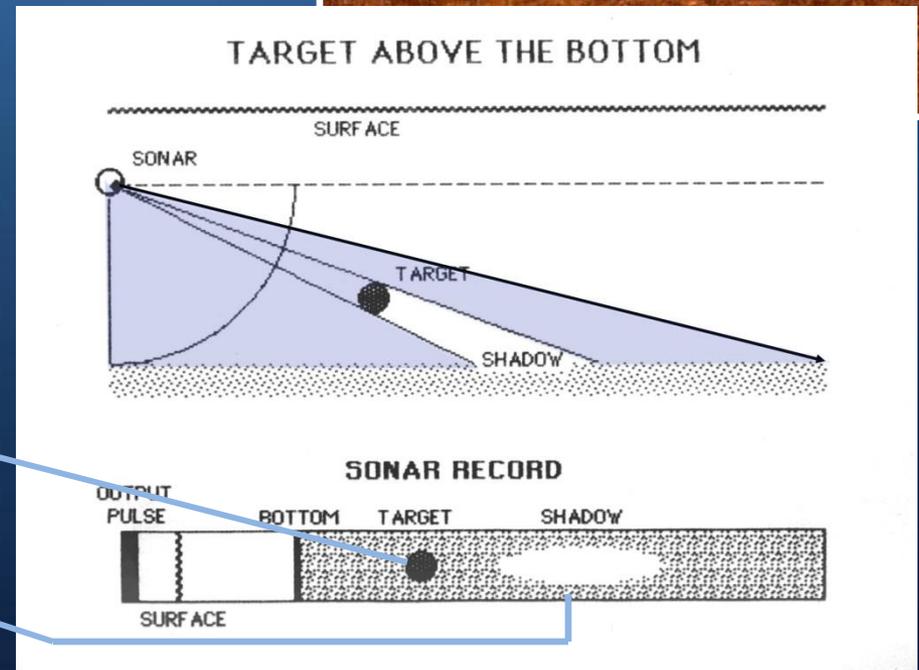
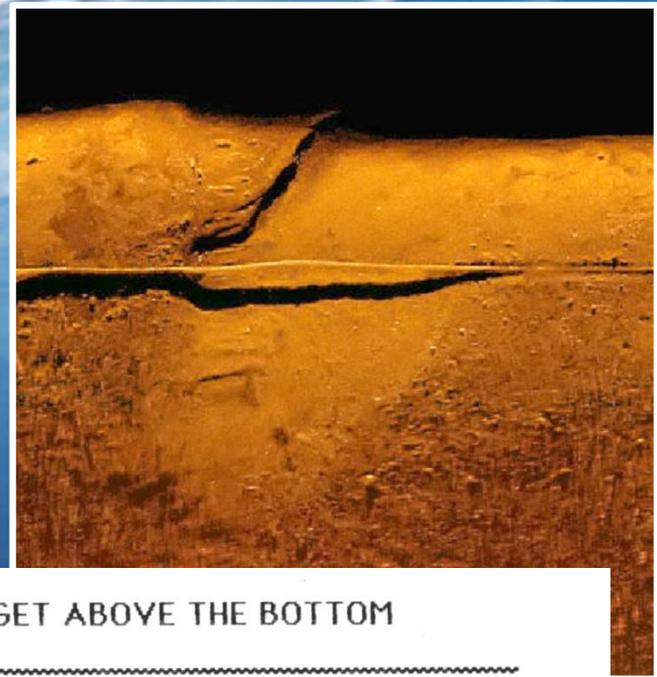
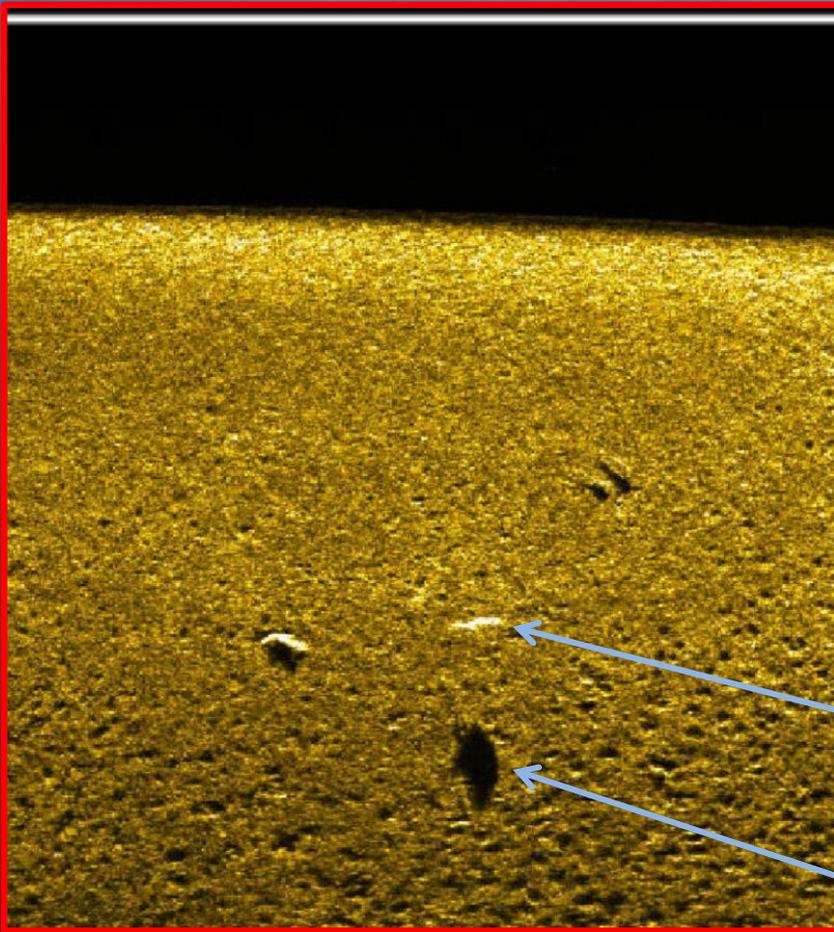
III. SSS Data Interpretation

Critter Pock Marks



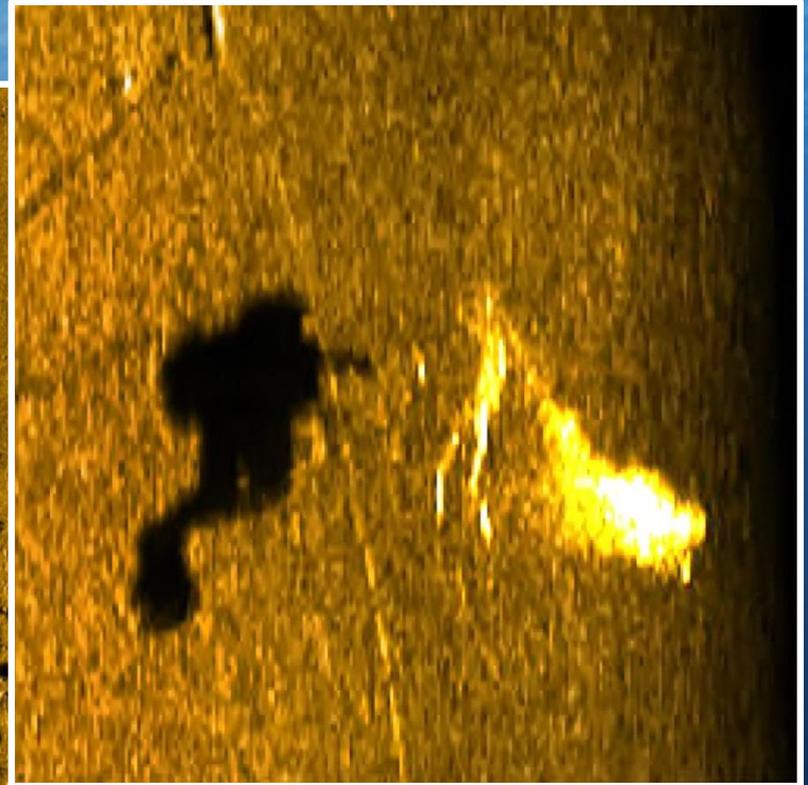
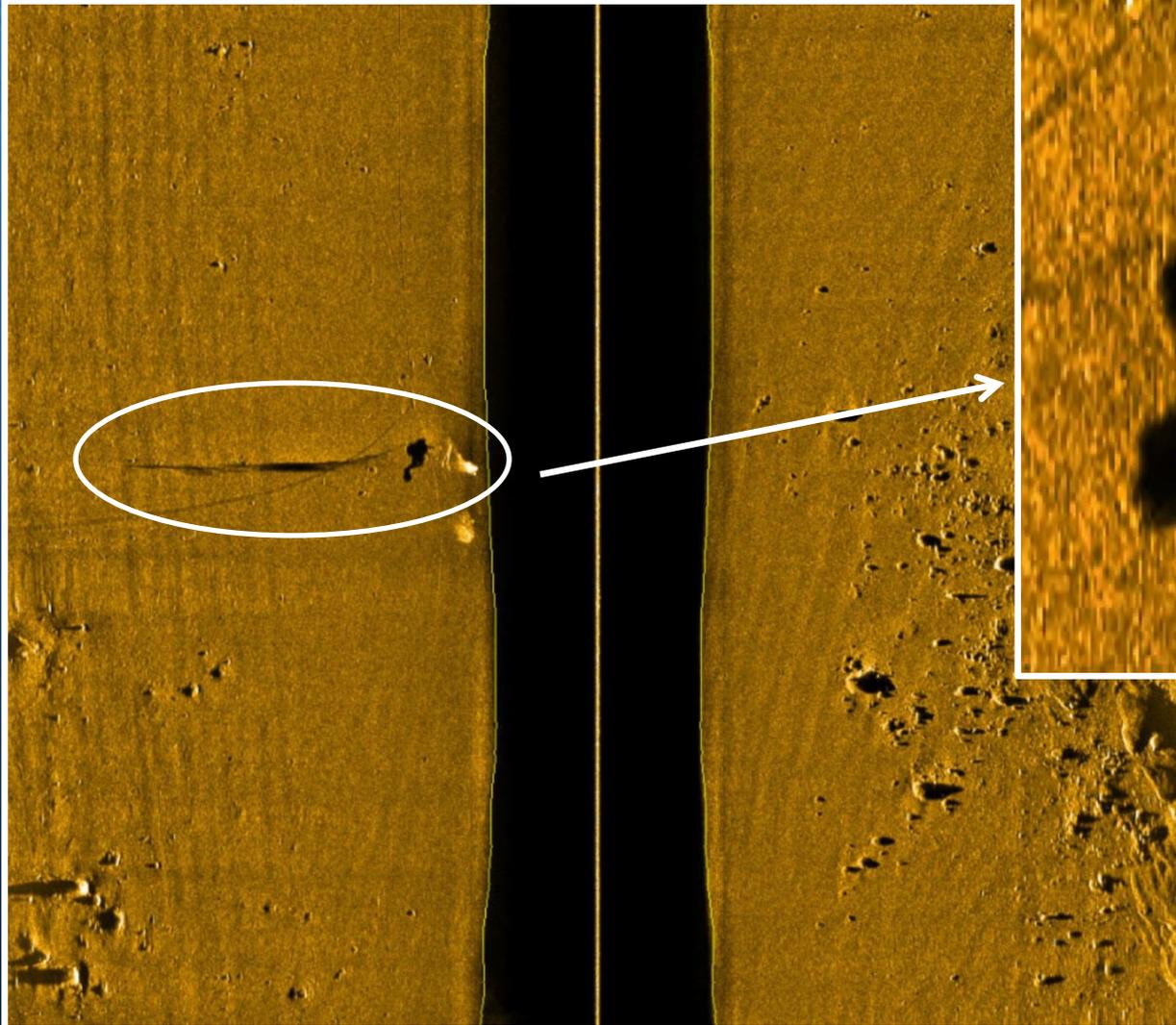
III. SSS Data Interpretation

Separated Shadow from Target



III. SSS Data Interpretation

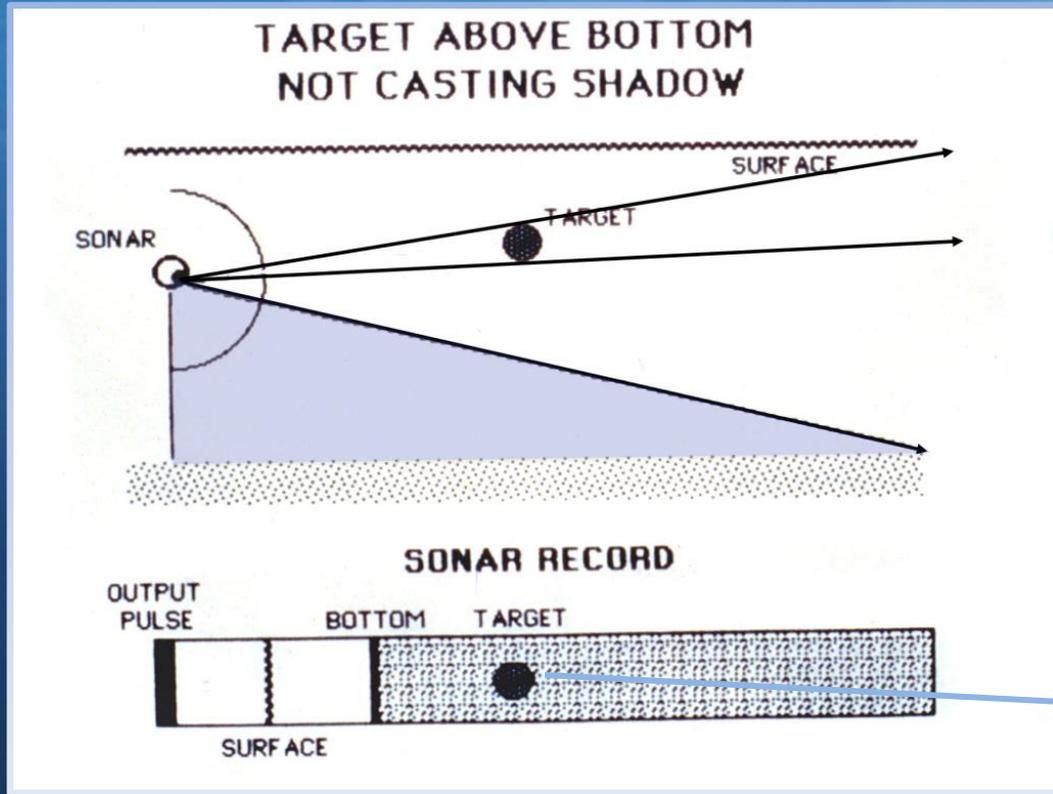
Separated Shadow from Target



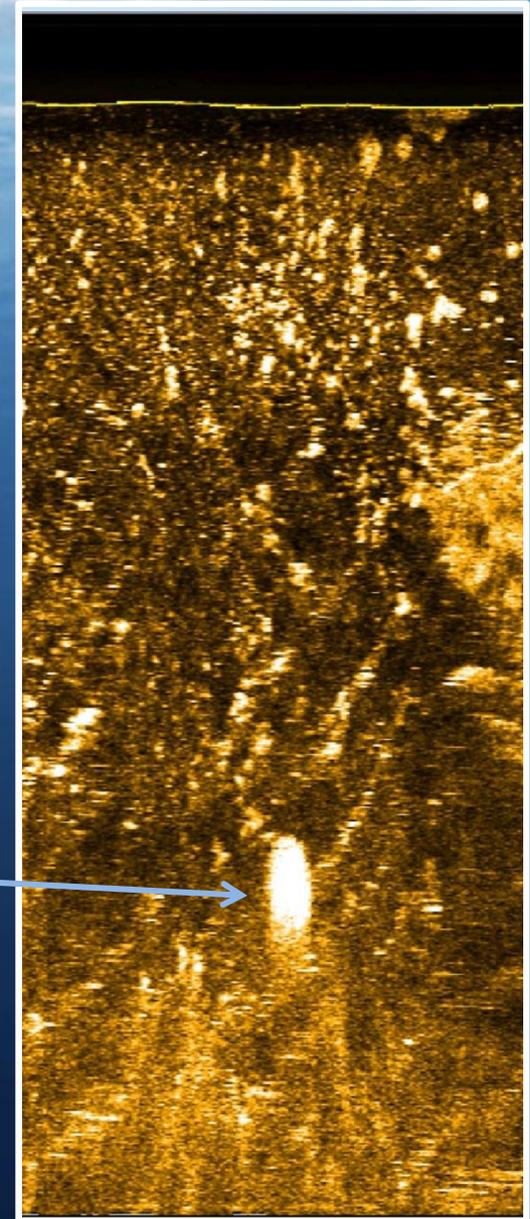
Diver swimming above seafloor

III. SSS Data Interpretation

Acoustic Shadows & Mid-Water Target

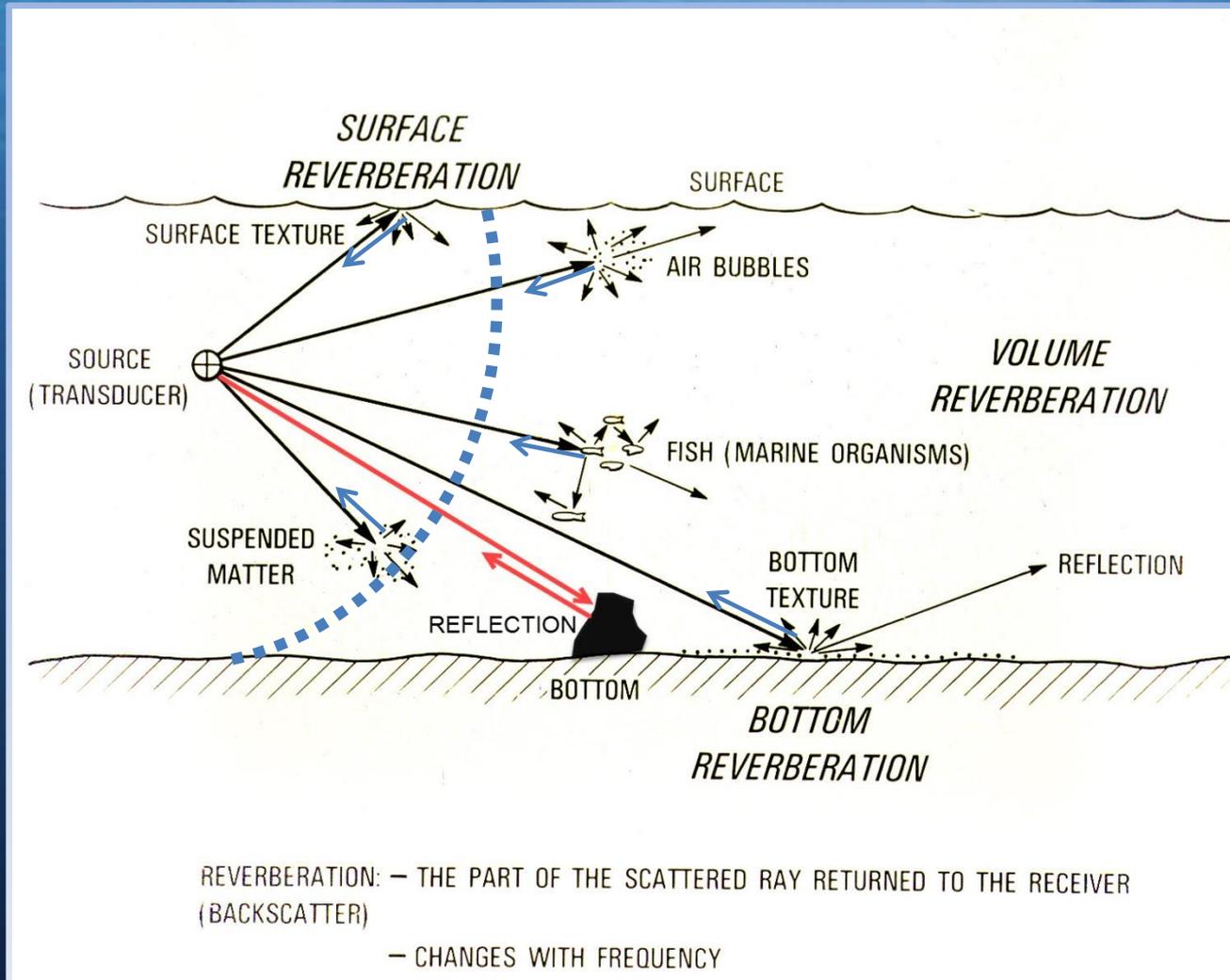


Repeatability Test: A second pass at a later time



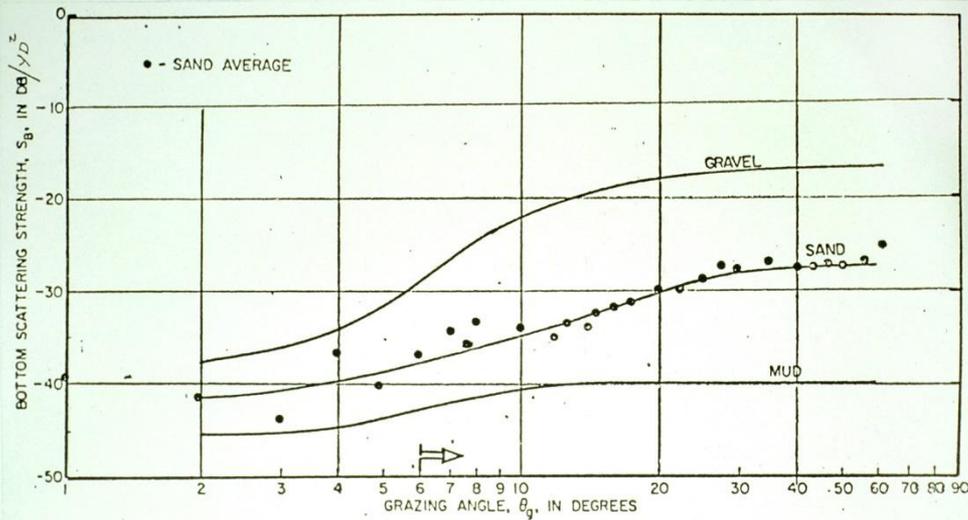
III. SSS Data Interpretation

Scattering & Back Scatter

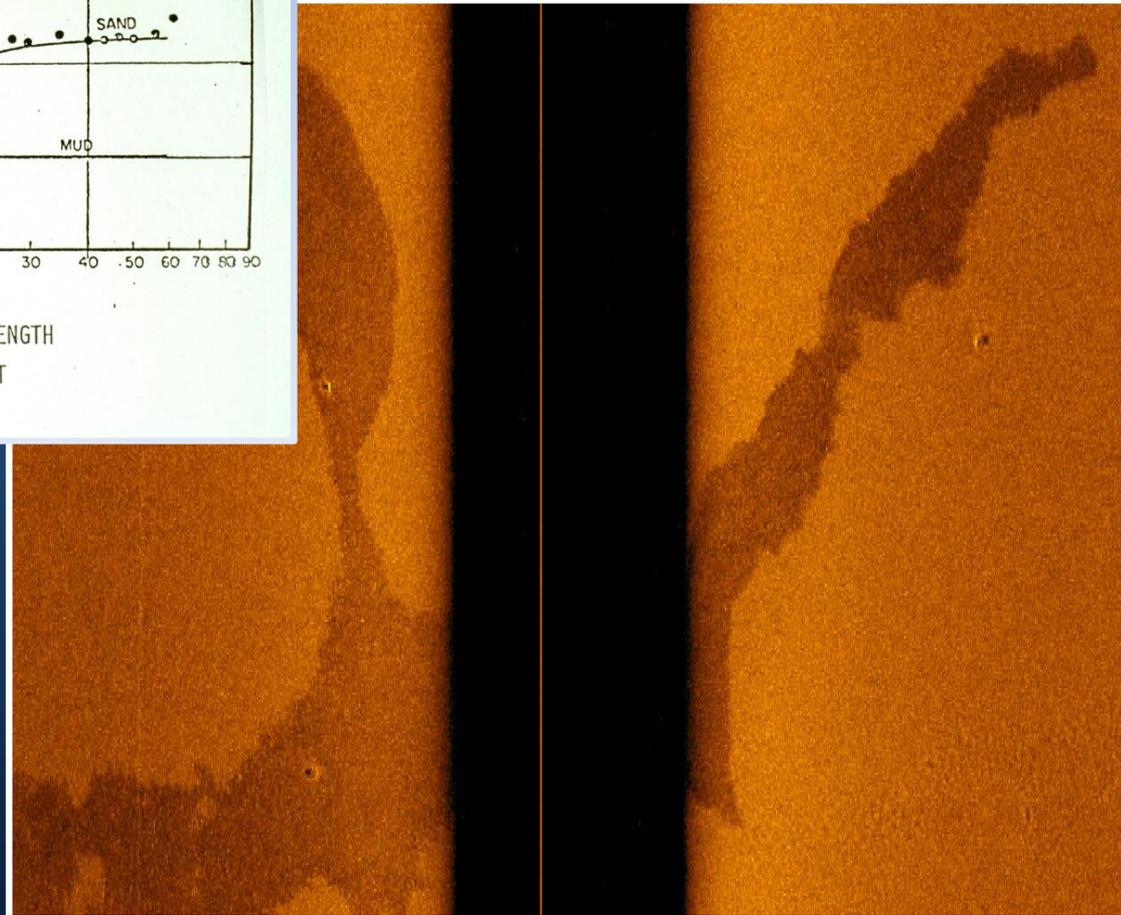


III. SSS Data Interpretation

Seafloor BackScatter

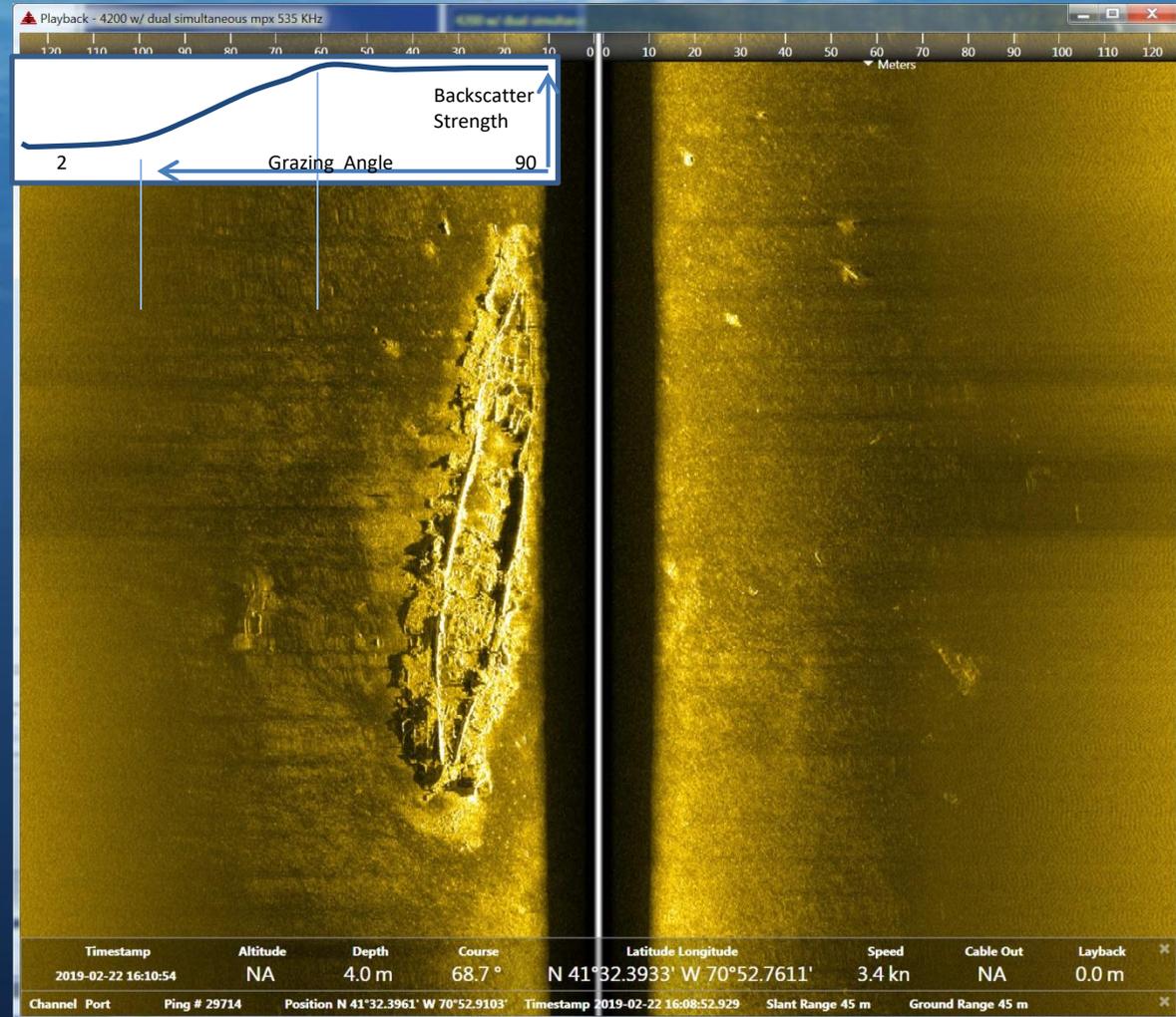
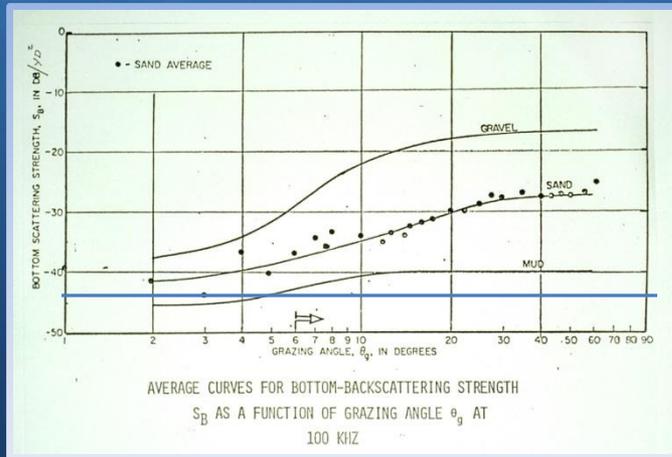


AVERAGE CURVES FOR BOTTOM-BACKSCATTERING STRENGTH
 S_B AS A FUNCTION OF GRAZING ANGLE θ_g AT
100 KHZ



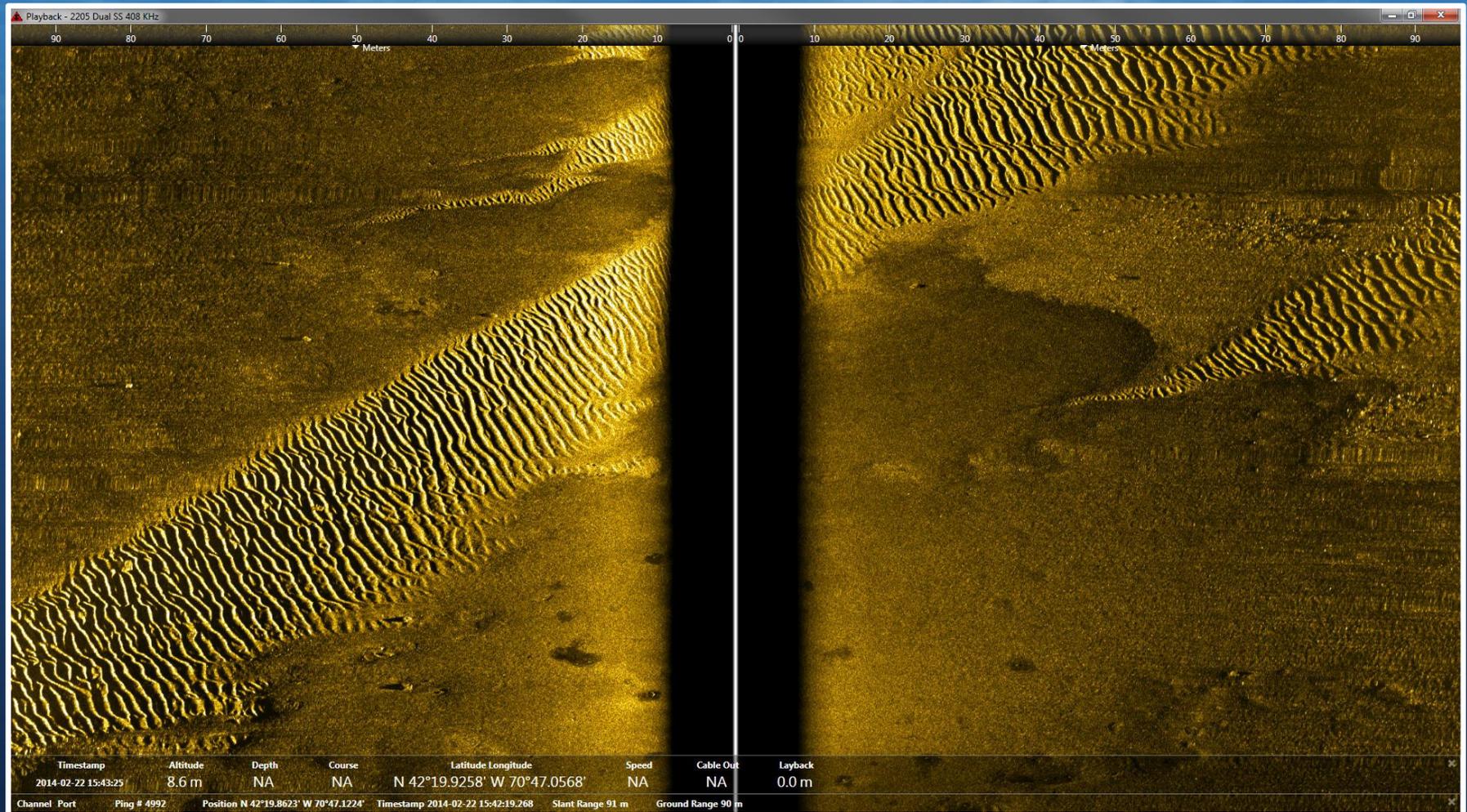
III. SSS Data Interpretation

Backscatter Range

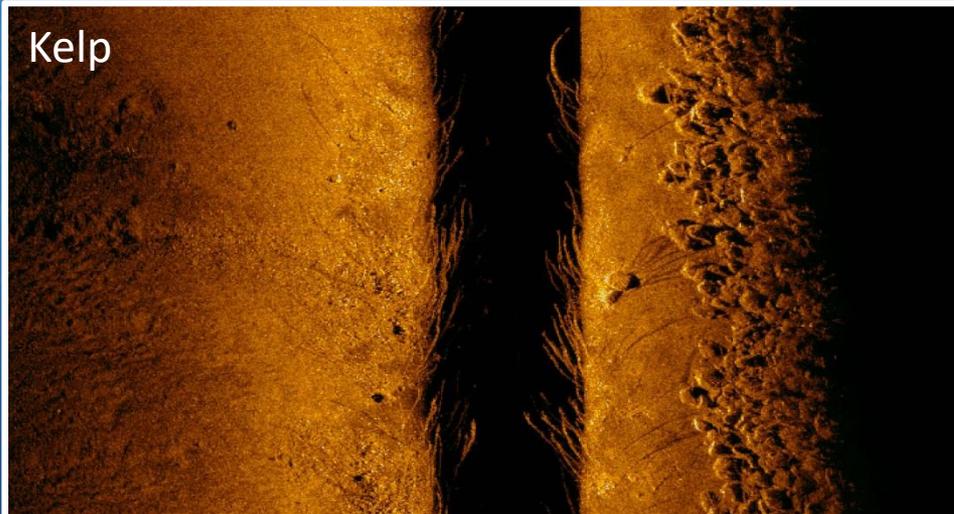


III. SSS Data Interpretation

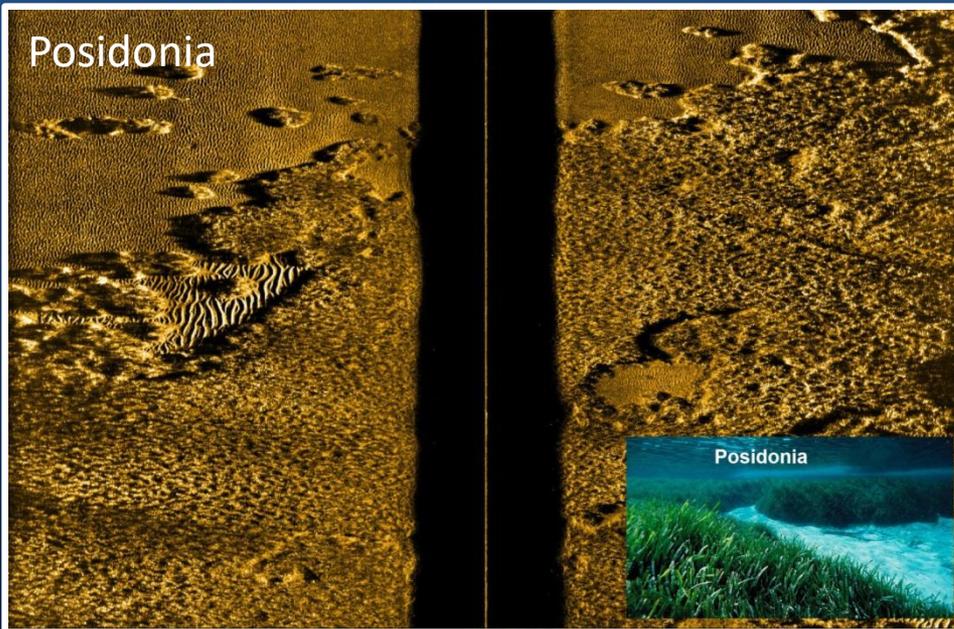
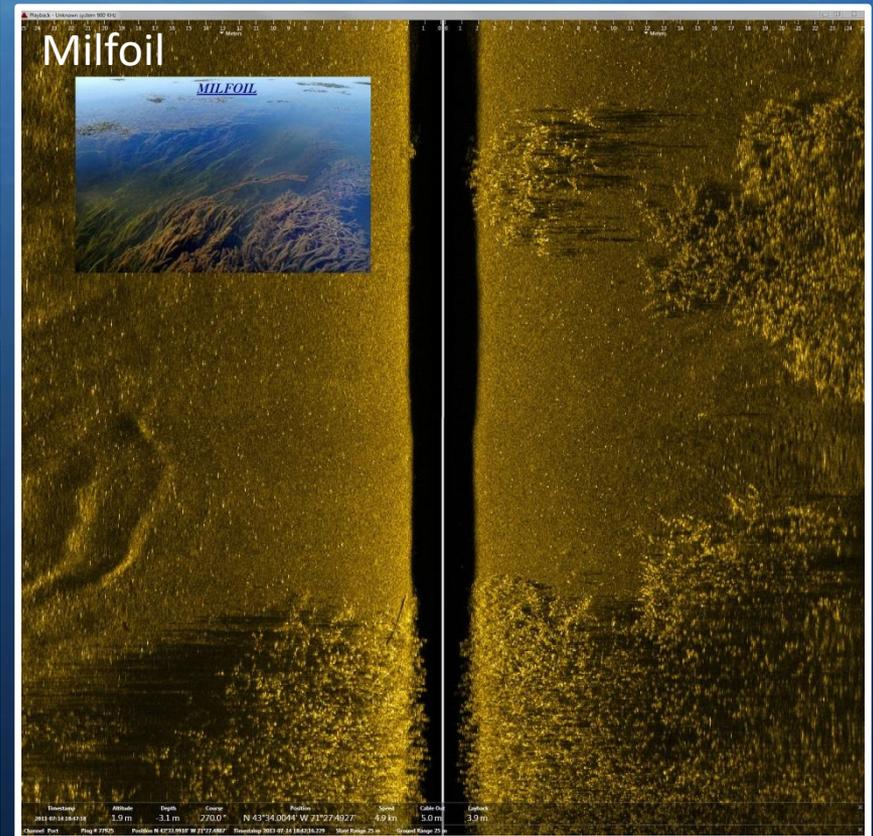
Reflection & Backscatter



III. SSS Data Interpretation

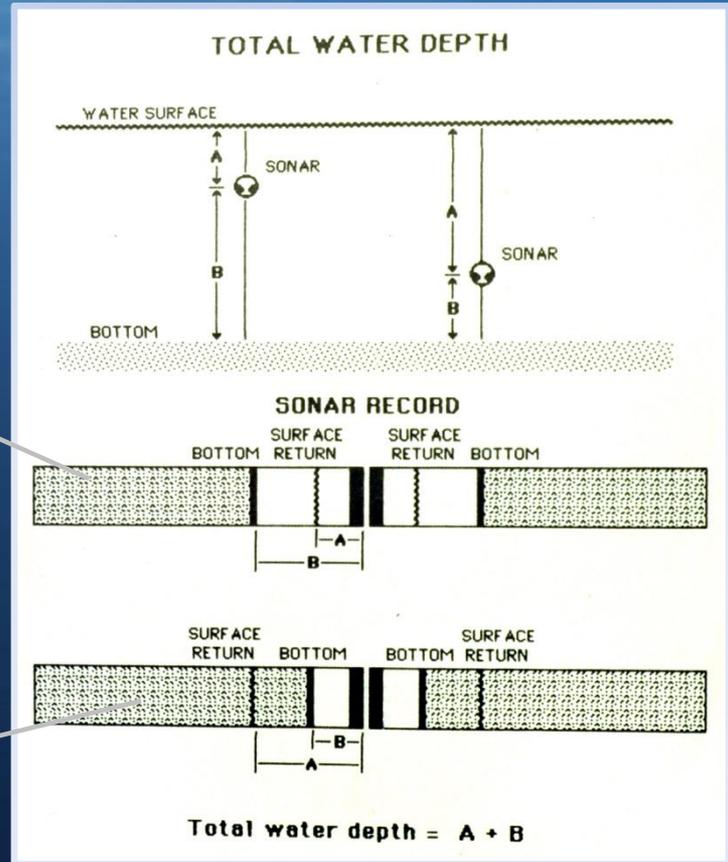
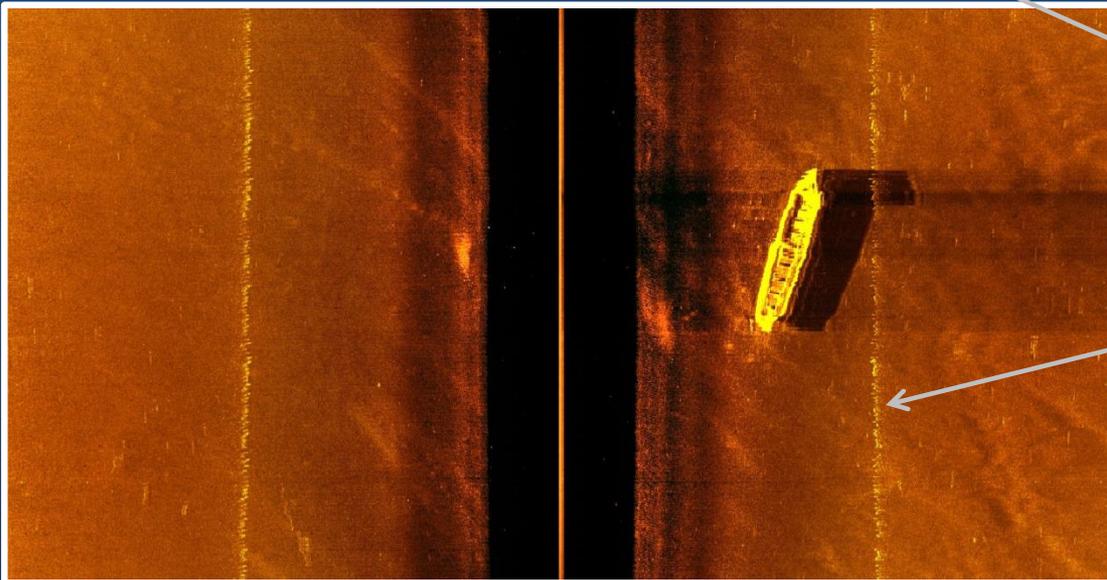
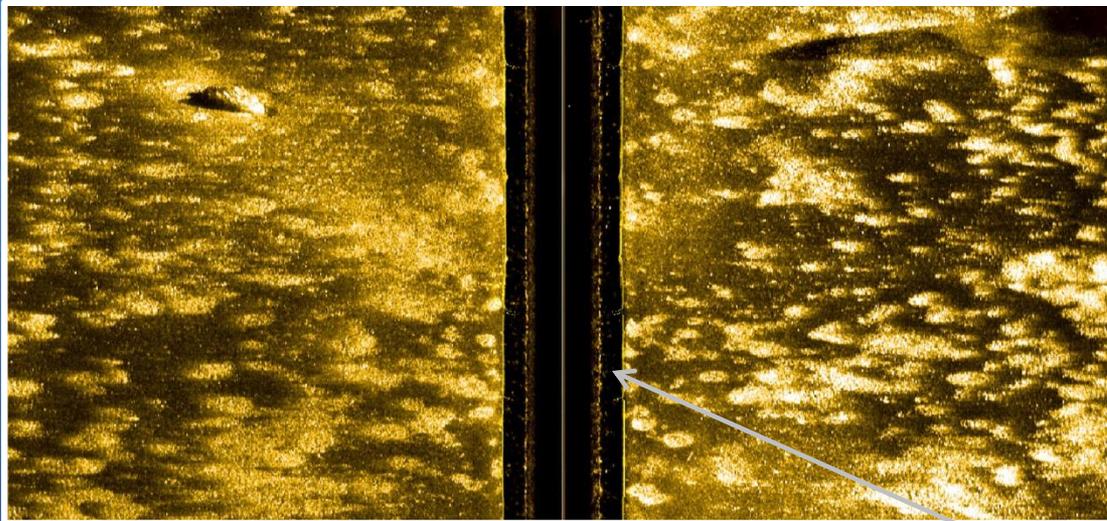


Vegetation



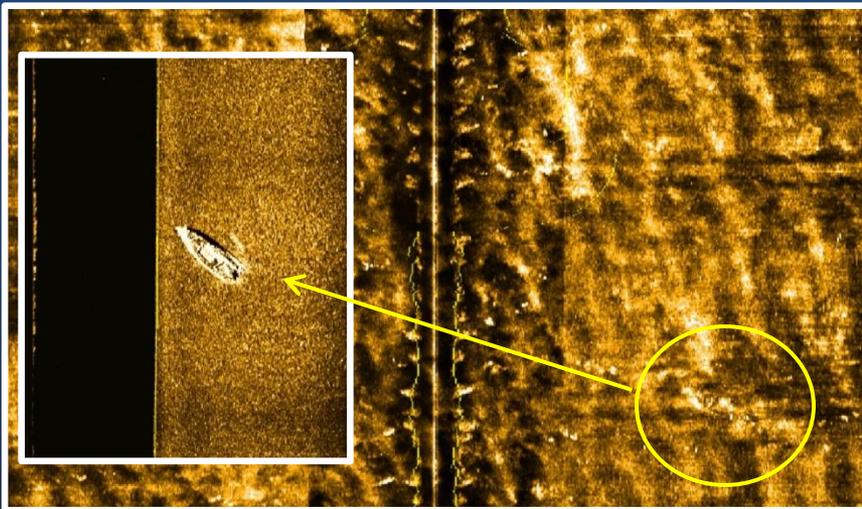
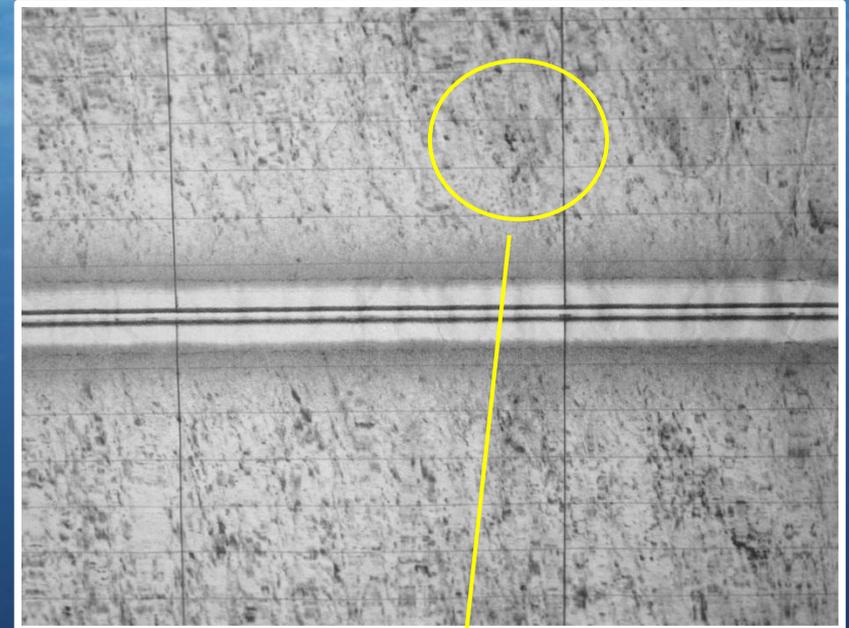
III. SSS Data Interpretation

Surface Return



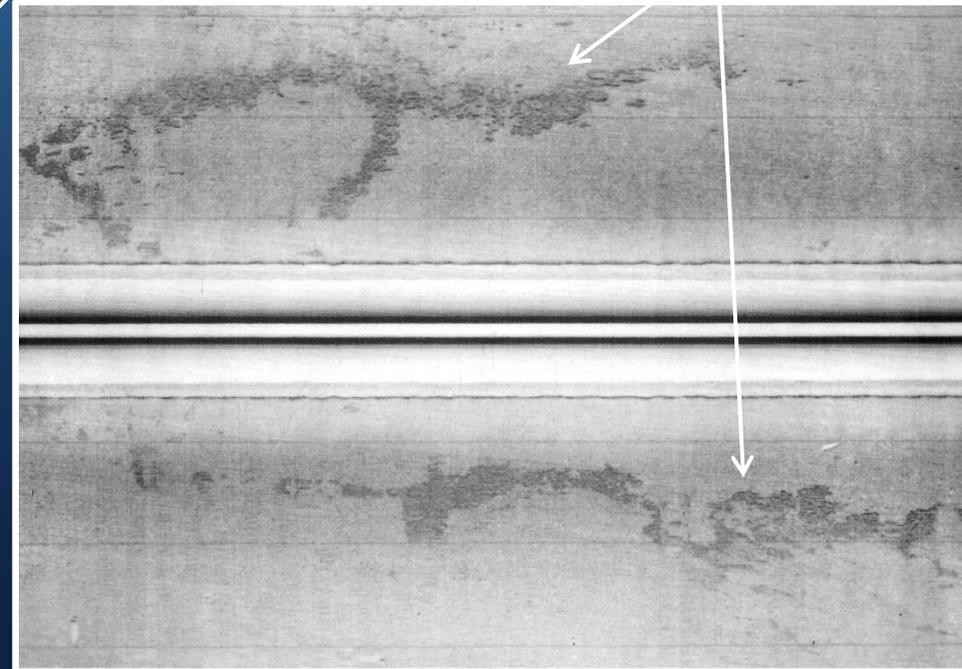
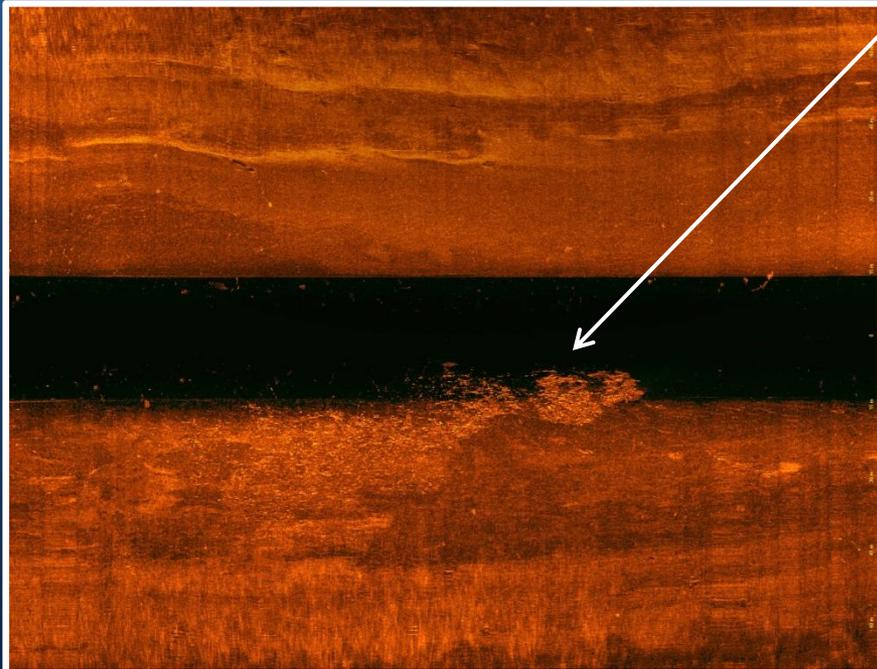
III. SSS Data Interpretation

Surface Clutter



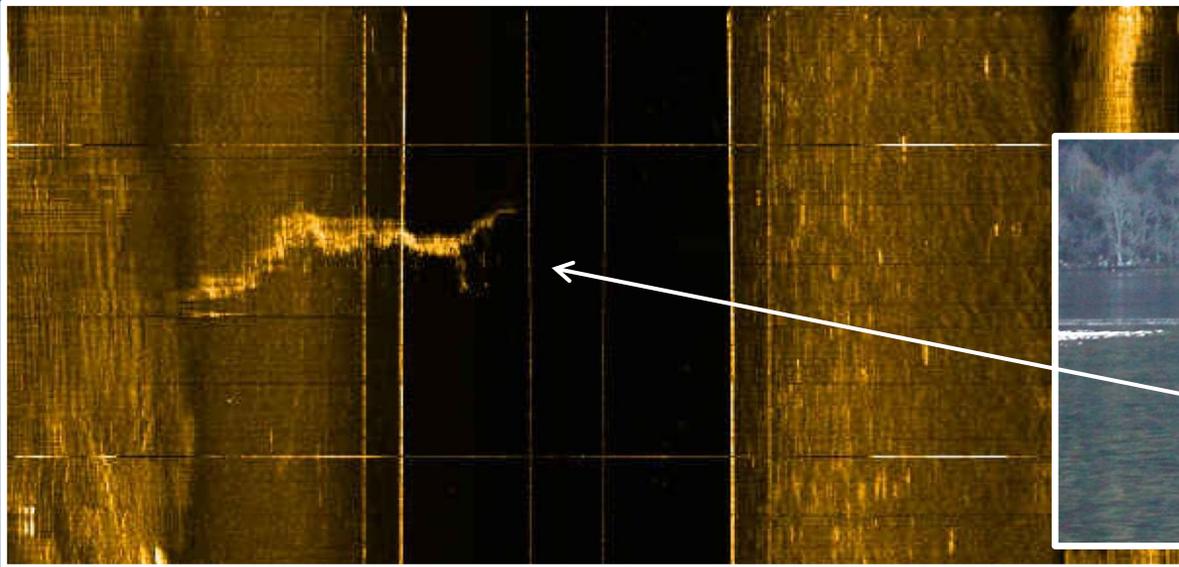
III. SSS Data Interpretation

Surface Targets



III. SSS Data Interpretation

Surface Targets



Surface Shear



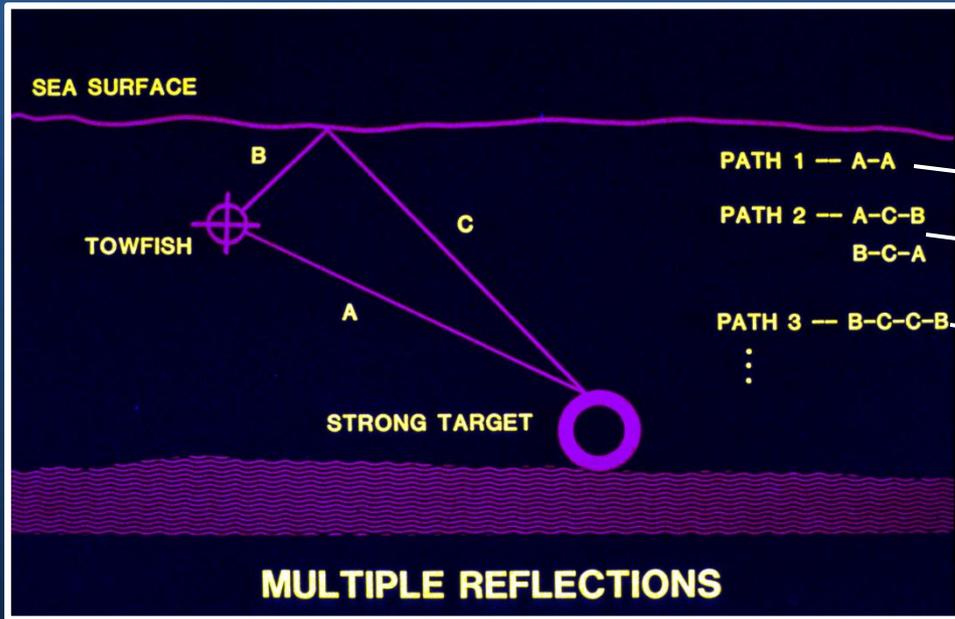
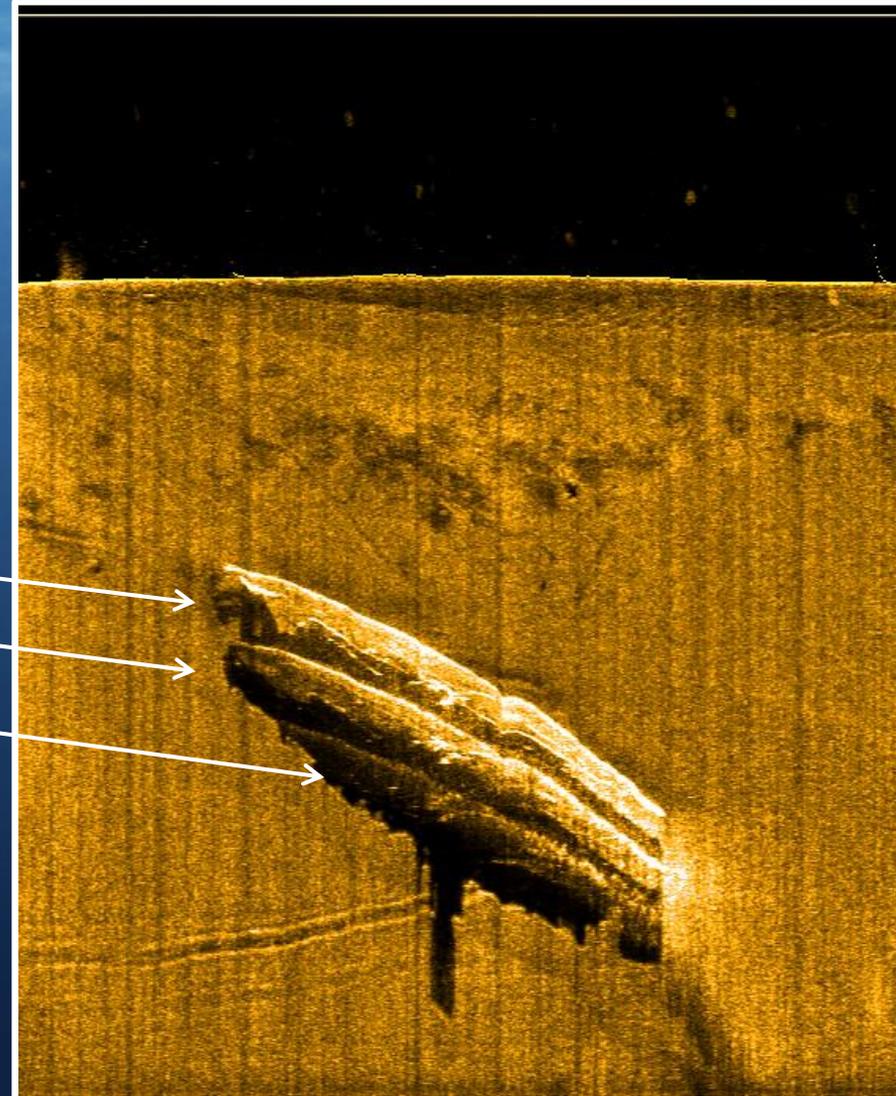
Sea Foam



Pollen

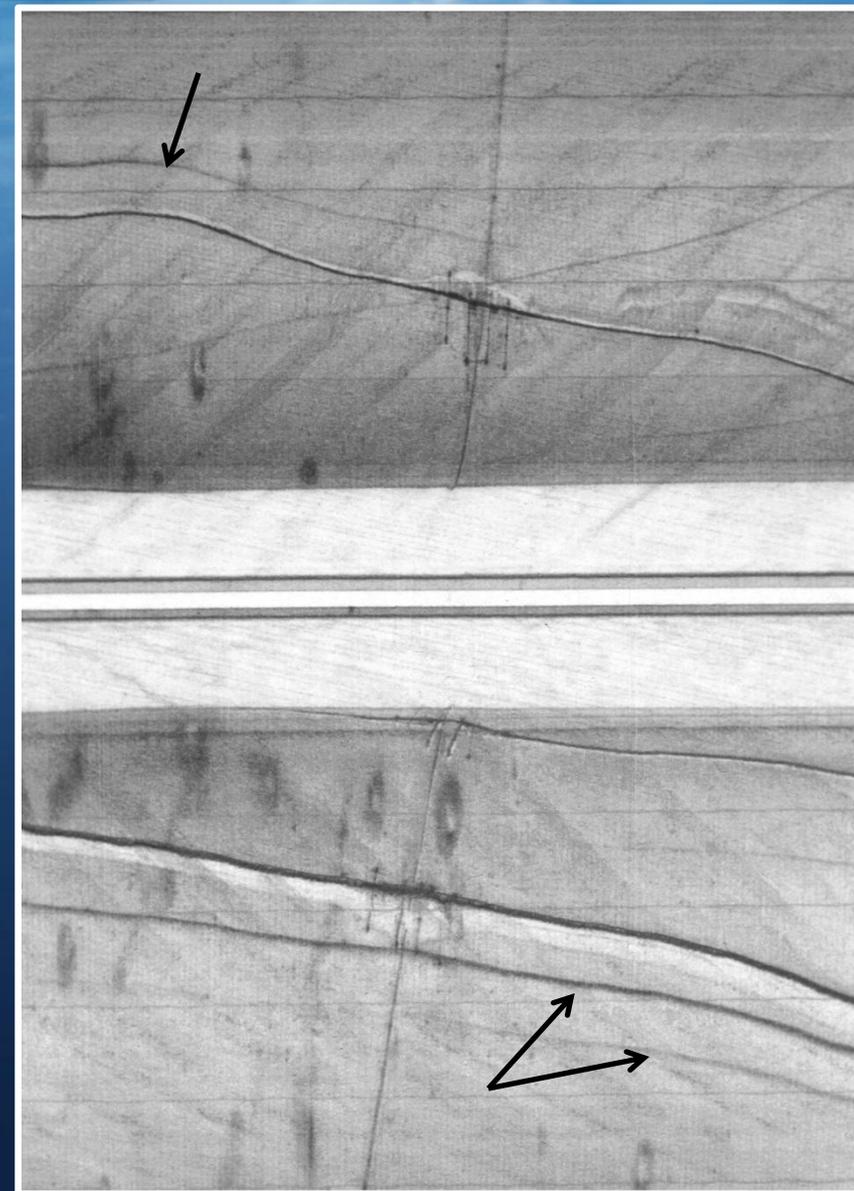
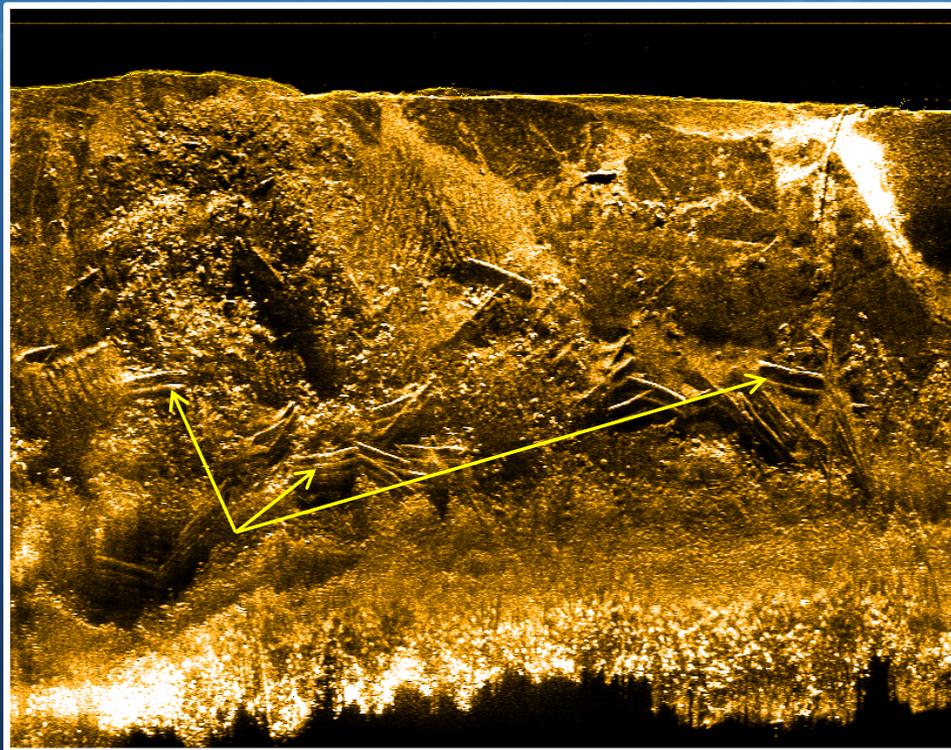
III. SSS Data Interpretation

Multipath

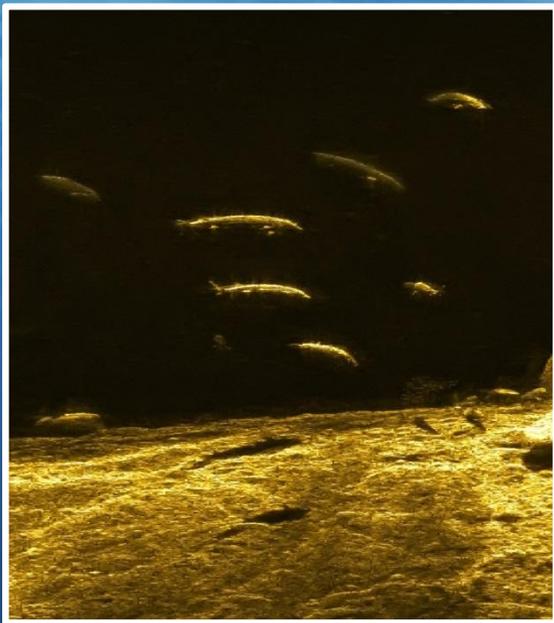


III. SSS Data Interpretation

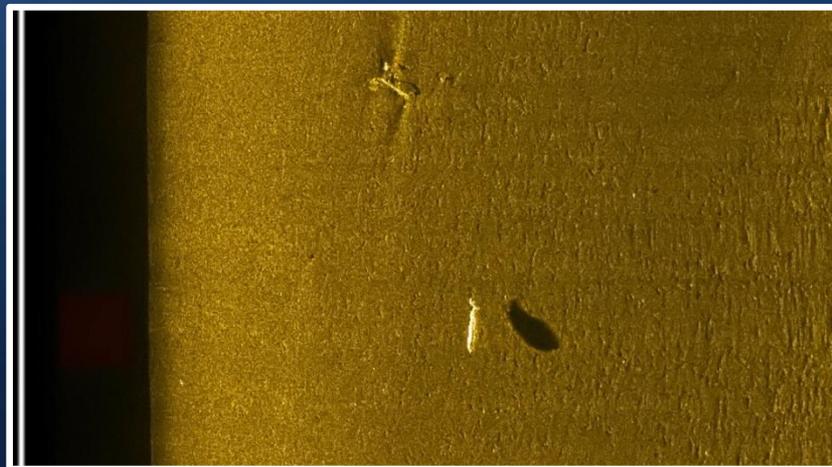
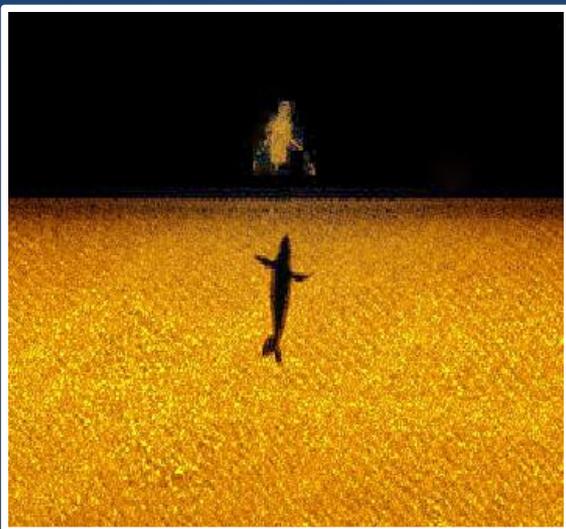
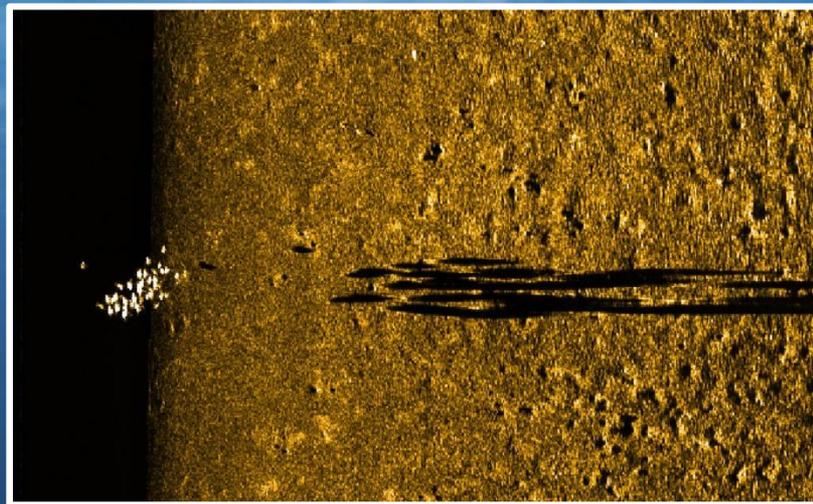
Multipath



III. SSS Data Interpretation

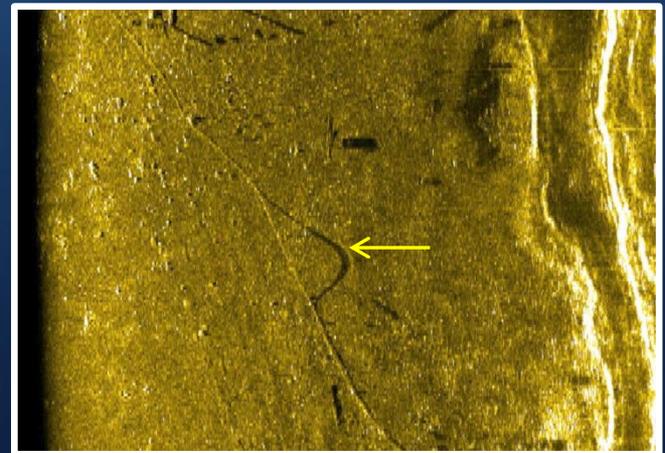
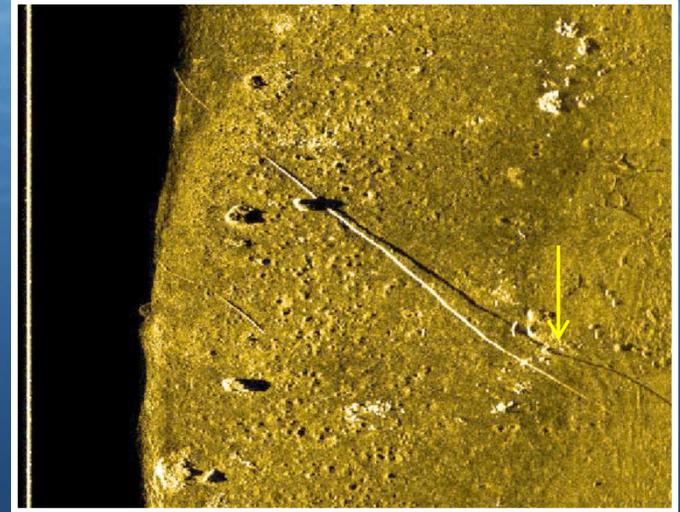
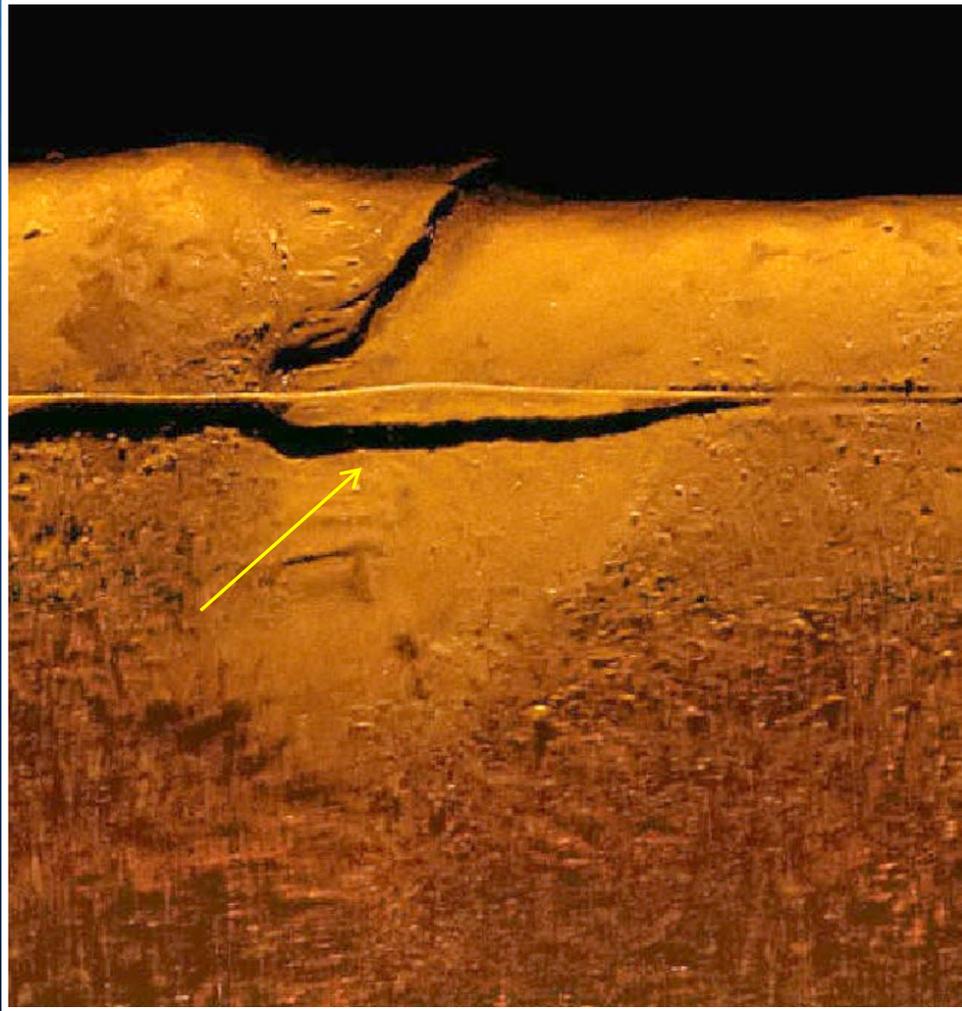


Mid-Water Targets: Fish



III. SSS Data Interpretation

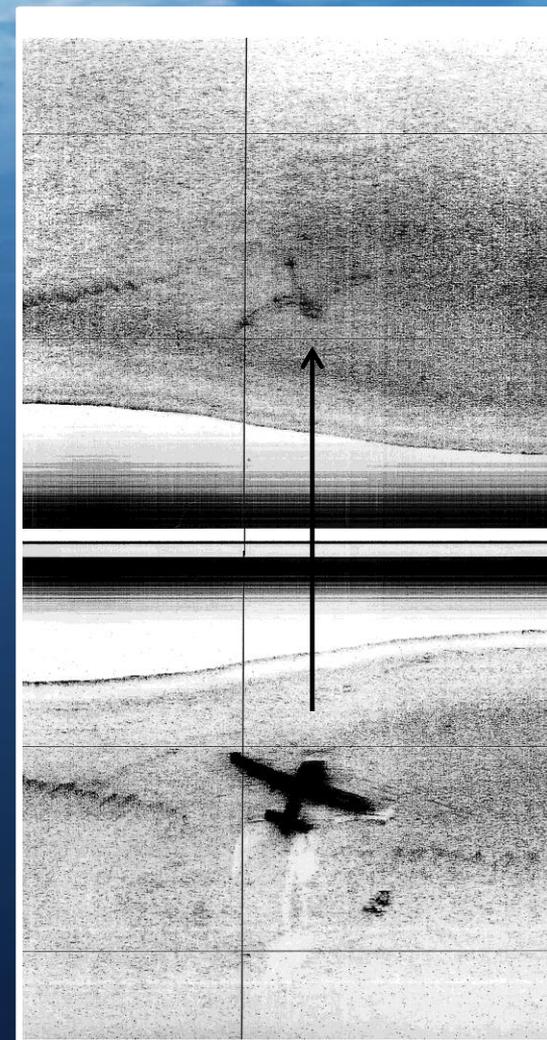
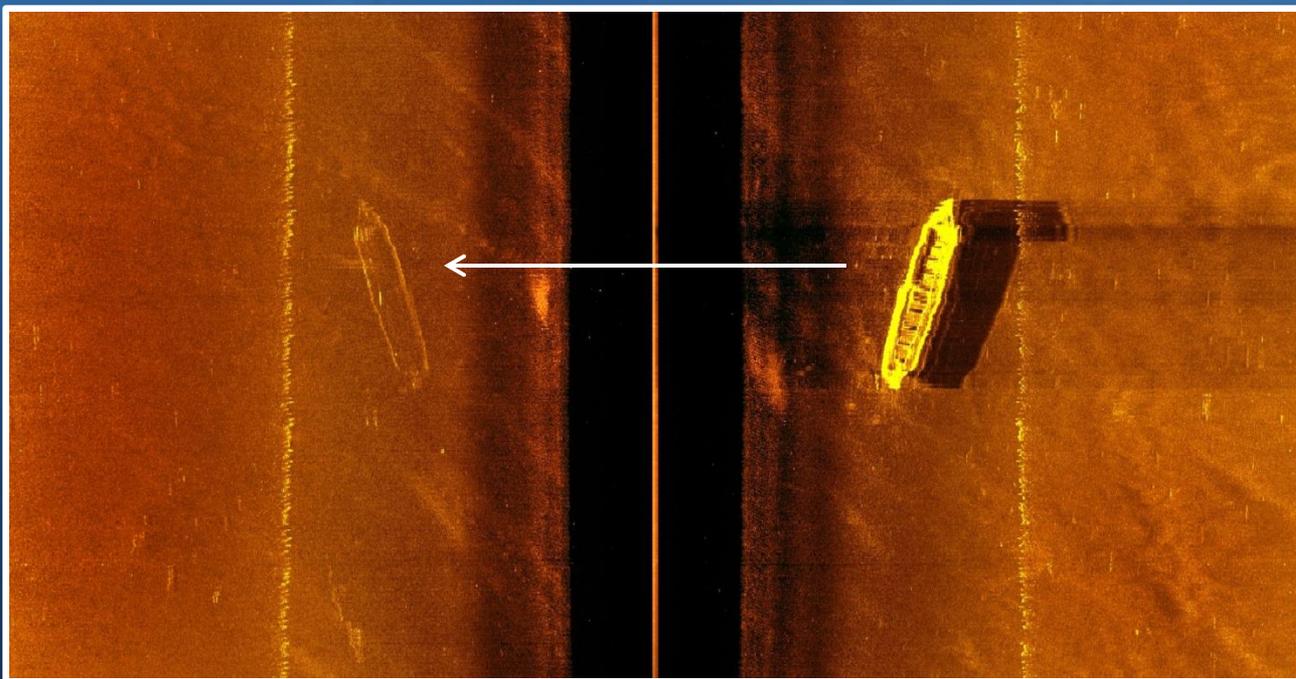
Suspension's: Pipelines & Cables



III. SSS Data Interpretation

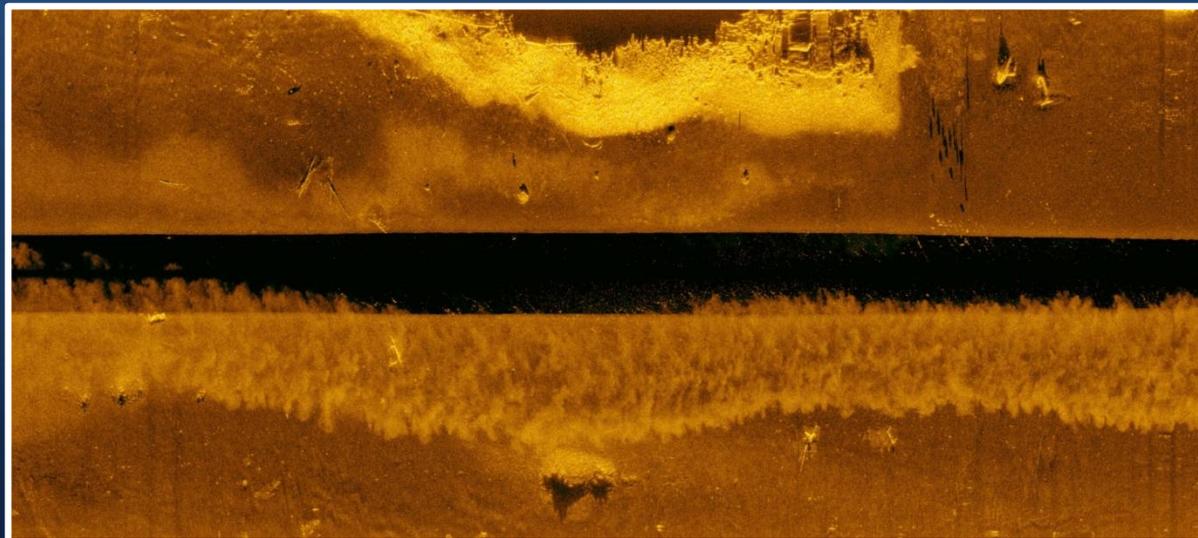
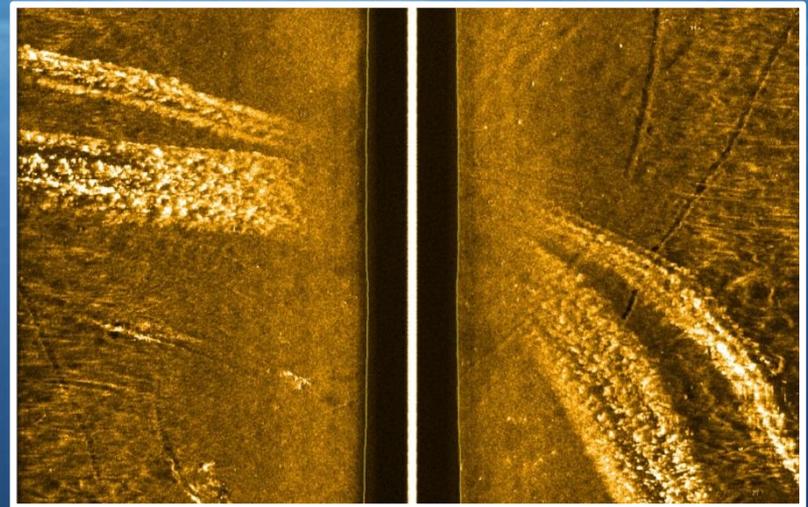
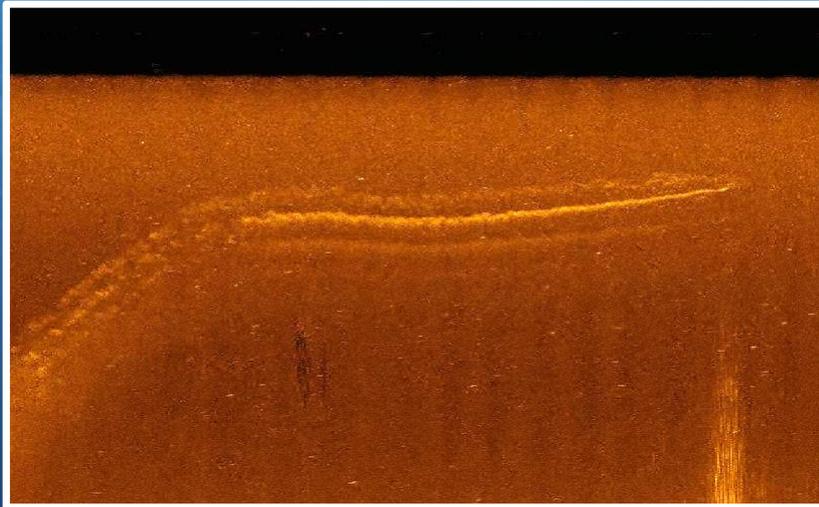
Cross Talk

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



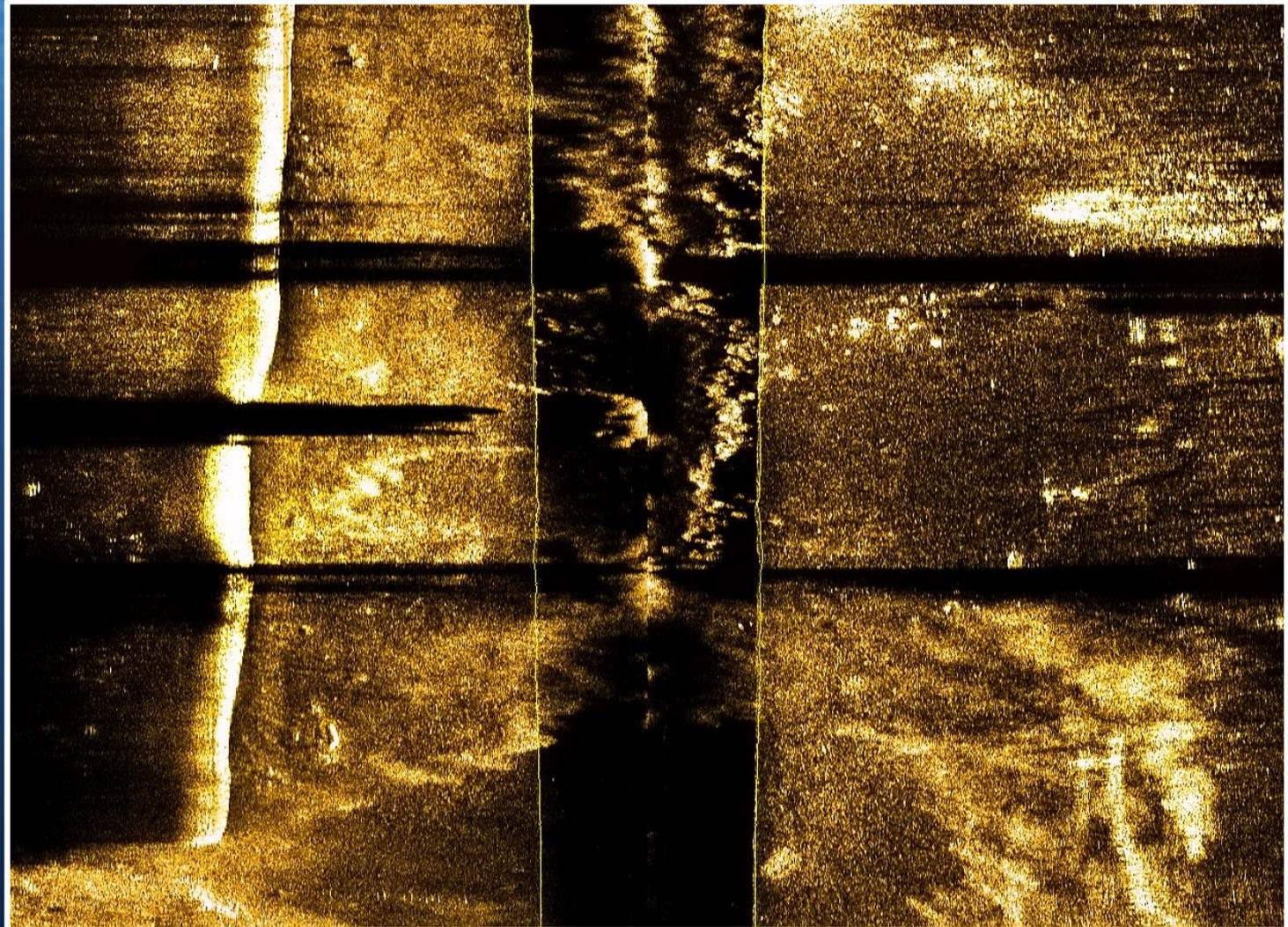
III. SSS Data Interpretation

Boat Turbulence



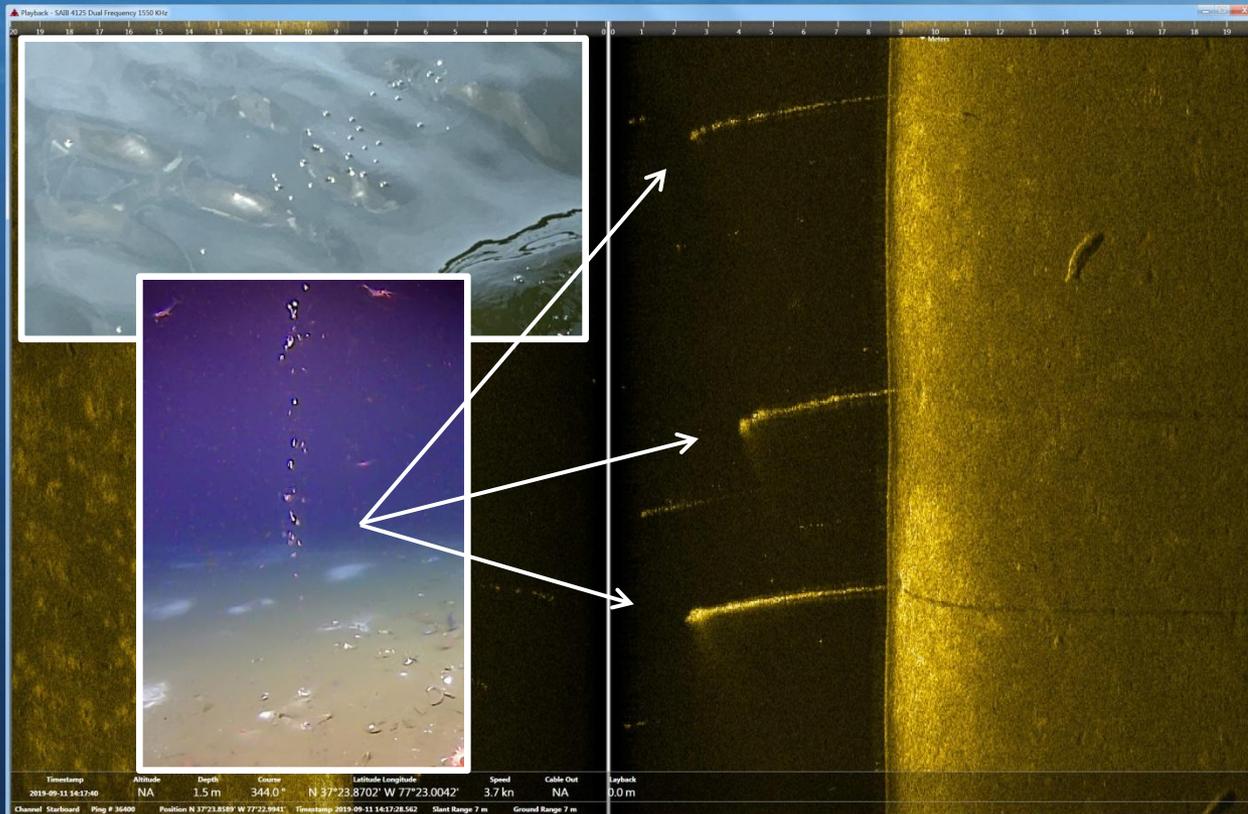
III. SSS Data Interpretation

Quenching

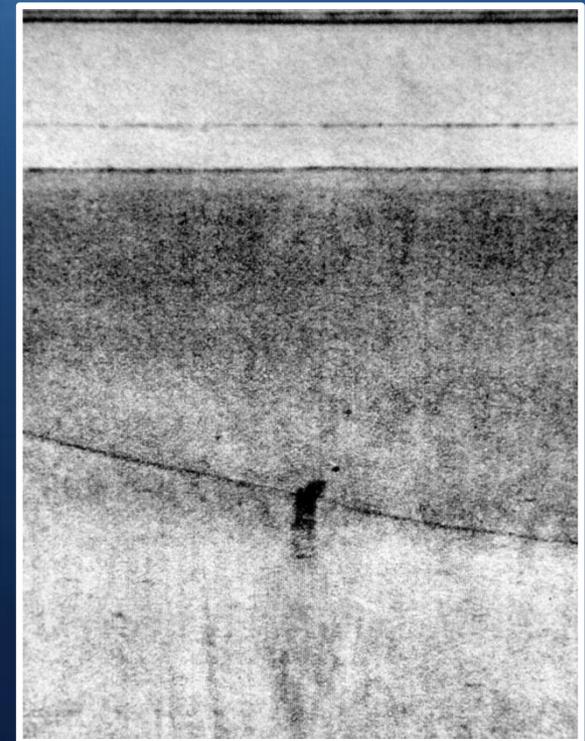


III. SSS Data Interpretation

Gas Bubbles



6 inch Pipeline Gas Leak



Gas Leaking from Seafloor

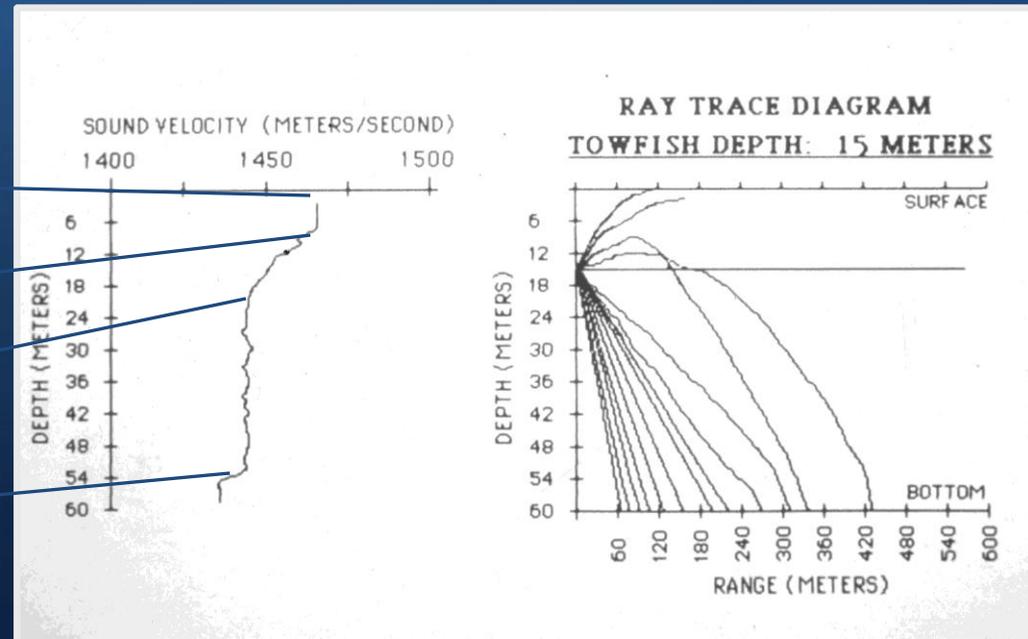
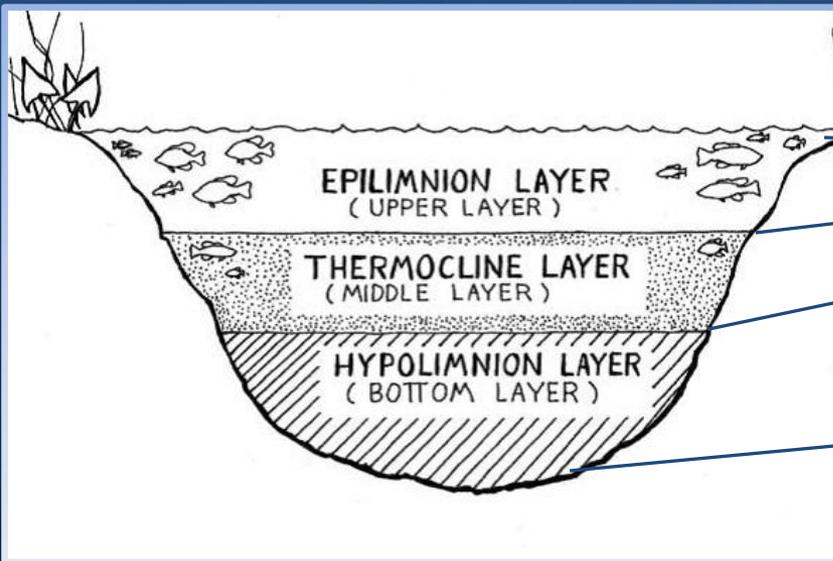
III. SSS Data Interpretation

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

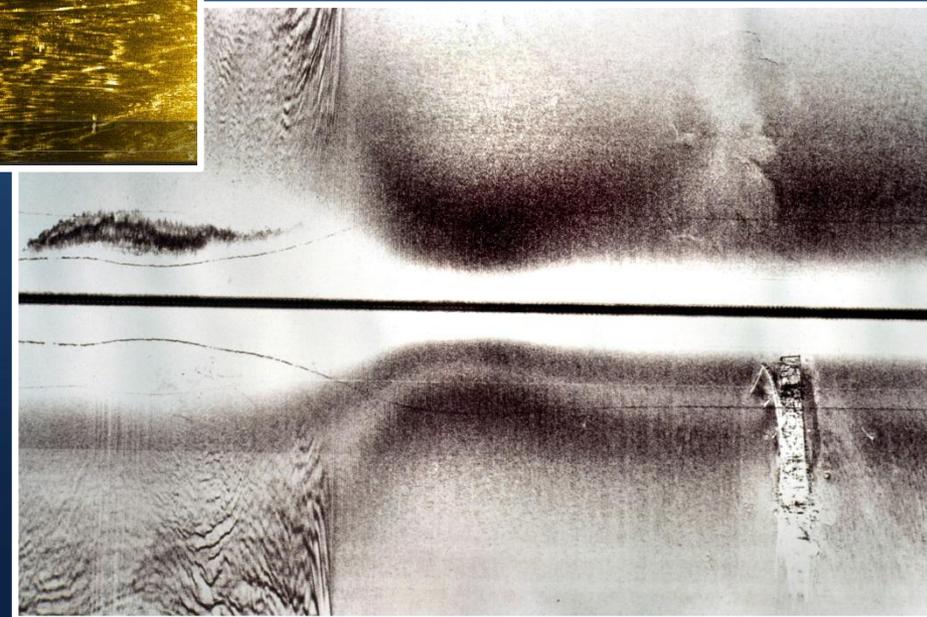
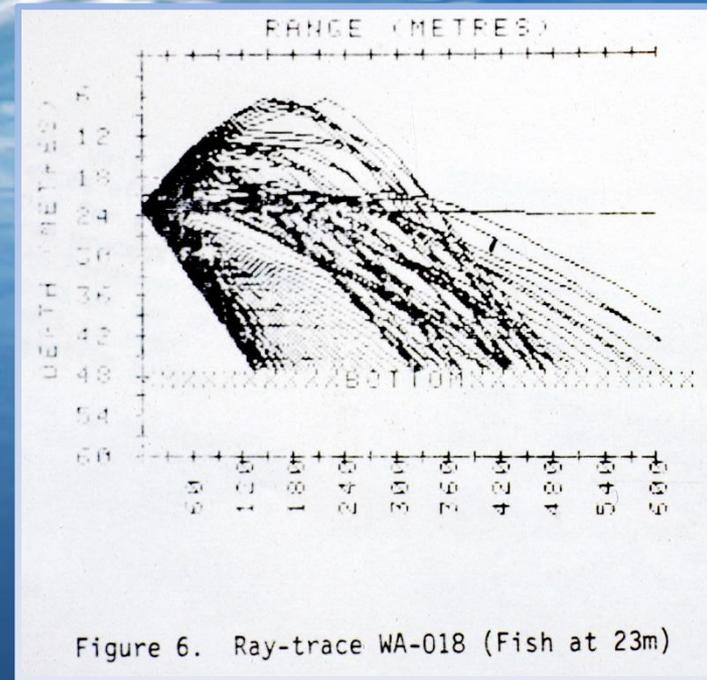
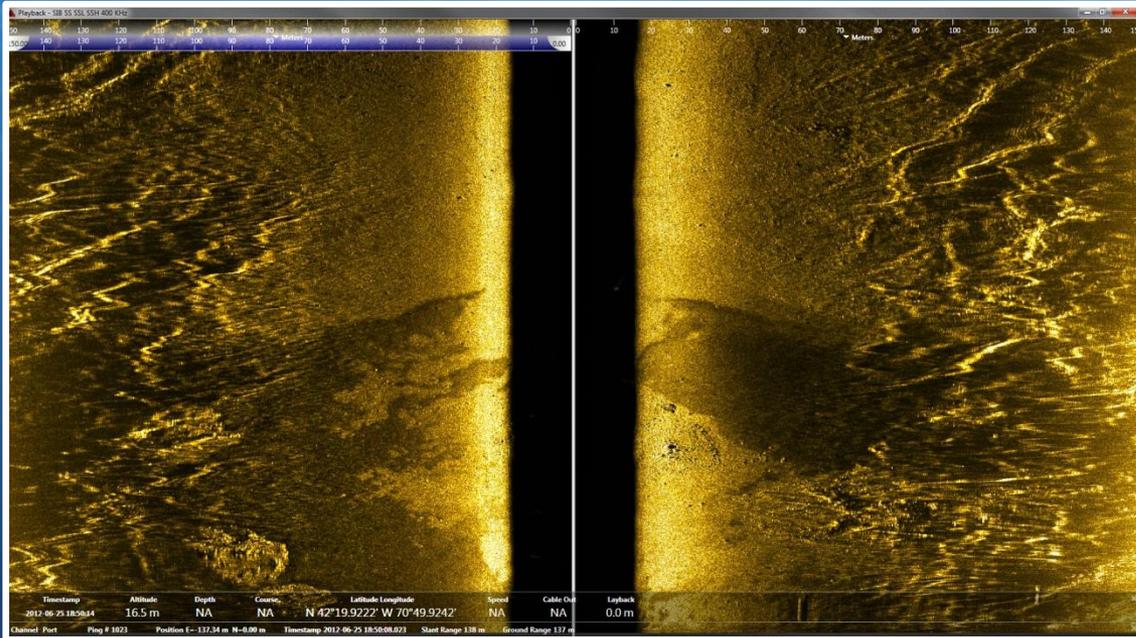
VELOCITY GRADIENT FACTORS

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



III. SSS Data Interpretation

Refraction

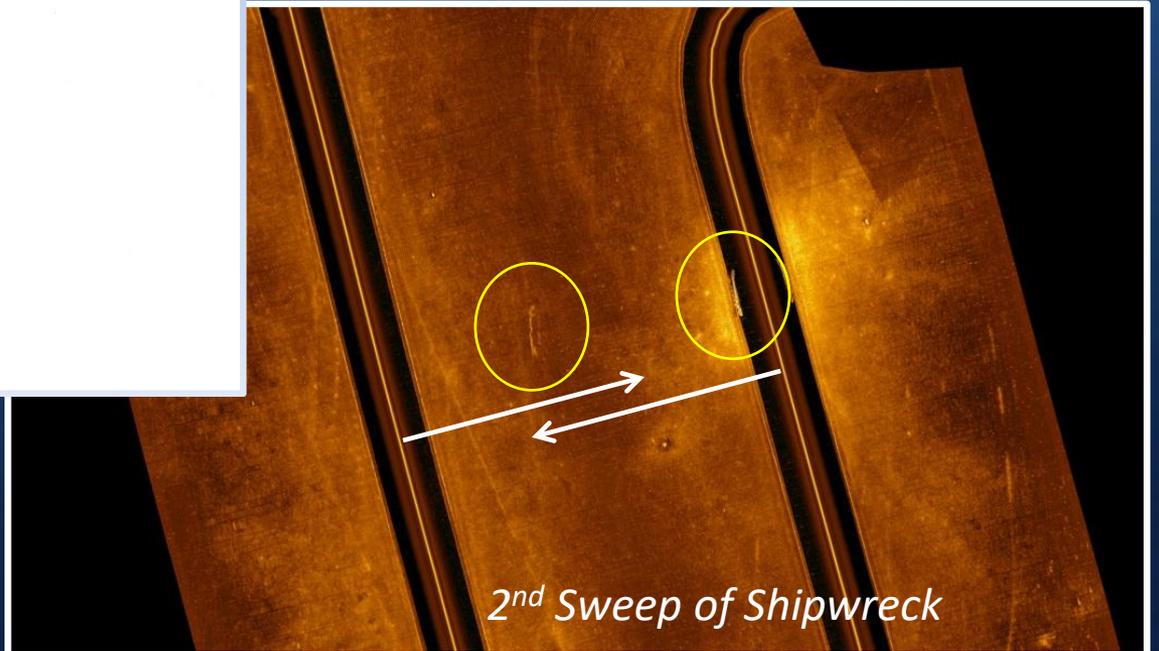
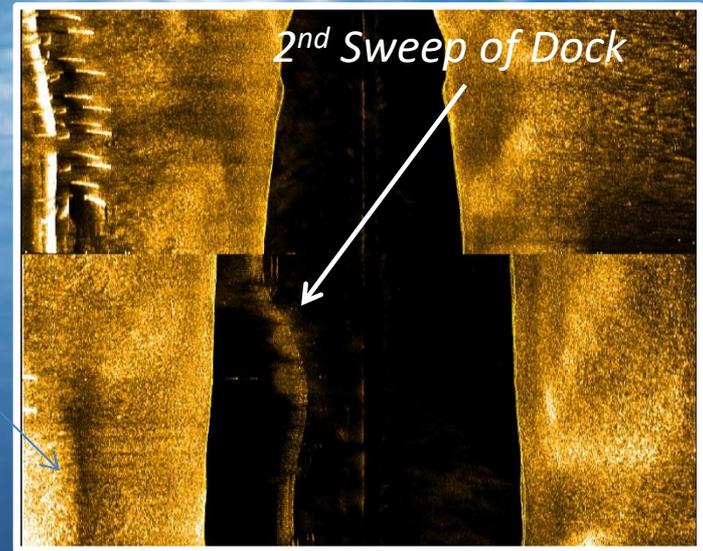
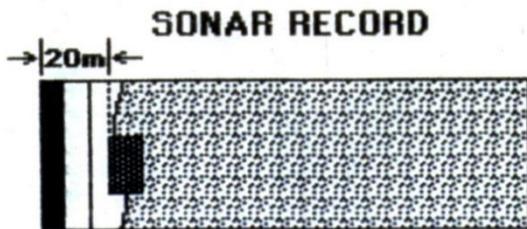
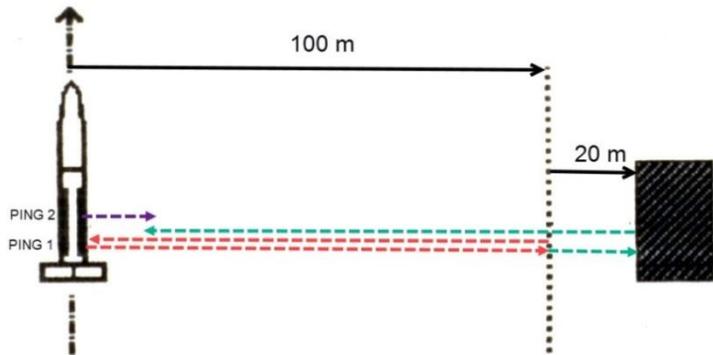


Refraction effects may be reduced by adjusting towfish depth

III. SSS Data Interpretation

2nd Sweep Return

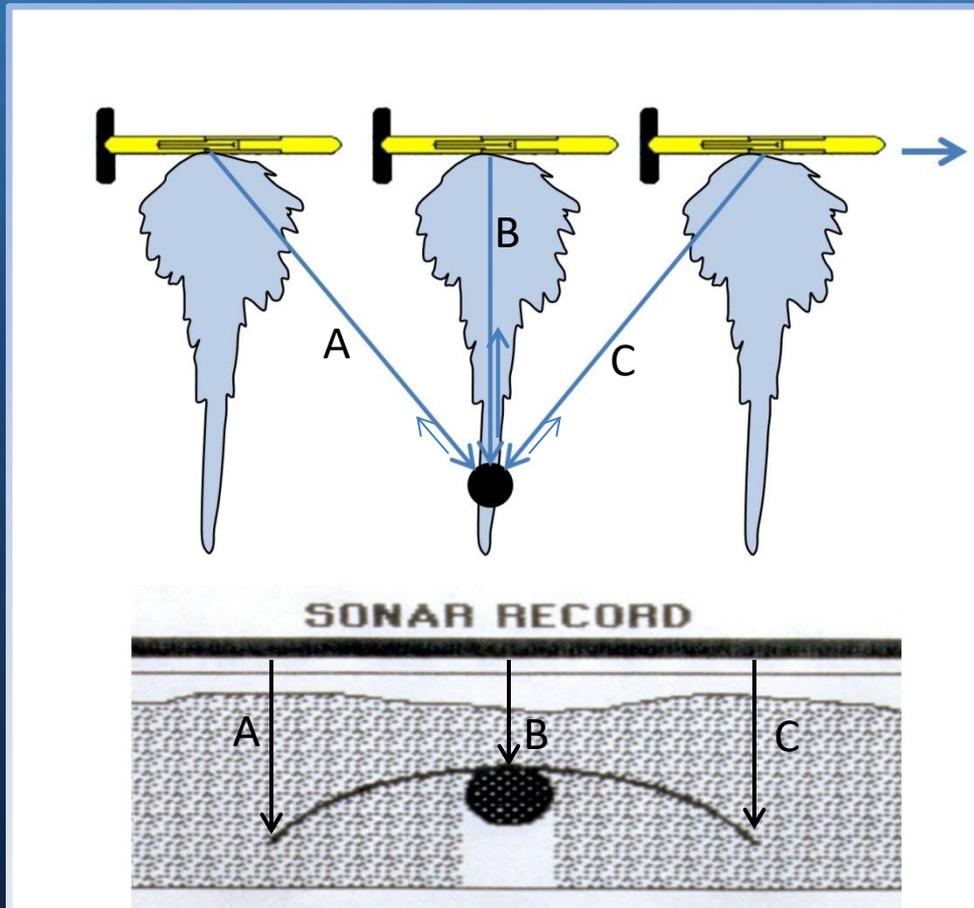
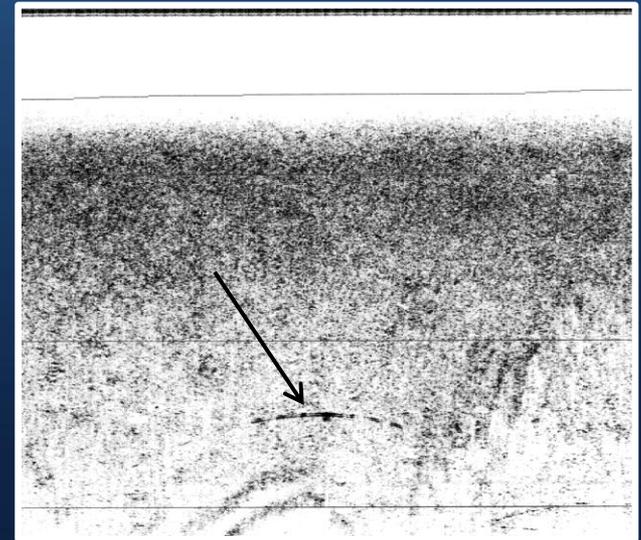
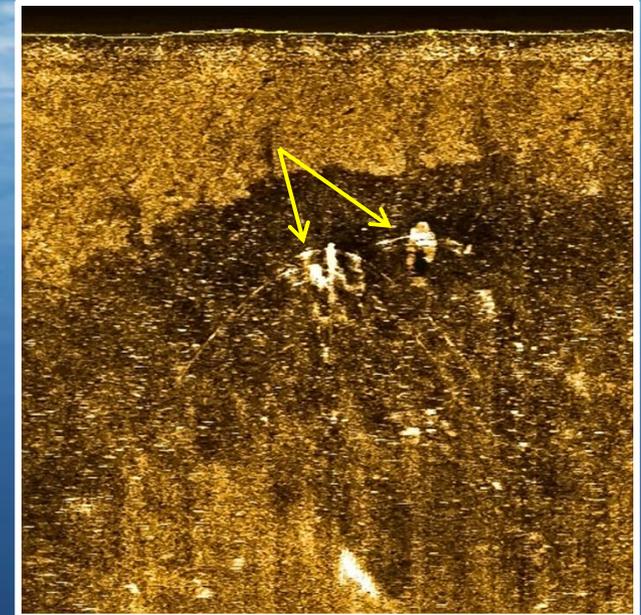
SECOND SWEEP RETURNS



III. SSS Data Interpretation

Hyperbolic Artifact

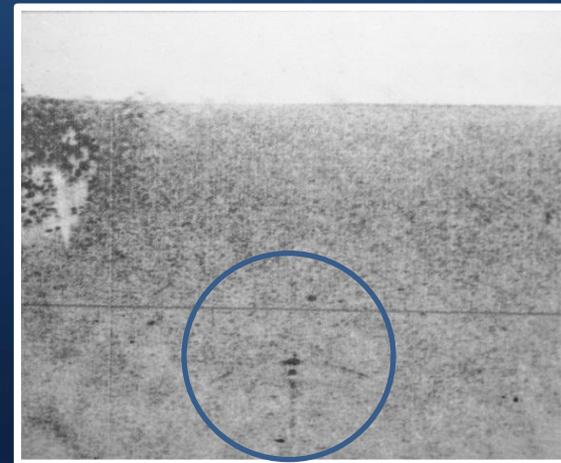
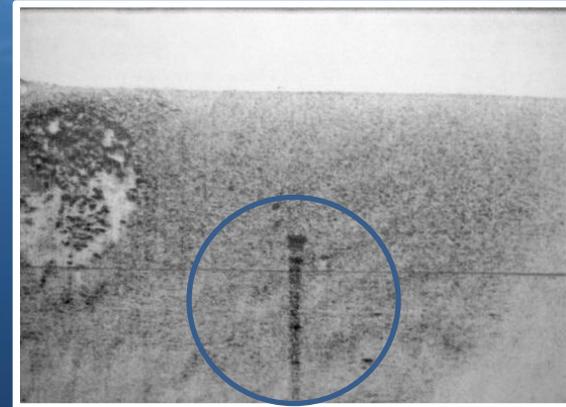
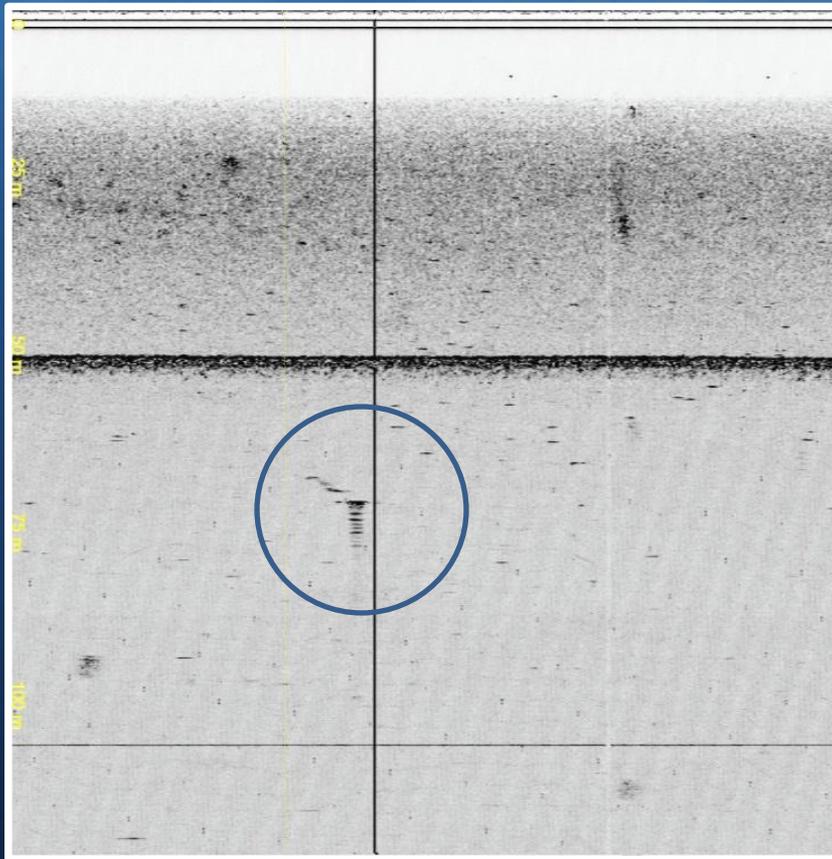
Hyperbolic artifacts are produced from spherical or vertical cylindrical objects and shapes



III. SSS Data Interpretation

Ringing

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

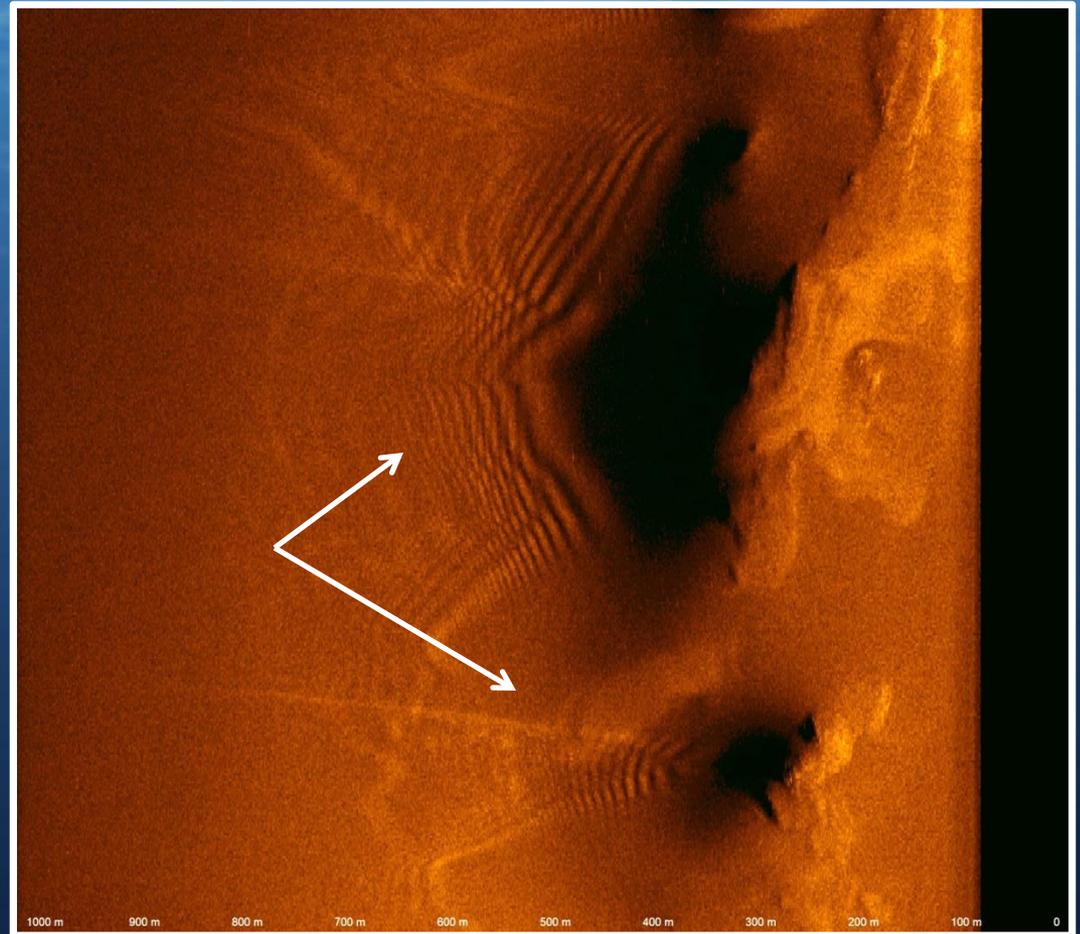


III. SSS Data Interpretation

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



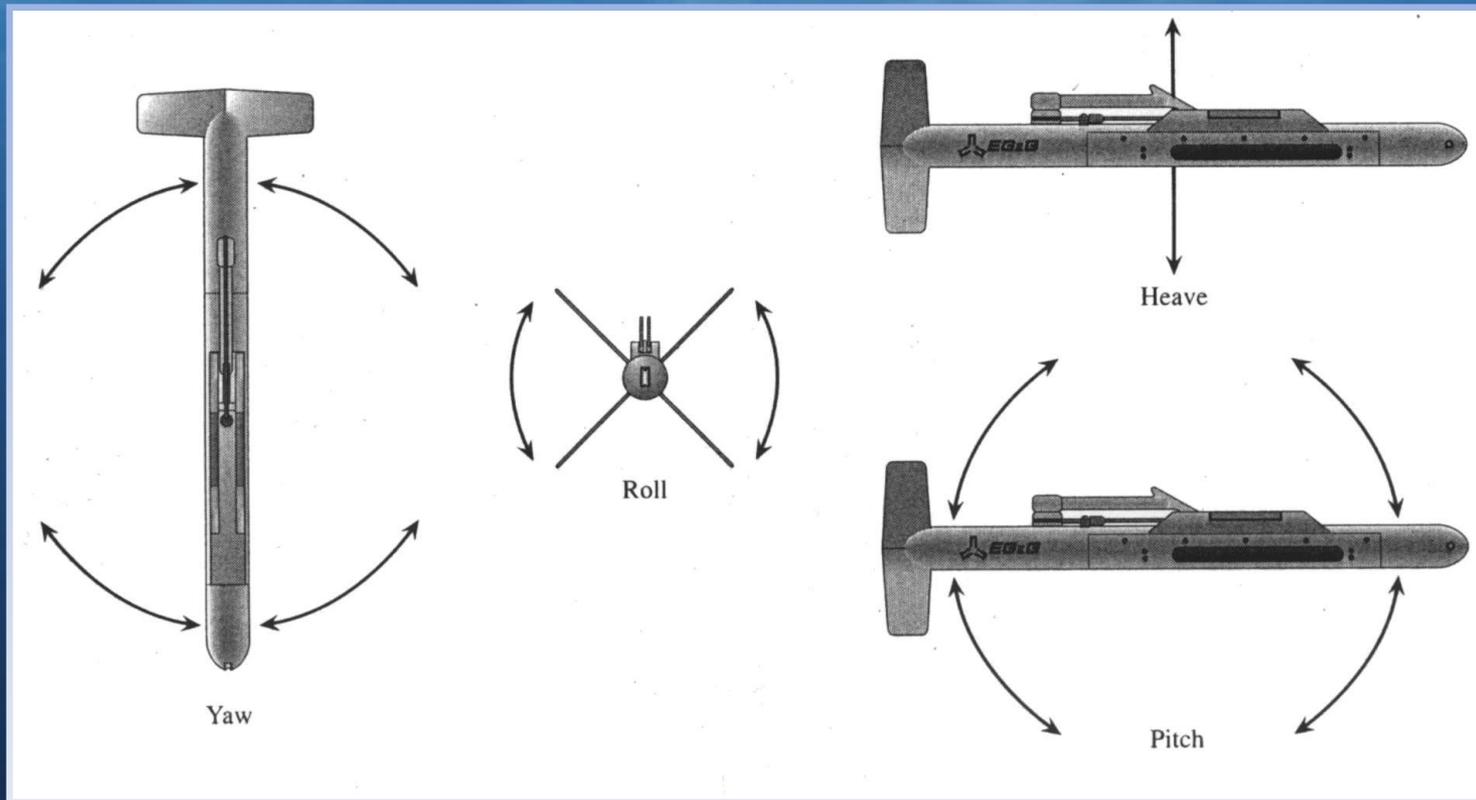
III. SSS Data Interpretation

Towfish Motion Distortion

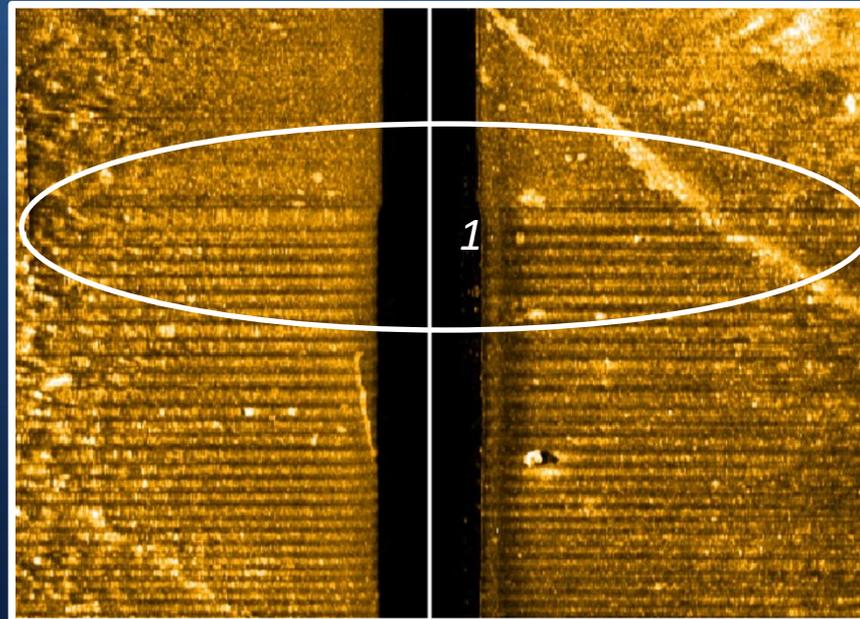
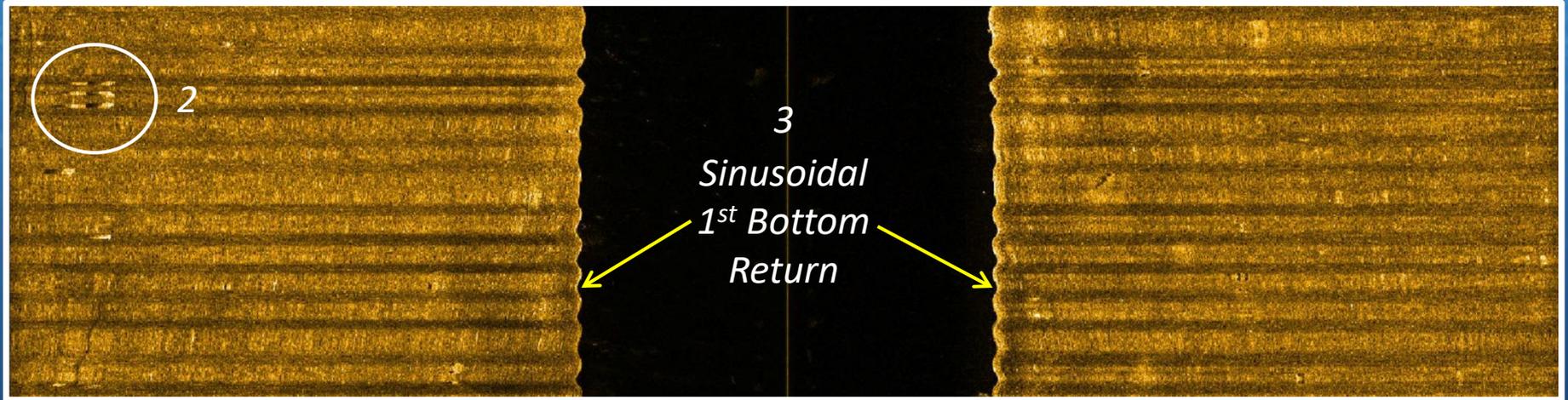


III. SSS Data Interpretation

Towfish Motion Distortion



III. SSS Data Interpretation Towfish Motion Distortion Pitch



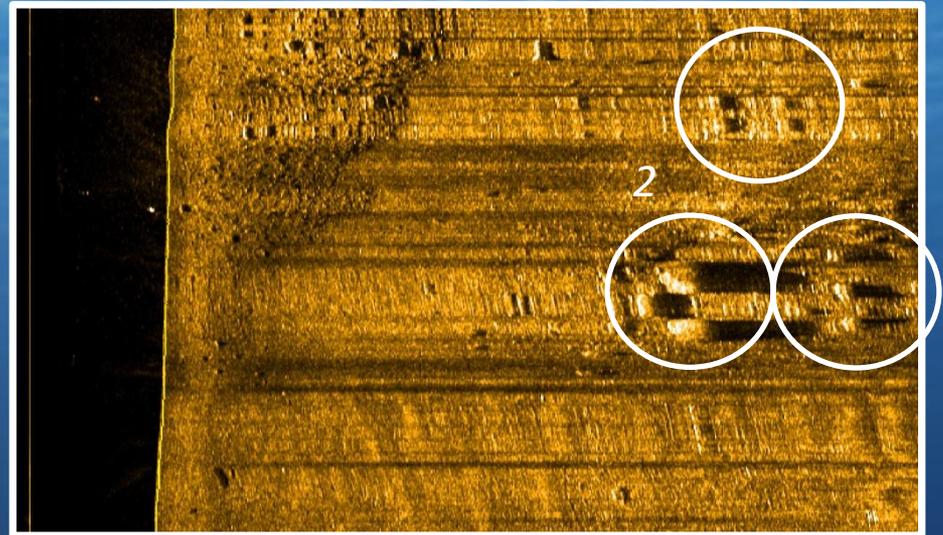
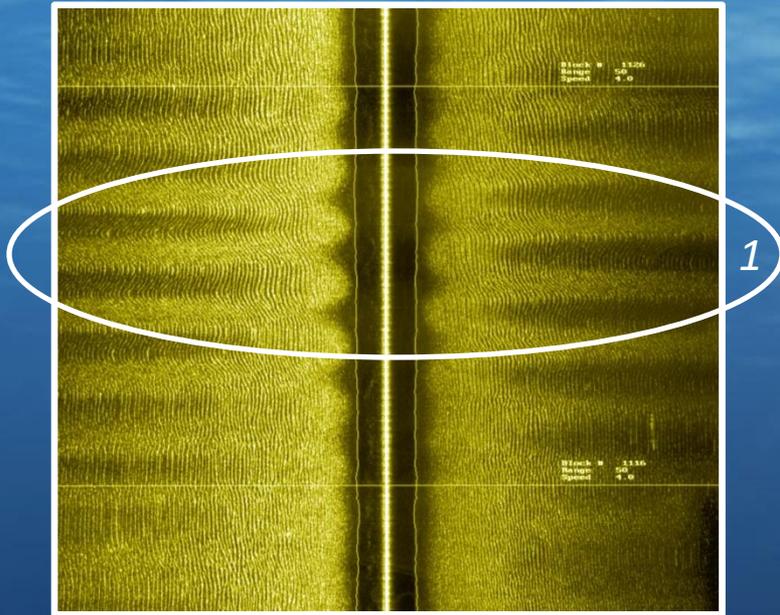
1. Synchronies
Banding

2. Multiple Targets

3. Sinusoidal 1st
Bottom Return

III. SSS Data Interpretation Towfish Motion Distortion

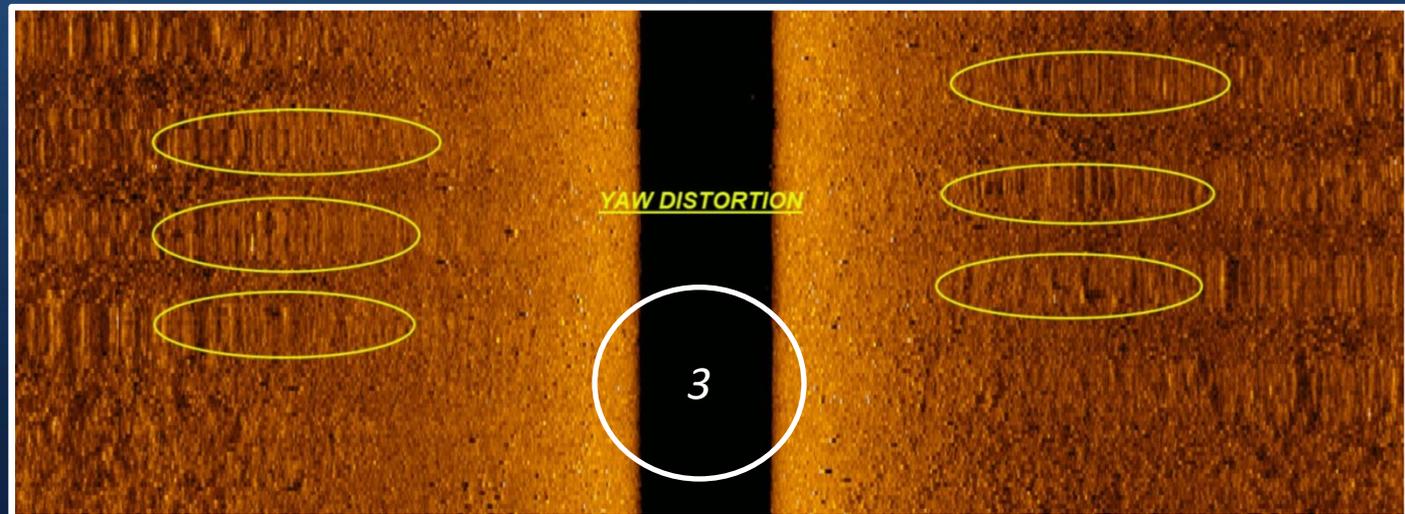
Yaw



1. A-Synchronies
Banding

2. Multiple Targets

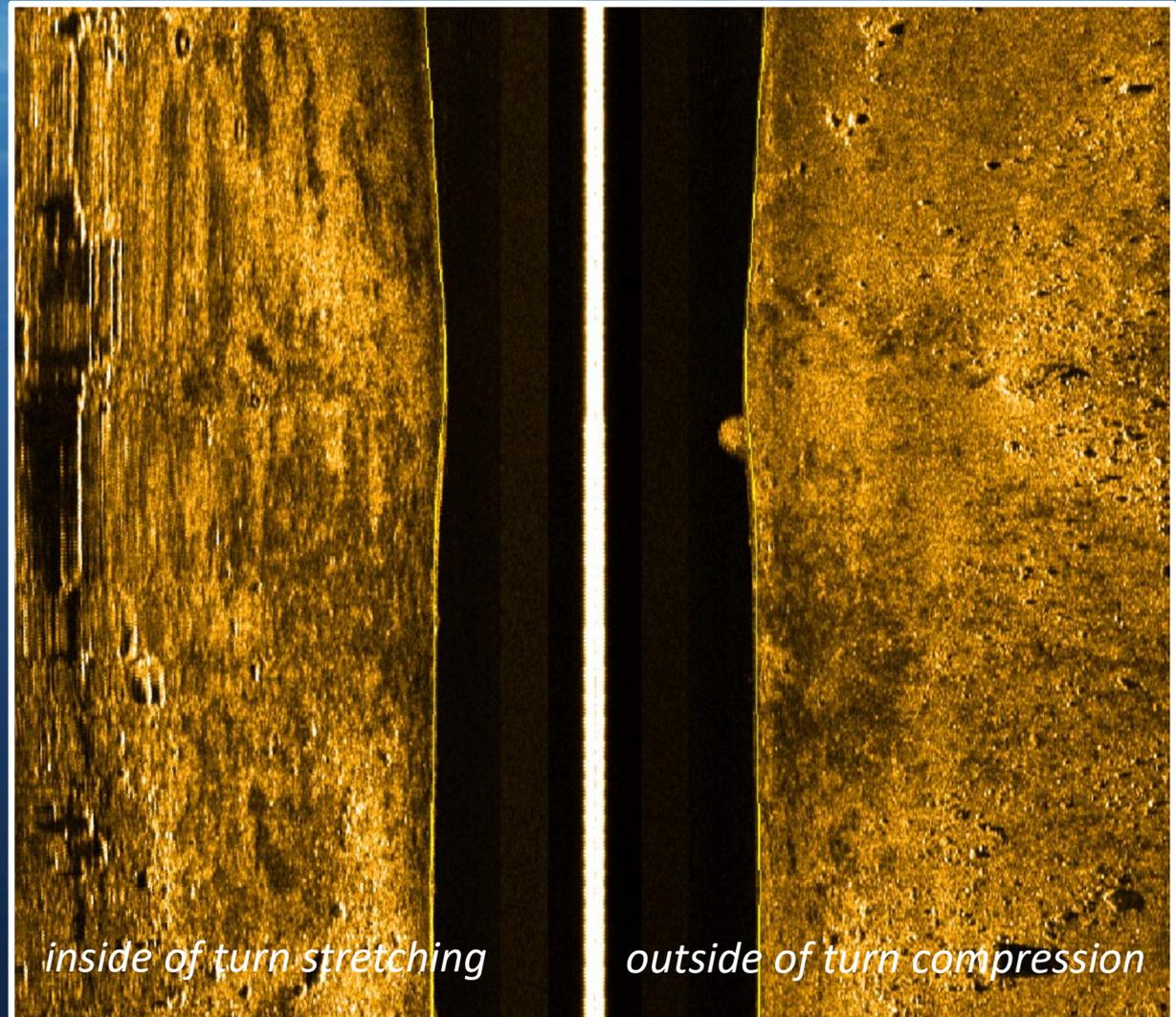
3. Smooth 1st
Bottom Return



III. SSS Data Interpretation Towfish Motion Distortion Turns

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

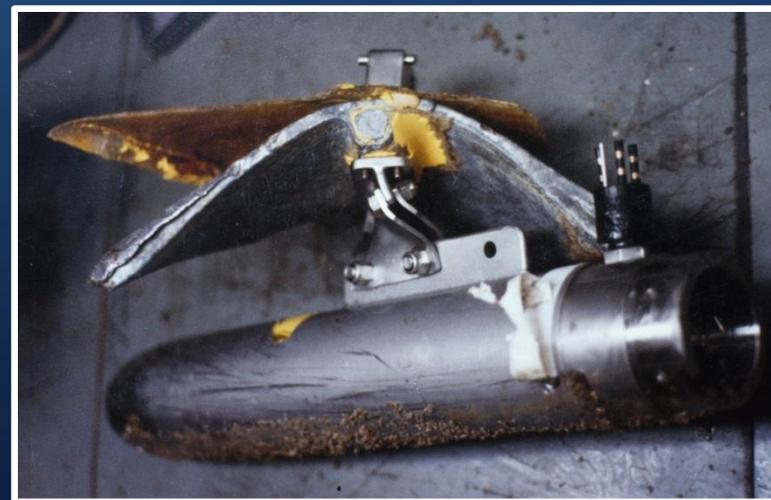
Do not use turn data in target analysis



III. SSS Data Interpretation

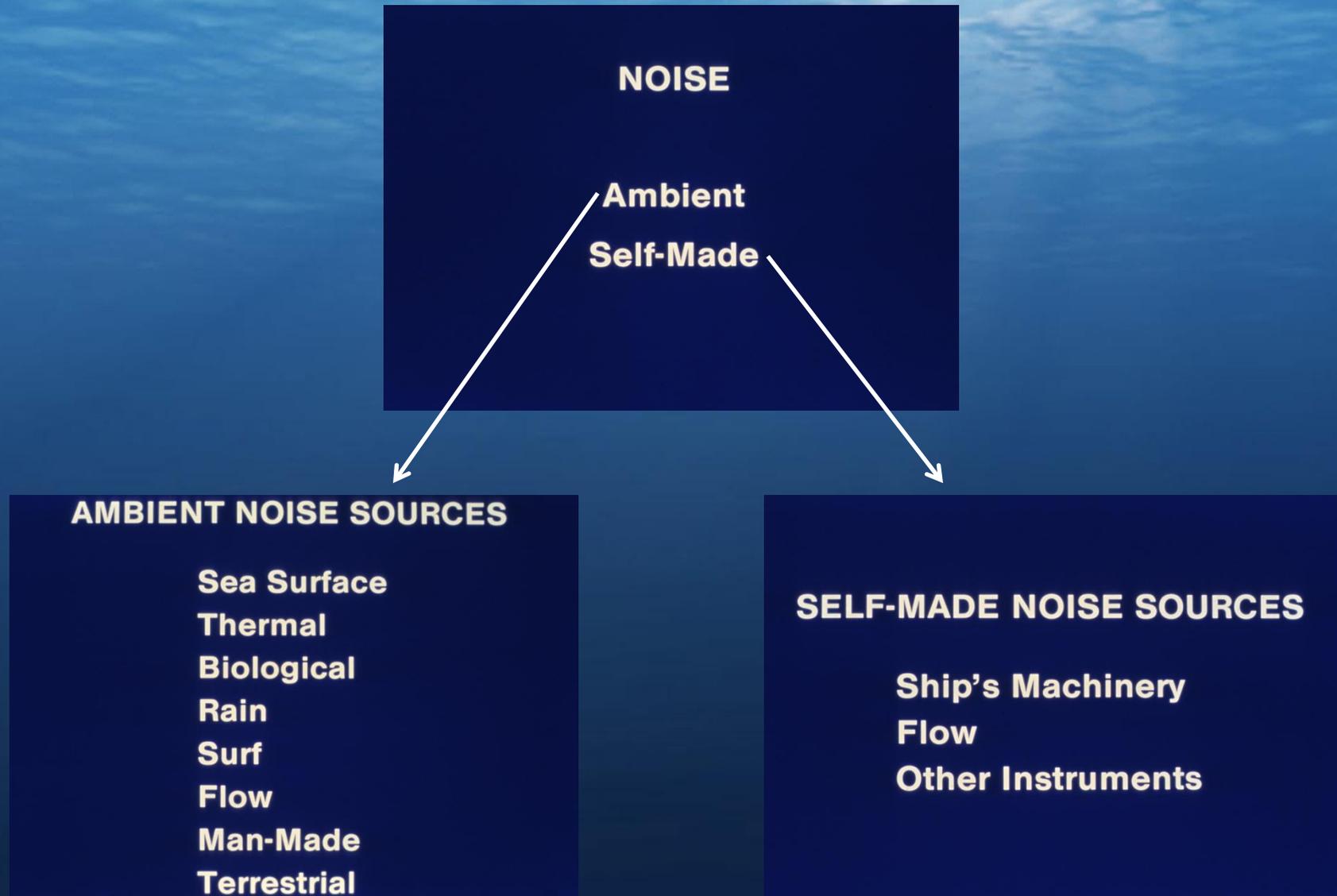


Hitting
the
Seafloor



III. SSS Data Interpretation

Noise

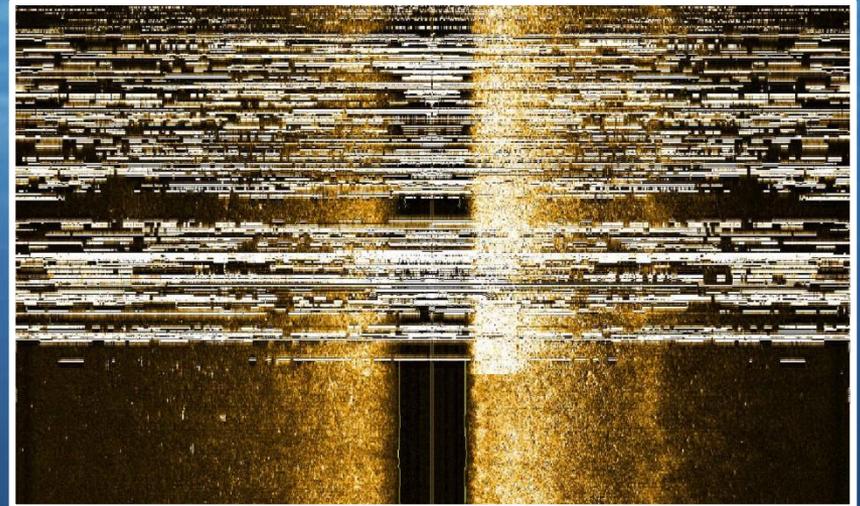
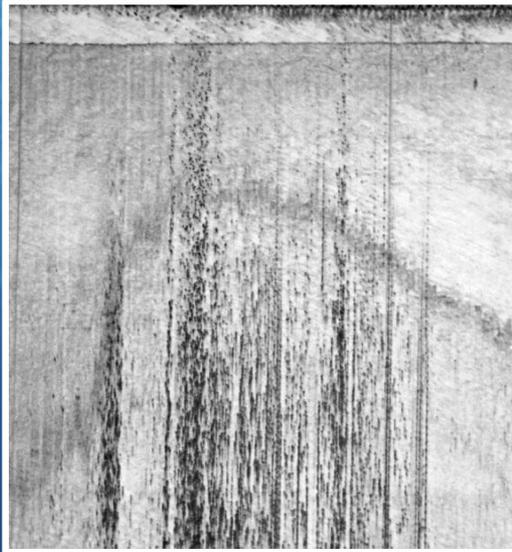


III. SSS Data Interpretation

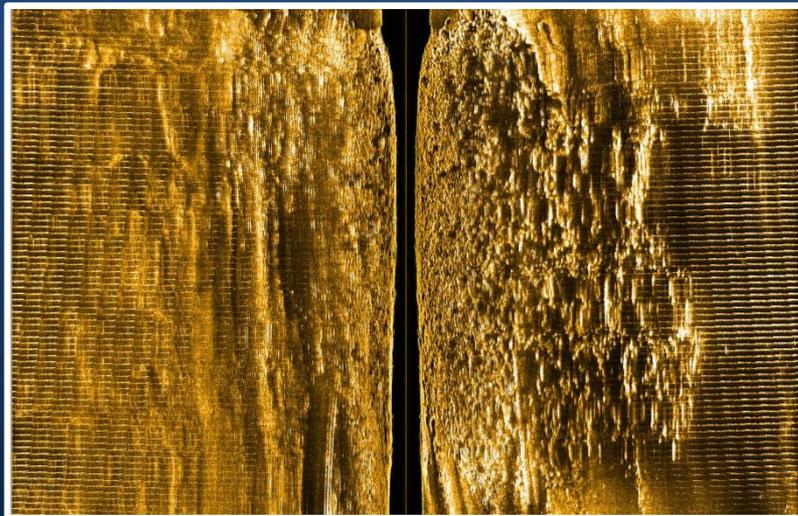
Noise



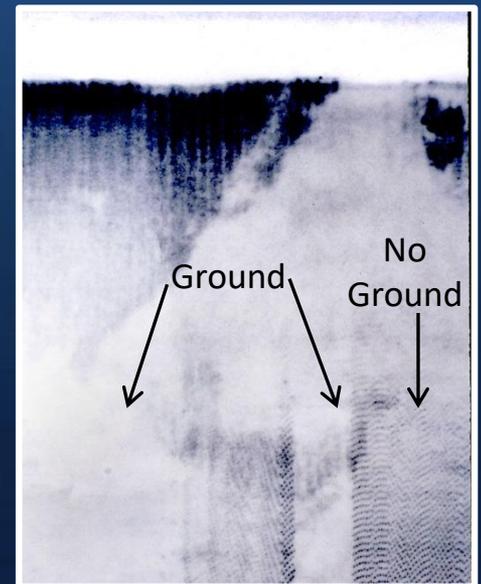
Porpoise Pings



*Electrical Noise:
Slip Ring, Cable
Failure, etc.*



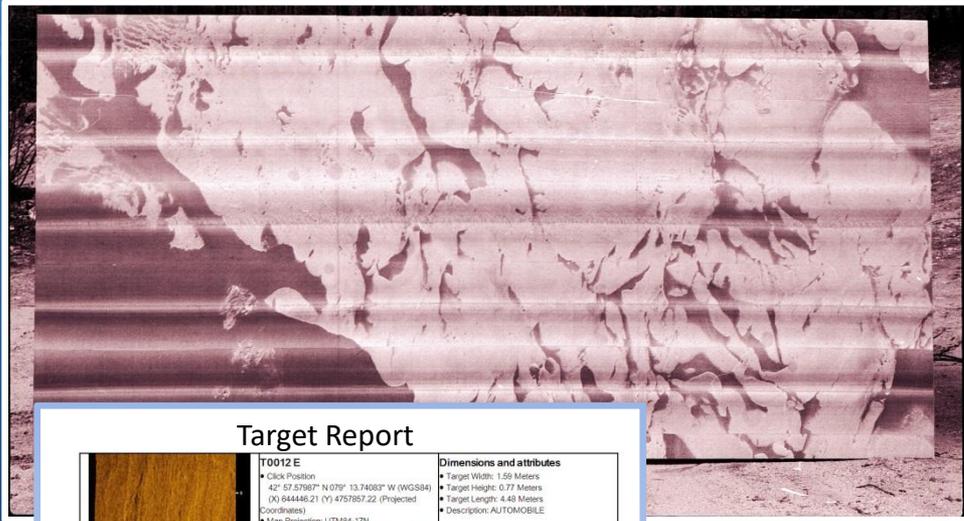
Echo Sounder Pings



*Sea Grounding
the Sonar
System*

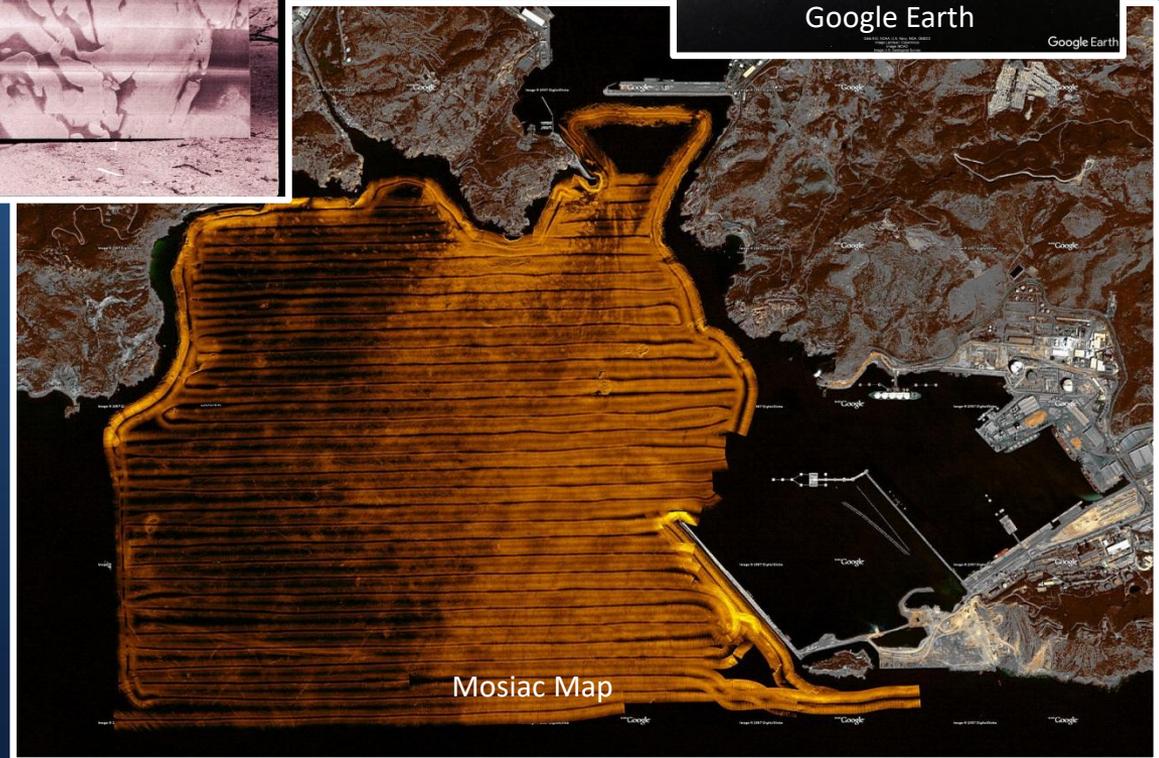
III. SSS Data Interpretation

Data Processing & Mosaics



Target Report

	<p>T0012 E</p> <ul style="list-style-type: none"> Click Position <ul style="list-style-type: none"> 42° 57.57982' N 079° 13.74082' W (WGS84) (0) 644445.21 (Y) 4757675.22 (Projected Coordinates) Map Projection: UTM84-17N Acoustic Source File: C:\Users\GK\Desktop\Bt Lawrence Seaway Demo\Welland Data\20190709171008.jpf Range to target: 41.25 Meters Fish Height: 5.74 Meters Heading: 0.000 Degrees 	<p>Dimensions and attributes</p> <ul style="list-style-type: none"> Target Width: 1.59 Meters Target Height: 0.77 Meters Target Length: 4.48 Meters Description: AUTOMOBILE
	<p>T0013 F</p> <ul style="list-style-type: none"> Click Position <ul style="list-style-type: none"> 42° 57.46859' N 079° 13.77579' W (WGS84) (0) 644401.88 (Y) 4757705.77 (Projected Coordinates) Map Projection: UTM84-17N Acoustic Source File: C:\Users\GK\Desktop\Bt Lawrence Seaway Demo\Welland Data\20190709171910.jpf Range to target: 12.27 Meters Fish Height: 8.18 Meters Heading: 0.000 Degrees 	<p>Dimensions and attributes</p> <ul style="list-style-type: none"> Target Width: 4.92 Meters Target Height: 0.00 Meters Target Length: 5.59 Meters Description: HOLE WITH WHAT APPEARS A PIPE
	<p>T0014 G</p> <ul style="list-style-type: none"> Click Position <ul style="list-style-type: none"> 42° 57.47699' N 079° 13.75798' W (WGS84) (0) 644426.81 (Y) 4757671.52 (Projected Coordinates) Map Projection: UTM84-17N Acoustic Source File: C:\Users\GK\Desktop\Bt Lawrence Seaway Demo\Welland Data\20190709171910.jpf Range to target: 19.09 Meters Fish Height: 8.44 Meters Heading: 0.000 Degrees 	<p>Dimensions and attributes</p> <ul style="list-style-type: none"> Target Width: 1.80 Meters Target Height: 1.16 Meters Target Length: 4.59 Meters Description: AUTOMOBILE
	<p>T0015 G</p> <ul style="list-style-type: none"> Click Position <ul style="list-style-type: none"> 42° 57.48114' N 079° 13.75359' W (WGS84) (0) 644432.74 (Y) 4757674.11 (Projected Coordinates) Map Projection: UTM84-17N Acoustic Source File: C:\Users\GK\Desktop\Bt Lawrence Seaway Demo\Welland Data\20190709174357.jpf Range to target: 28.35 Meters Fish Height: 10.56 Meters Heading: 0.000 Degrees 	<p>Dimensions and attributes</p> <ul style="list-style-type: none"> Target Width: 0.00 Meters Target Height: 0.00 Meters Target Length: 0.00 Meters Description: AUTOMOBILE



IV. Field Operations

Operational Considerations

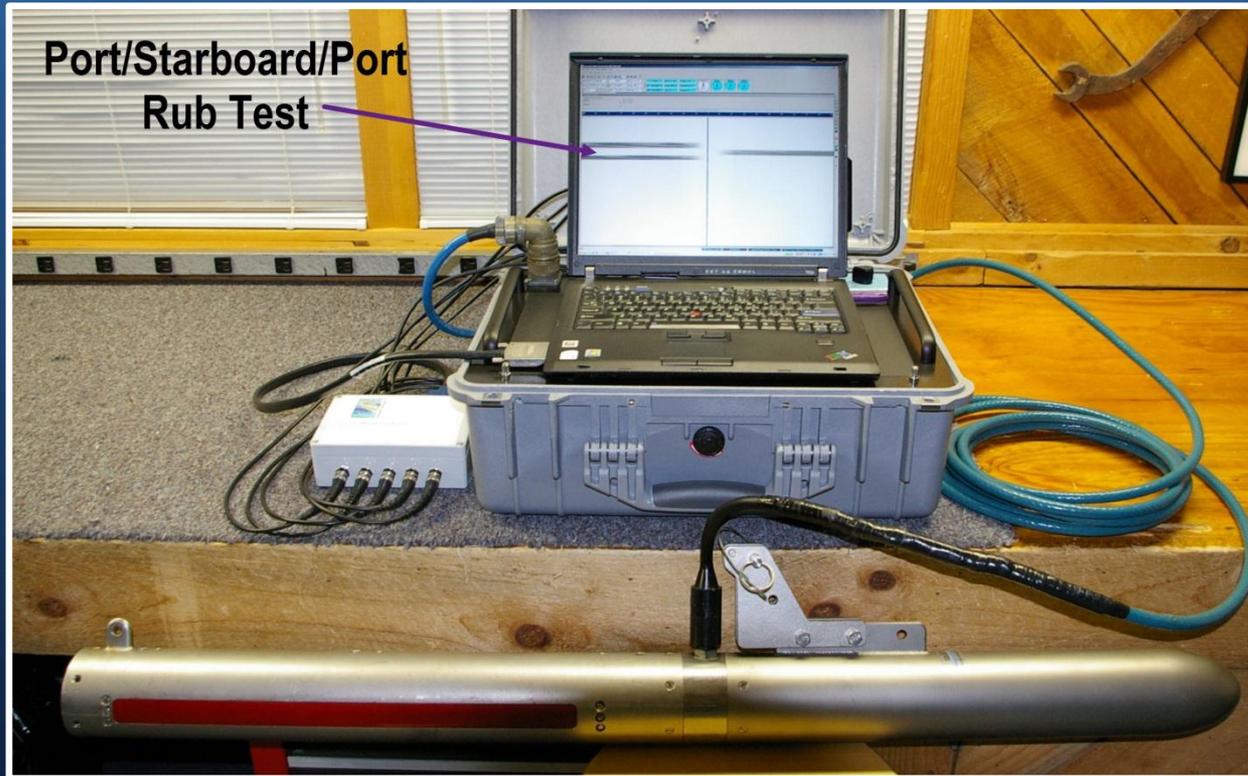
- *Mobilization Systems Check*
- *Pre-Survey Start “House Keeping”*
- *Survey Platform*
- *Towfish Frequency*
- *Range Scale*
- *Towing Speed*
- *Towfish Altitude*
- *Towing Method*
- *Towfish Deployment*
- *Cable Type*
- *Depressor*
- *Towfish Positioning*

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 minutes due to possible electronics overheating.



IV. Field Operations

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, NEVER 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) BEFORE LINE START.

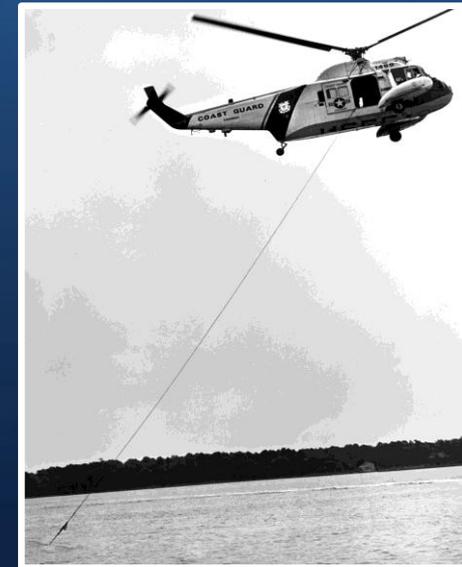
IV. Field Operations

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

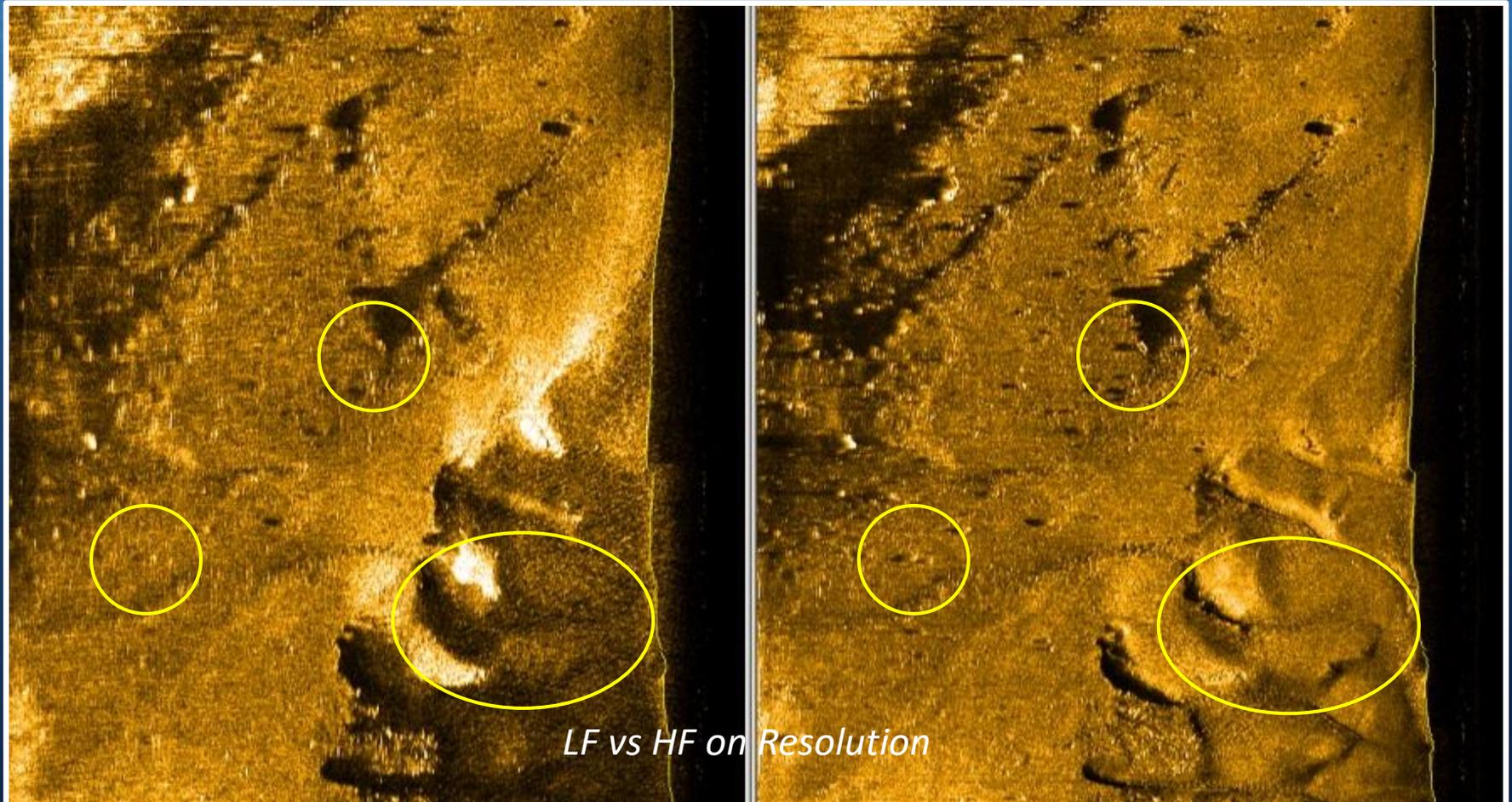
Survey Platforms



IV. Field Operations

Range / Resolution Tradeoff

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



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

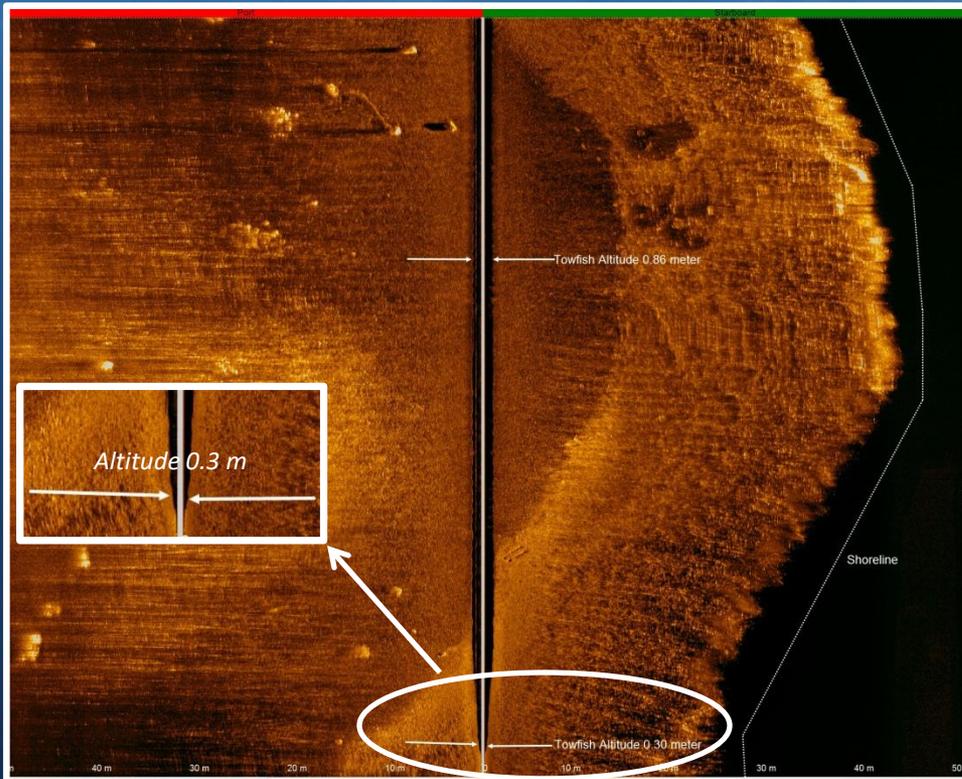
Mosaics: 10% to 20% of the sonar range scale

COMMON SENSE MUST BE USED IN RUGGED TERRAIN

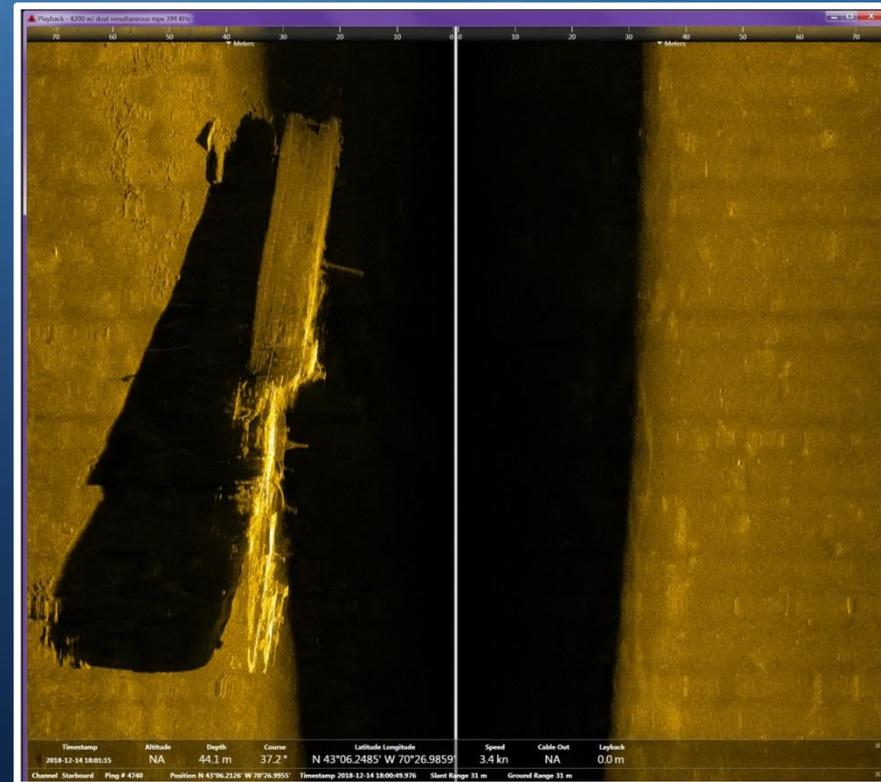
IV. Field Operations

Towfish Altitude – How Low, How High ?

Altitude Less Than 1% of Range Scale



Altitude Greater Than 40% of Range Scale

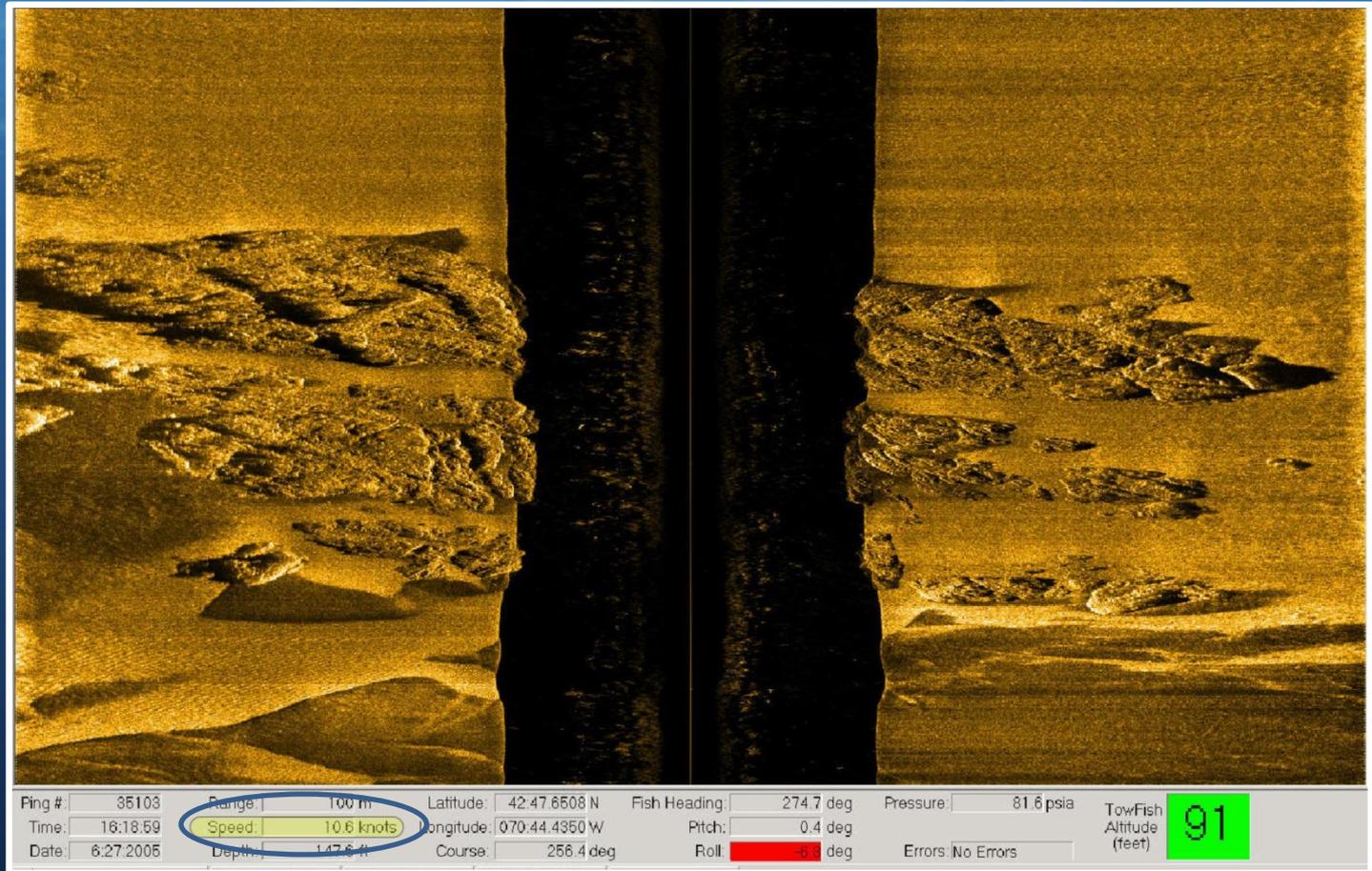


IV. Field Operations

Towing Speed

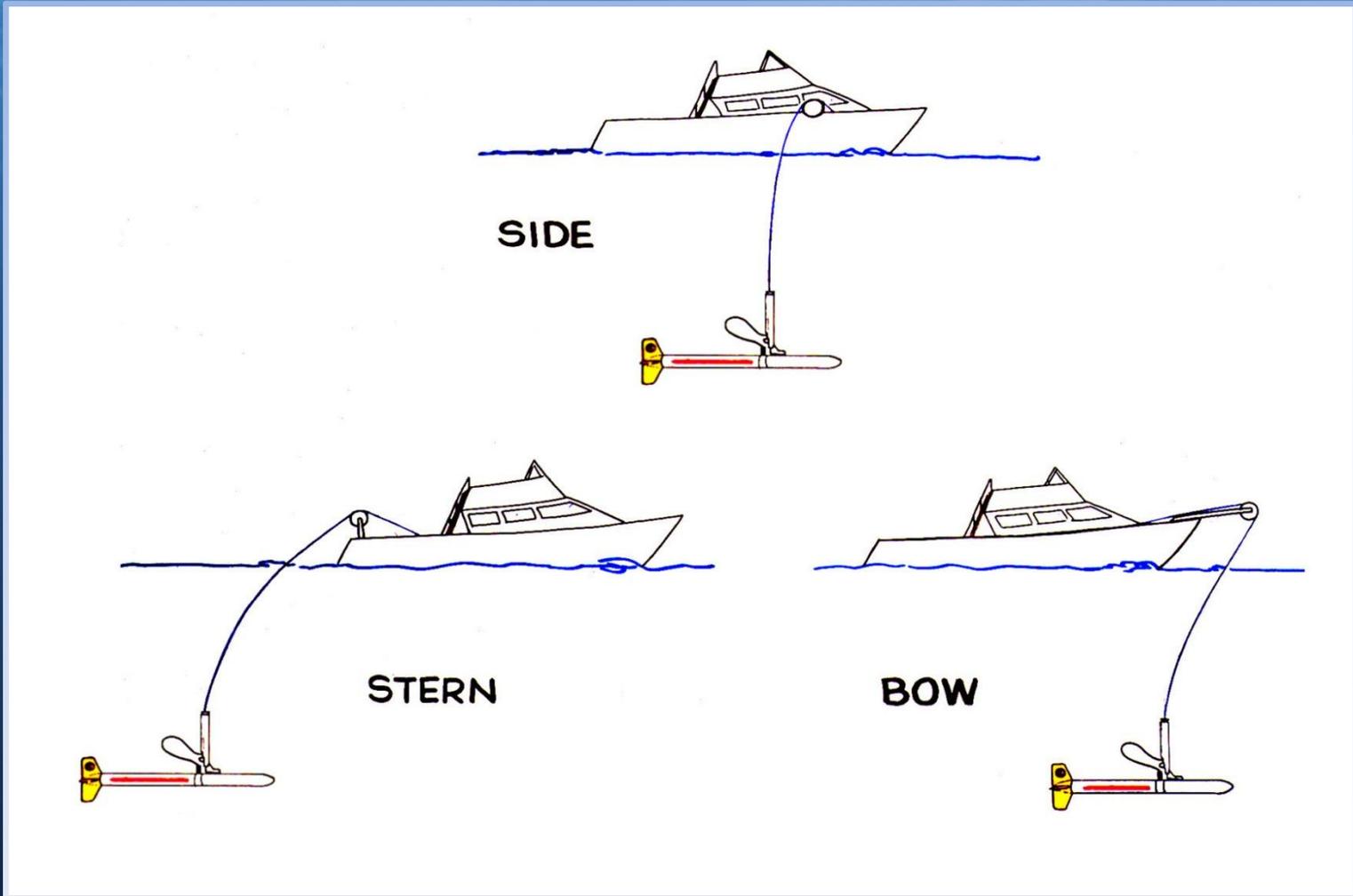
The best tow speed for the sonar is from 2.5 to 5 knots.

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



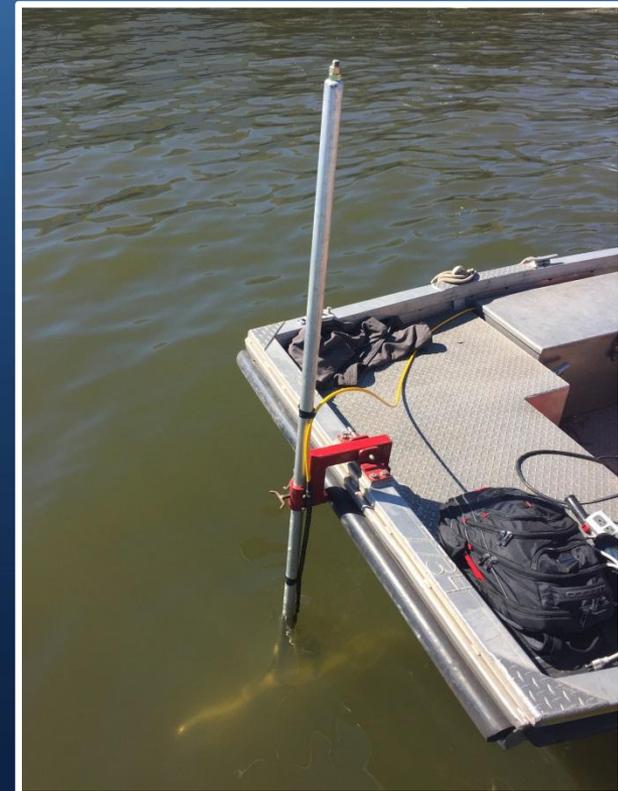
IV. Field Operations

Towing Methods



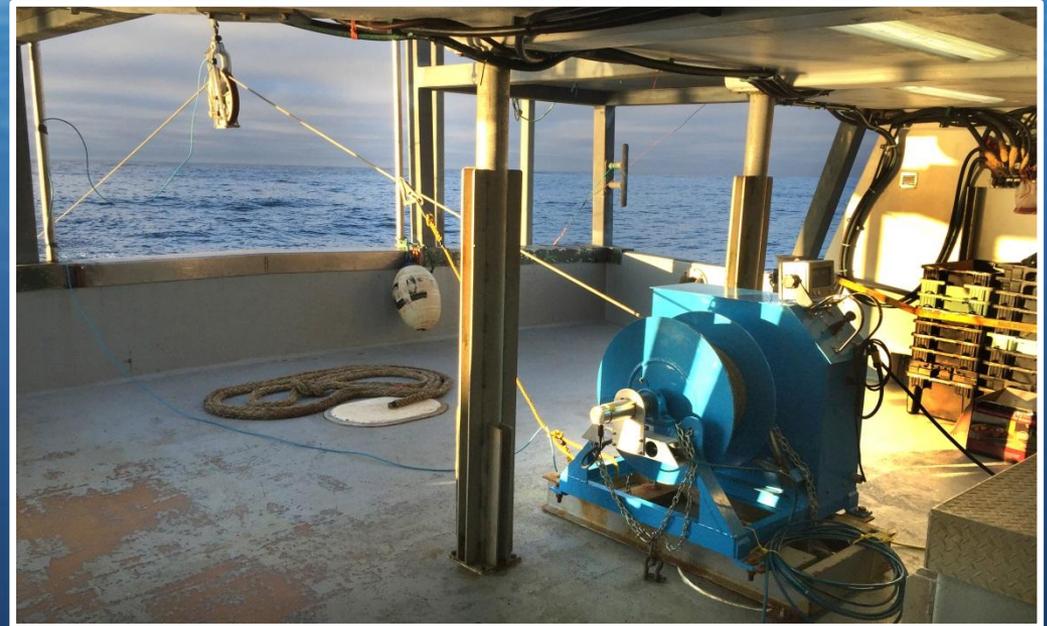
IV. Field Operations

Bow & Side Towing Methods



IV. Field Operations

Cable Types, Winches, Cable
Counters, & Slip Rings



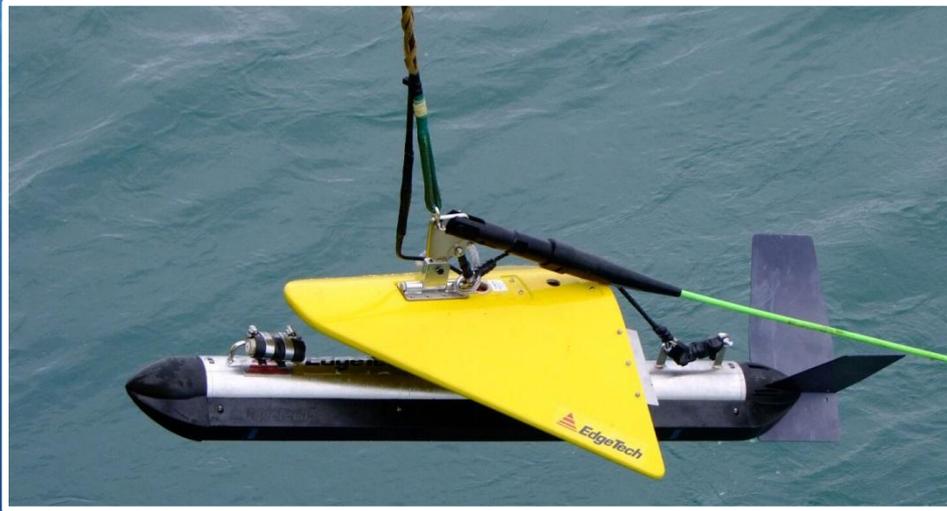
IV. Field Operations

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



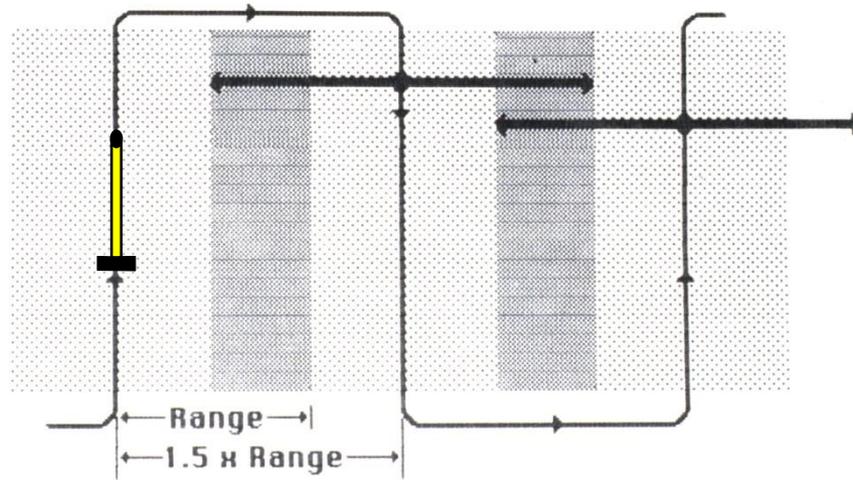
Depressors



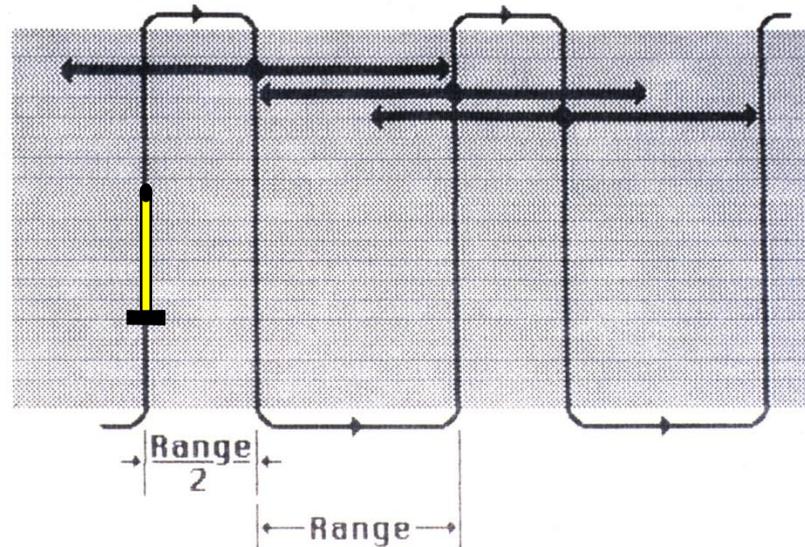
IV. Field Operations

Survey Patterns

Large target search



Small target search



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

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

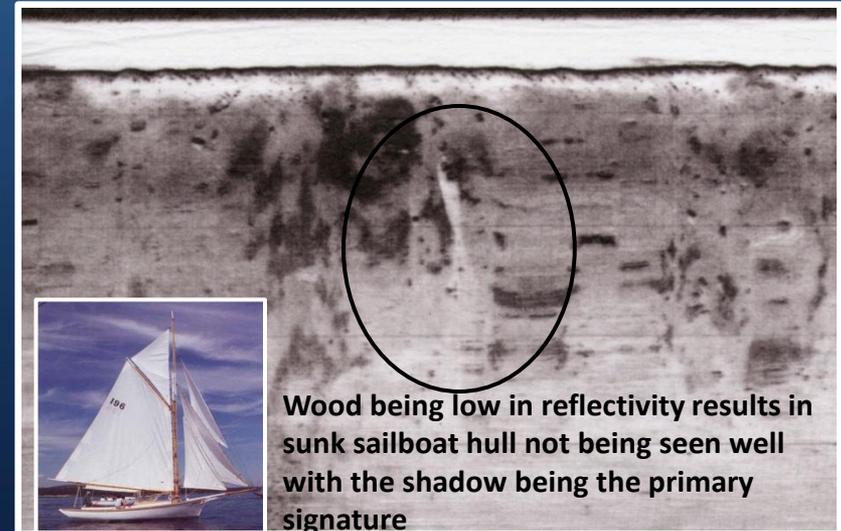
$$M = \frac{pc \text{ material}}{pc \text{ water}}$$

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

Target Reflectivity



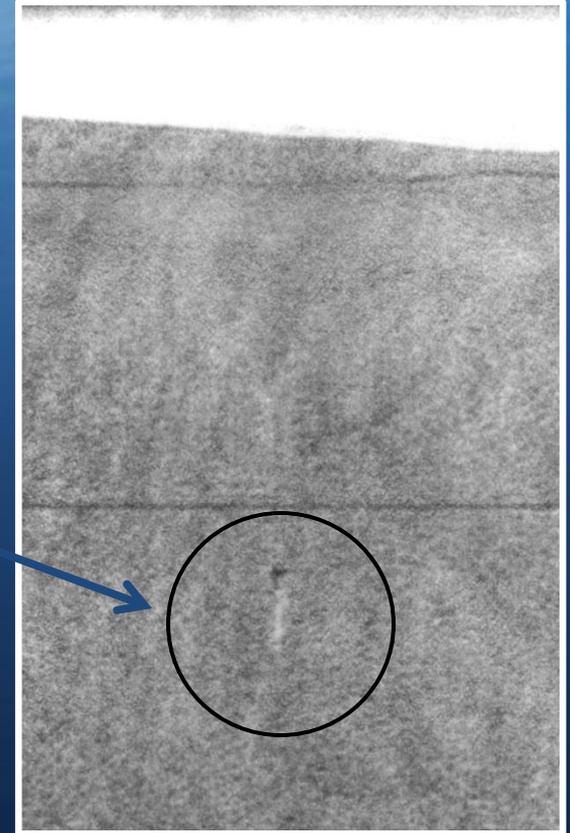
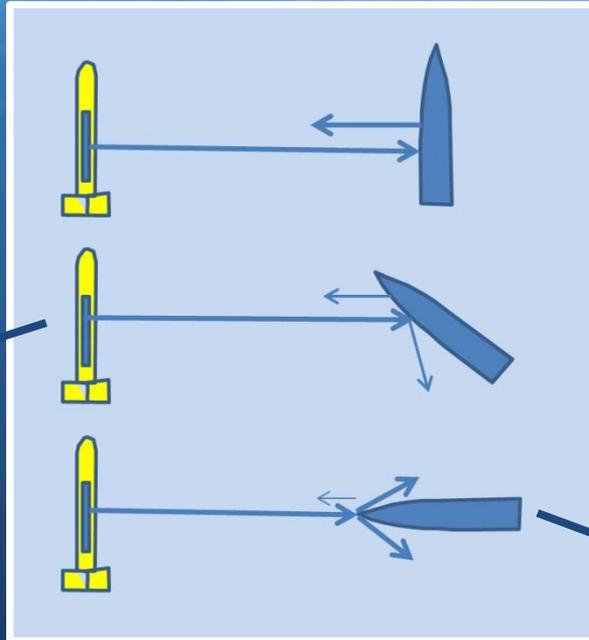
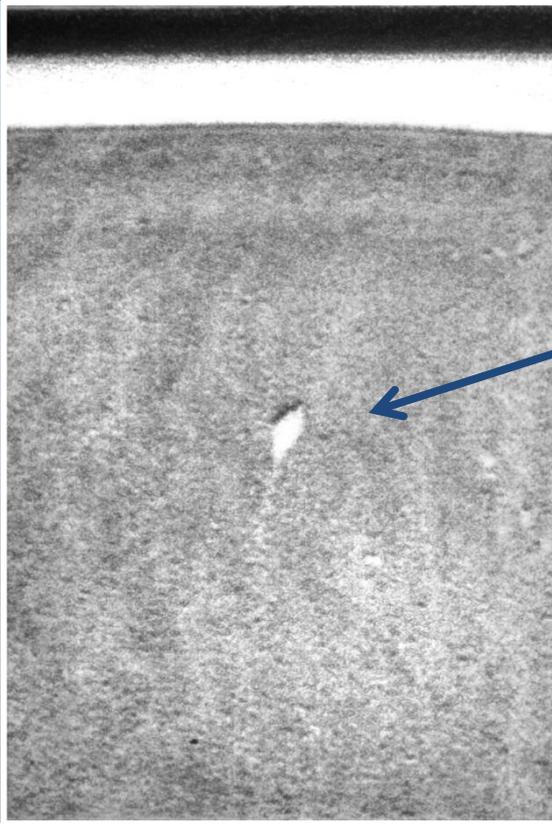
Anechoic Rubber Tiles on Sub hull to reduce reflectivity



Wood being low in reflectivity results in sunk sailboat hull not being seen well with the shadow being the primary signature

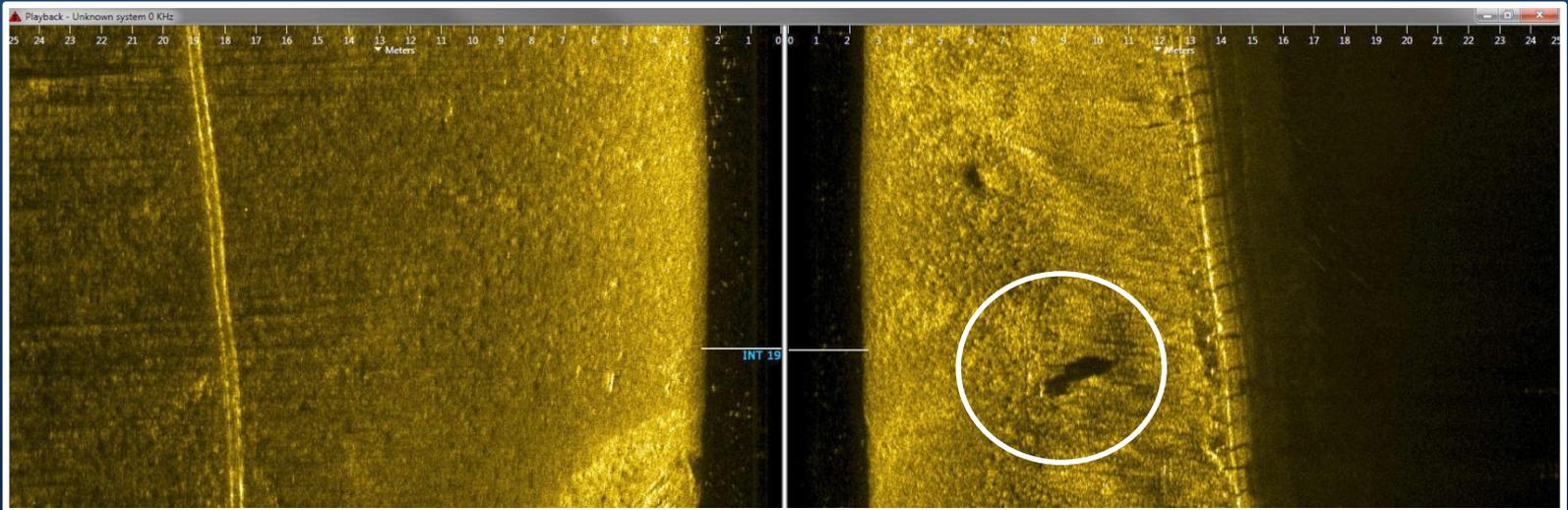
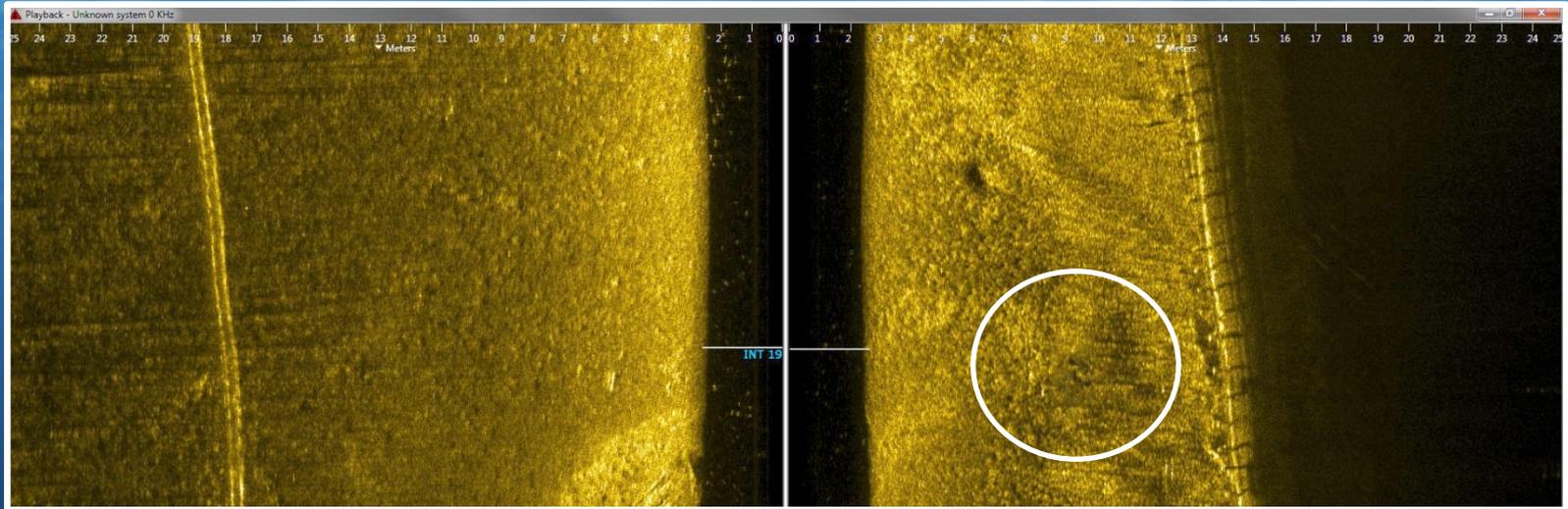
IV. Field Operations

Aspect Critical Targets



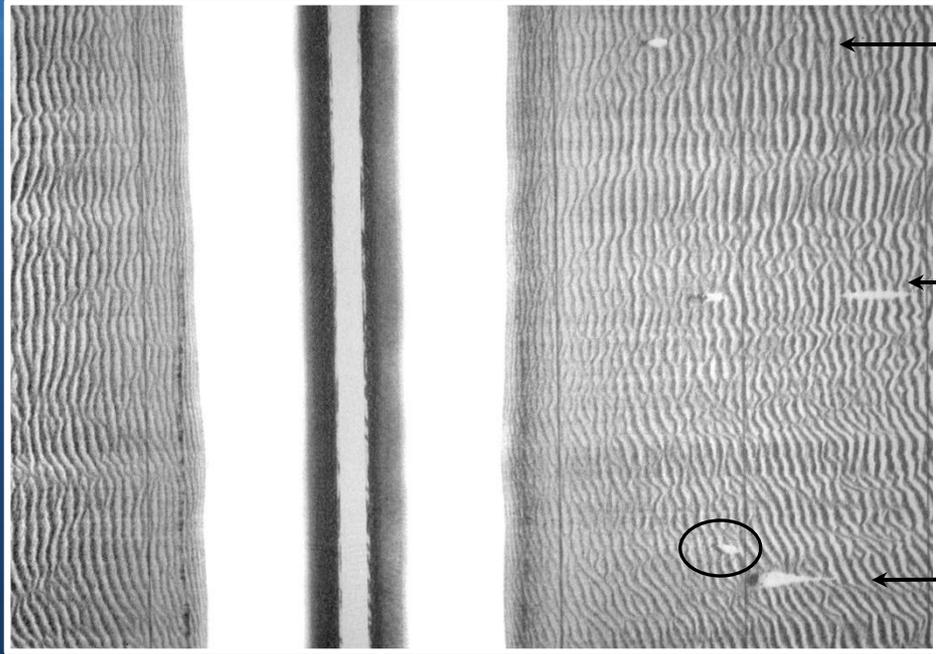
IV. Field Operations

Anechoic Targets & Acoustic Shadows

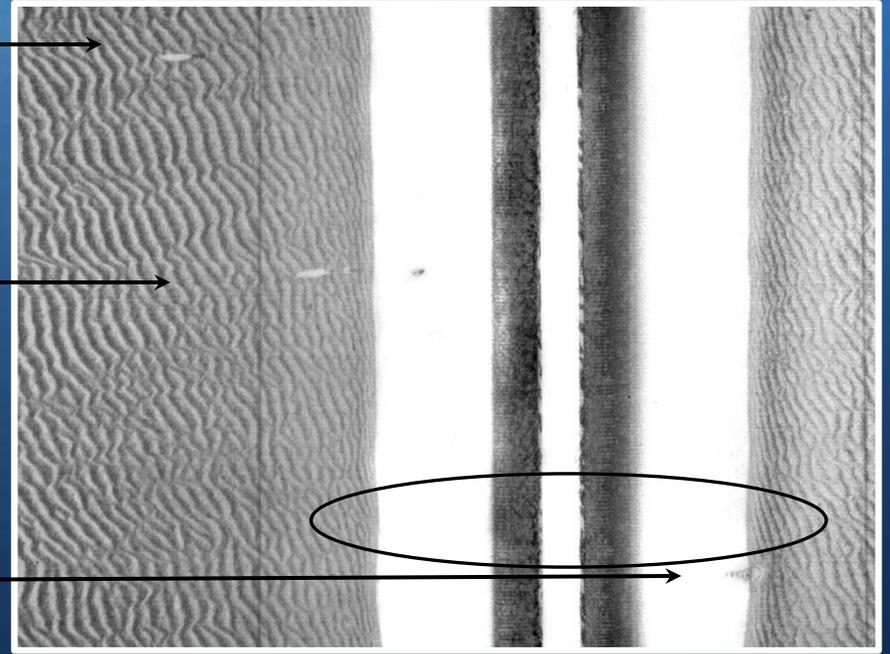


IV. Field Operations

Nadir & Small Targets



1.5 m Steel Cylinder is Detected

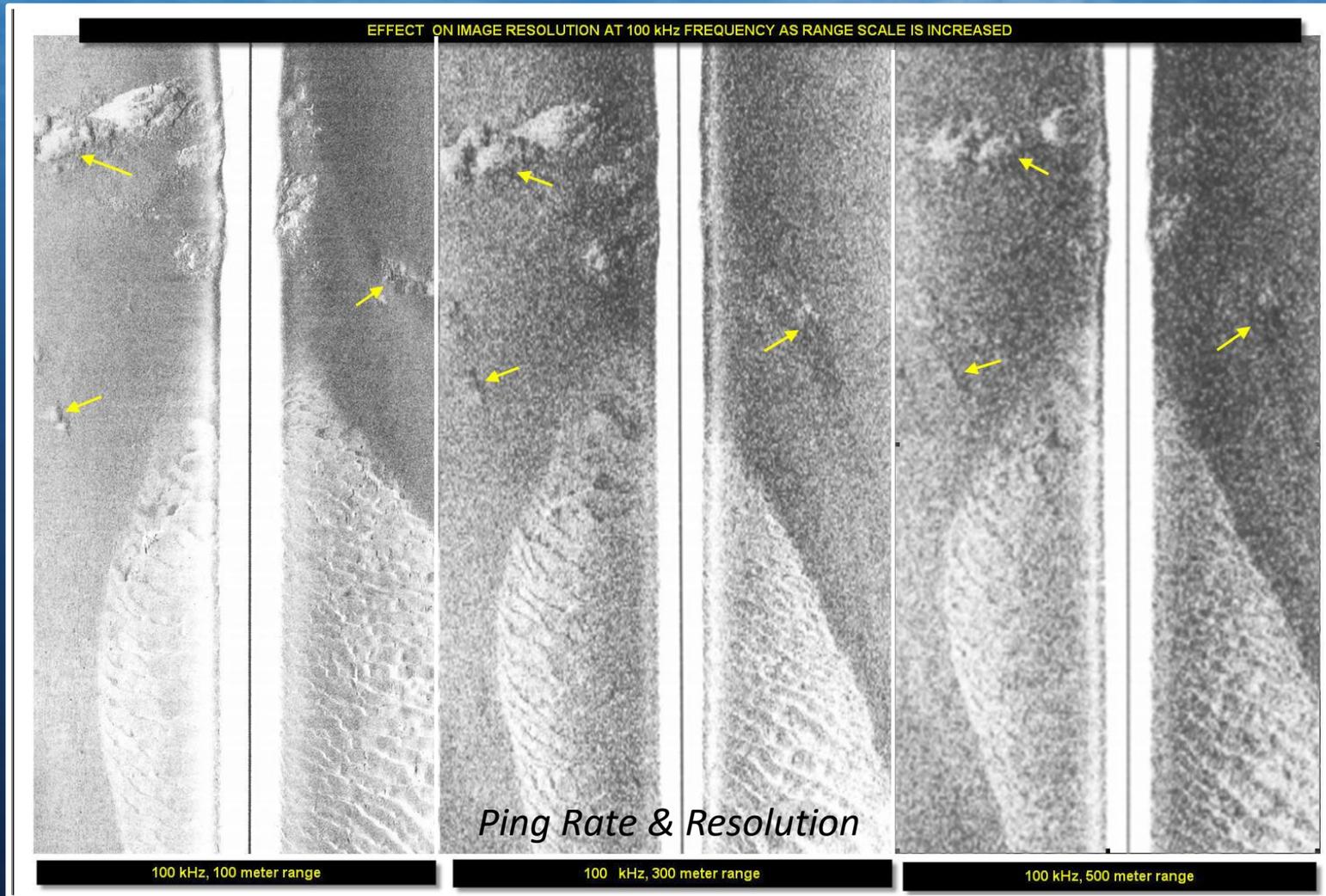


1.5 m Steel Cylinder in Nadir is not Detected

IV. Field Operations

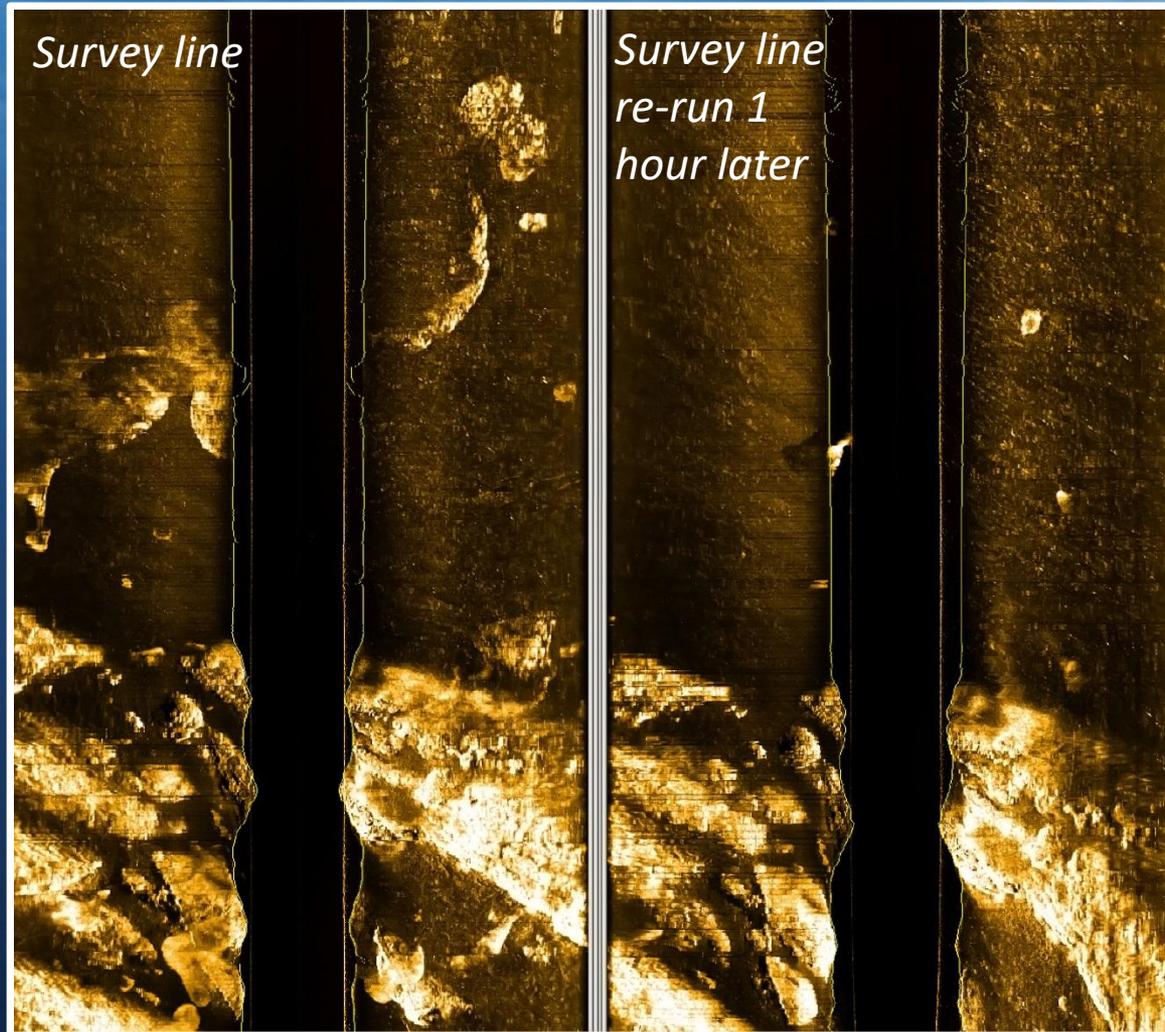
Range / Resolution Tradeoff

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



IV. Field Operations

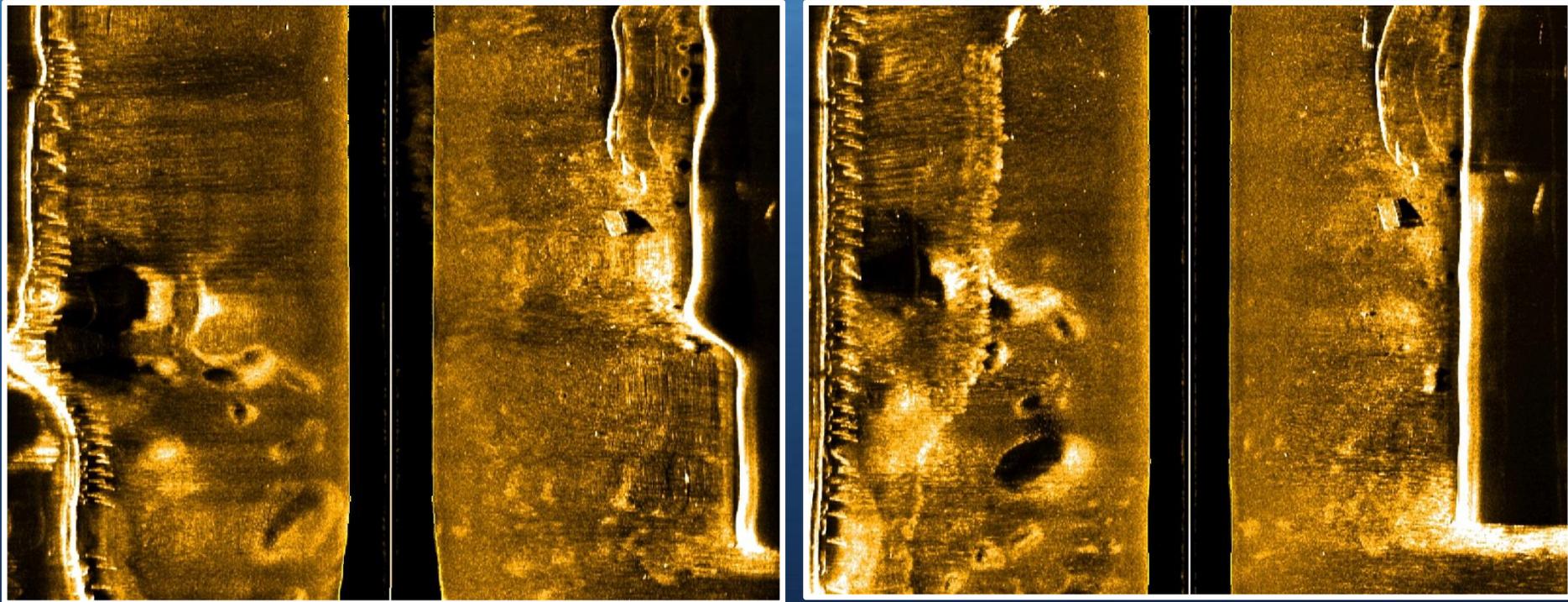
Repeatability



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.

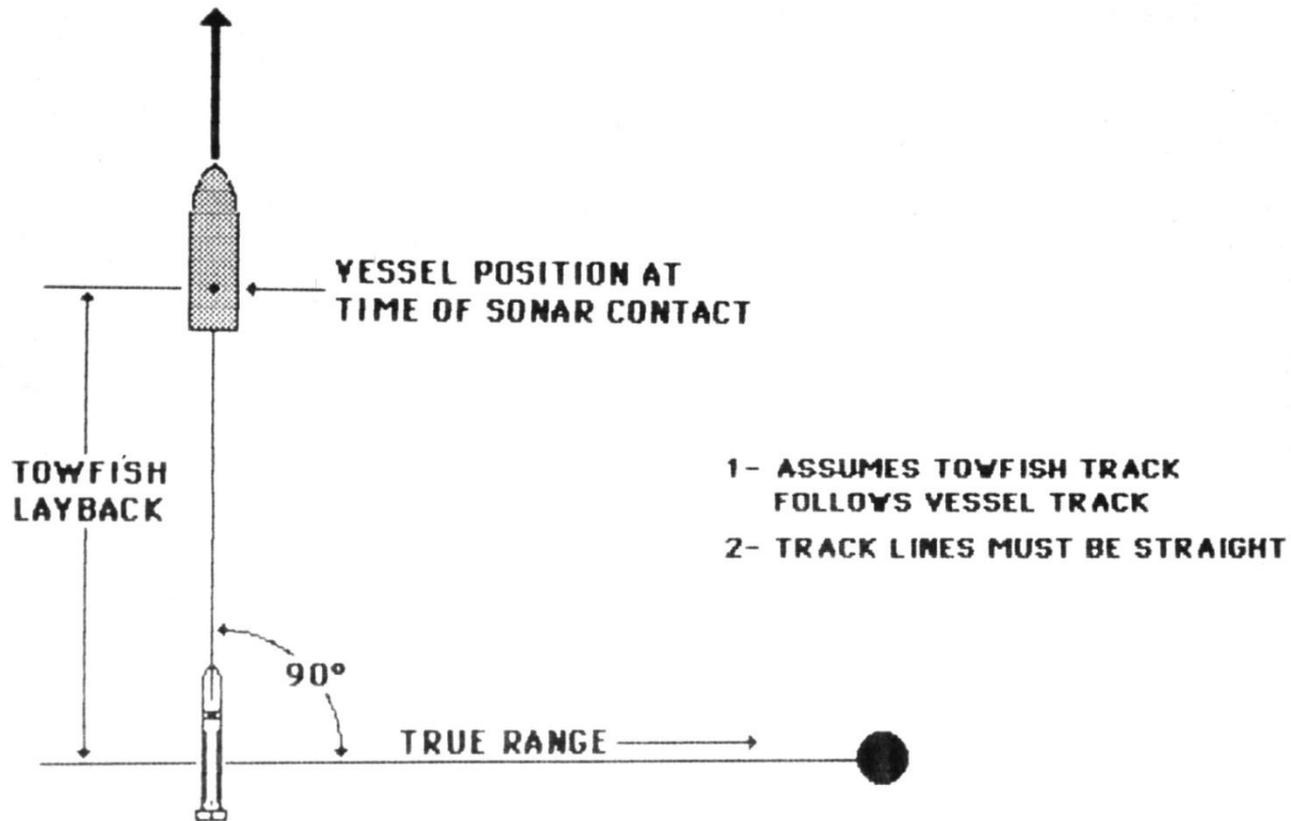
IV. Field Operations

Only Good Data is Straight Line Survey Data



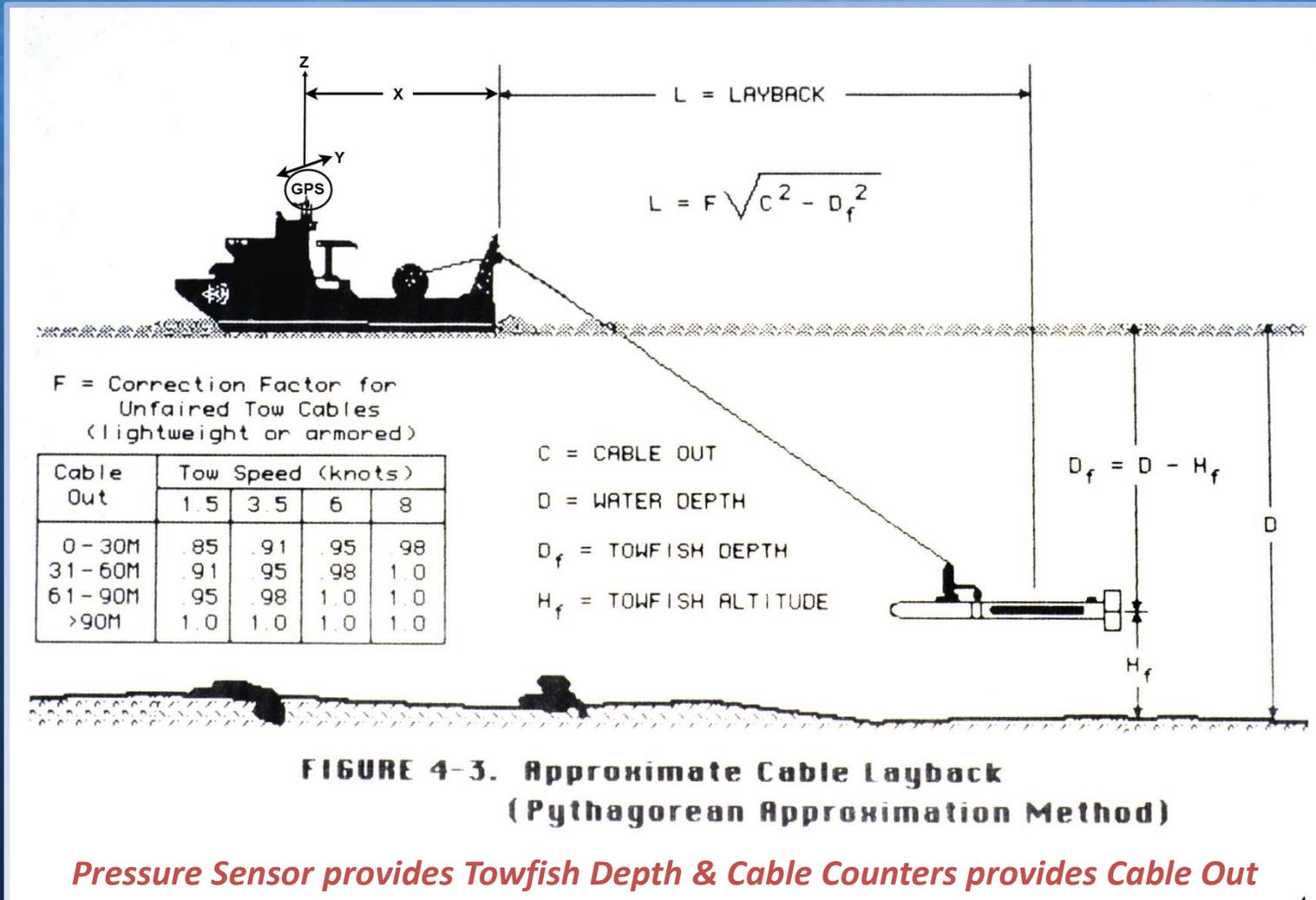
IV. Field Operations

Target Positioning by Layback



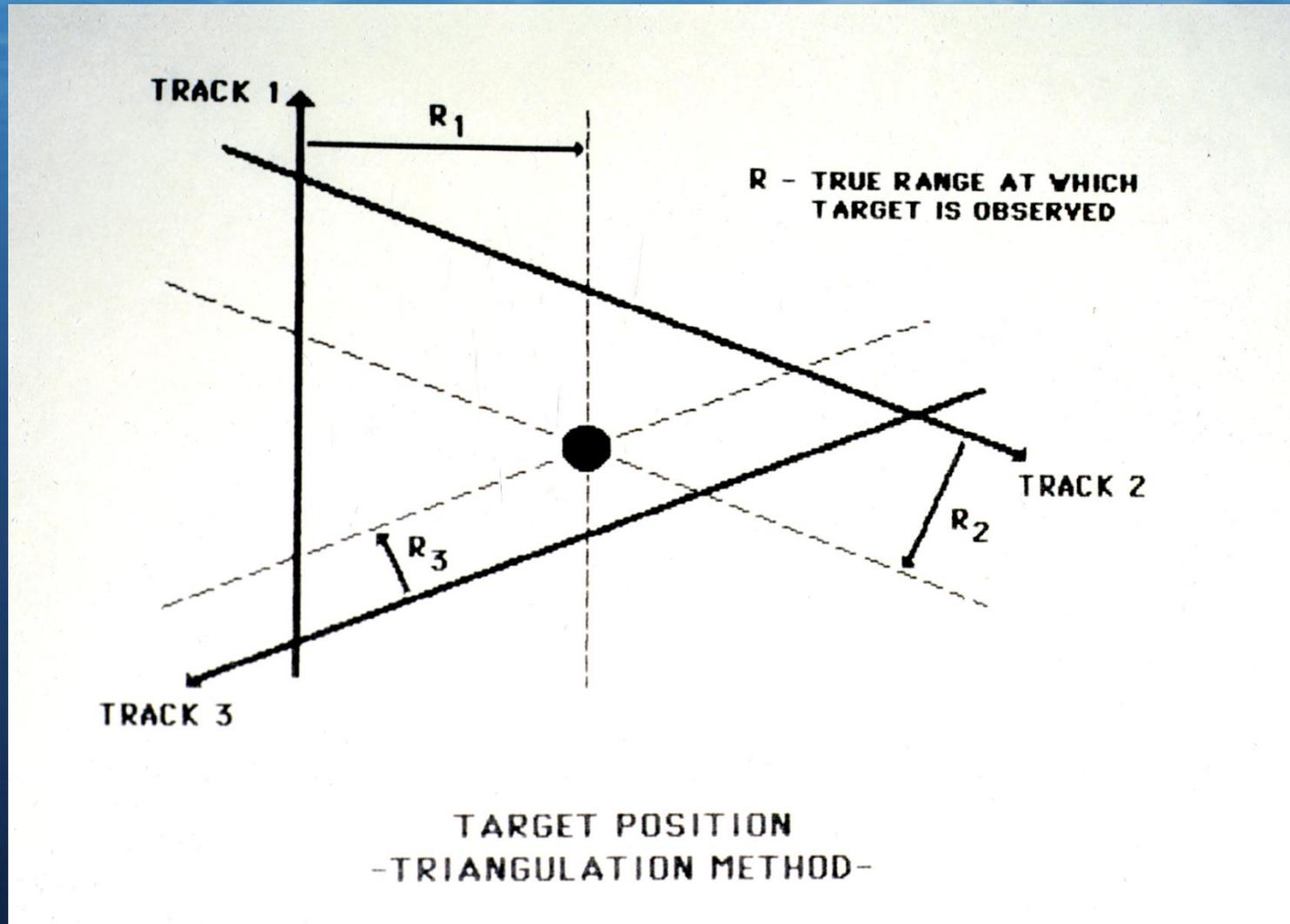
IV. Field Operations

Towfish Layback and Position



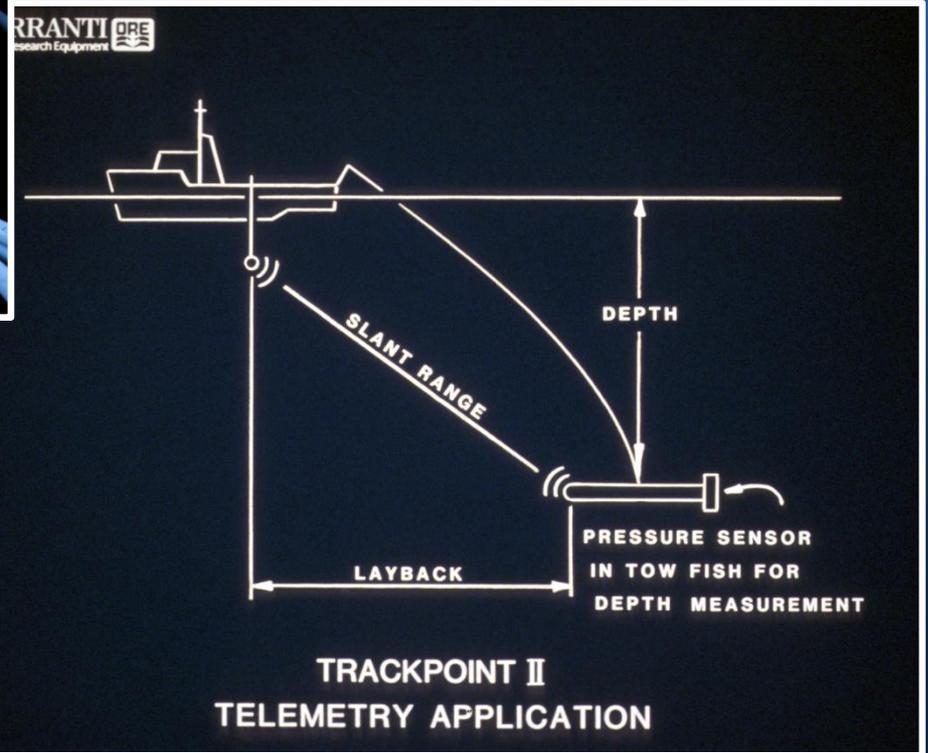
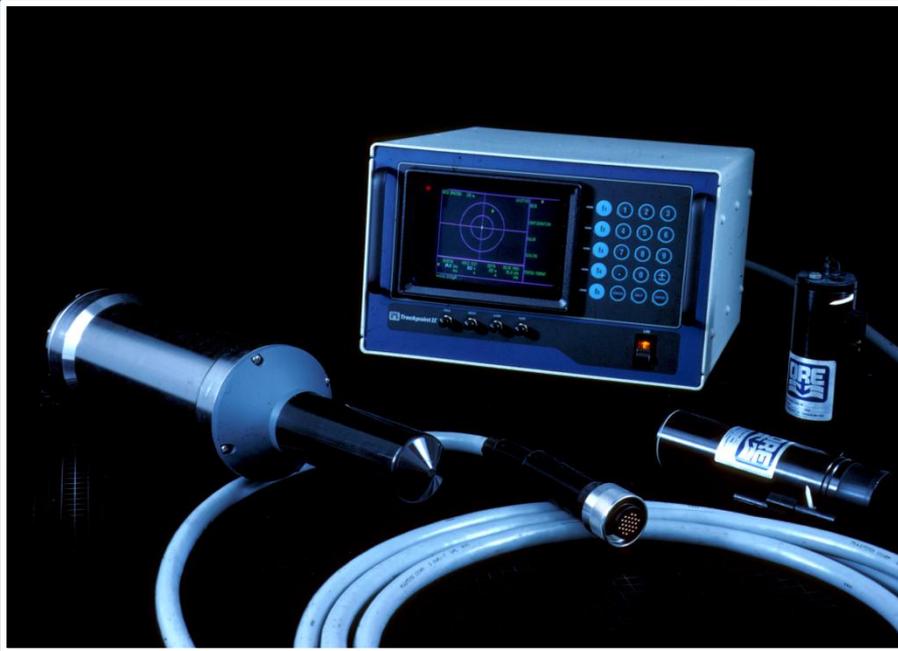
IV. Field Operations

Target Position by Triangulation



IV. Field Operations

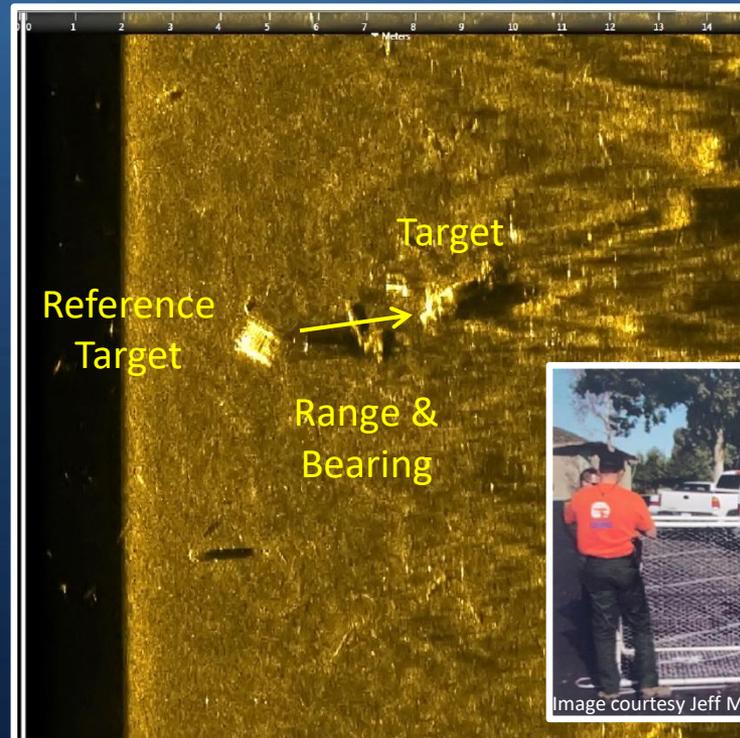
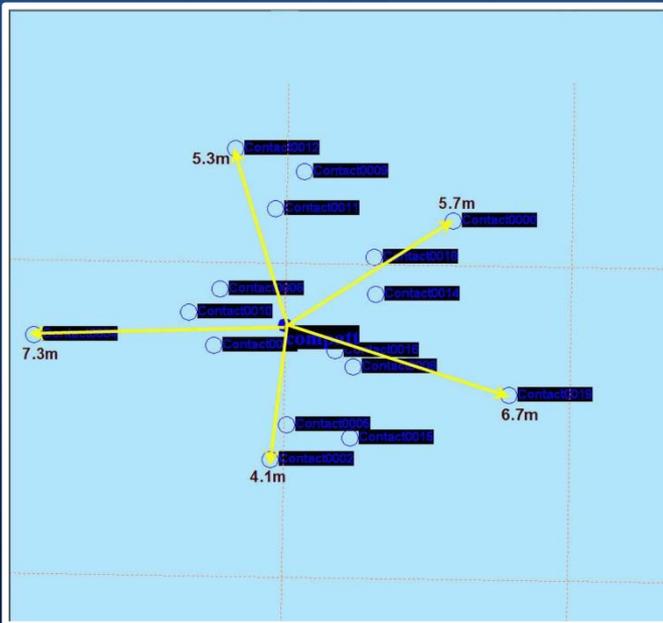
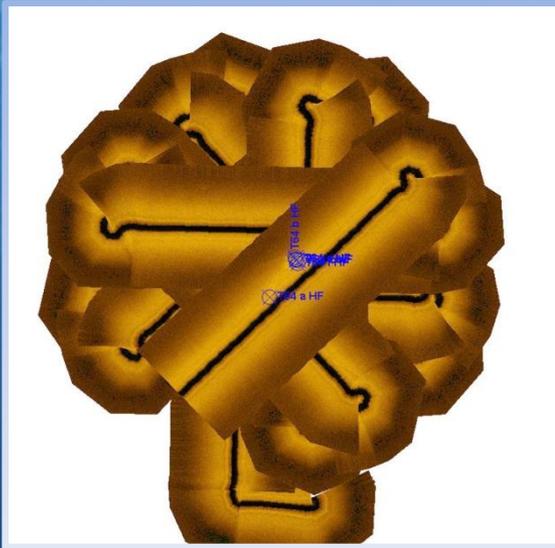
USBL Acoustic Positioning System



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



IV. Field Operations



Deep Tow Winch with 10,000 meters of tow cable

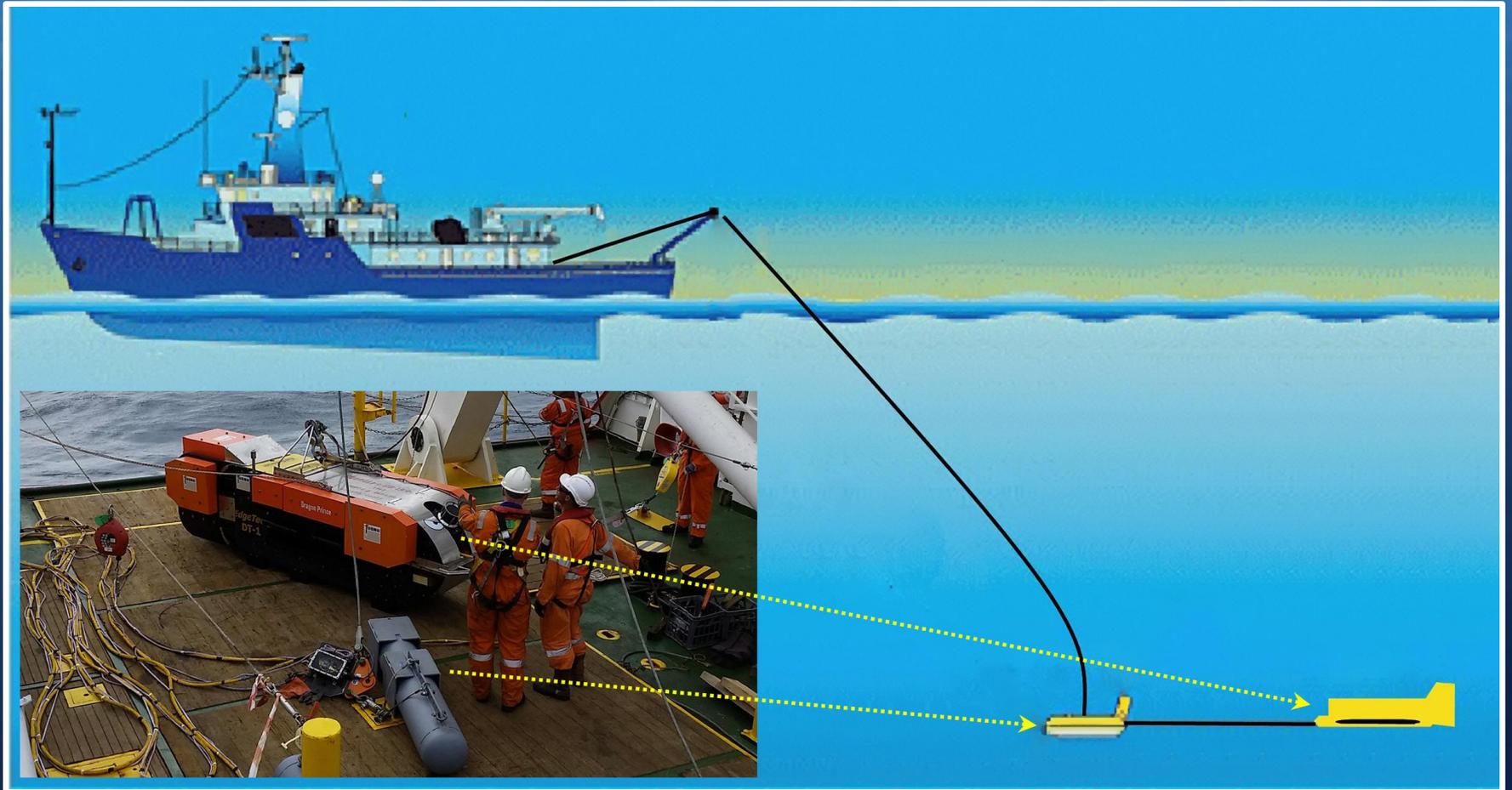
Deep Tows – A Dying Breed

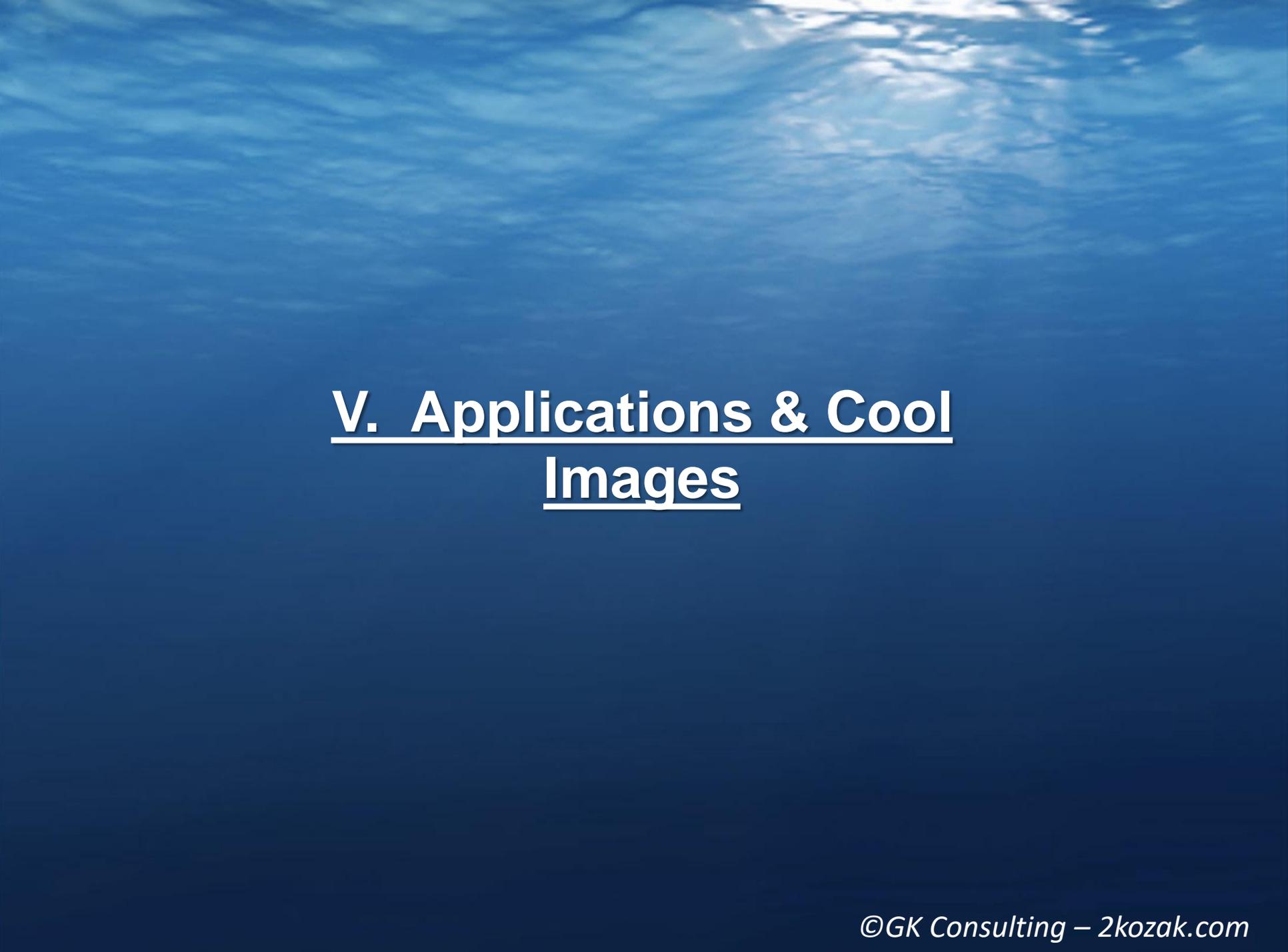
6000 meter Rated Deep Tow with INS, DVL, & Acoustic Positioning



IV. Field Operations

Deep 2 Part Tows





V. Applications & Cool Images

V. Applications



Search - Shipwrecks

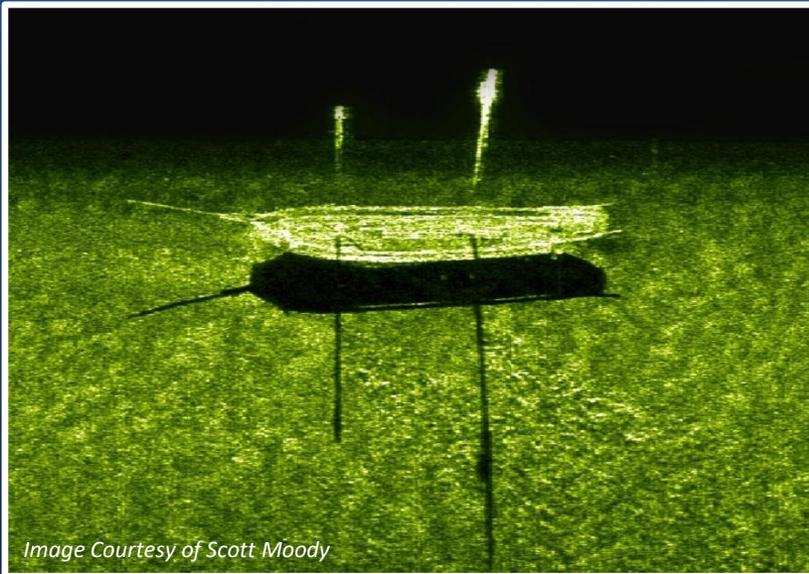
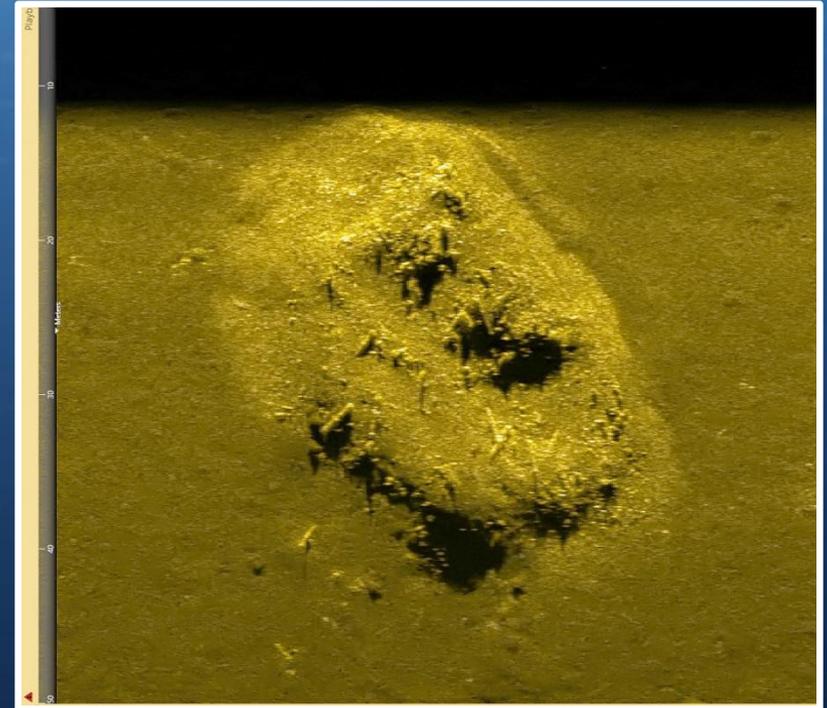
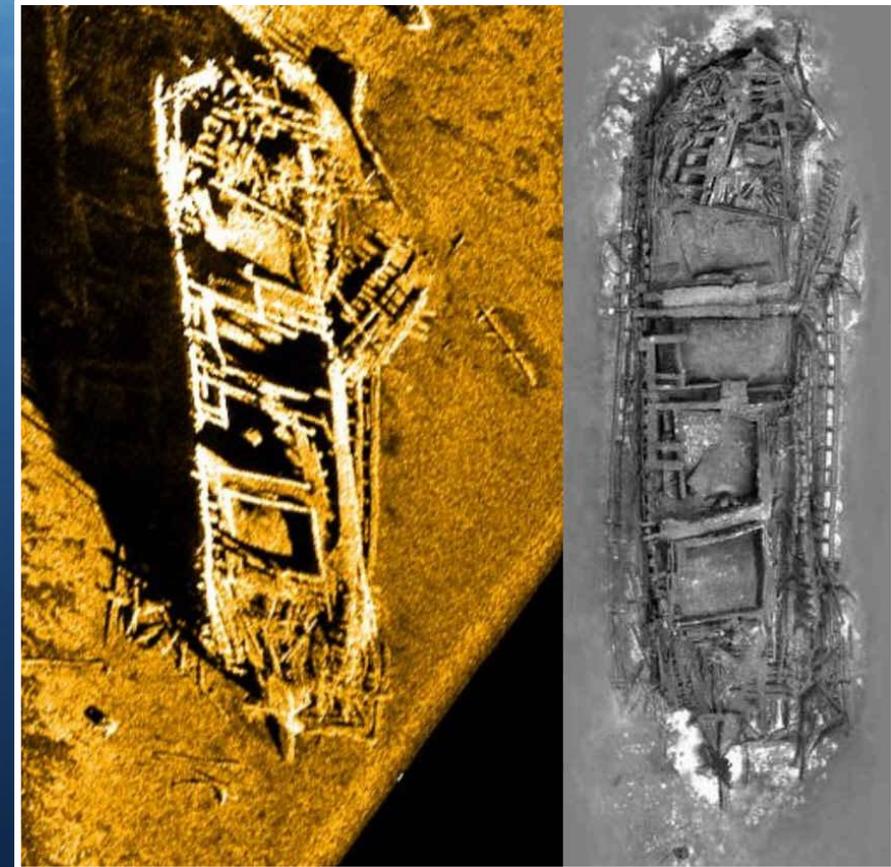
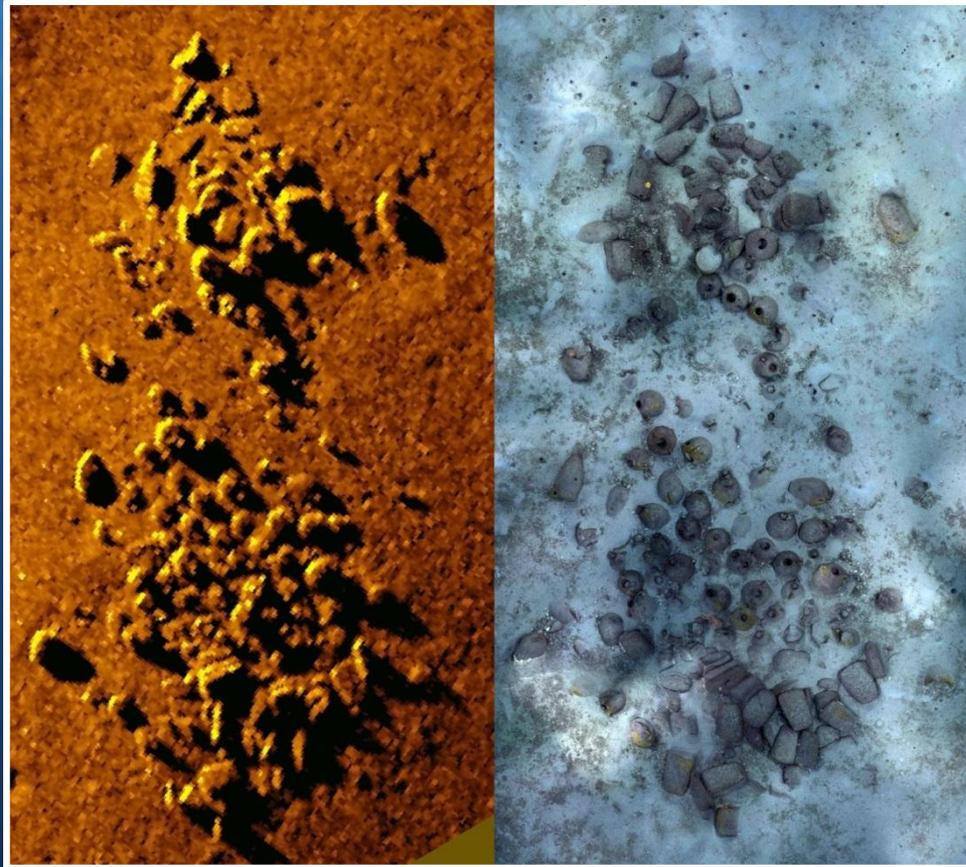


Image Courtesy of Scott Moody

V. Applications

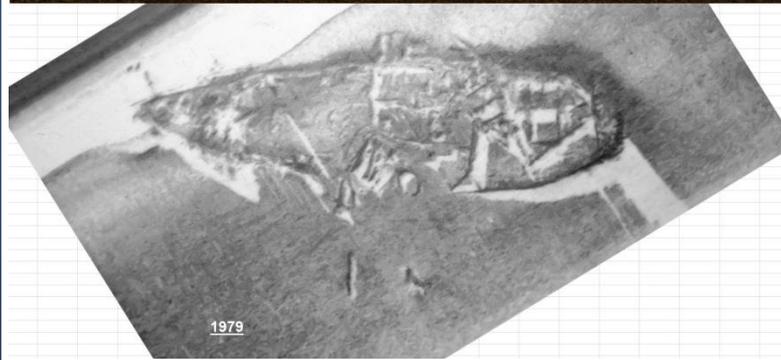
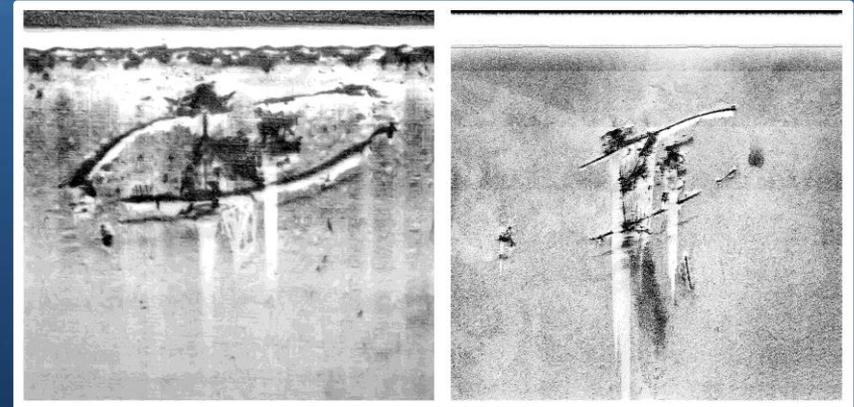
Shipwreck Comparison Of SSS Image to Camera Image



V. Applications

Search - Shipwrecks

An ongoing philosophy of the underwater archeological community is that the best preservation and protection of cultural resources/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

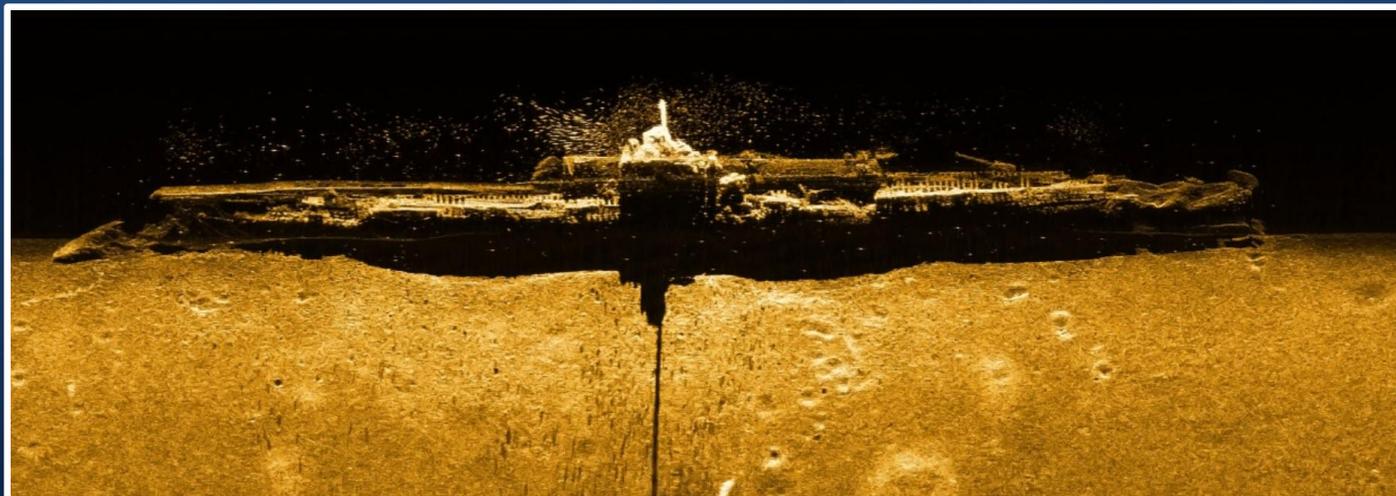
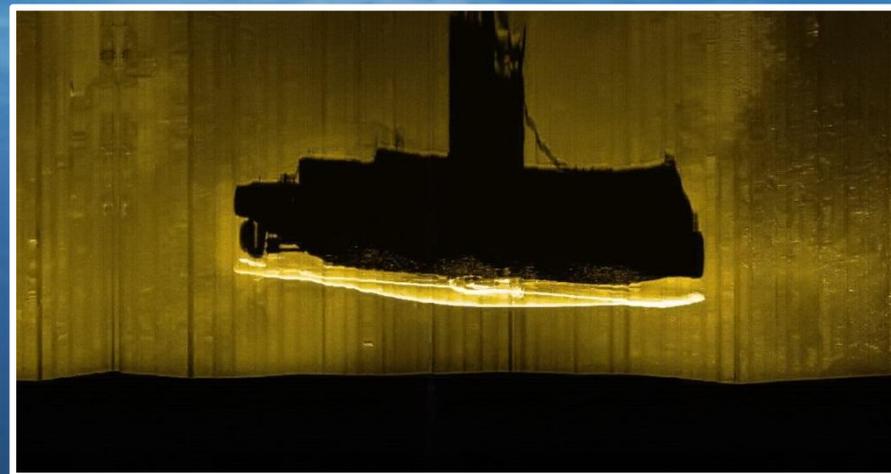
Though a MB system produces both point cloud and backscatter data, the resolution and acoustic shadowing ability is less especially in a cluttered seafloor. They work well in shallow benign seafloors but are not efficient in deep or geologically cluttered seafloors.

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

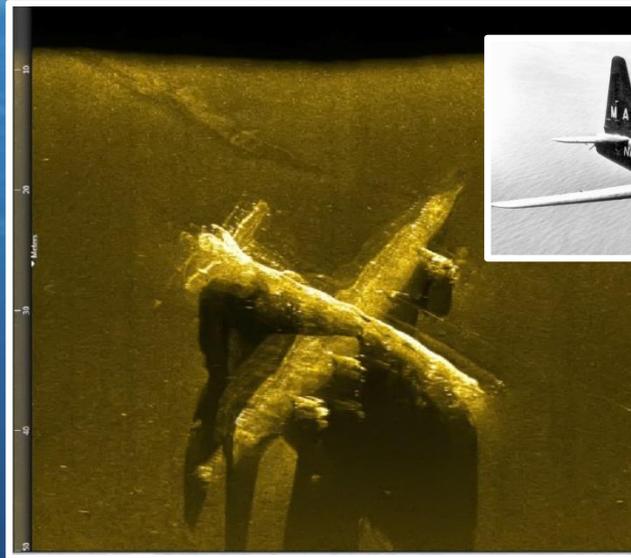


V. Applications

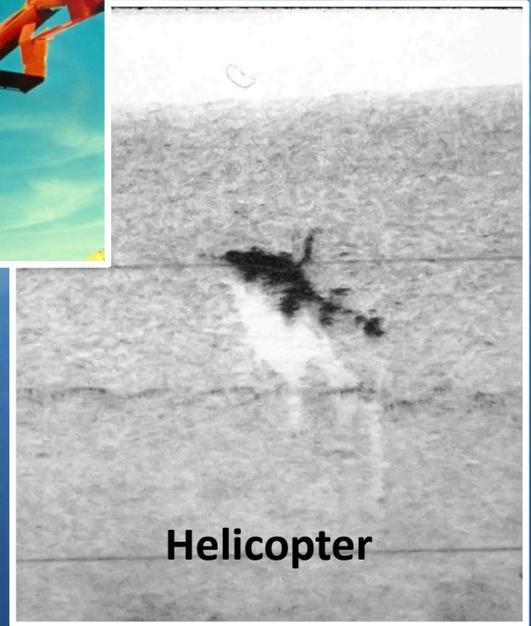
Search - Submarines



V. Applications



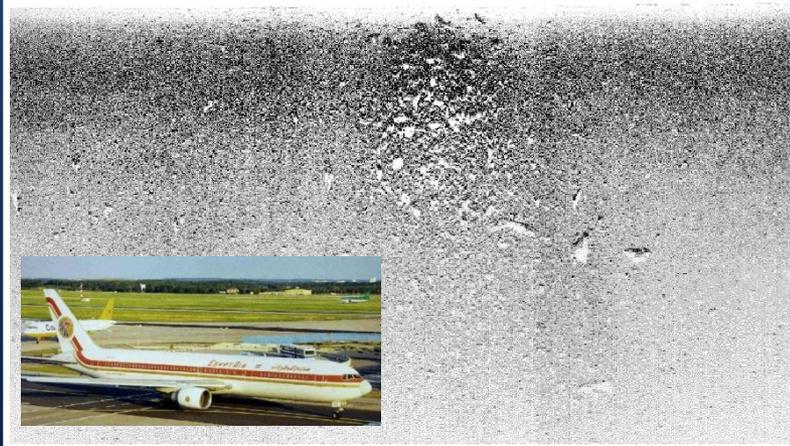
PB4Y



Helicopter

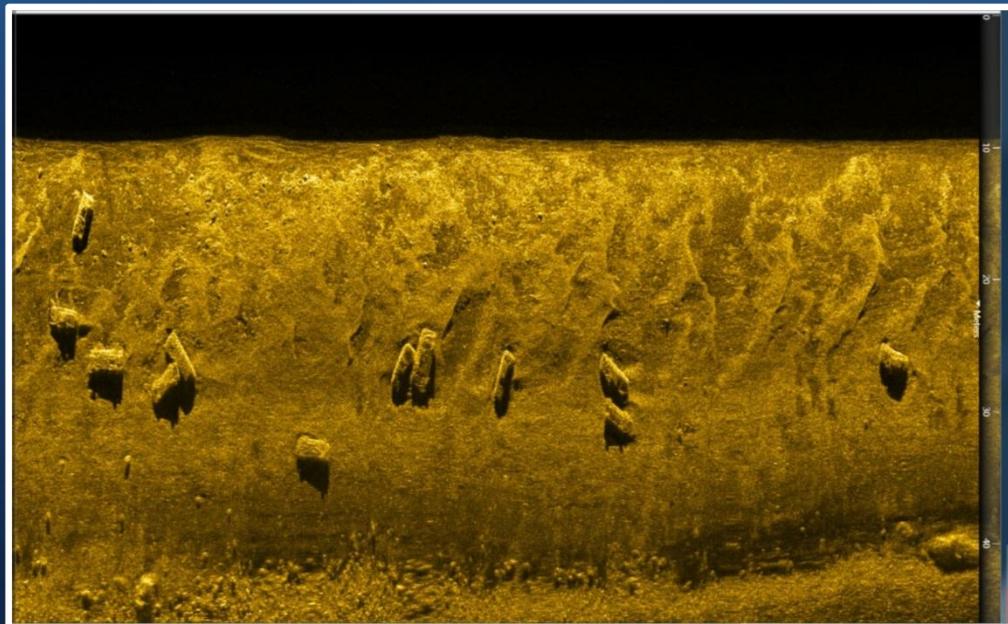
Search - Aircraft

767 Airplane Crash



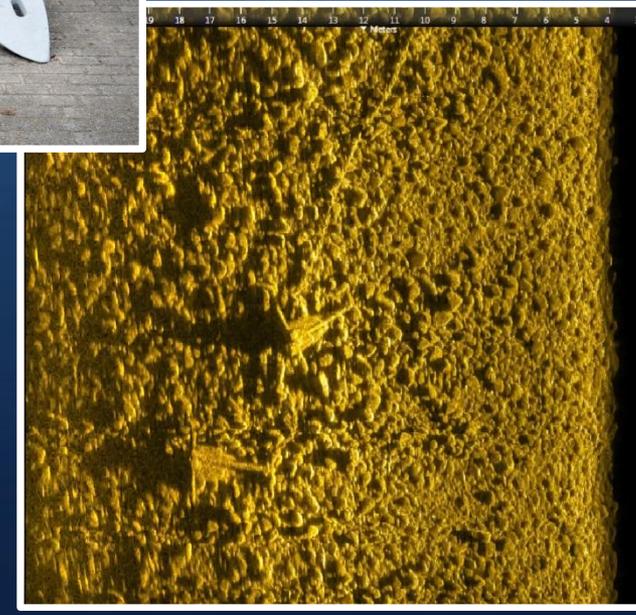
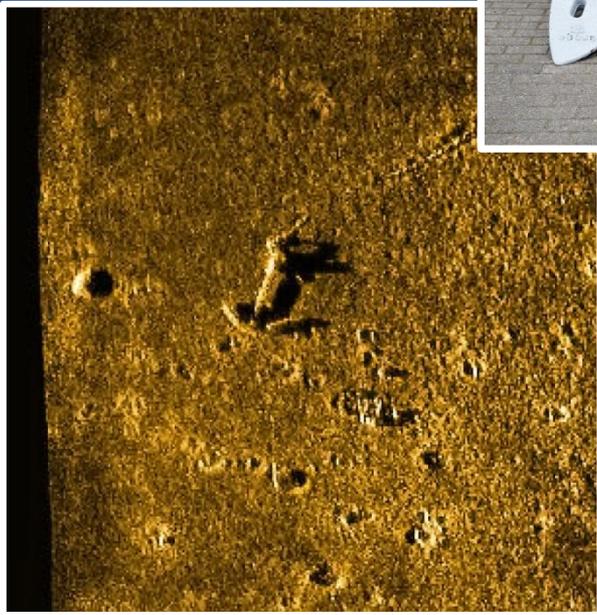
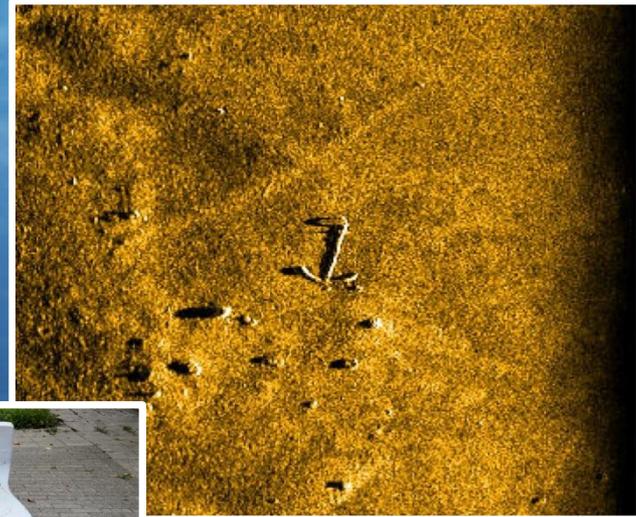
V. Applications

Search - Automobiles



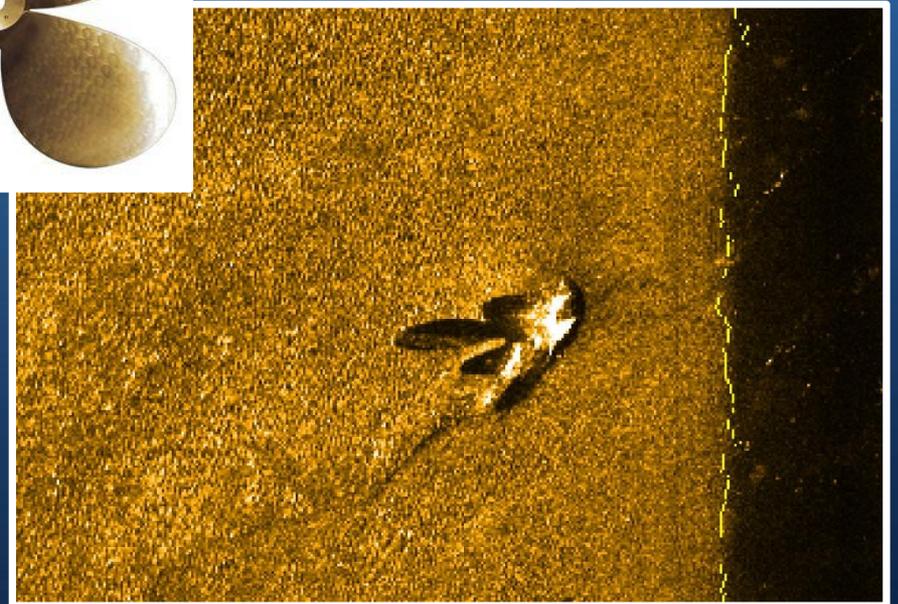
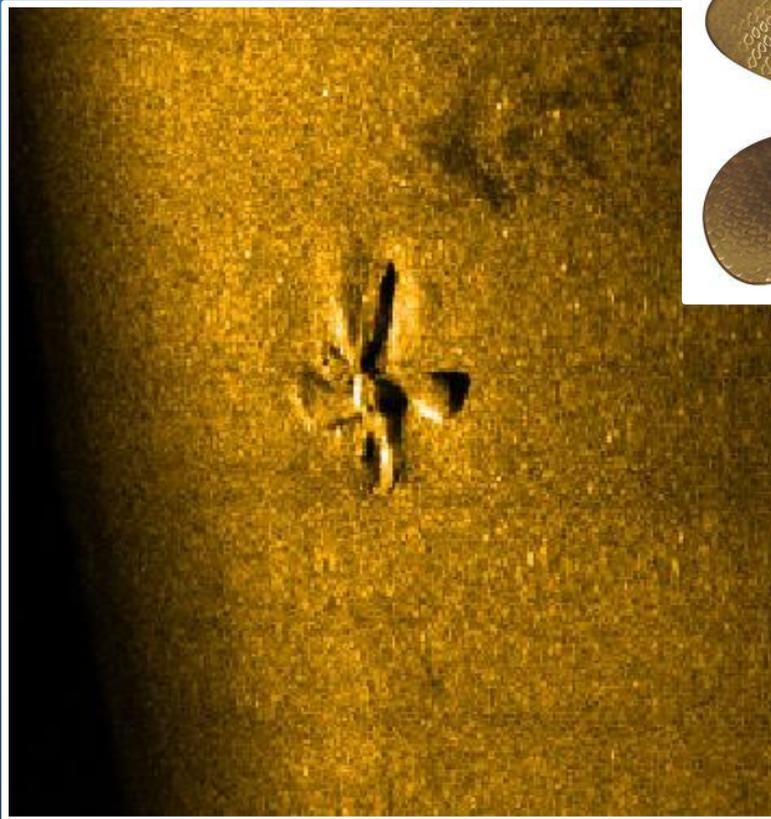
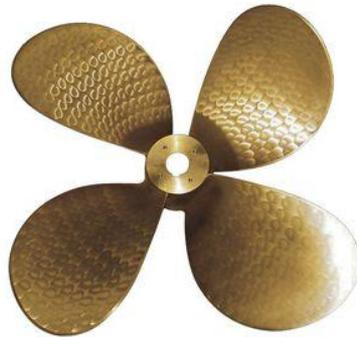
V. Applications

Search - Anchors



V. Applications

Search – Lost Propellers



V. Applications

Search – Barrels / Hazardous Waste

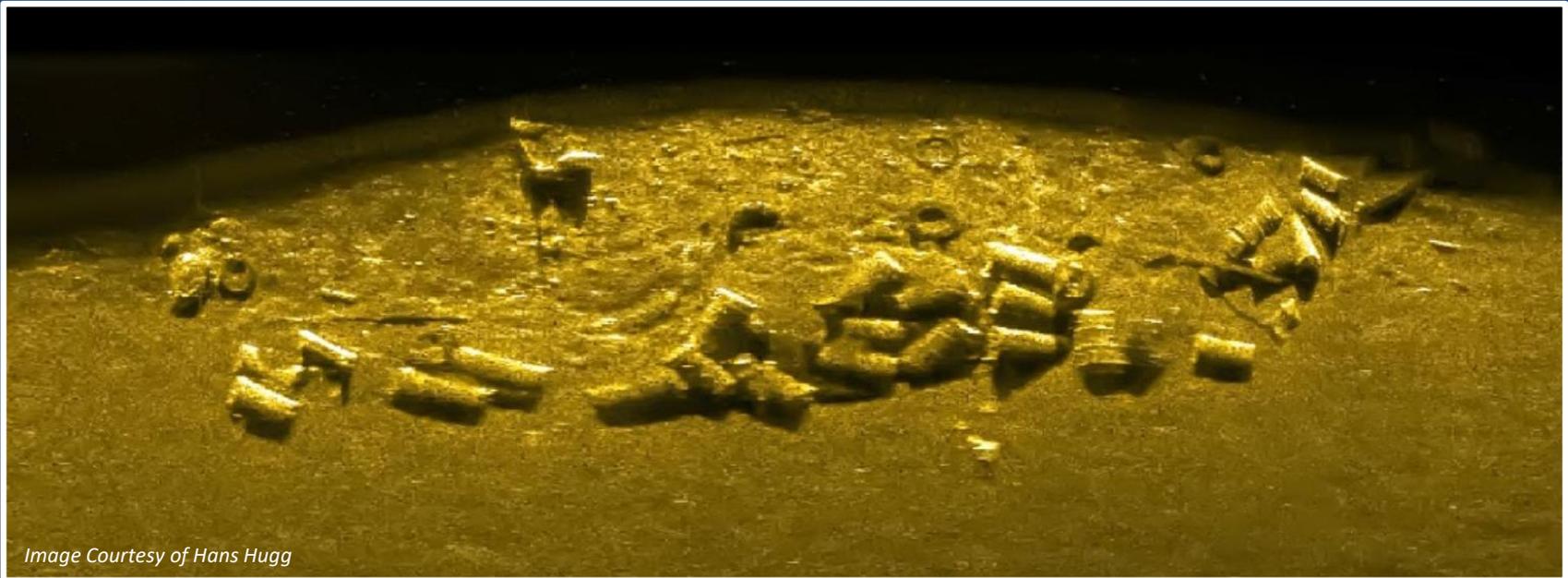
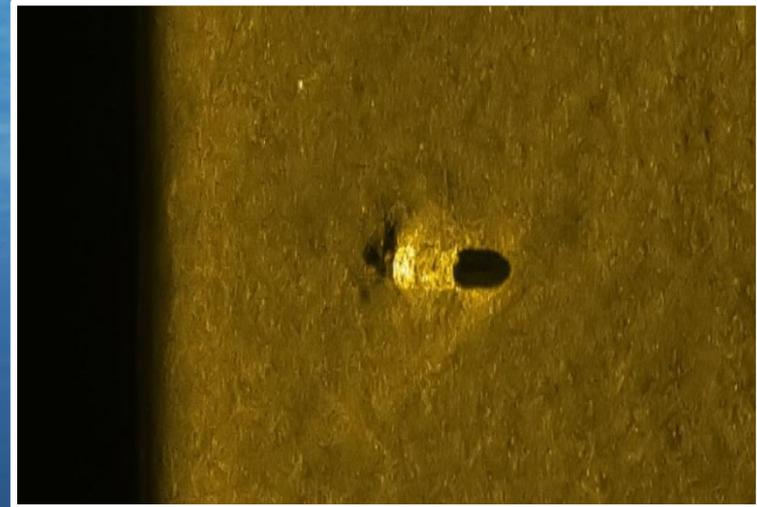
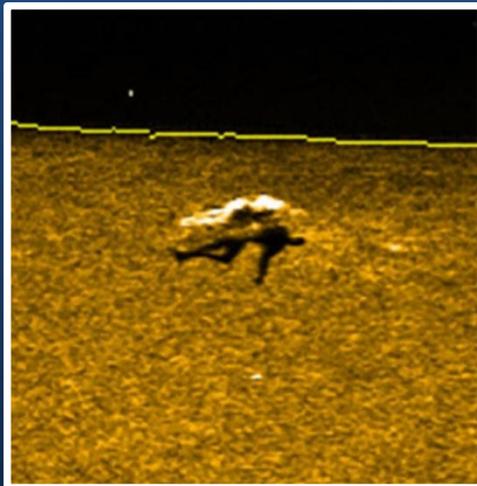
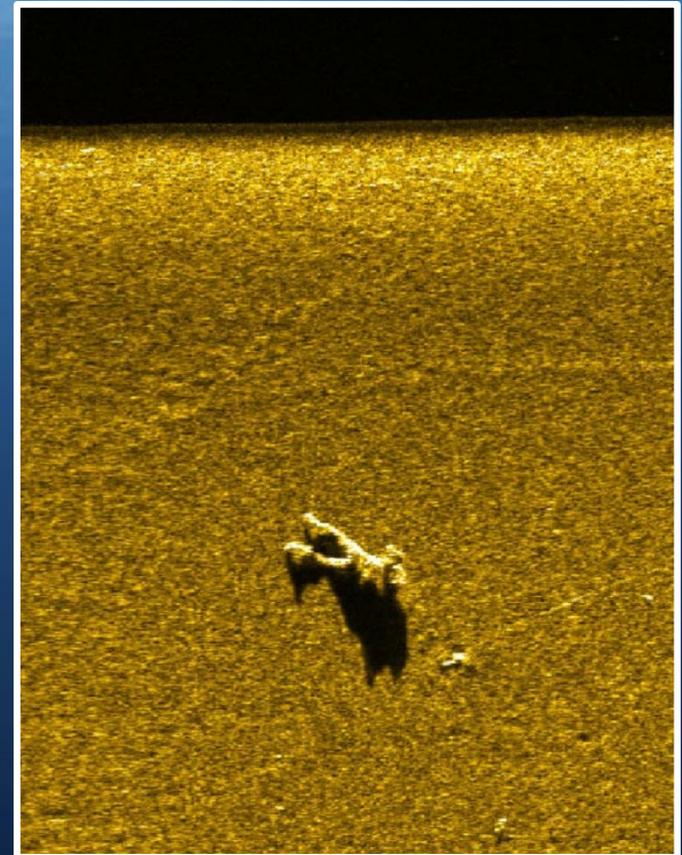
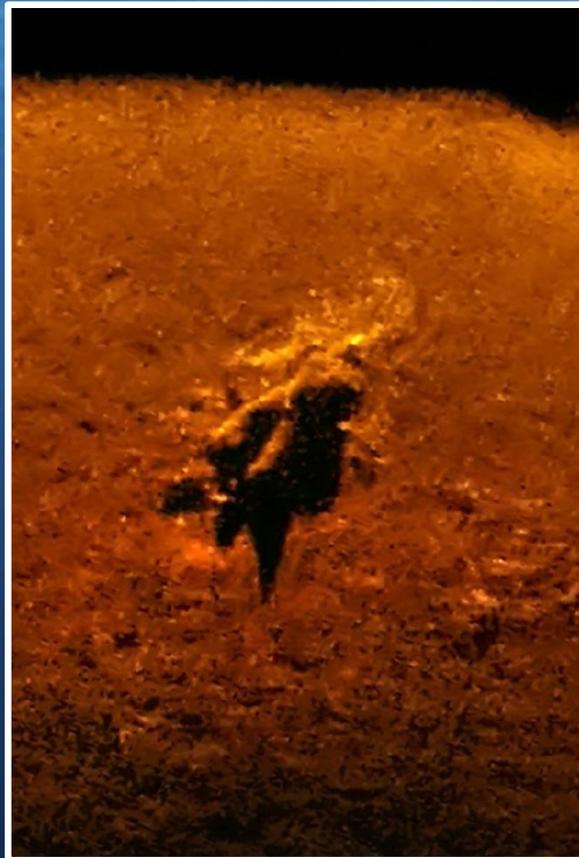


Image Courtesy of Hans Hugg

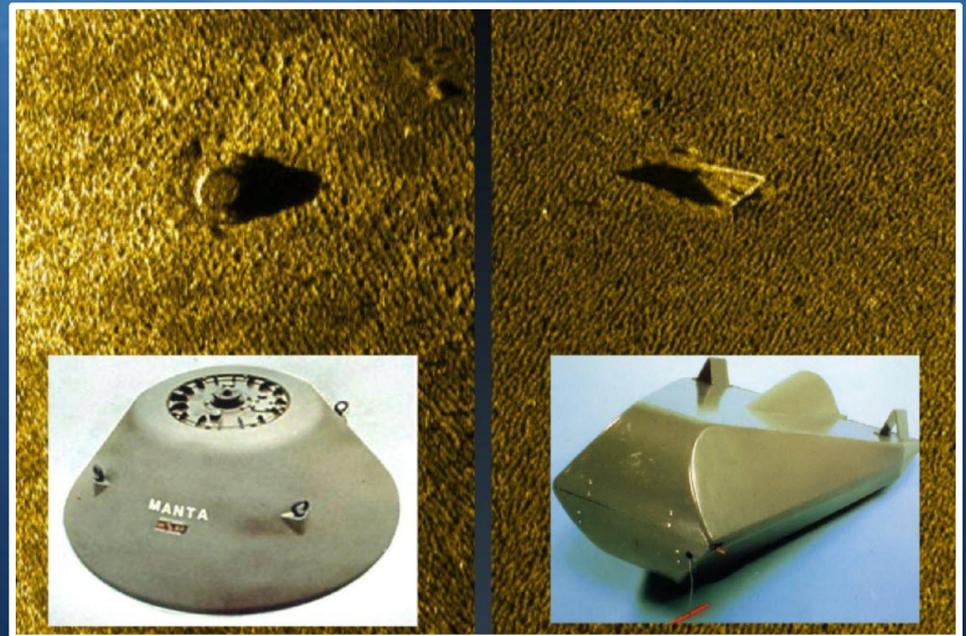
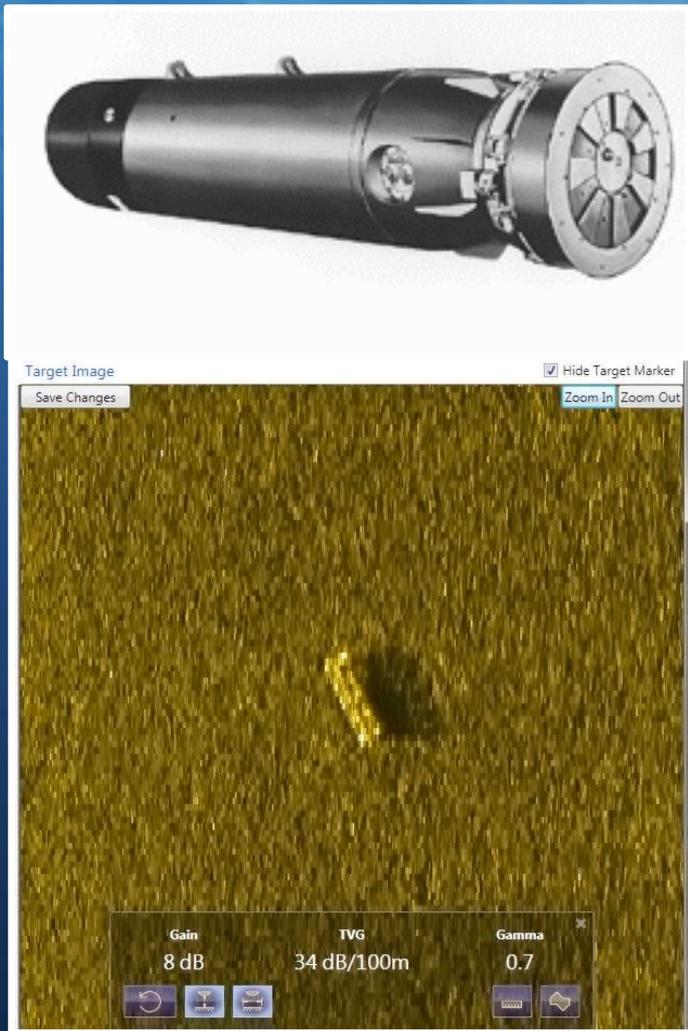
V. Applications

Search – Drowning Victims



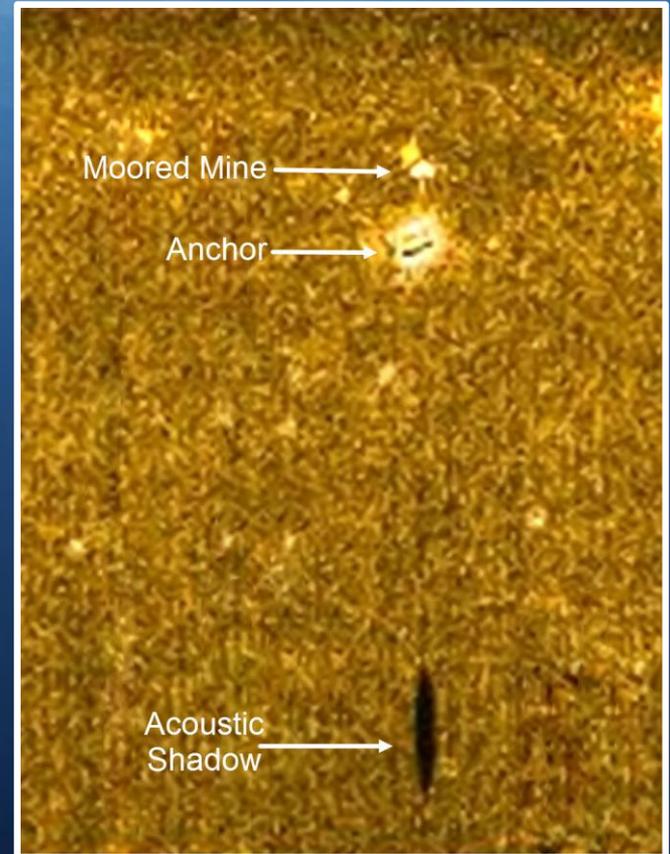
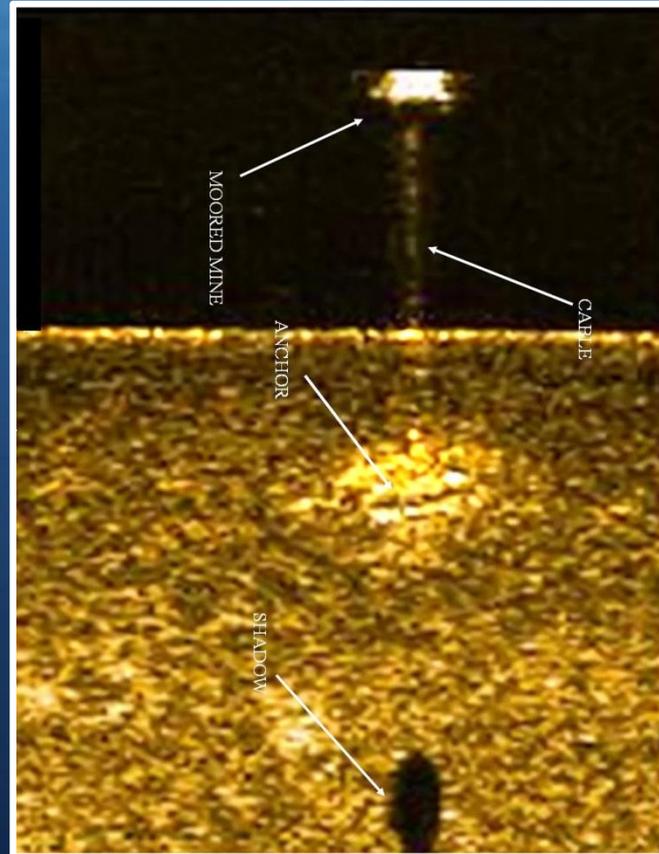
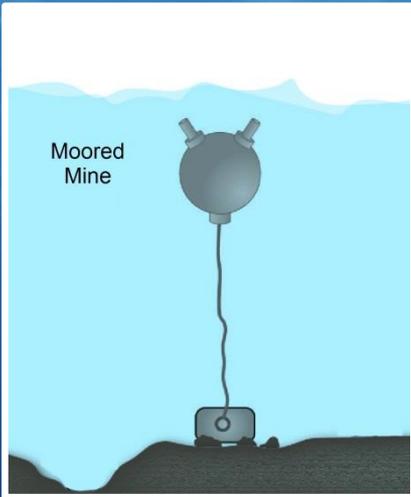
V. Applications

Search – Naval
Ground Mines



V. Applications

Search – Naval Moored Mines



V. Applications

Search -Torpedoes

Current
US Navy
Torpedoes



MK-44



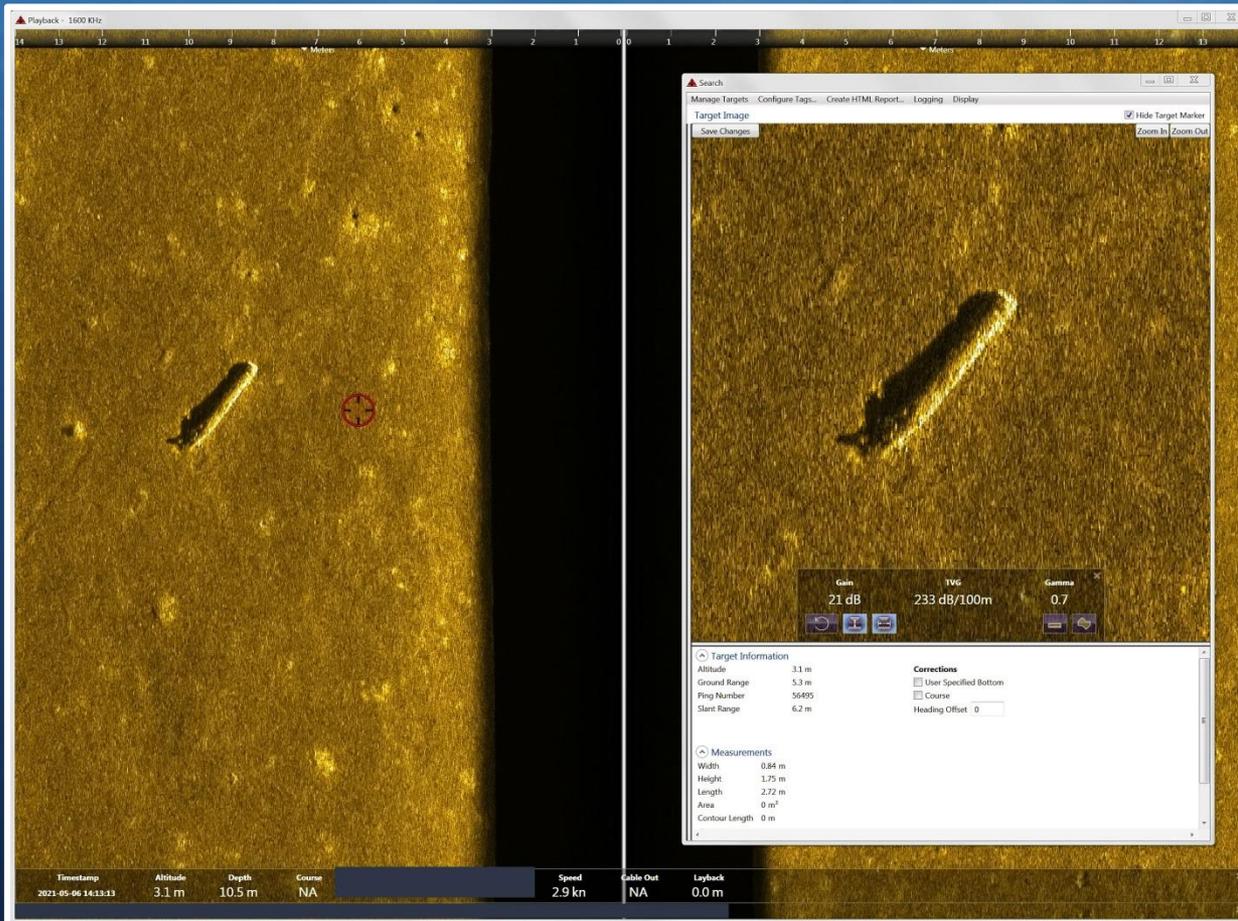
MK-46



MK-50
MK-54

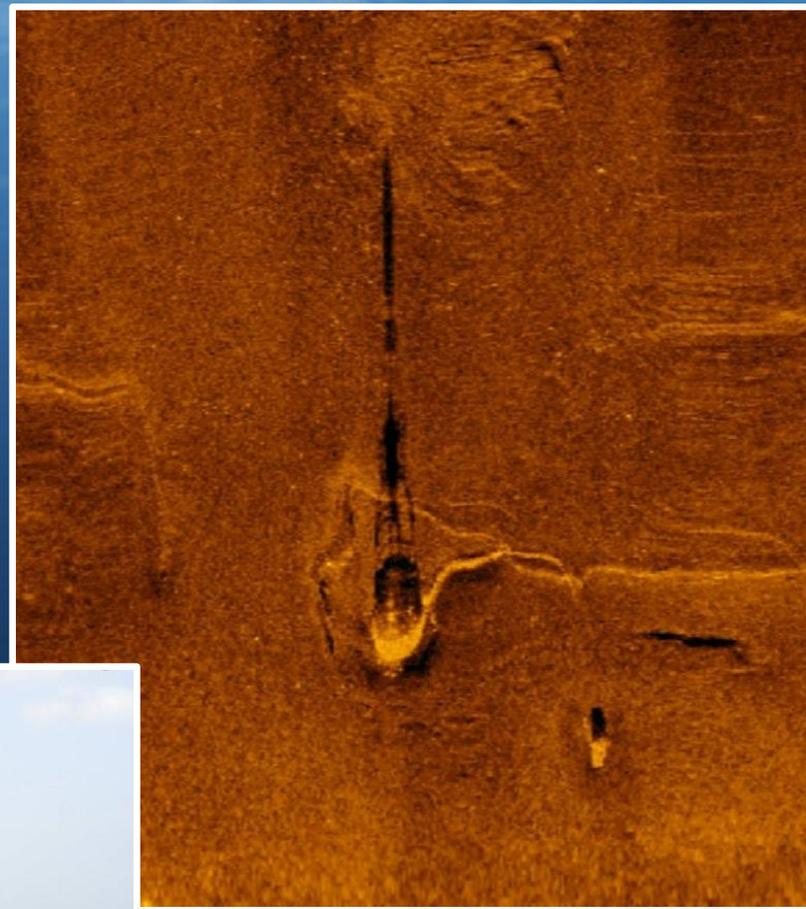
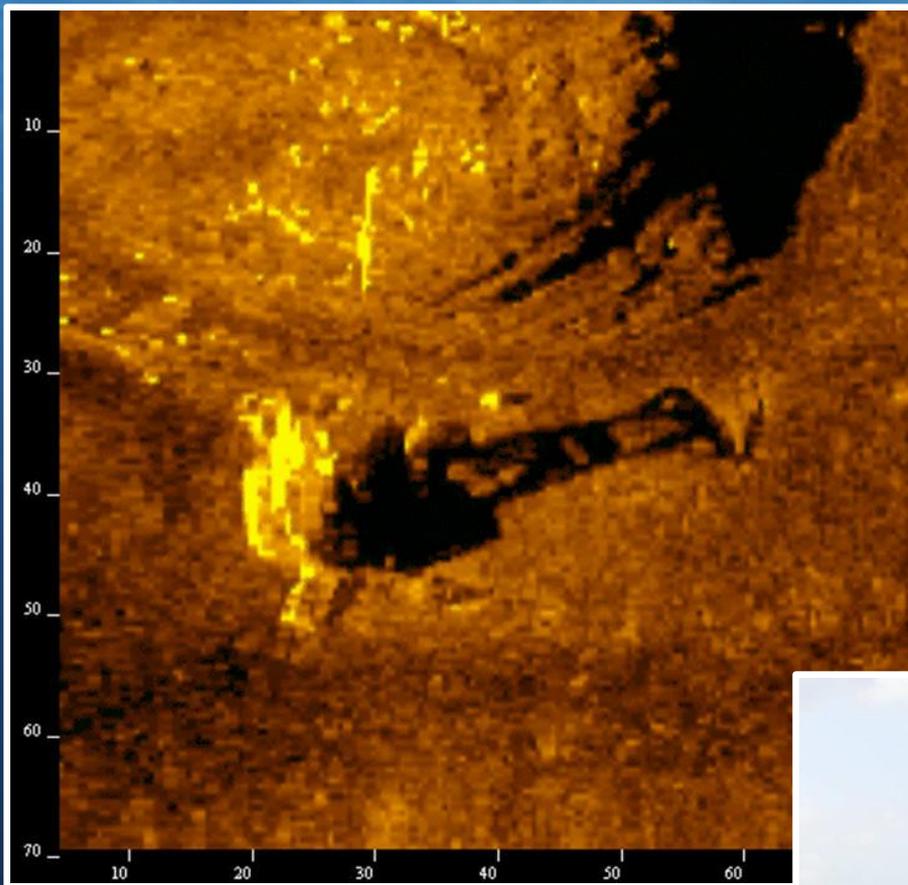


MK-48



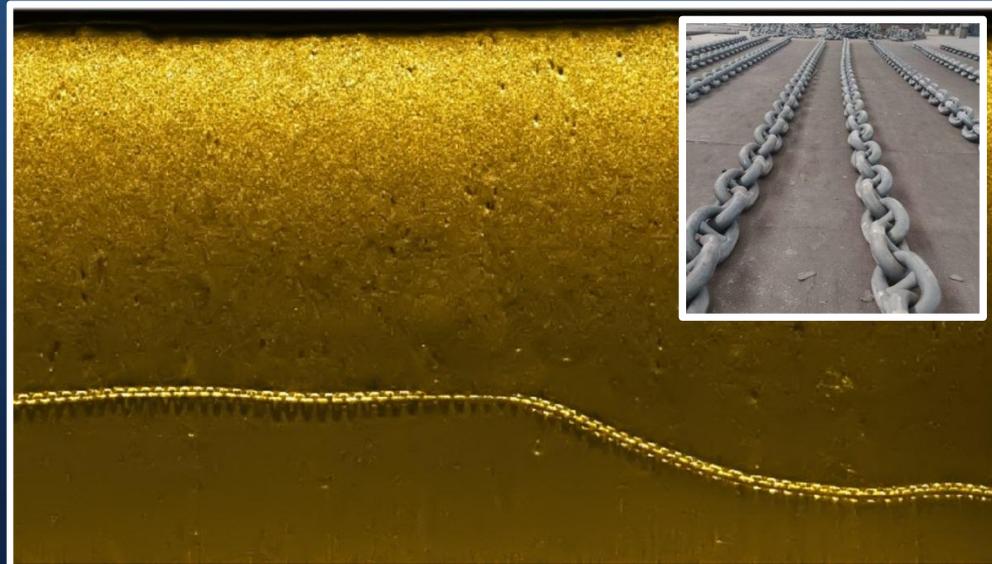
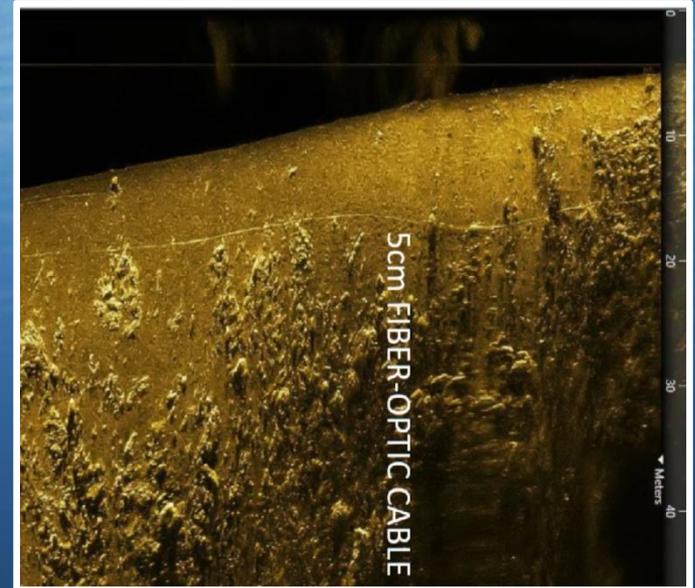
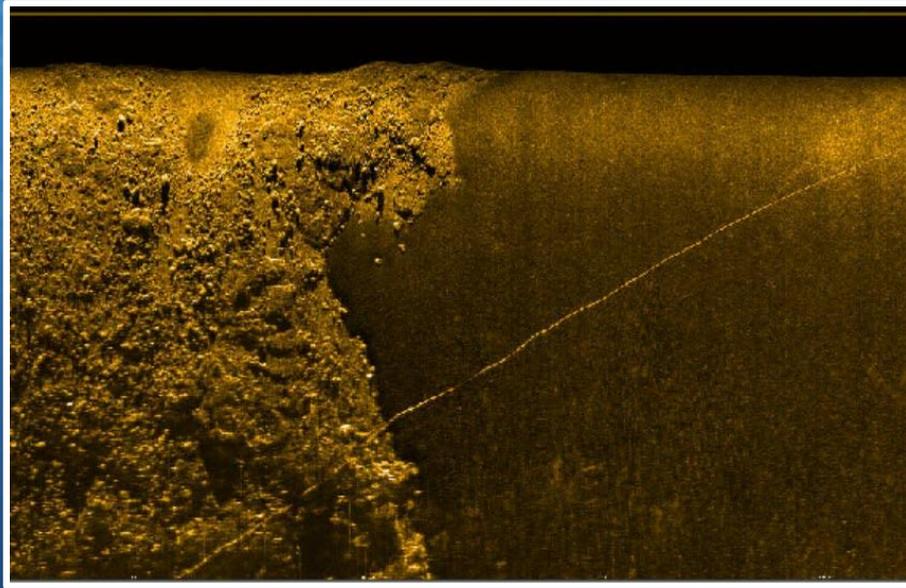
V. Applications

Search – Lost Buoys



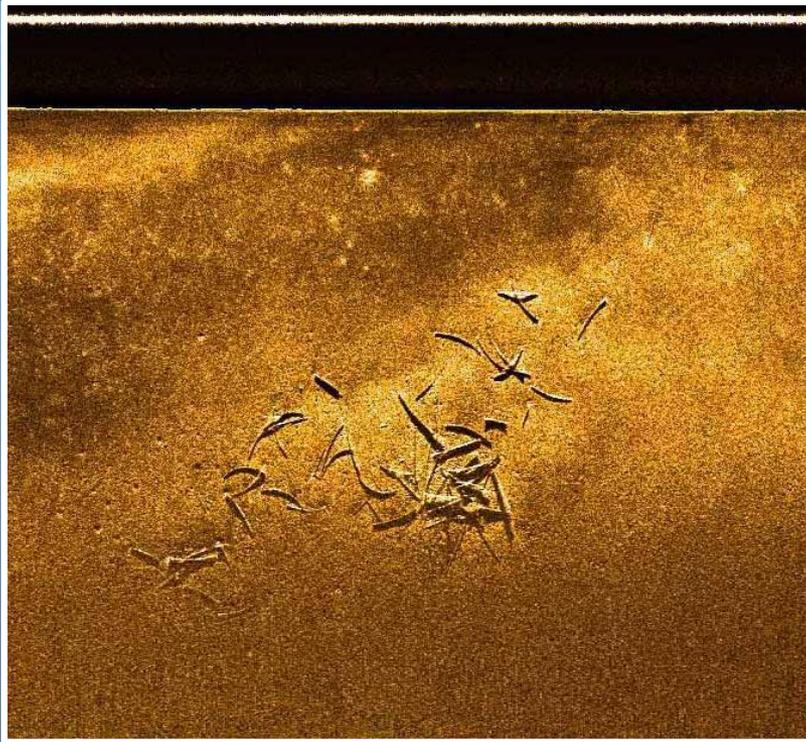
V. Applications

Search – Chain & Cables



V. Applications

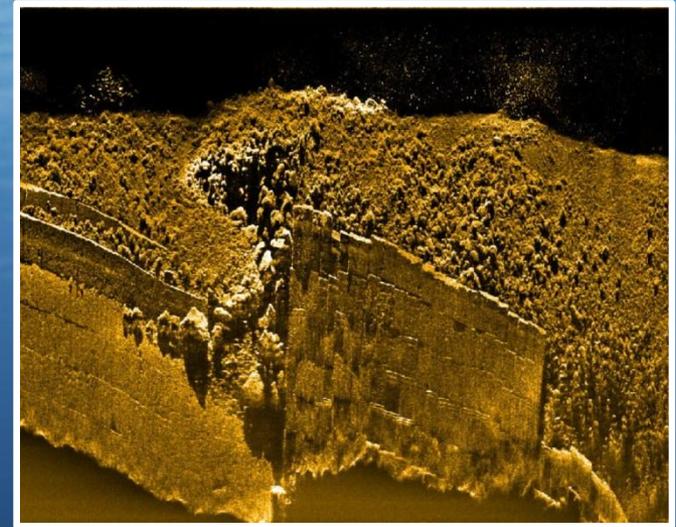
Search – Logging



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

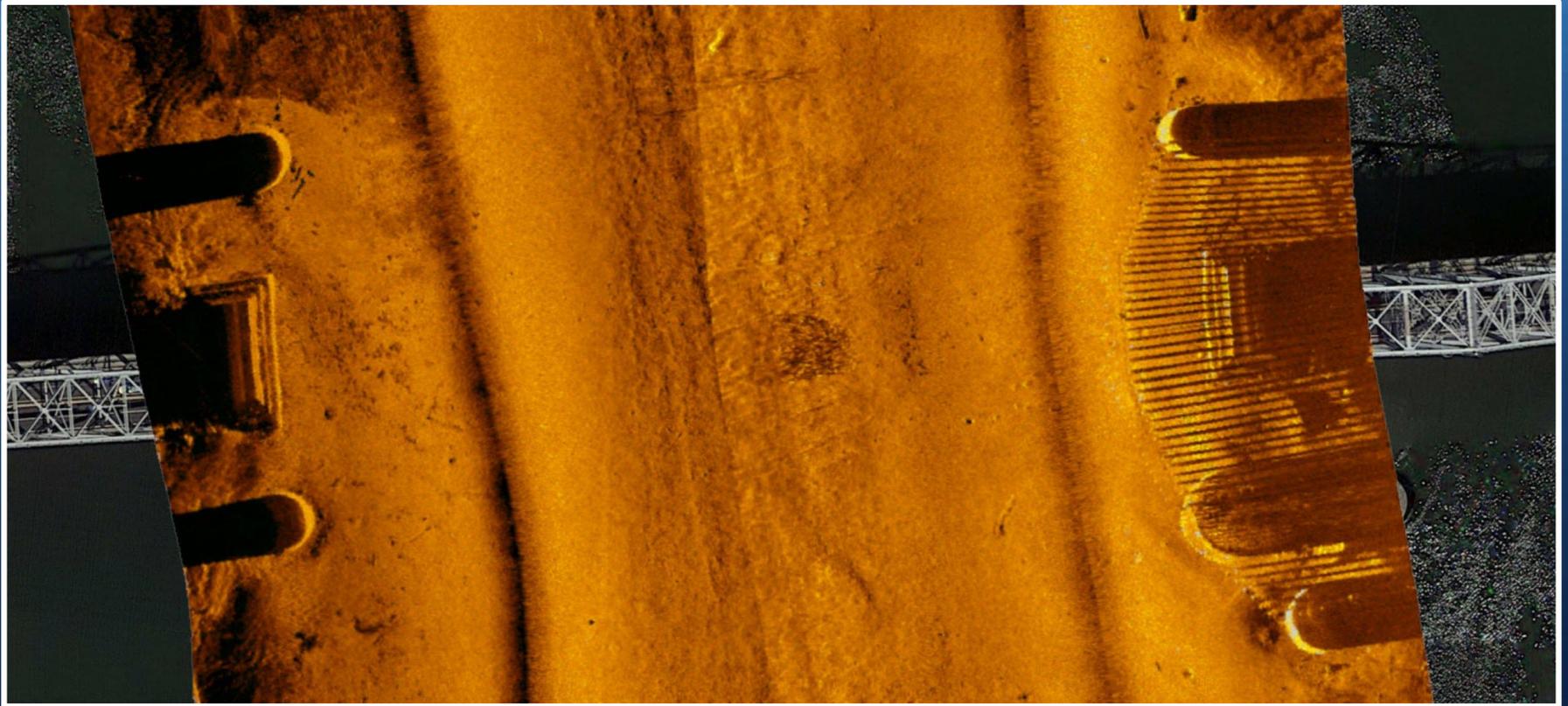
V. Applications

Structure Surveys - Breakwalls



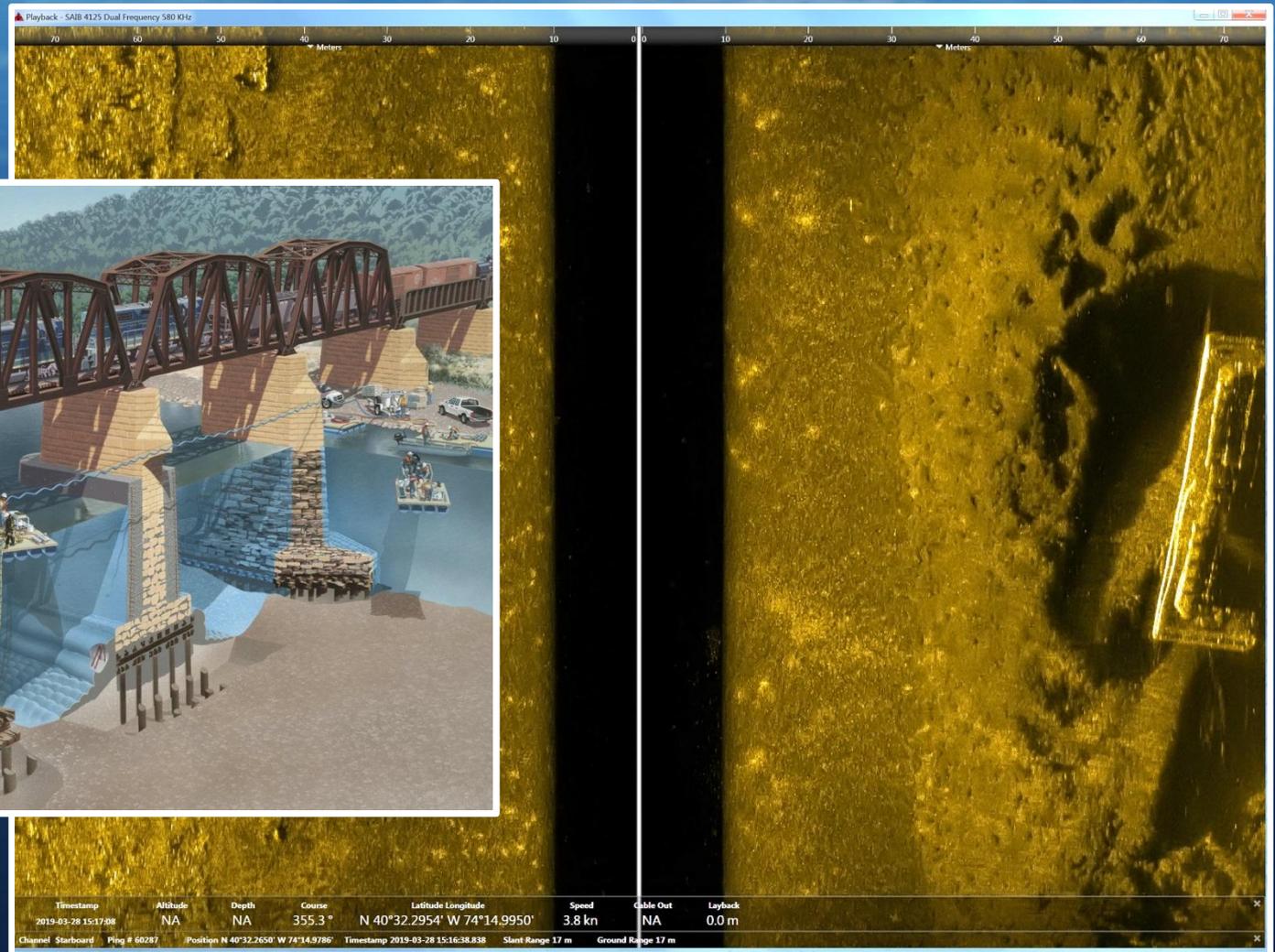
V. Applications

Structure Surveys – Bridge Footings



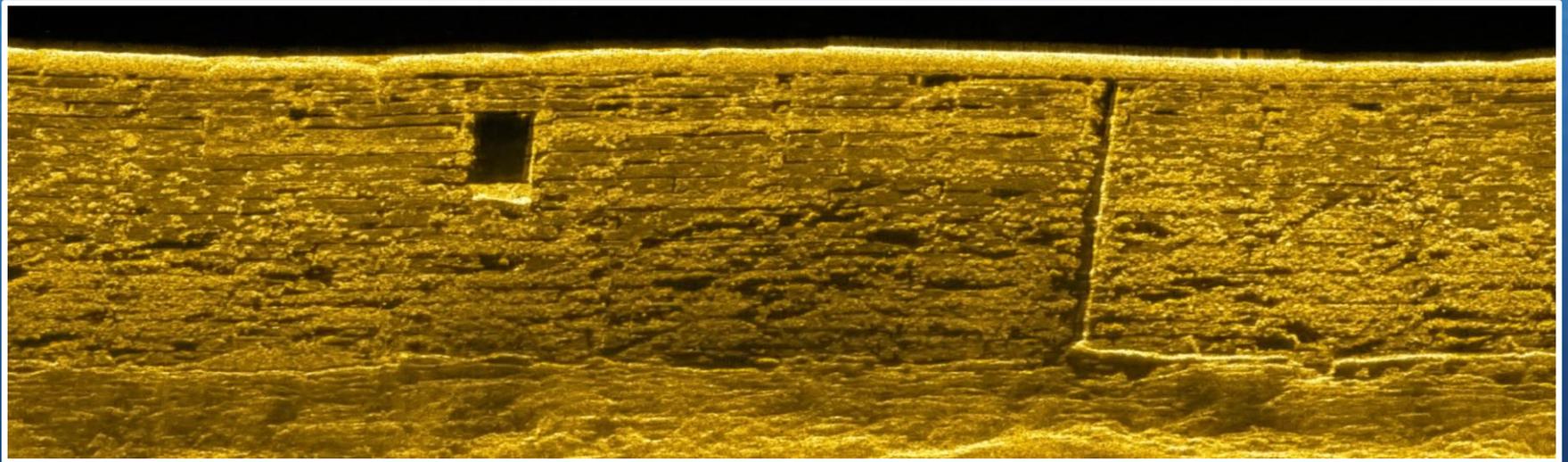
V. Applications

Structure Surveys – Bridge Footing Scour Detection



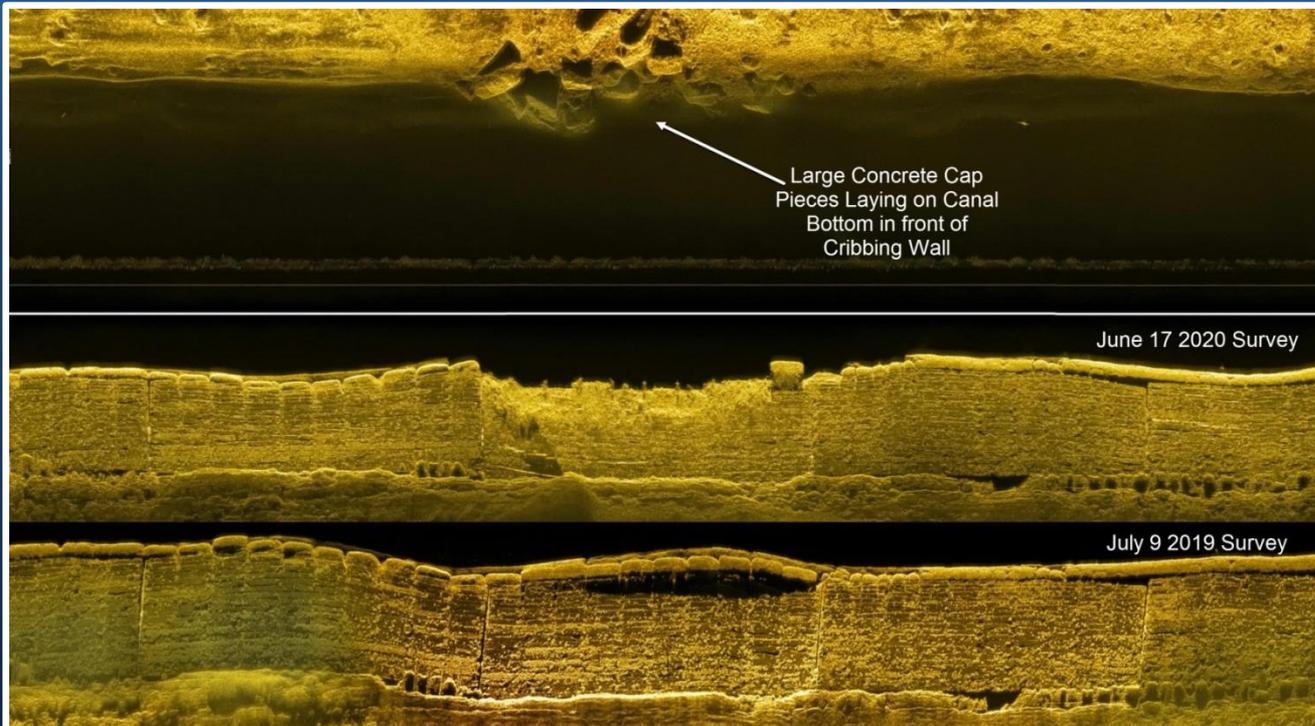
V. Applications

Structure Surveys – Vertical Dock & Pier Walls



V. Applications

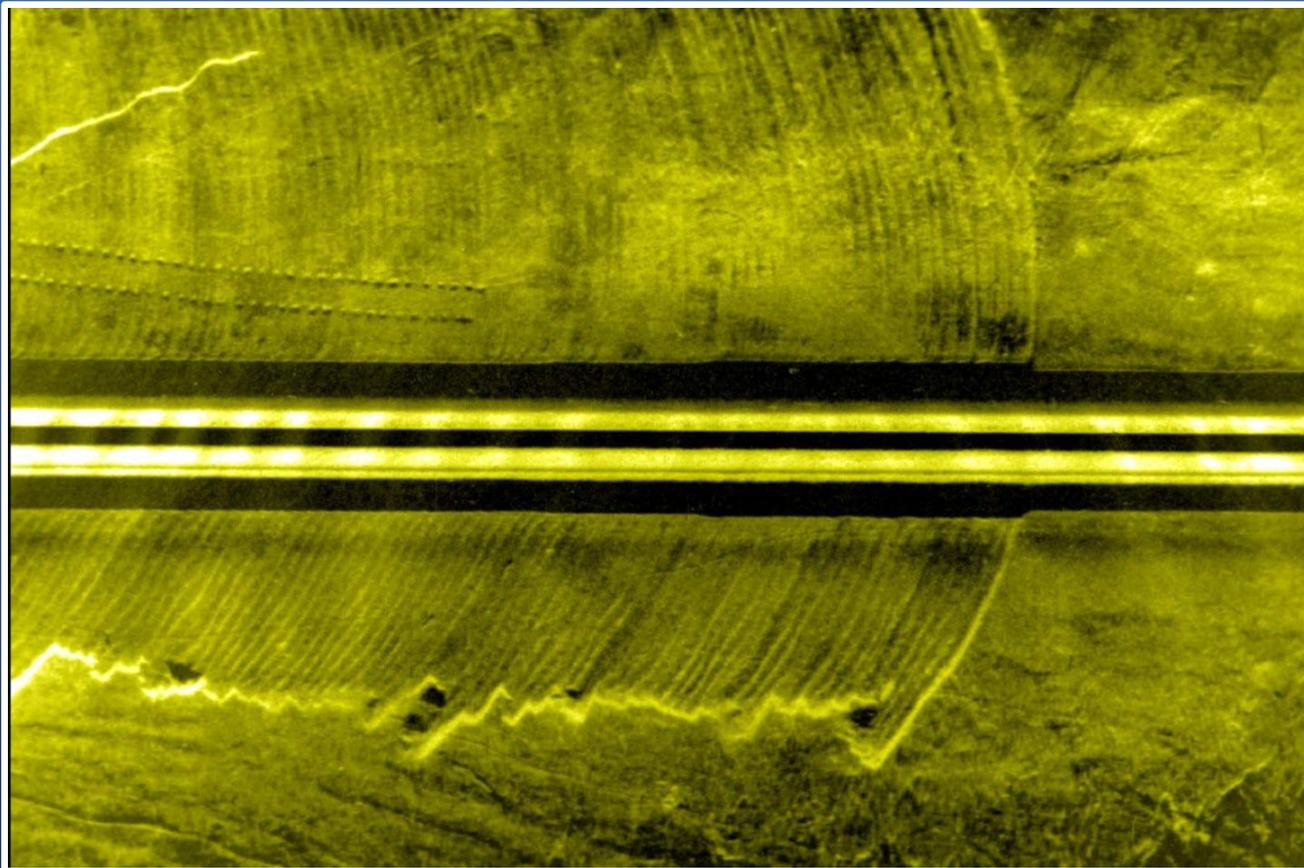
CHANGE DETECTION: comparing an earlier base line survey with future surveys allows easy detection of changes over time



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

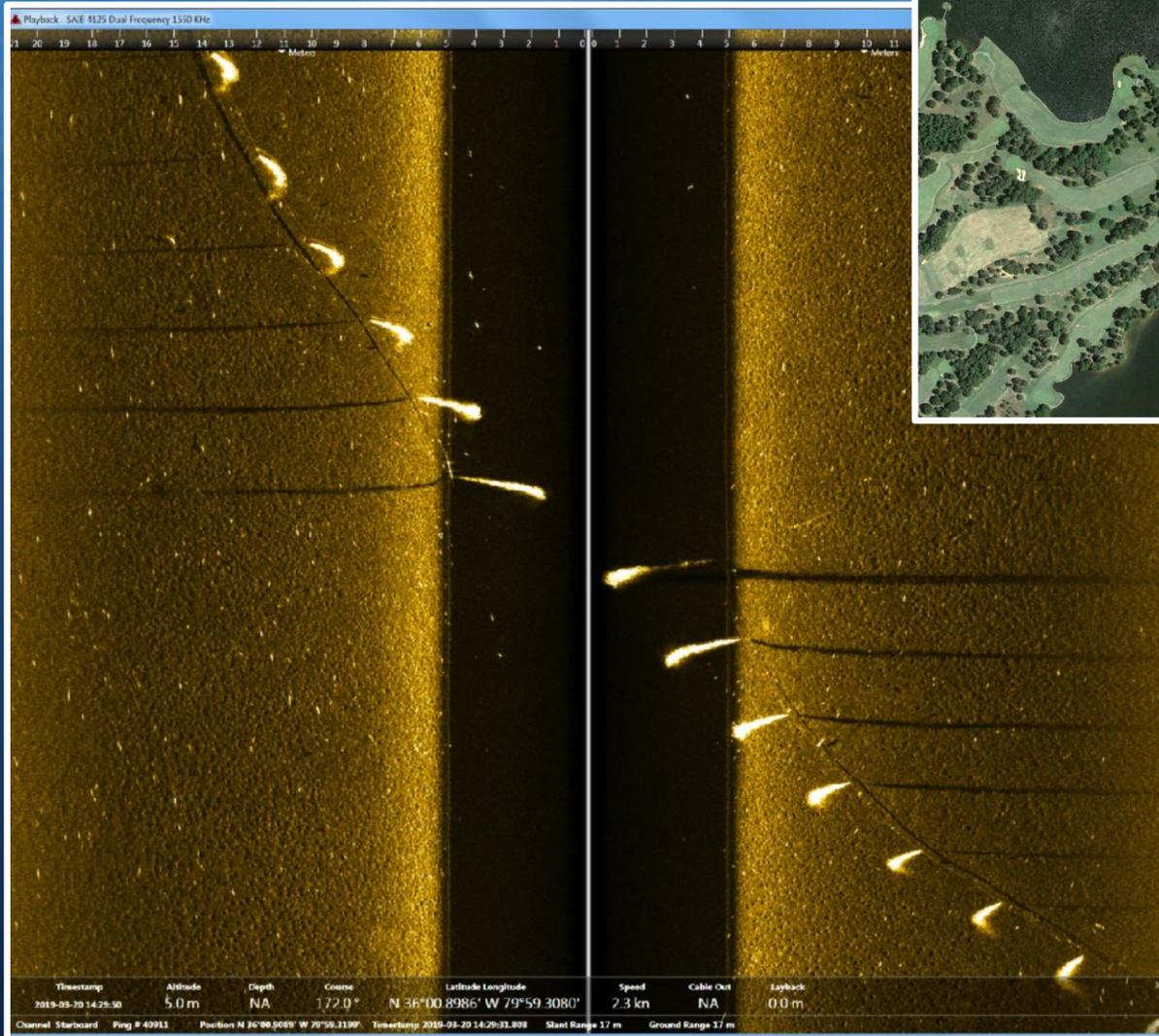
V. Applications

Dredge Monitoring



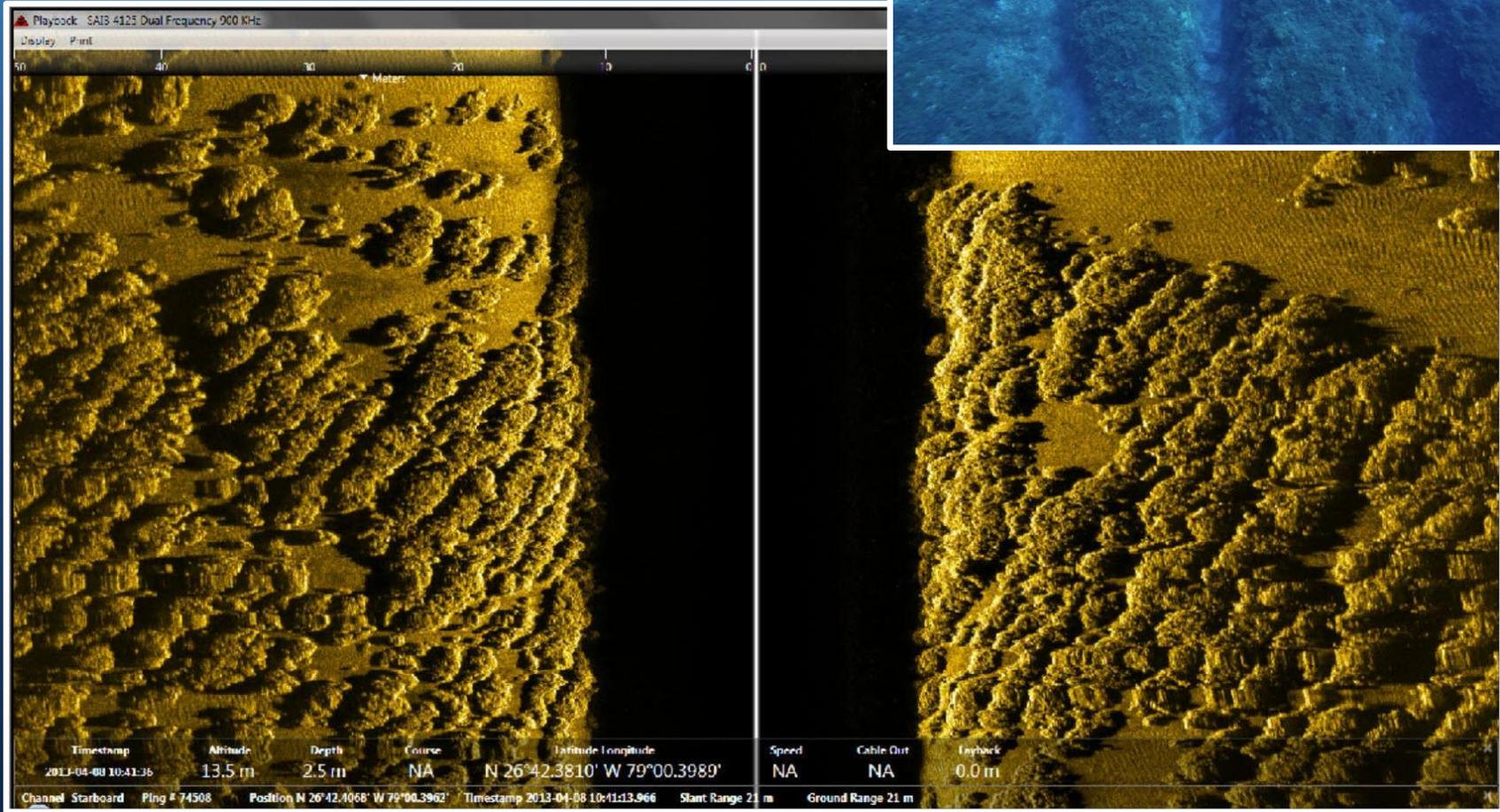
V. Applications

Mapping – Aeration System

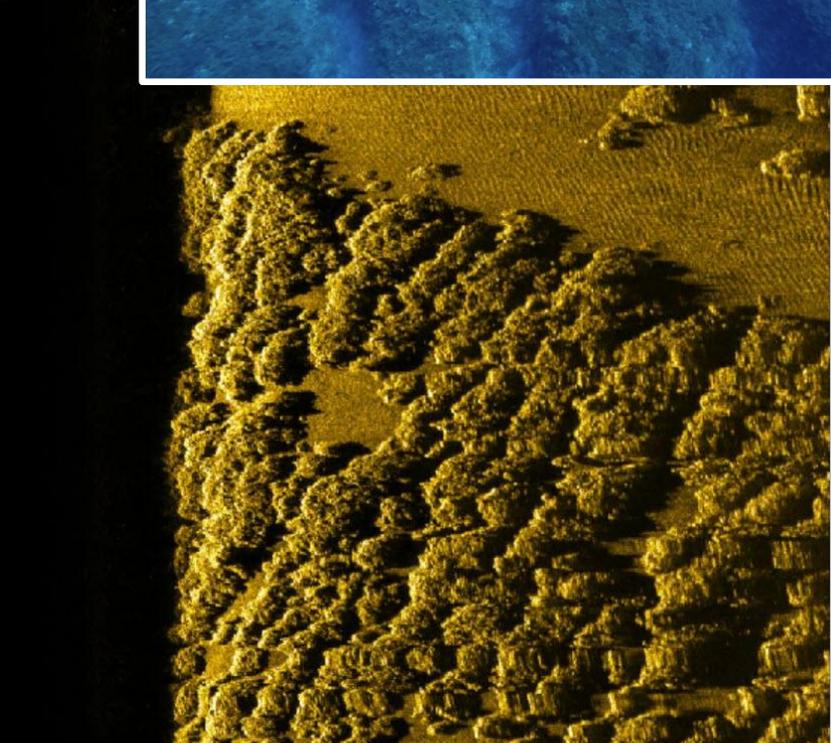
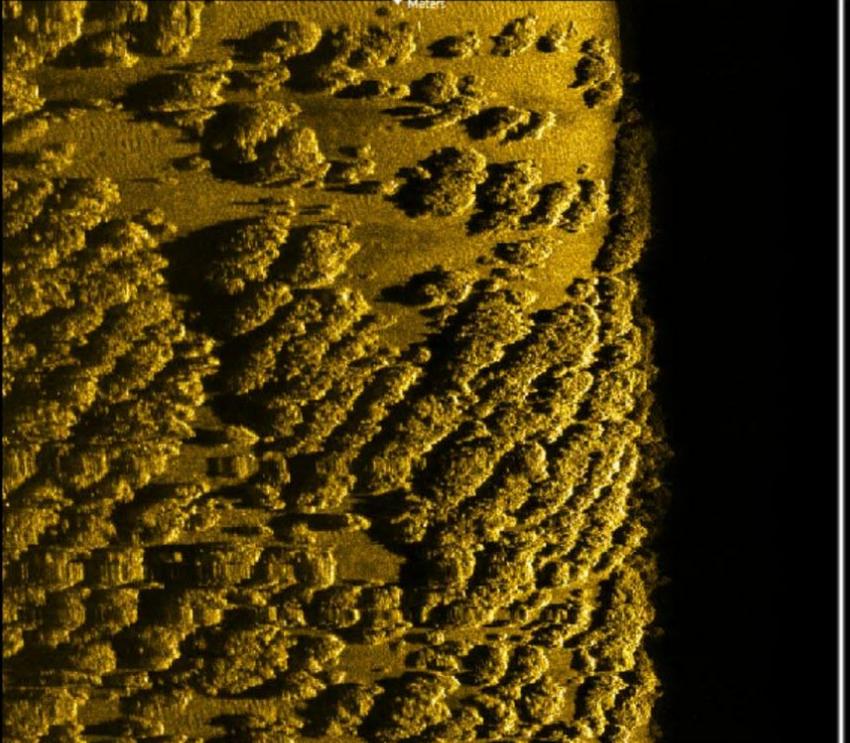


V. Applications

Mapping – Coral Reefs



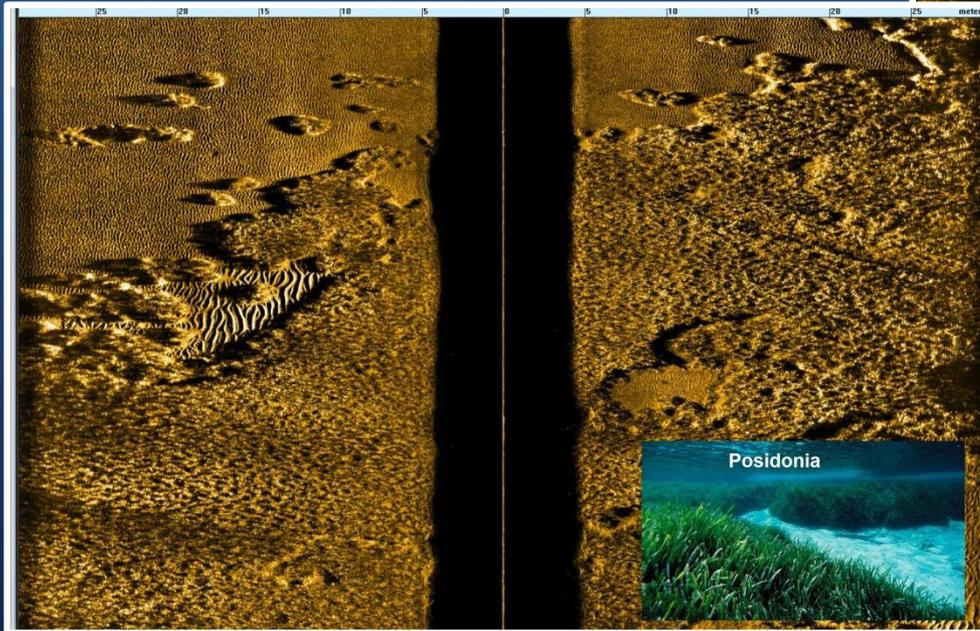
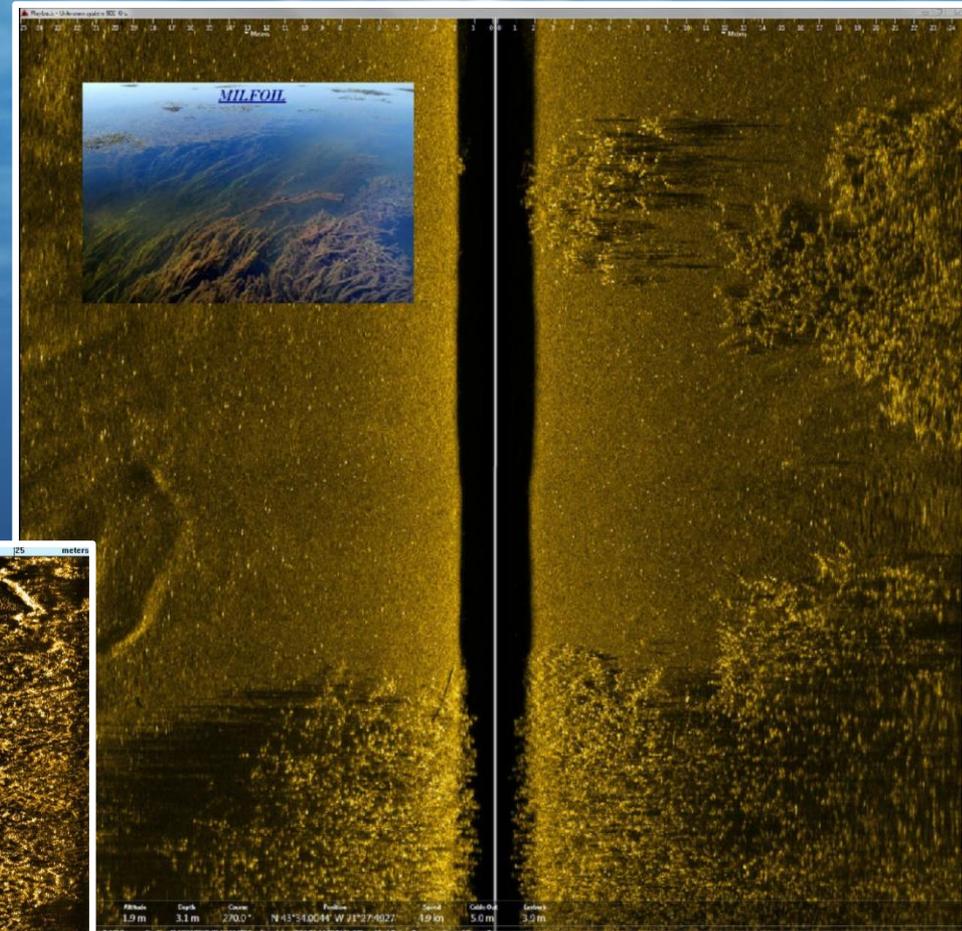
Playbook: SAIS 4125 Dual Frequency 900 KHz
Display Print
50 40 30 20 10 0 0



Timestamp	Altitude	Depth	Course	Latitude Longitude	Speed	Cable Out	Layback
2013-04-08 10:41:36	13.5 m	2.5 m	NA	N 26°42.3810' W 79°00.3989'	NA	NA	0.0 m
Channel Starboard	Ping # 74508	Position N 26°42.4068' W 79°00.3962'	Timestamp 2013-04-08 10:11:13.966	Slant Range 21 m	Ground Range 21 m		

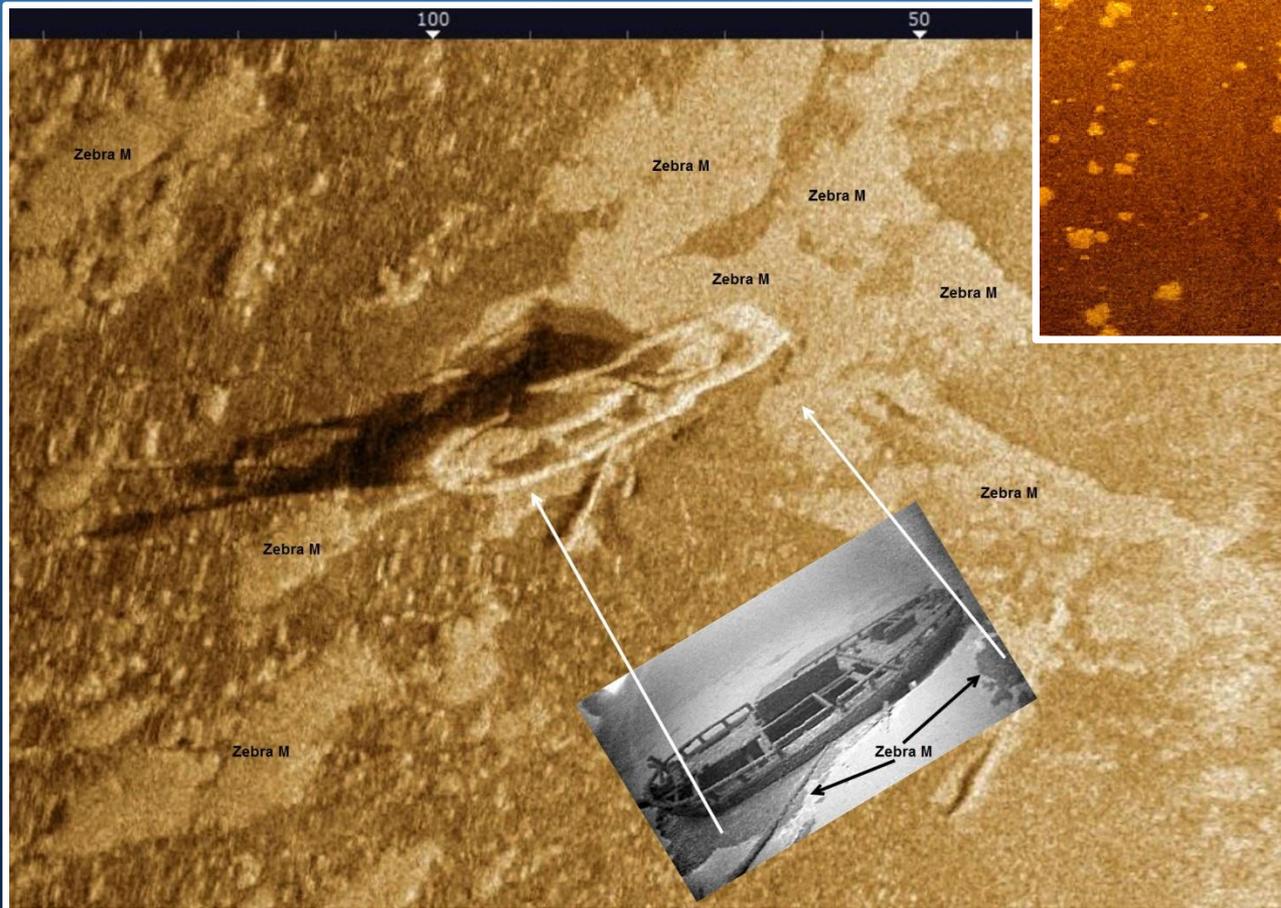
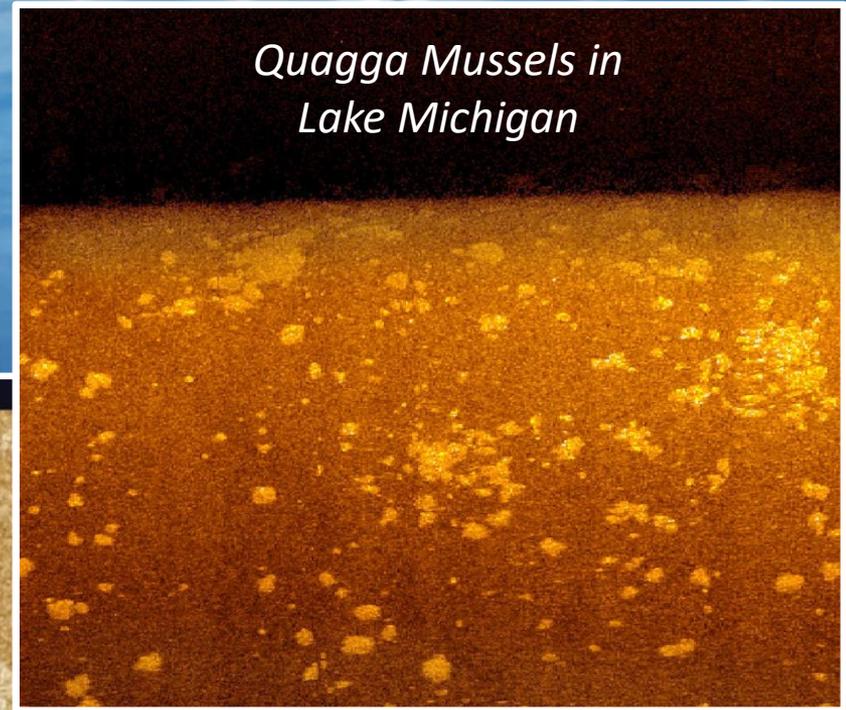
V. Applications

Mapping – Vegetation



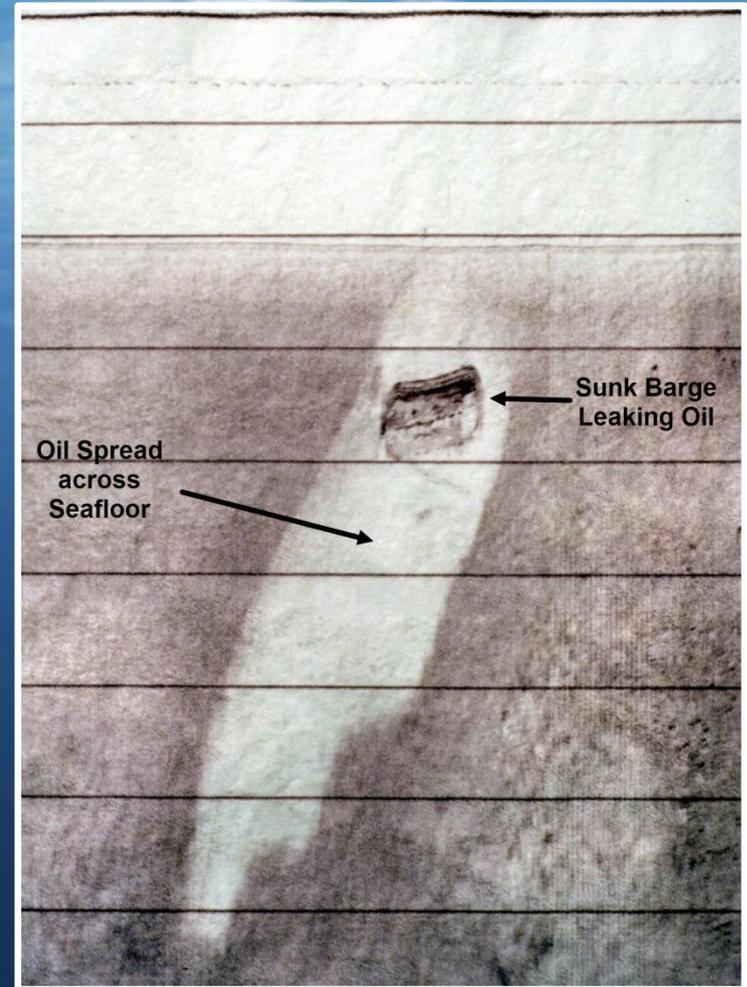
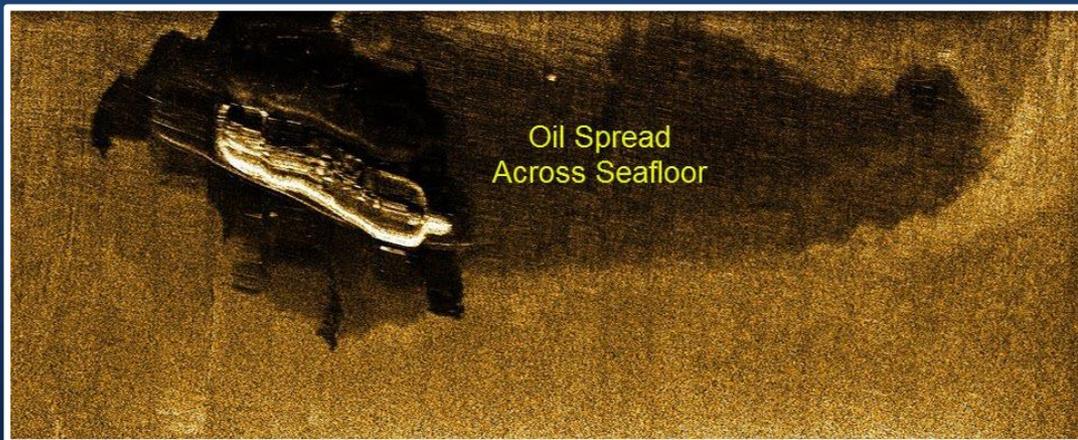
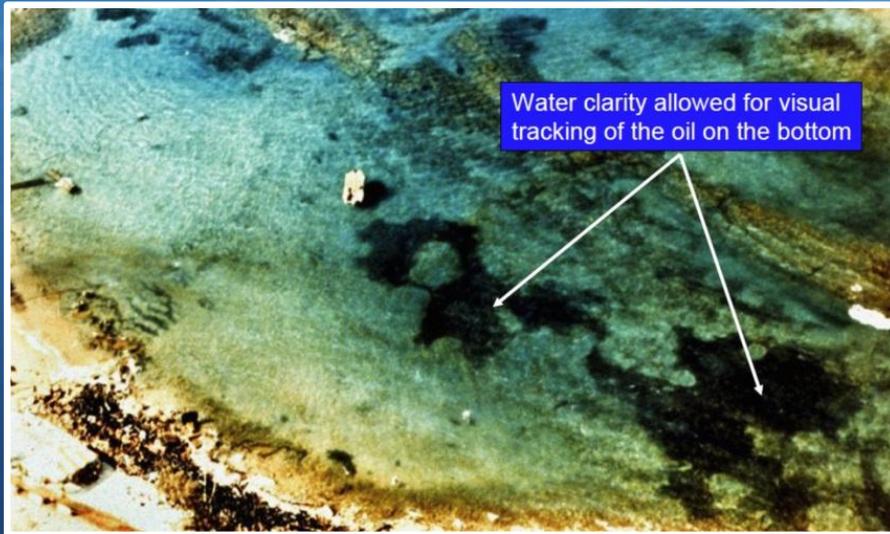
V. Applications

Mapping – Zebra & Quagga Mussels Invasive Species

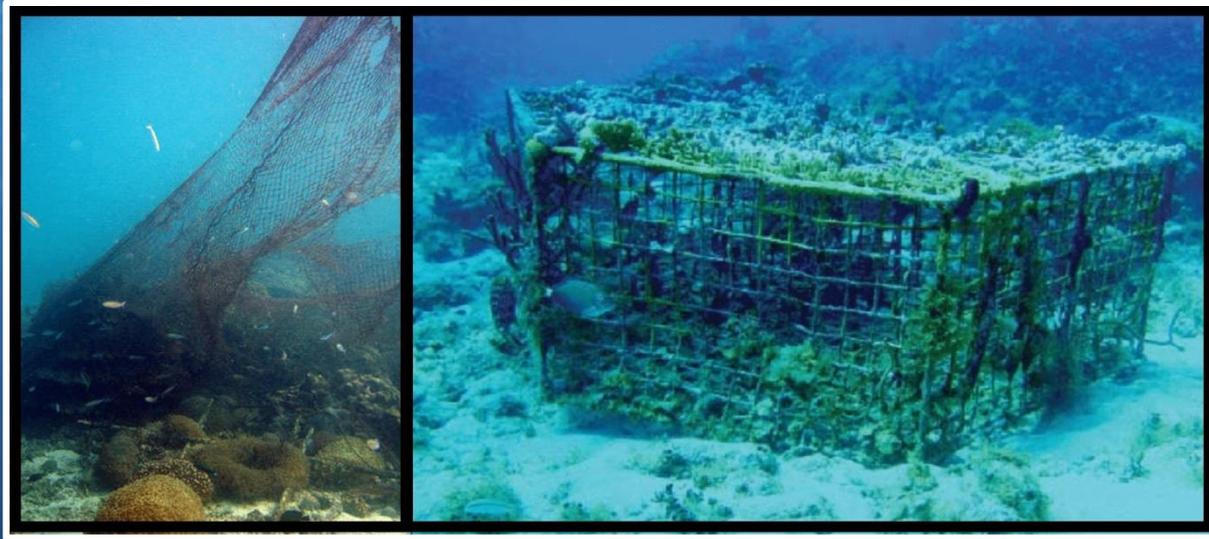


V. Applications

Mapping – Oil Spills



V. Applications

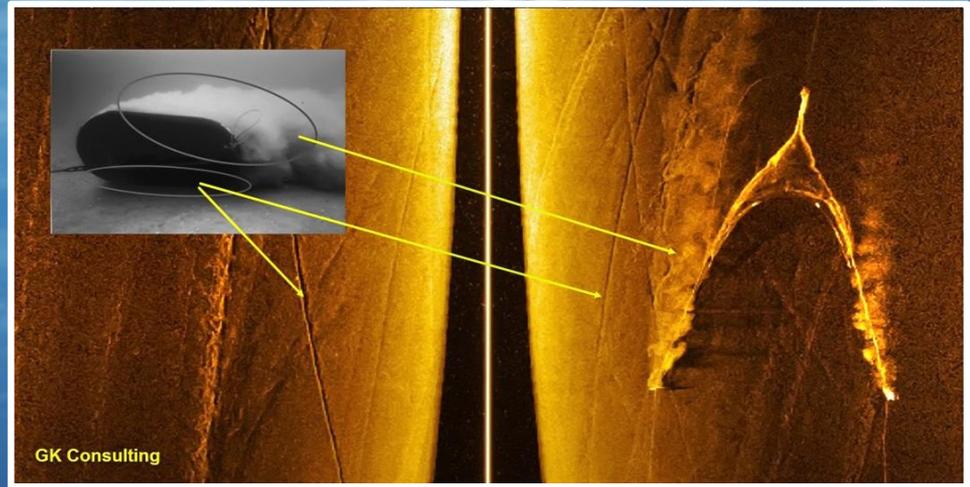


Ghost Gear:
Traps & Nets

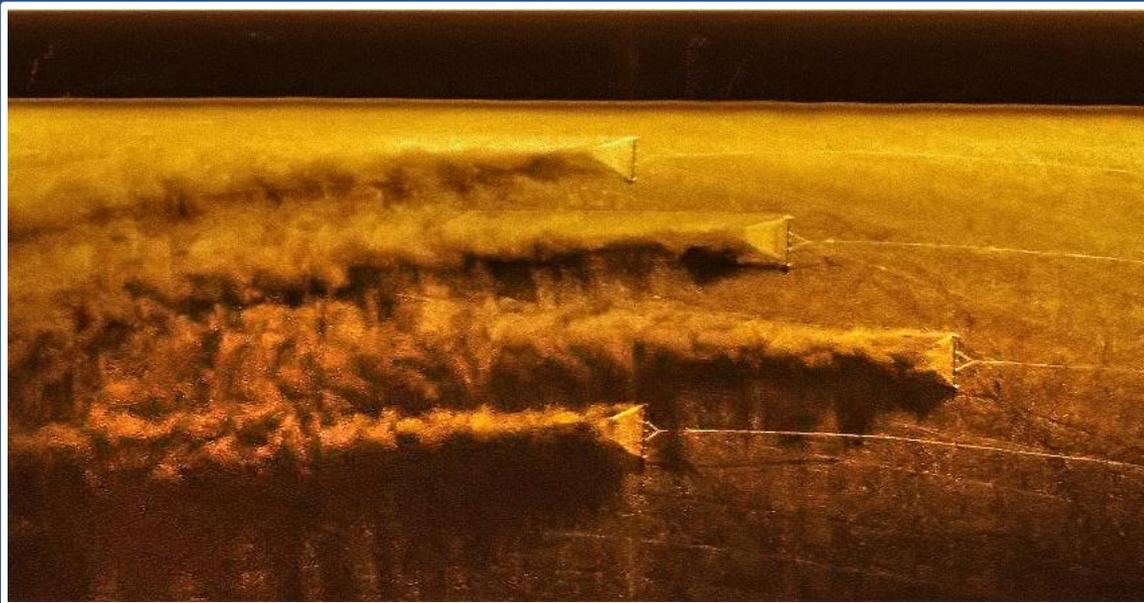


V. Applications

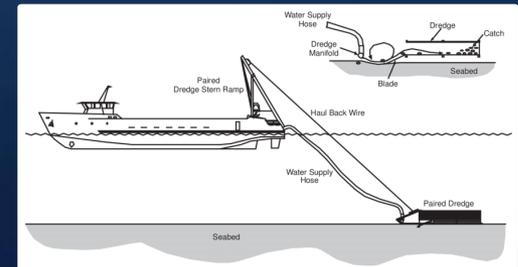
Monitoring Fishing Trawls



Trawl Net and Otter Boards

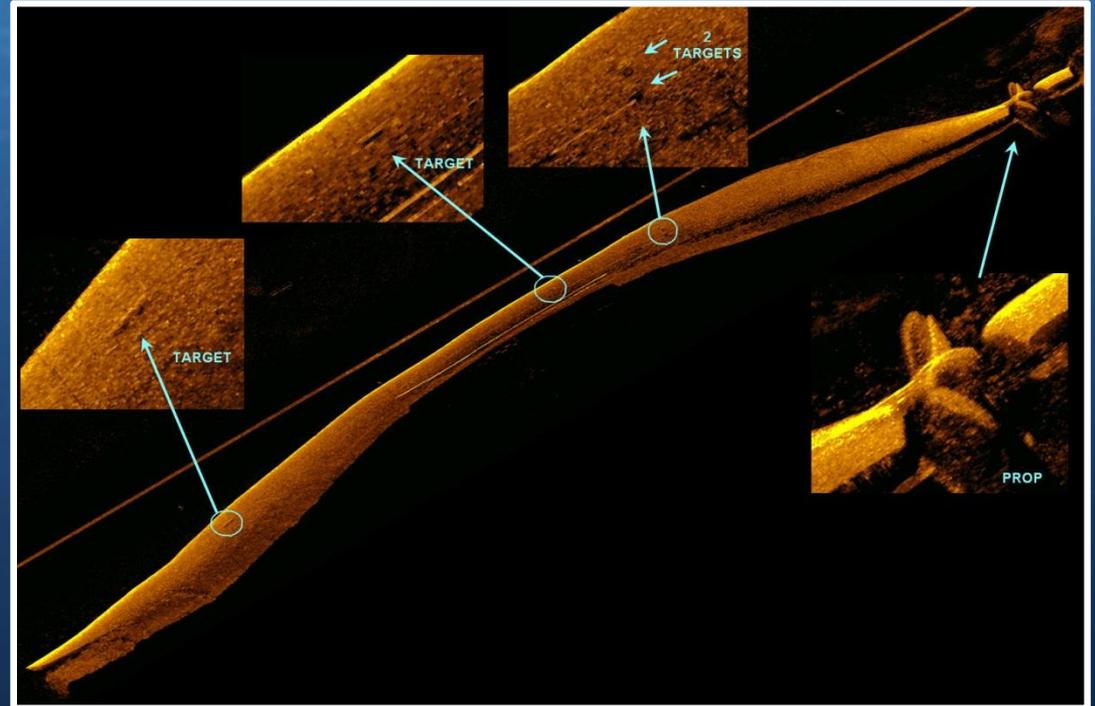
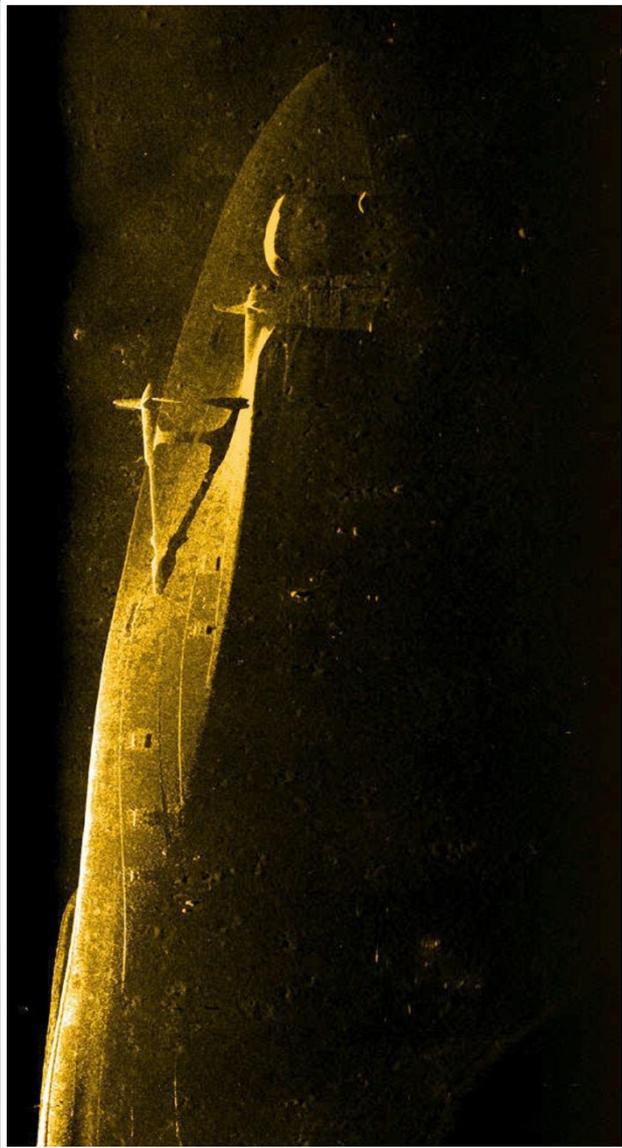


Hydraulic Dredges



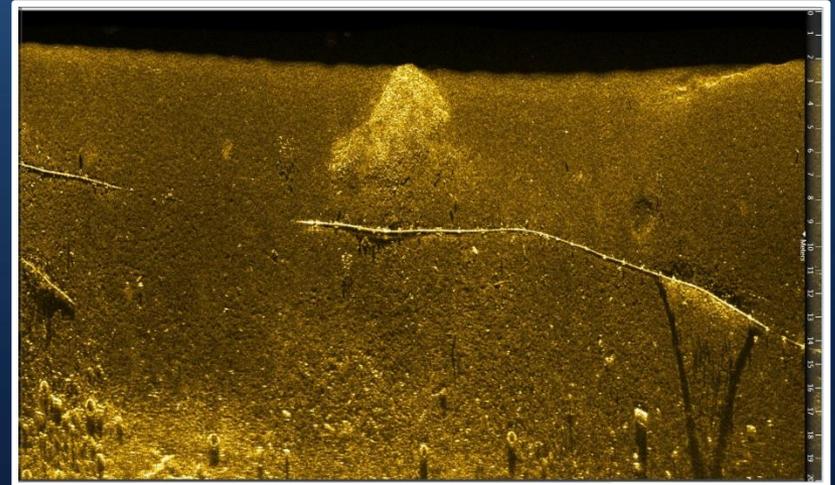
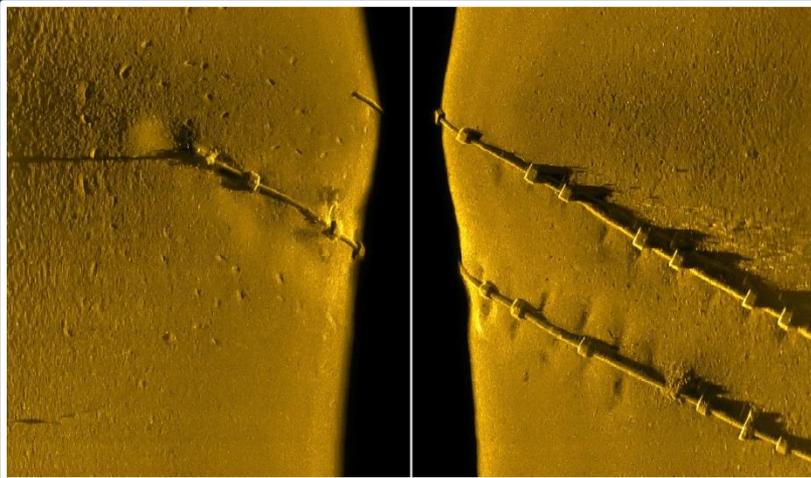
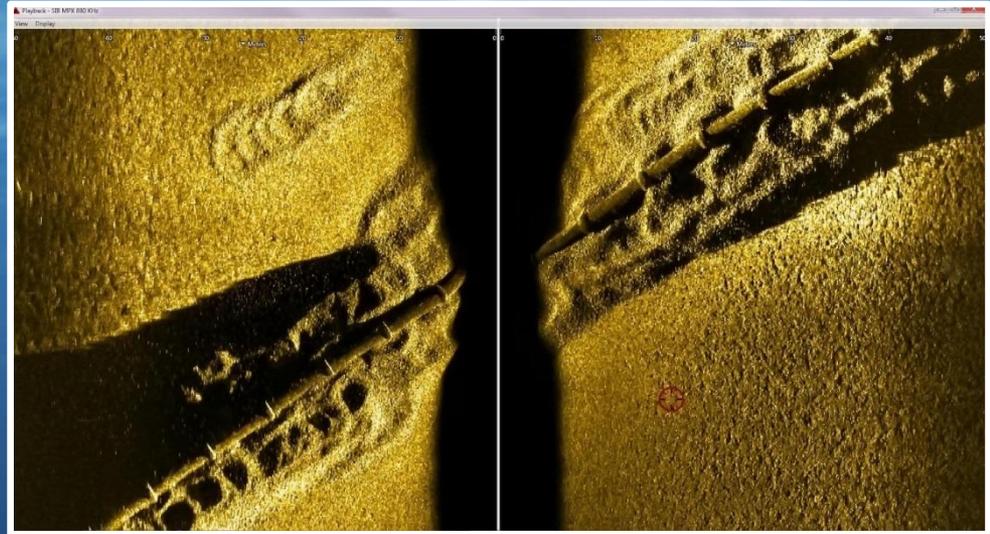
V. Applications

Hull Inspection



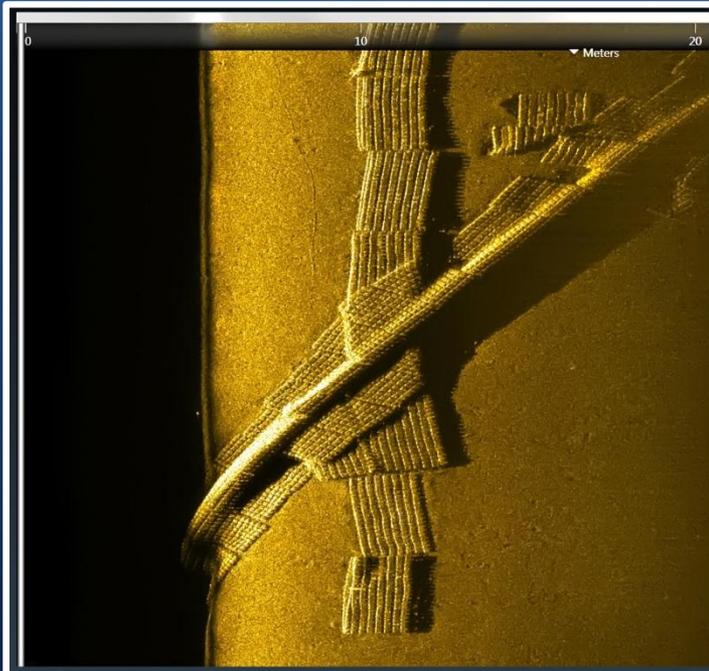
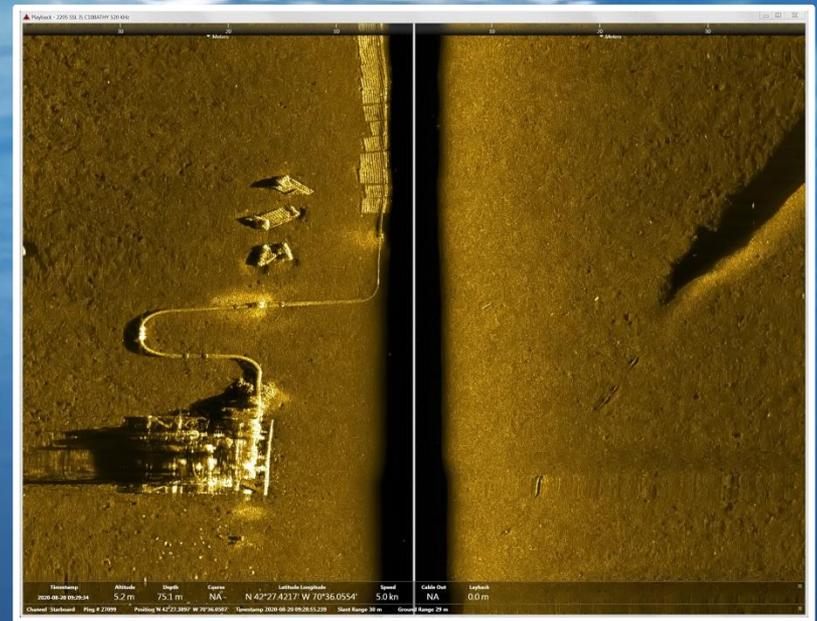
V. Applications

Pipeline Surveys



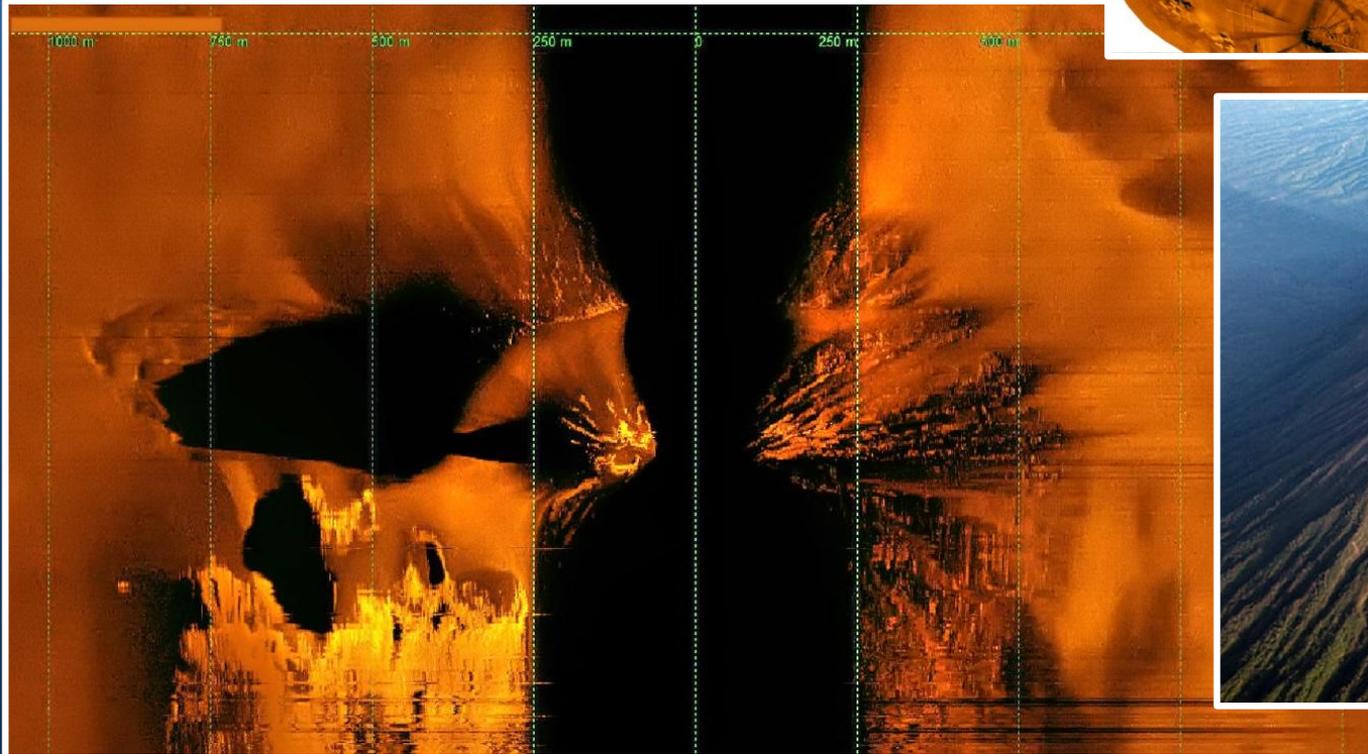
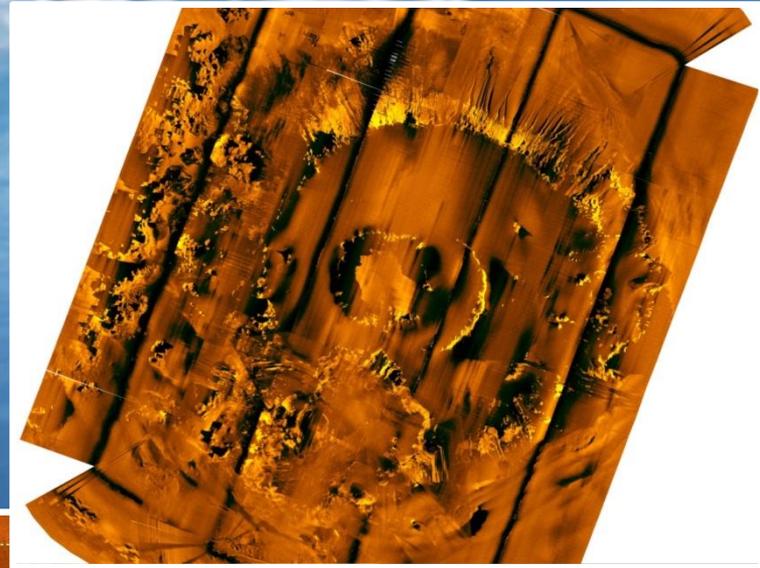
V. Applications

Pipeline Protective Concrete Mats



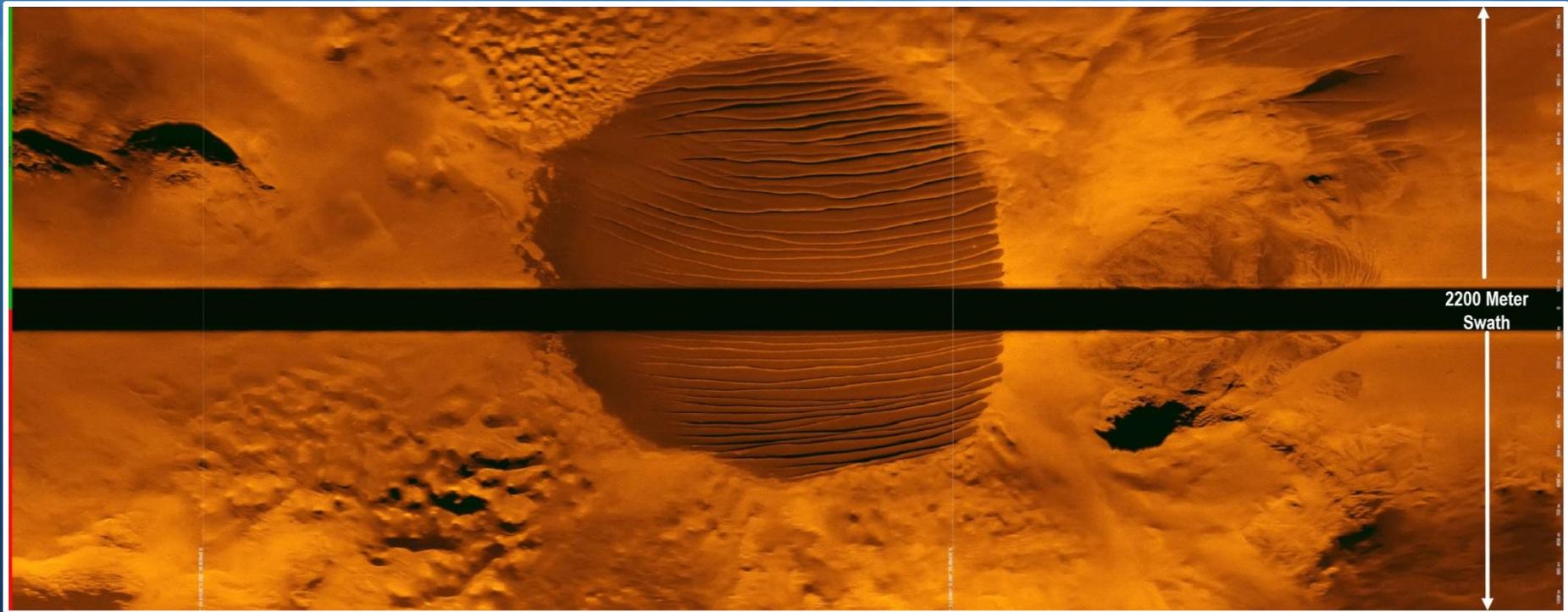
V. Applications

Geology - Volcanoes



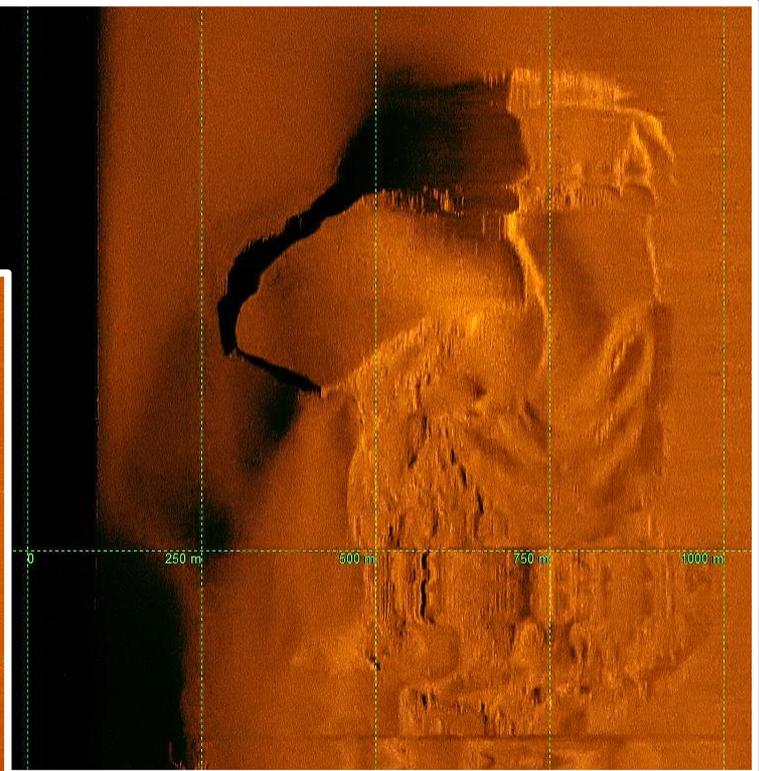
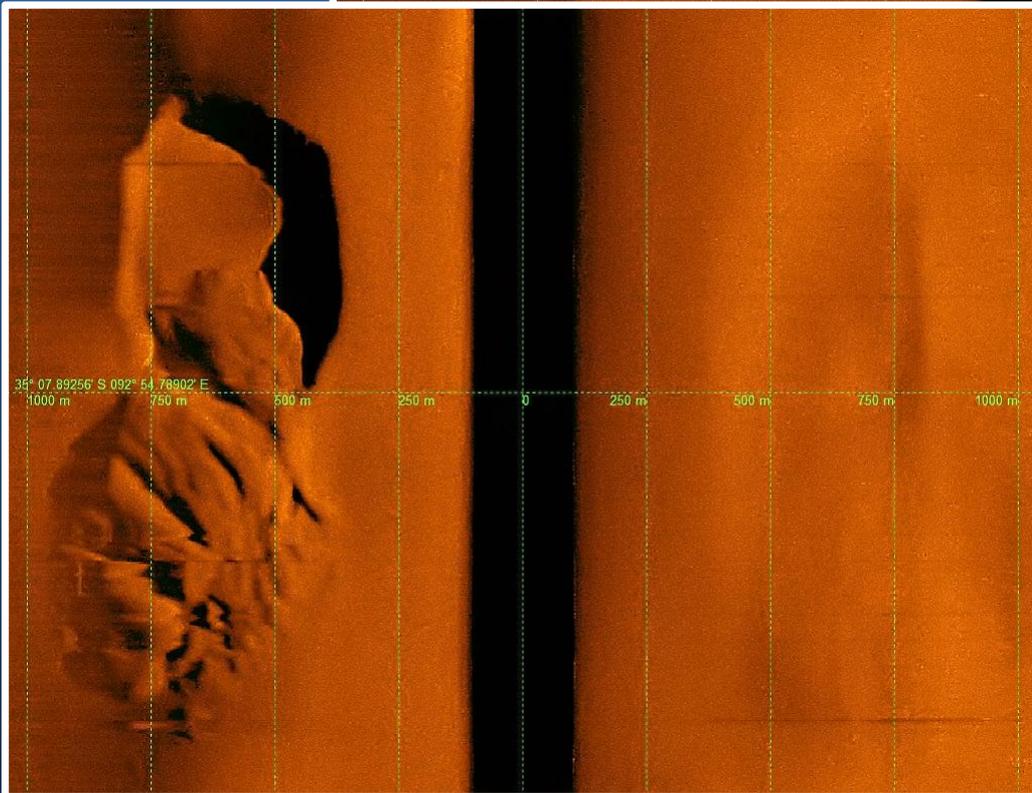
V. Applications

Geology – Cool
Feature



V. Applications

Geology – Underwater Slumps/Land Slides



V. Applications

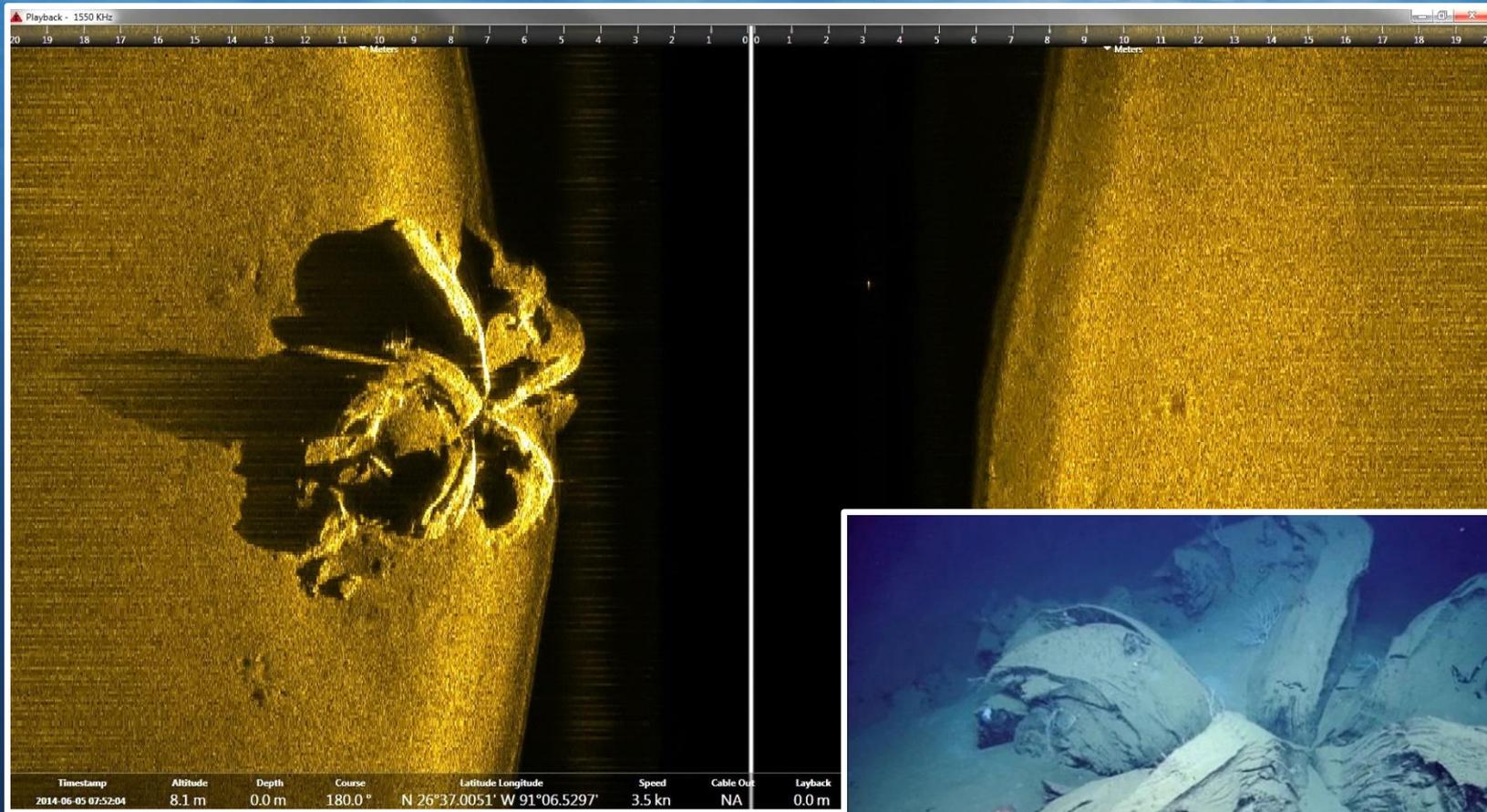
Geology – Cool
Feature



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

V. Applications

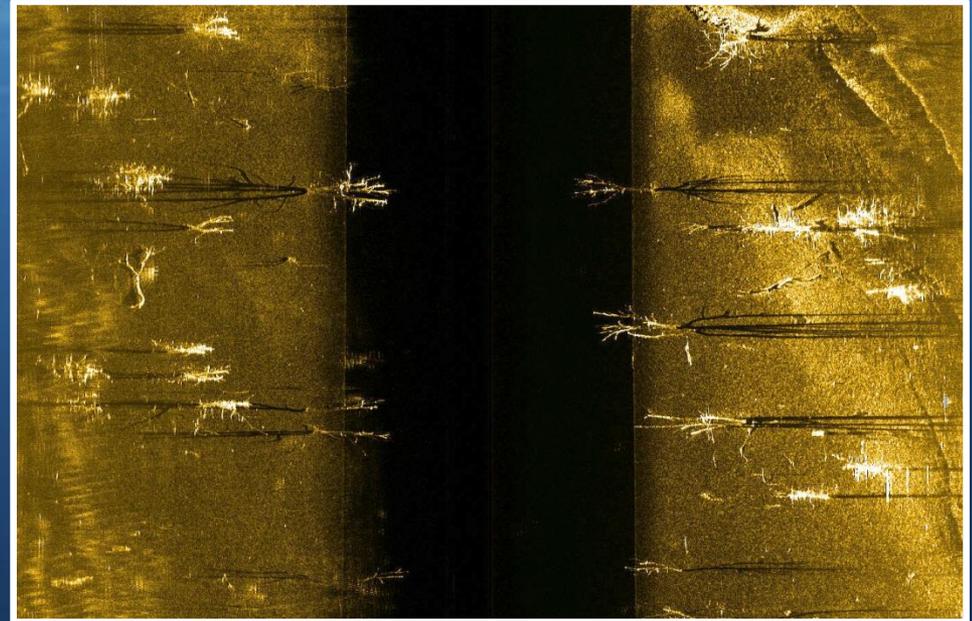
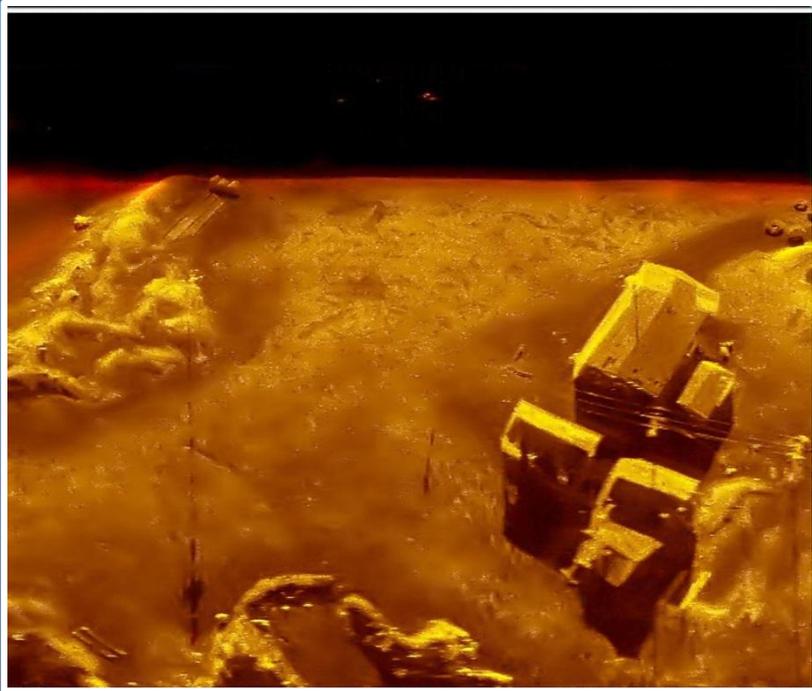
Geology – Cool Feature



Tar Lily – Image Courtesy Fugro

V. Applications

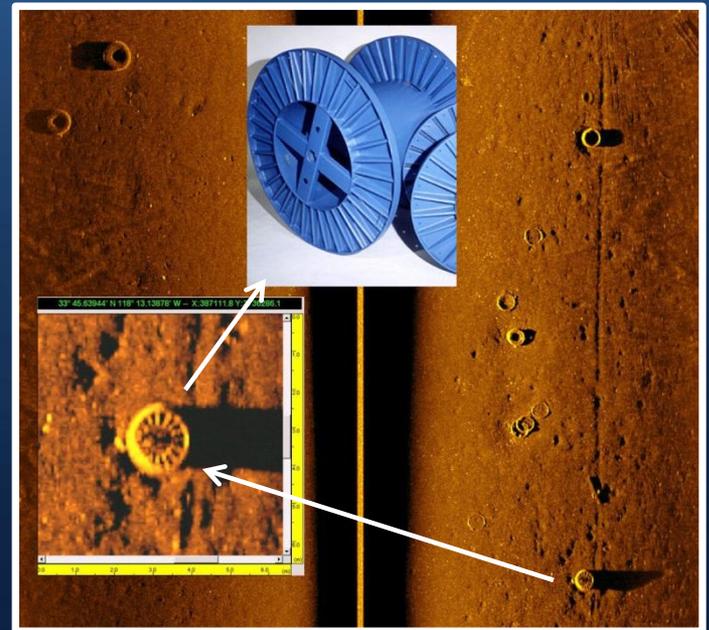
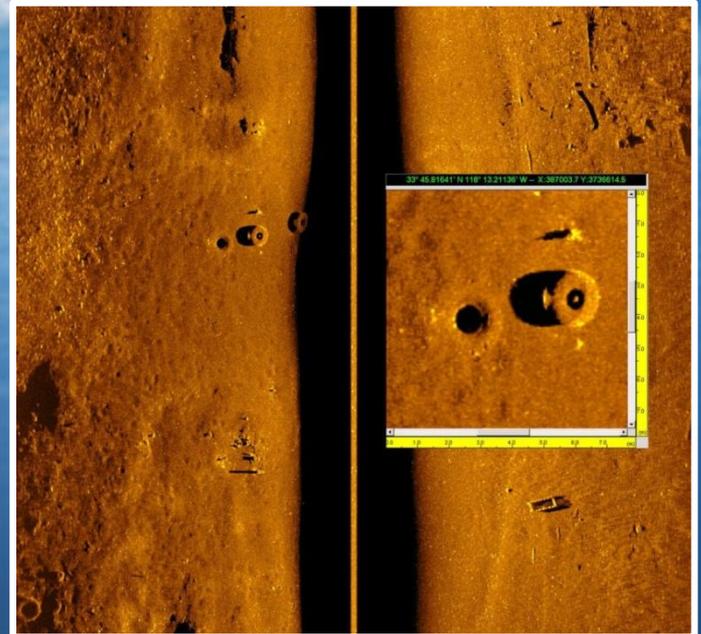
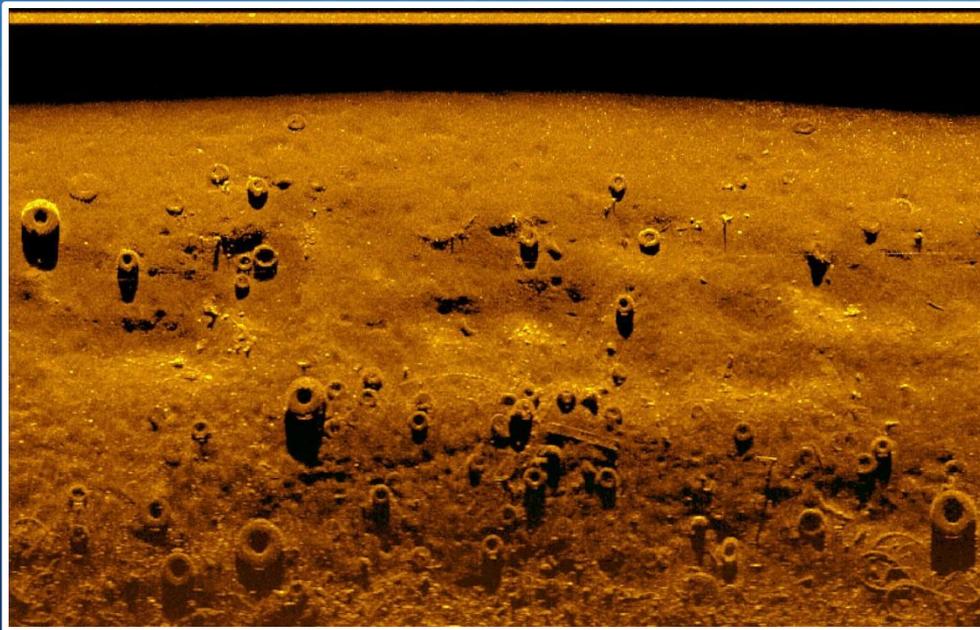
Structures – Cool Features



Man-Made Lake with Buildings and Trees still standing

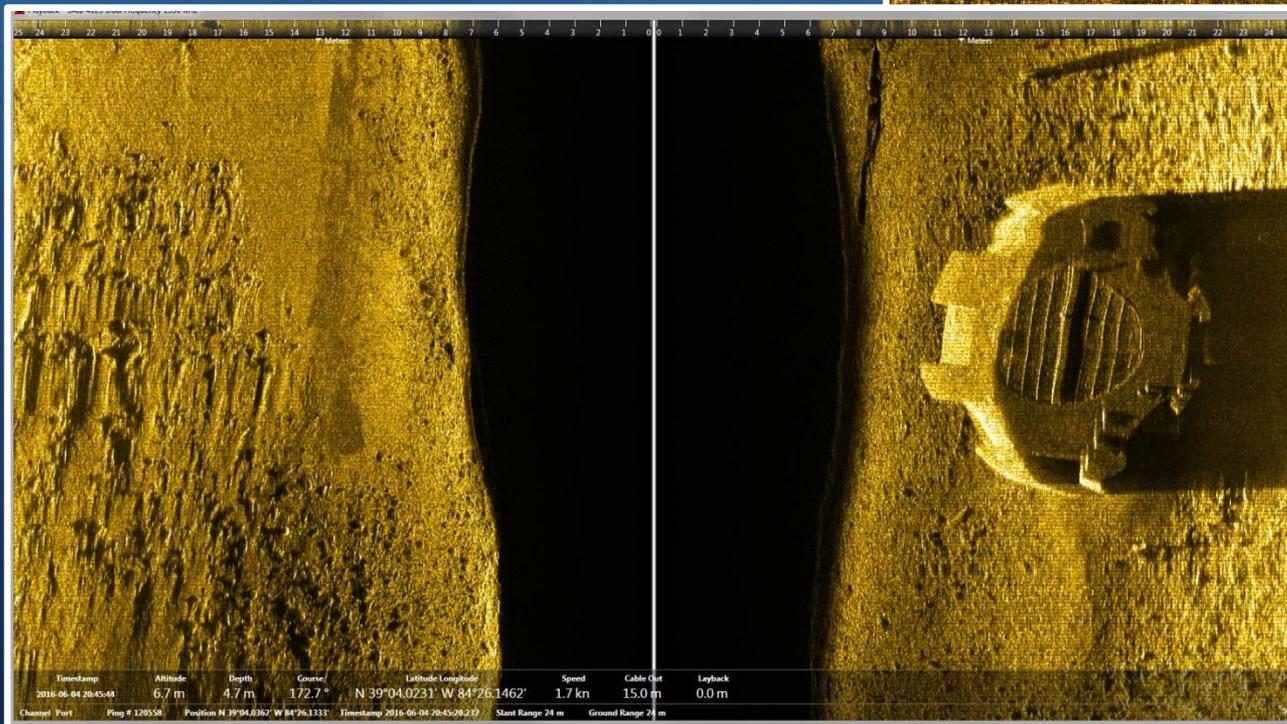
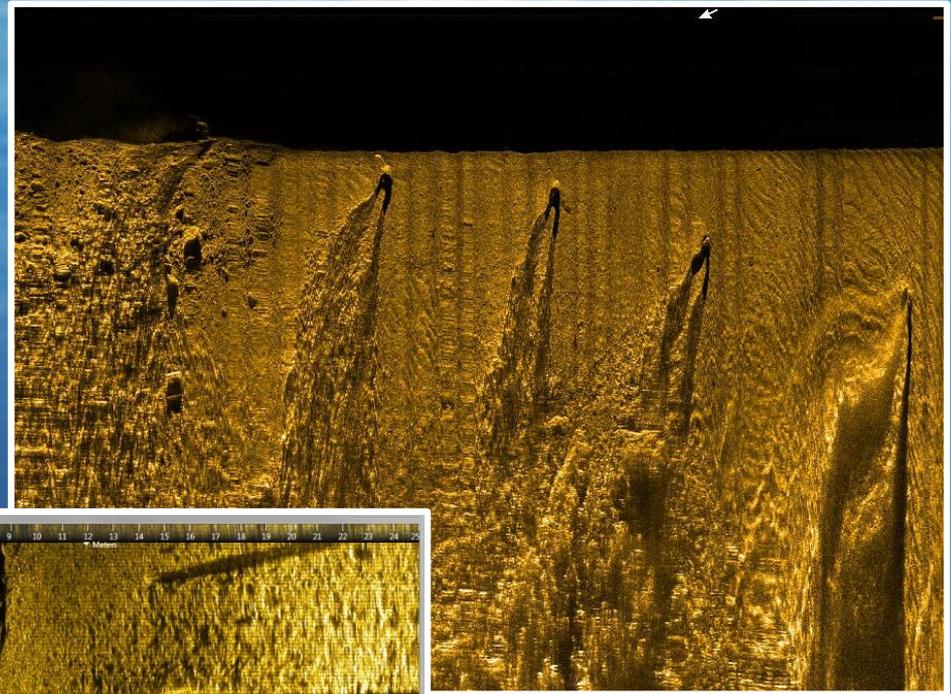
V. Applications

Tires



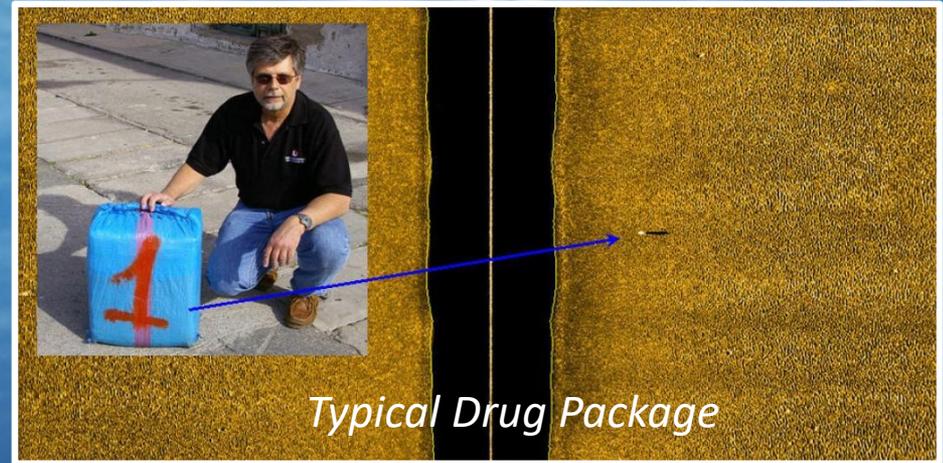
V. Applications

Water Intakes & Exhaust Diffusers



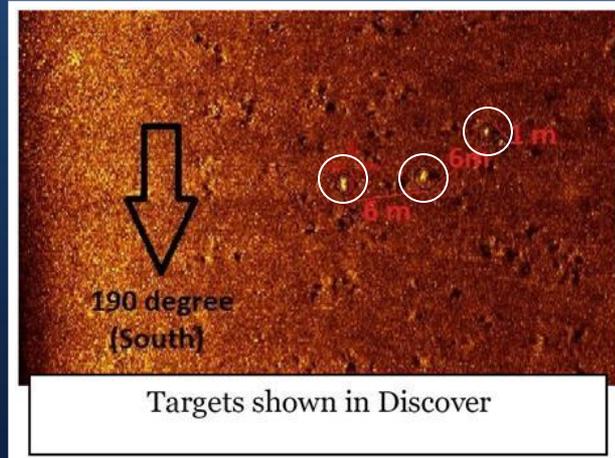
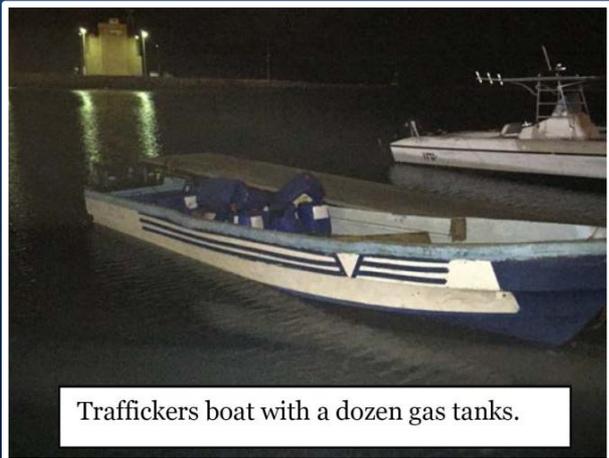
V. Applications

Jettisoned Drug Package Location



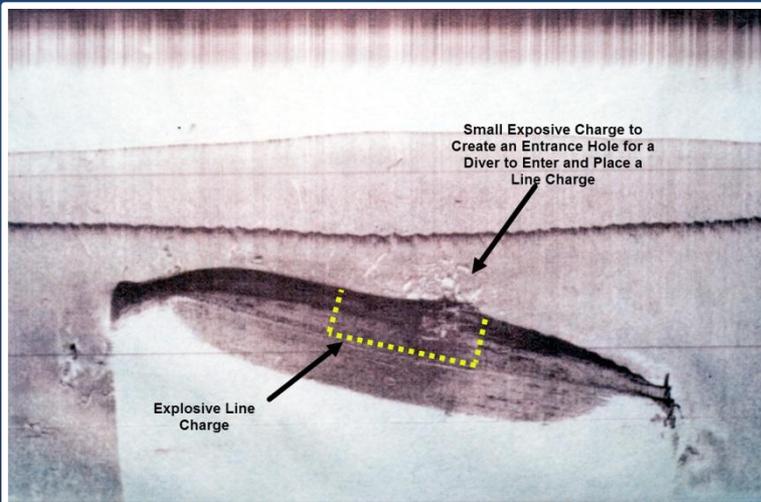
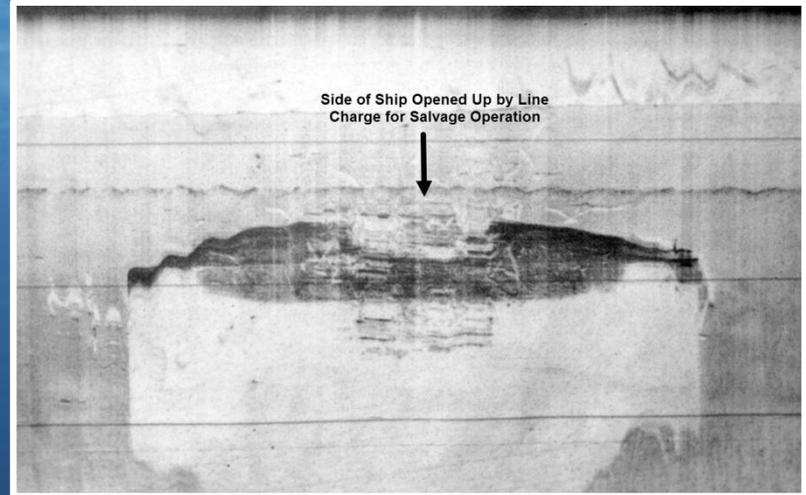
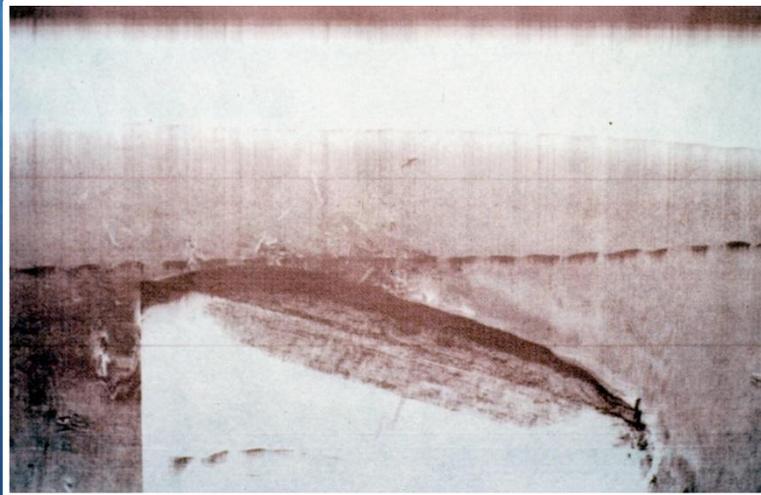
Saudi Arabia Coast Guard Drug Bust

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



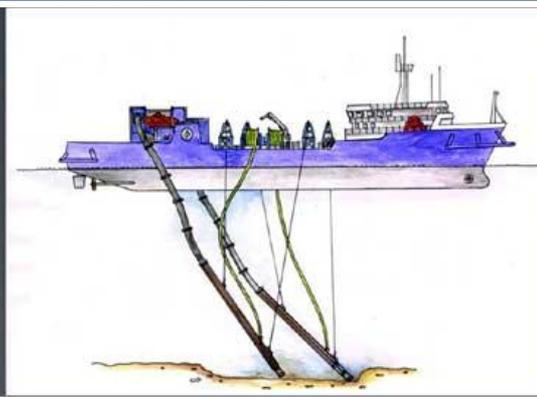
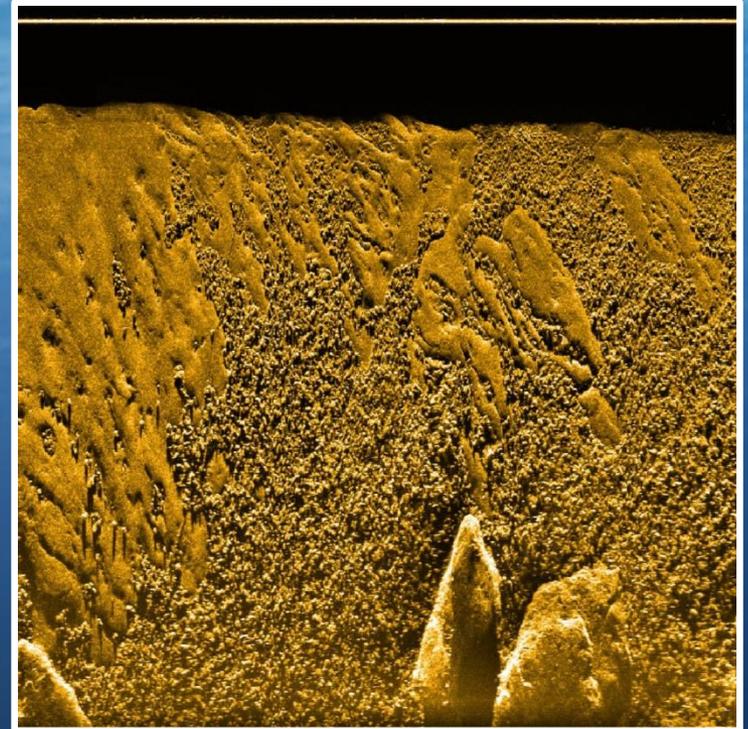
V. Applications

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



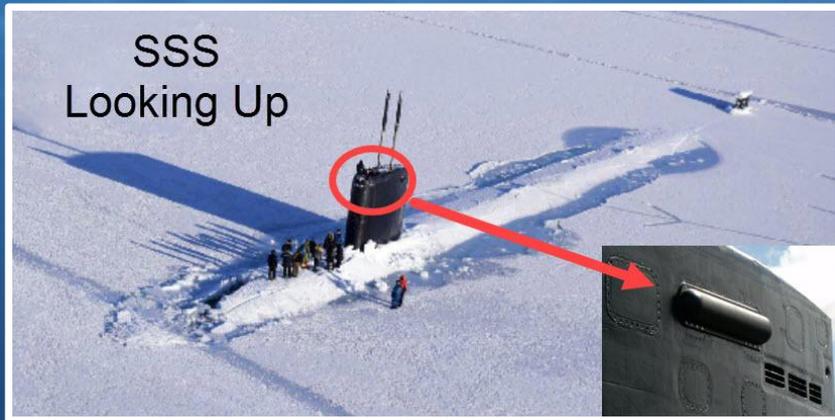
V. Applications

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

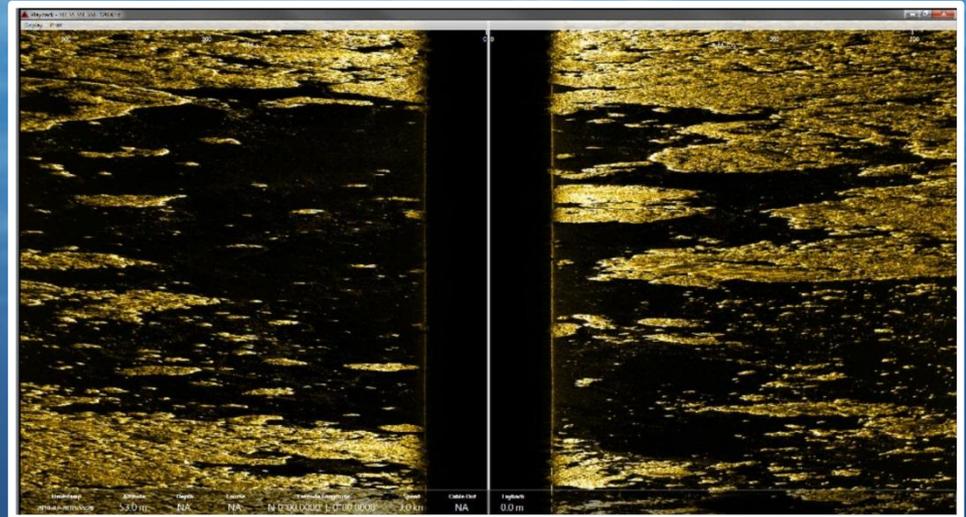


V. Applications

Under Ice Imaging



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



Under Arctic Ice SSS Images

