Best Management Practices (BMP) Workshop
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Characteristics of Sounds Emitted During High Resolution Marine Geophysical Surveys

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Acknowledgments

This study was conducted by the Dr. Steven Crocker and his Team at the Naval Undersea Warfare Center Division Newport.

The United States Geological Survey (USGS) was essential in this study with their contribution of equipment, manpower and technical expertise during the testing.

URL for the final Report of Phase I is:

http://www.data.boem.gov/PI/PDFImages/ESPIS/5/5551.pdf

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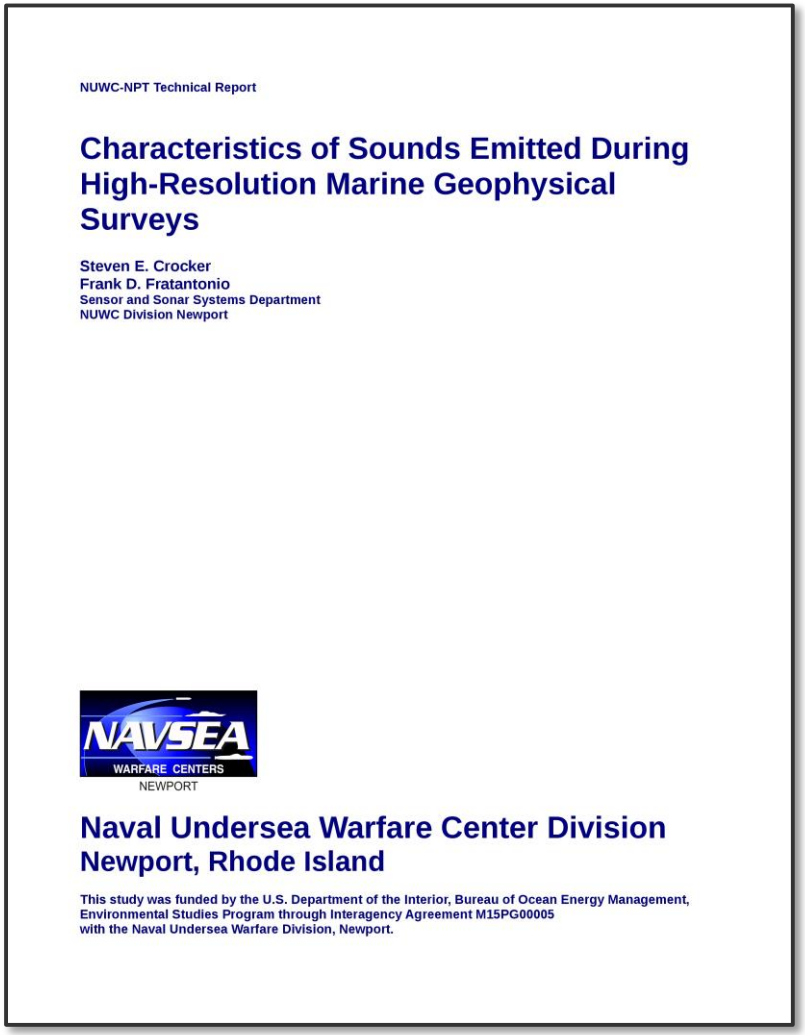
CSA Ocean Sciences, Inc. for the details on Phase II of this project.


NUWC-NPT Technical Report

Characteristics of Sounds Emitted During High-Resolution Marine Geophysical Surveys

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NAVSEA WARFARE CENTERS NEWPORT

Naval Undersea Warfare Center Division Newport, Rhode Island

This study was funded by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program through Interagency Agreement M15PG00005 with the Naval Undersea Warfare Division, Newport.

Background

Marine Mammal Protection Act

The MMPA prohibits, with certain exceptions, the **"take"** of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S.

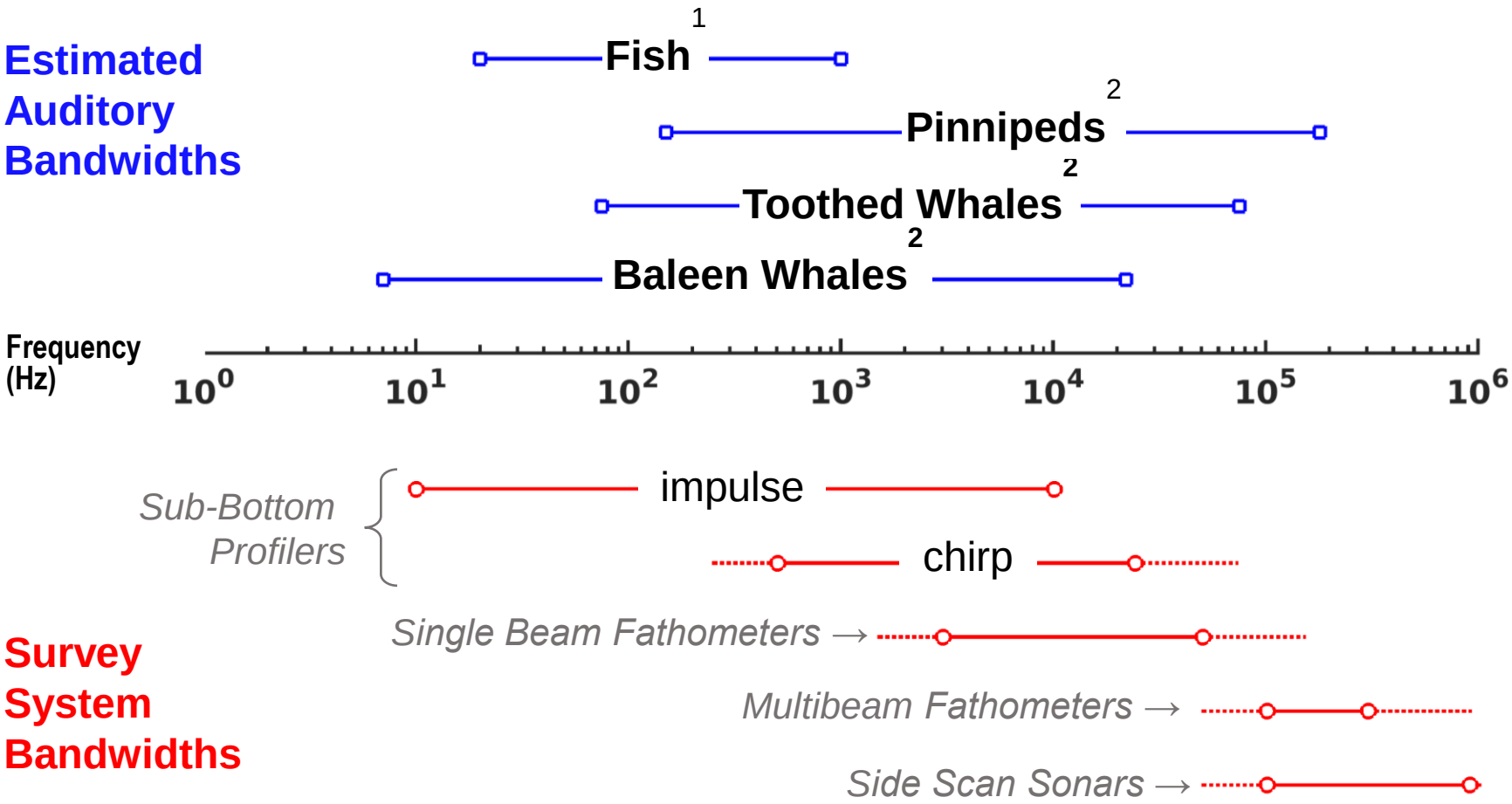
Definitions

Take: To harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.

Harass: Any act of pursuit, torment, or annoyance which - (i) has the potential to injure a marine mammal or marine mammal stock in the wild [Level A]; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering [Level B].

Sources: Marine Mammal Protection Act (MMPA) Sec. 3 (18); http://www.nmfs.noaa.gov/pr/laws/mmpa/; http://www.boem.gov/BOEM-Science-Note-March-2015/

Acoustic Spectrum Usage



1) Hastings and Popper, 2005
2) Southhall et. al., 2007

Project Plan Development

- **BOEM realized that this project needed to address the following issues:**
  - Utilized by BOEM's 3 Programs - Oil & Gas, Marine Minerals and Renewables Programs
  - Wide range of source types and models
  - Concentrate on shallow water – primarily the continental shelf
  - Applicable throughout the US EEZ waters
  - The project couldn't measure every situation and that ultimately predictive acoustic modeling would be needed
  - Required measured data to "prove" or validate future analyses and environmental compliance documents
  - Needed to examine the entire acoustic scenario – source to receiver, near & far field issues, etc.
  - Needed to examine current "hot" issues – harmonics and subharmonics, SPL and SEL, etc.
- **BOEM recognized that USGS had similar issues and approached them to team on this project.**
- **BOEM identified a 3 Phased approach to minimize technical uncertainties:**
  - **Phase I** – Quantify what the sources were actually producing
  - **Phase II** – In-situ measurements at three general depths (10, 30, and 50-100m), in areas with 2 sediment types if possible. Utilize Phase I data to optimize the test planning.
  - **Phase III** – Use results from Phases I & II to examine the acoustic propagation models and the supporting databases currently to identify which should be used in this shallow water situation and to identify recommendations for best practices in their employment.

Project Schedule

- **Phase I** – Calibrated Source Measurements
  - Measurements completed.
  - Final Report available in online through BOEM's ESPIS

- **Phase II** – At-Sea System Measurements
  - Test completed, analysis is currently underway
  - Measurements at 5 Mid-Atlantic Sites in June/July 2016

- **Phase III** – Acoustic Propagation Modeling Analysis
  - RFP released in Winter 2017, for FY 2018 start (funding permitting).
  - To be completed in early FY 2019.

Study Objective

Given the scientific questions and uncertainty about the potential impact of noise in the marine environment, a number of regulatory requirements and precautionary mitigation strategies are being applied to lower energy geophysical surveys.

The U.S. Bureau of Ocean Energy Management is working to ensure that environmental mitigation requirements are scientifically supported, cost effective, operationally feasible and impact reducing. The Bureau is advancing this objective by characterizing the acoustic energy radiated by geophysical survey systems used in shallow bodies of water under U.S. jurisdiction.

The objective of this study is to characterize the acoustic fields radiated by marine geophysical survey systems as a critical first step to understanding the potential impacts to marine ecosystems.

Geophysical Survey Systems

Seafloor Mapping		*Sub-Bottom Profiling*	
System	*Description*	*System*	*Signal*
Echotrac CV100	Single Beam Fathometer	AA* 200	Impulse
Reson 7111	Multibeam Fathometer	AA* 251	Impulse
Reson T20-P	Multibeam Fathometer	AA* S-Boom	Impulse
Sea Swath Plus	Interferometer	FSI** Bubble Pulse	Impulse
Klien 3000	Side Scan Sonar	EdgeTech 424	FM Chirp
Klien 3900	Side Scan Sonar	EdgeTech 512i	FM Chirp
EdgeTech 4200	Side Scan Sonar	Knudsen 3202	FM Chirp

*Applied Acoustics, Ltd.
**Falmouth Scientific, Inc.

Reported Parameters

Source level (rms 90%)	dB re 1μPa@1m
Peak acoustic pressure	dB re 1μPa@1m
Peak-to-peak acoustic pressure	dB re 1μPa@1m
Sound exposure level	dB re 1μPa^{2}s@1m
Spectrum level	dB re 1μPa^2/Hz@1m
Effective (90%) pulse width	seconds
Half-power (3 dB) bandwidth	Hz
Beam patterns	dB
Half-power (3 dB) beam width	degree
10 dB beam width	degree
Principal side lobe level	dB
Principal side lobe location	degree

Sub-Bottom Profiling Systems

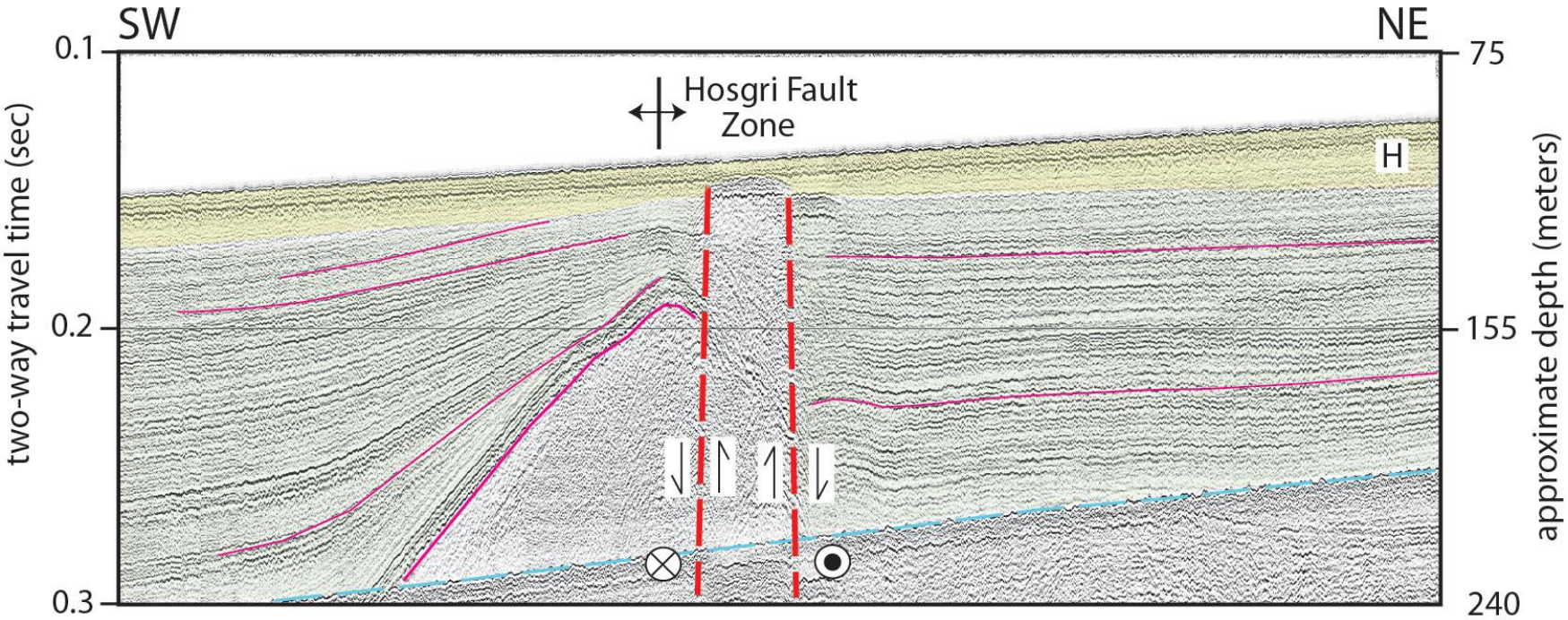
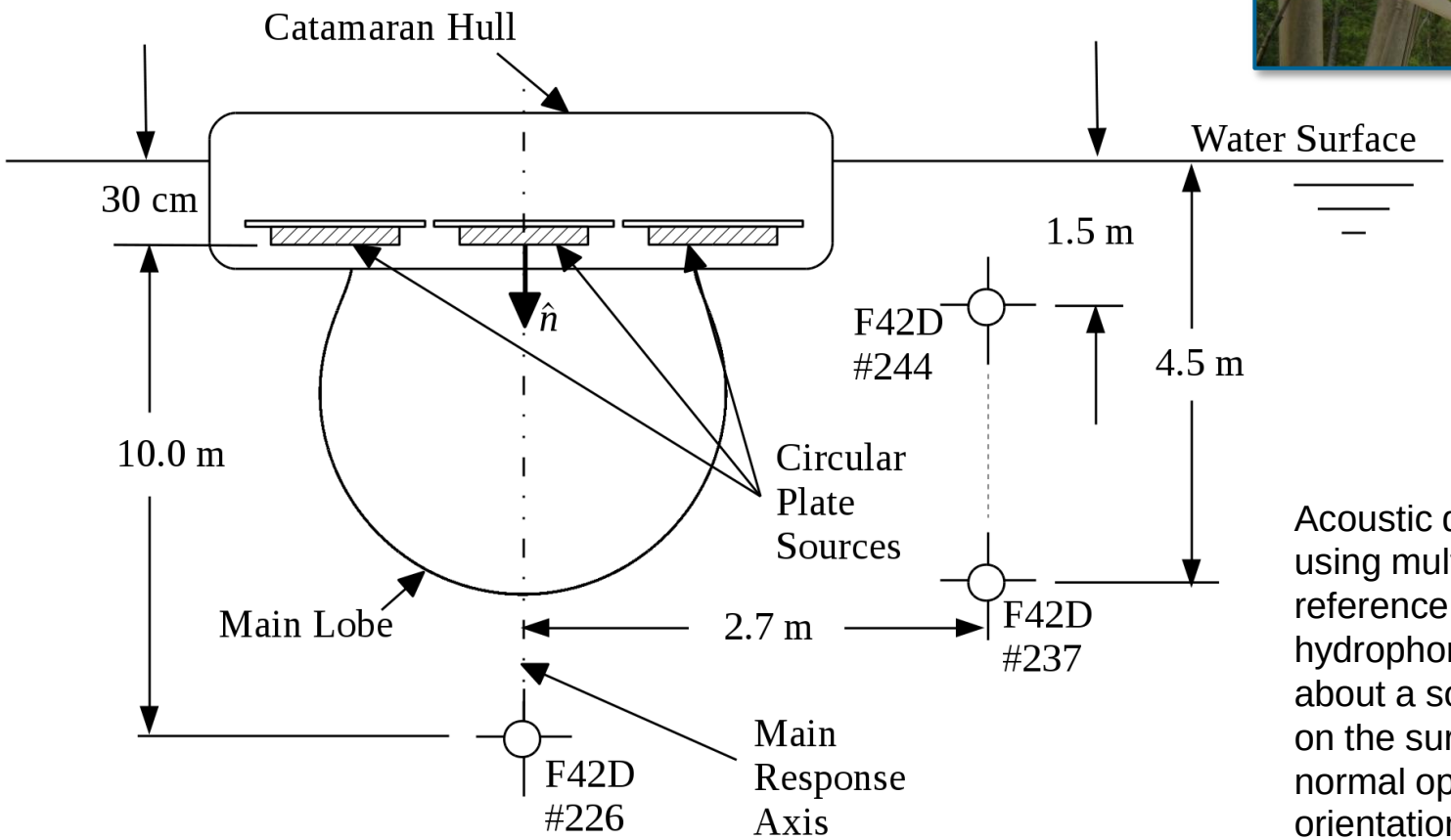


Image: United States Geological Survey

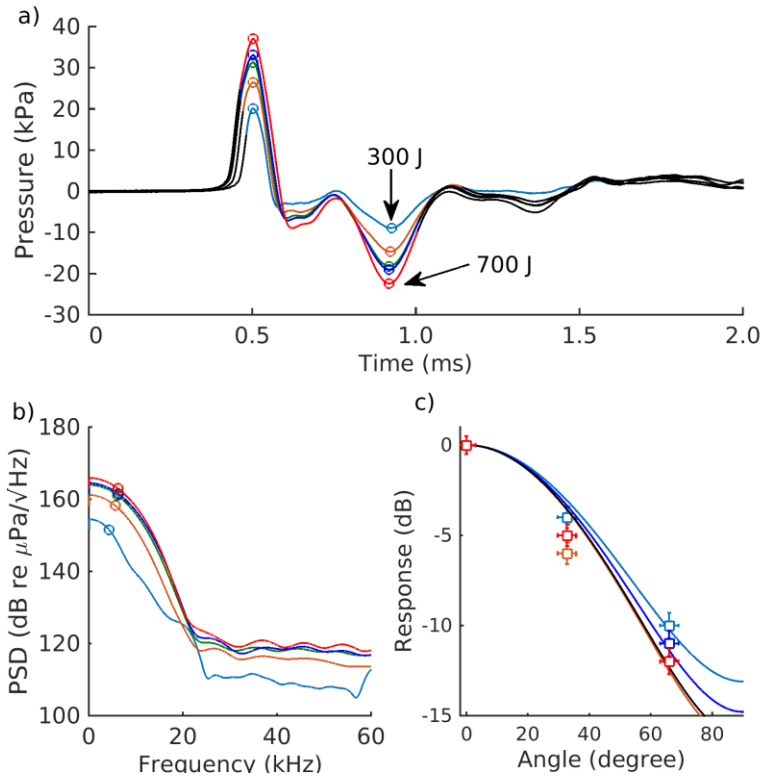
Applied Acoustic S-Boom Sub-Bottom Profiler



Acoustic data collected using multiple calibrated reference standard hydrophones distributed about a source deployed on the surface in its normal operating orientation

Applied Acoustic S-Boom Sub-Bottom Profiler

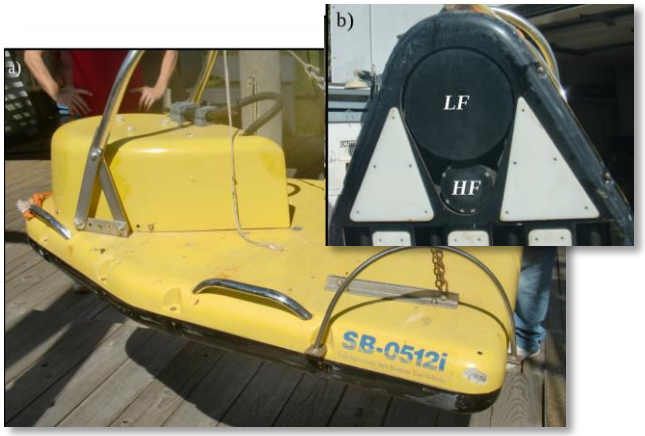
Signal characteristics measured for a wide variety of user selected operating modes

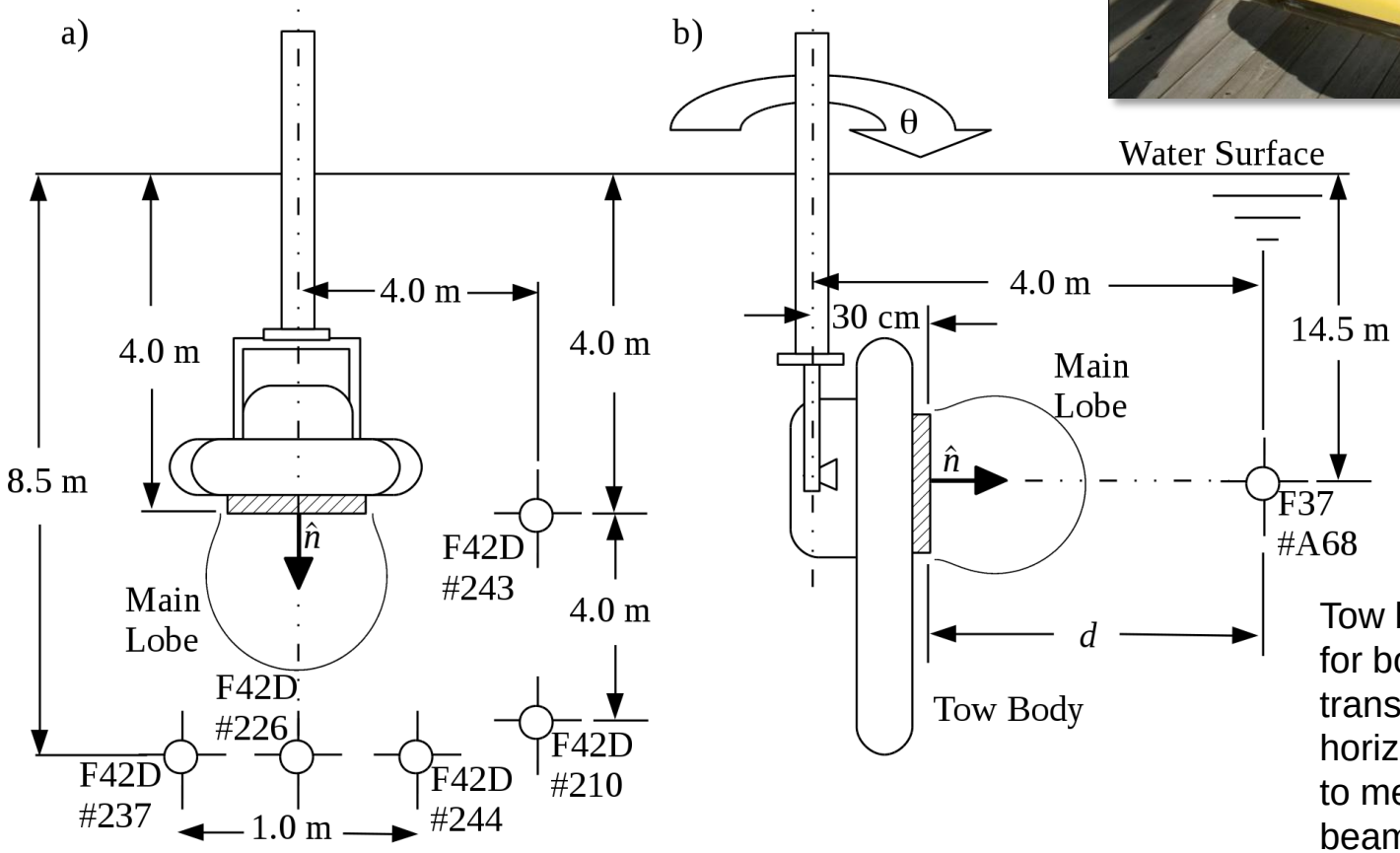


Source Setting (Joules)	Source Level (dB re 1μPa@1m) Pk-Pk	Pk	RMS	SEL	Pulse Width (ms)	Bandwidth 3 dB (kHz)	Beam Pattern ka	MRA Width 3 dB (deg)
100 (1)	202	199	189	157	0.6	7.5	1.2	N/A
100 (2)	202	199	187	157	1.1	4.4	2.1	98
100 (3)	199	196	185	155	1.2	3.3	2.6	78
100 (12)	203	200	190	158	0.6	9.1	3.0	66
100 (13)	203	200	188	157	0.8	5.4	3.1	64
200 (1)	203	201	191	159	0.7	5.7	0.6	N/A
200 (2)	204	201	190	160	1.0	4.4	2.1	98
200 (3)	202	199	187	158	1.2	3.5	2.5	82
200 (12)	205	202	192	160	0.7	6.4	2.9	67
200 (13)	205	202	189	160	1.3	4.1	2.8	70
300 (1)	207	203	195	164	0.8	4.5	0.0	N/A
300 (2)	208	204	195	164	0.9	4.6	2.1	98
300 (3)	206	202	193	163	0.9	4.0	2.1	98
300 (12)	209	205	196	165	0.8	4.8	2.5	80
300 (13)	209	205	194	165	1.1	4.1	2.7	75
300 (123)	209	206	194	165	1.1	4.3	3.1	62
400 (12)	212	208	200	168	0.6	6.1	2.7	75
400 (23)	212	208	199	168	0.8	5.0	2.9	68
400 (13)	212	208	197	168	1.2	4.0	2.6	78
400 (123)	212	208	200	168	0.7	5.6	3.2	60
500 (12)	213	209	202	170	0.7	5.5	2.6	76
500 (23)	214	209	201	170	0.8	4.8	2.8	71
500 (13)	213	209	199	170	1.2	3.8	2.5	80
500 (123)	214	210	202	170	0.6	6.1	3.2	61
600 (12)	214	209	202	170	0.6	5.7	2.5	81
600 (23)	214	210	201	171	0.9	4.6	2.8	71
600 (13)	214	209	200	170	1.2	3.6	2.5	80
600 (123)	214	210	203	171	0.6	6.3	3.2	60
700 (123)	216	211	205	172	0.6	6.2	3.2	61

NOTE: (1) Forward Plate, (2) Middle Plate, (3) Aft Plate

EdgeTech 512i Sub-Bottom Profiler



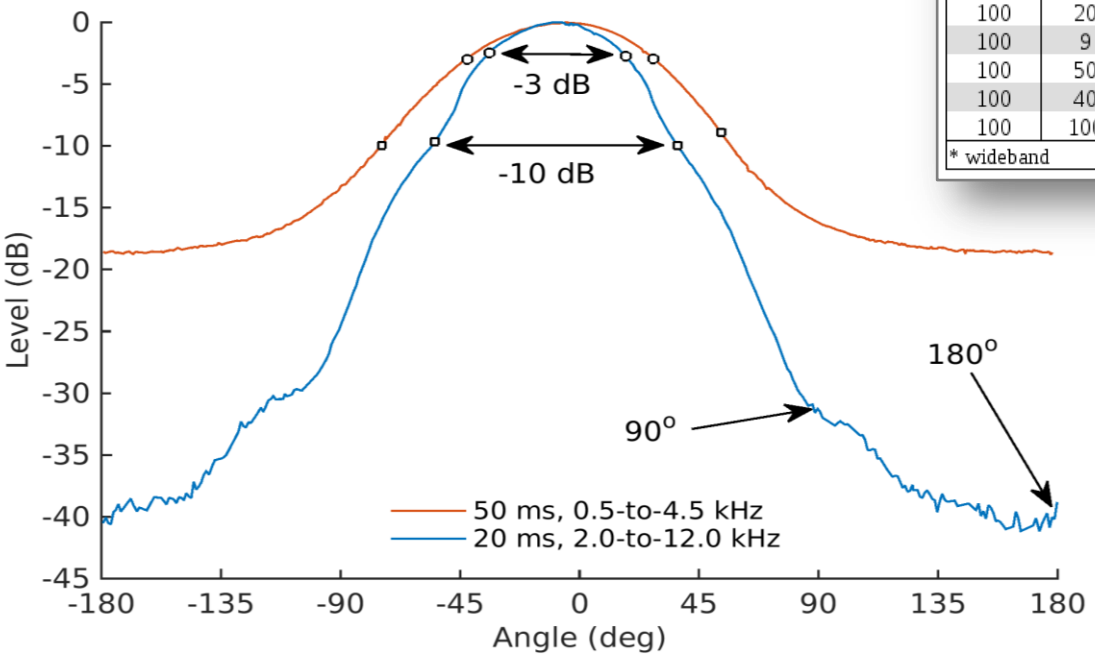


Tow bodies arranged for both normal (vertical) transmission and for horizontal transmission to measure acoustic beampatterns with an angular resolution on the order of one degree.

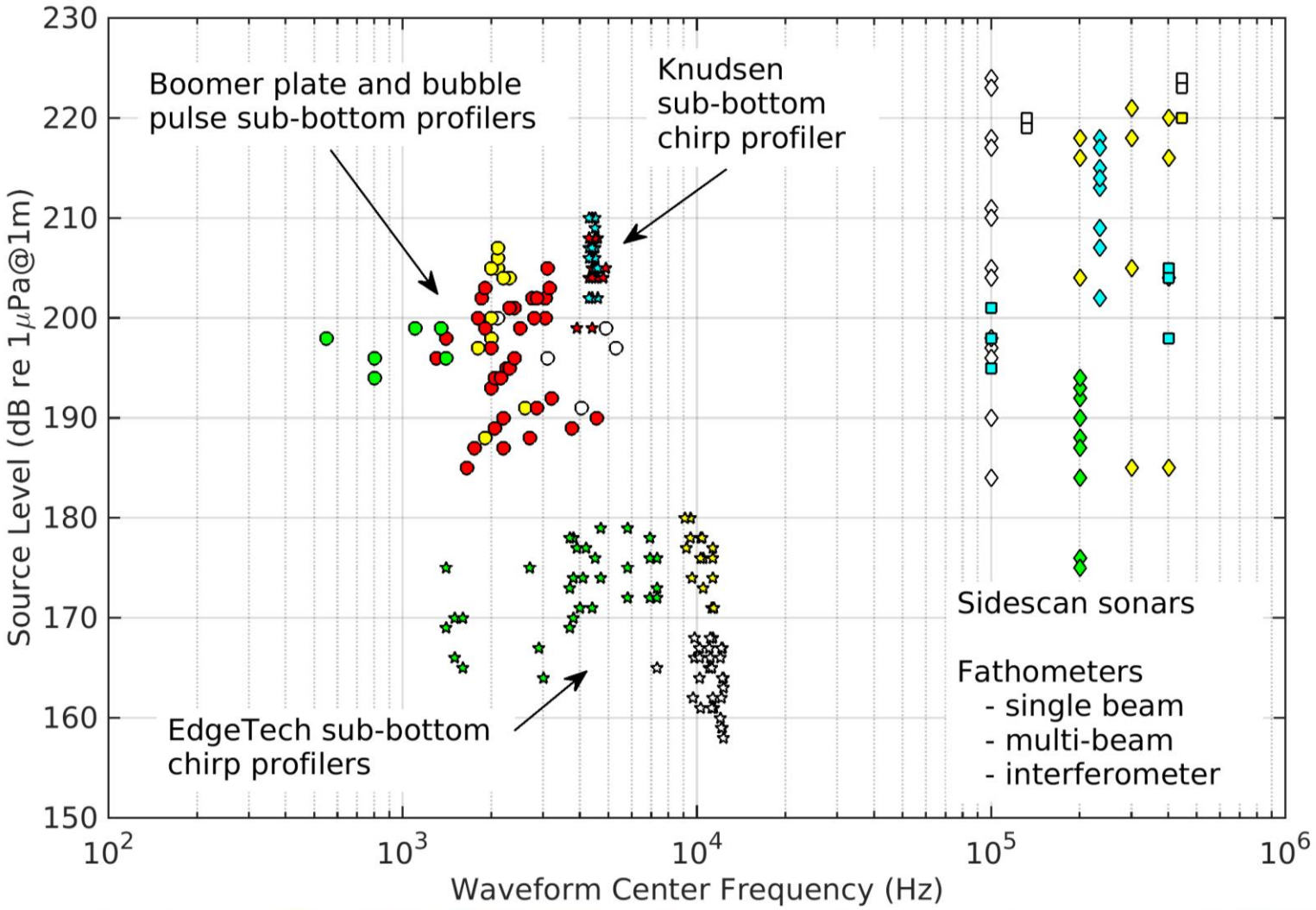
EdgeTech 512i Sub-Bottom Profiler

Beam patterns measured, with summaries tabulated for user selected operating modes

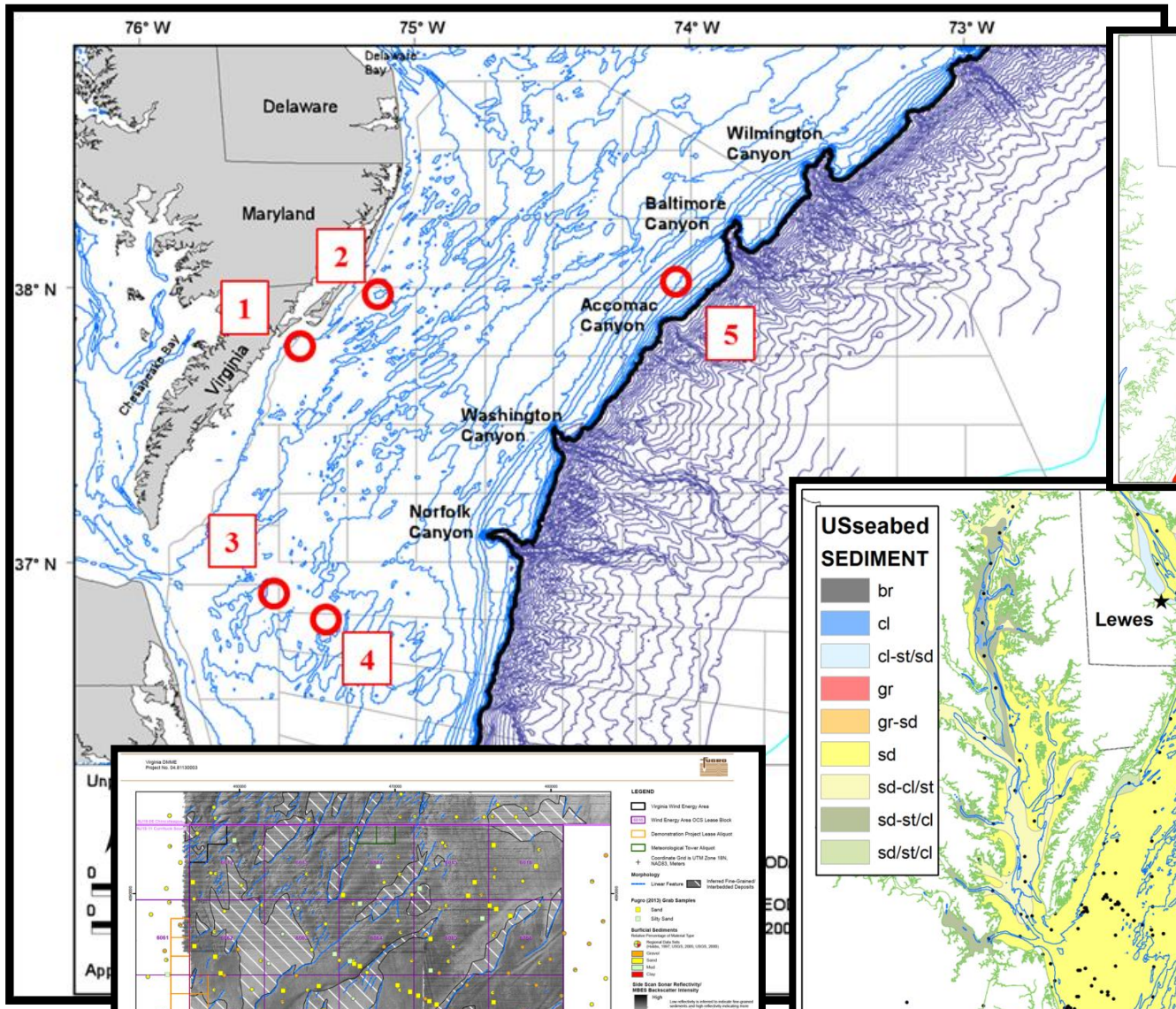
Source Settings			Beam Width (degrees)		Attenuation (dB)	
Power (%)	Pulse Width (ms)	Bandwidth (kHz)	-3 dB	-10 dB	90°	180°
100	20	2.0-to-12.0	51	91	31	40
100	40	1.0-to-6.0	66	112	27	31
100	5	1.0-to-10.0	65	110	29	32
100	20	0.7-to-12.0	60	99	26	29
100	5	0.5-to-8.0	70	108	25	26
100	30	0.5-to-7.2	71	112	24	26
100	20	0.5-to-7.0*	71	127	20	26
100	9	0.5-to-6.0	65	108	23	25
100	50	0.5-to-4.5	70	128	16	19
100	40	0.4-to-4.0*	80	153	15	20
100	100	0.5-to-2.7	74	150	16	22
* wideband						

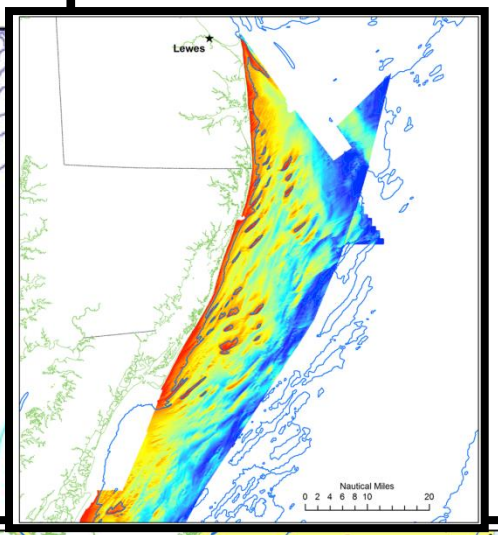


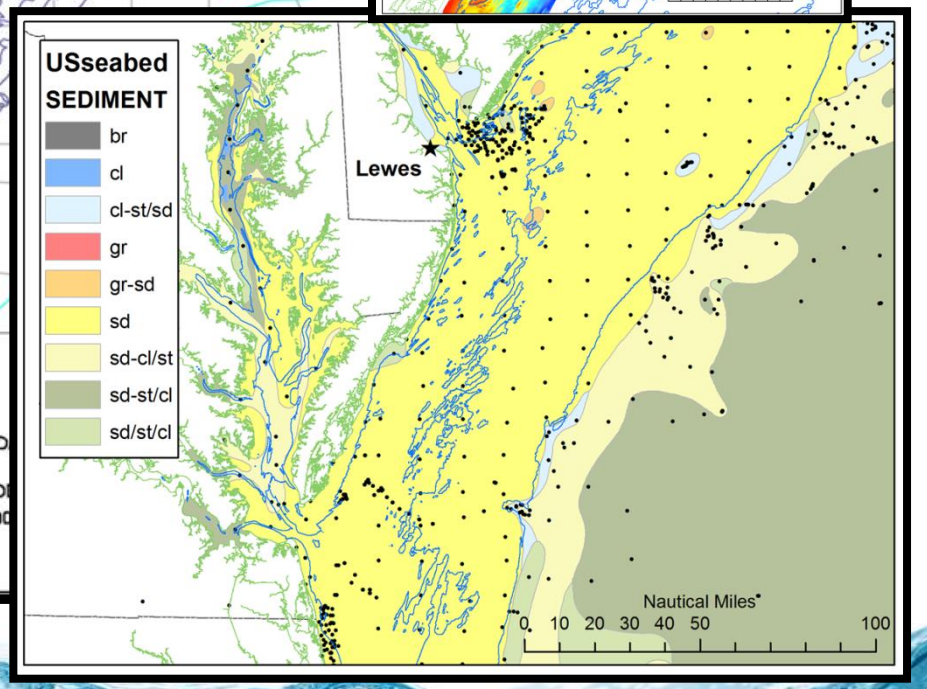
Measurement Summary



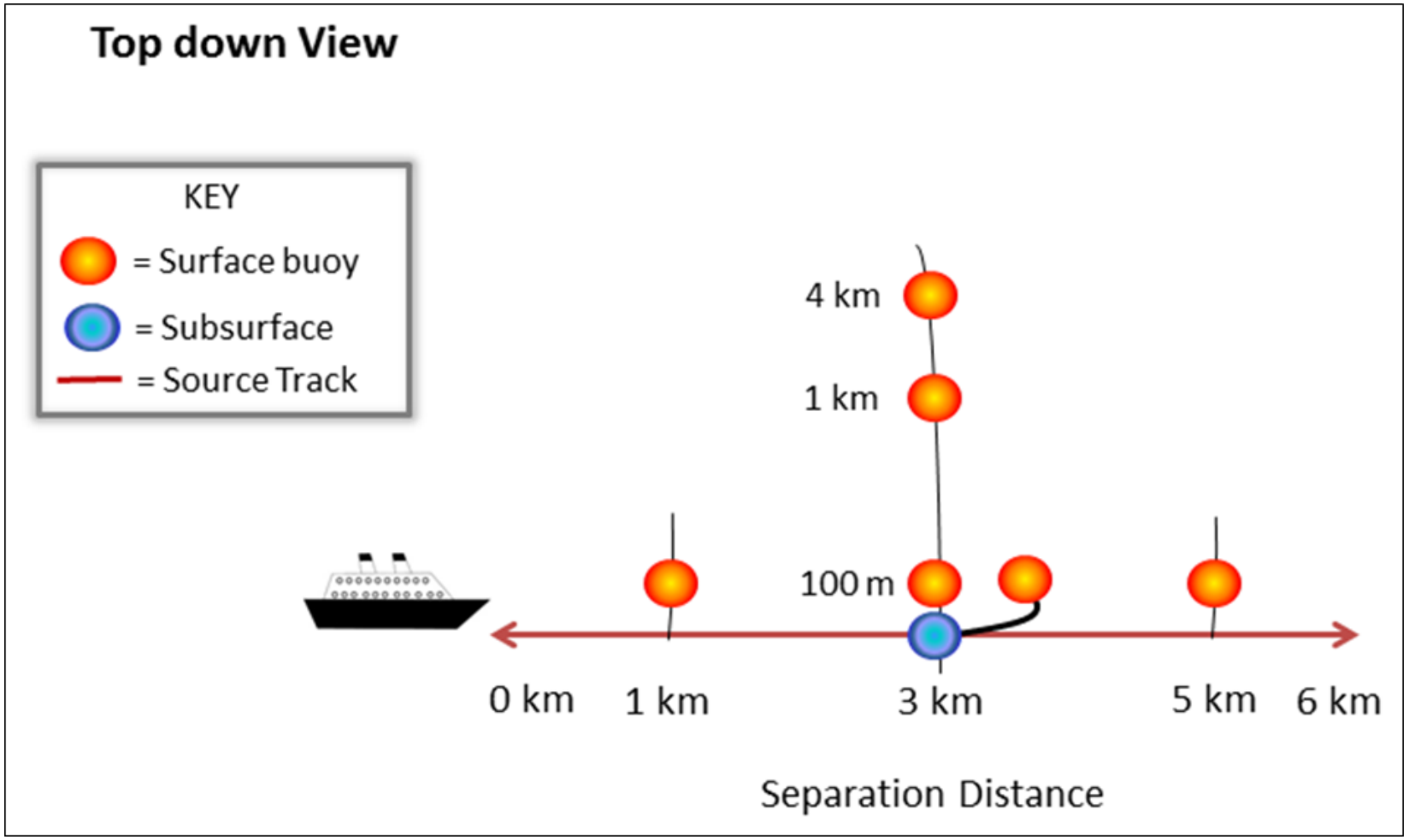
Phase II – At-Sea Measurements Locations







Phase II – Standard Test Geometry

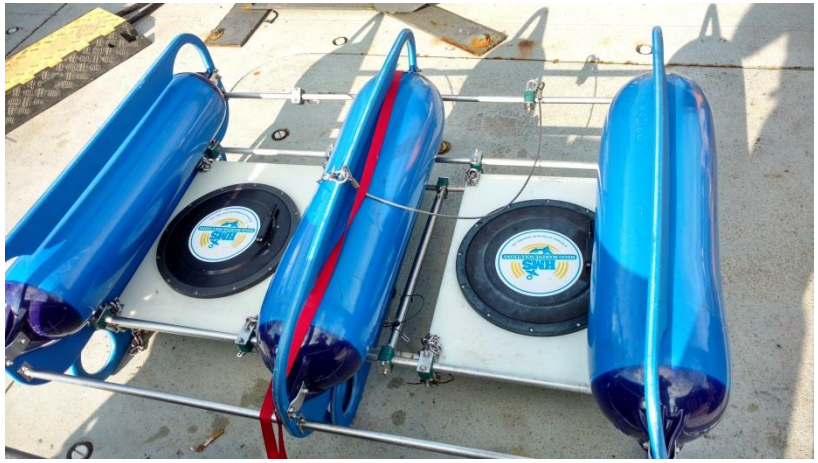


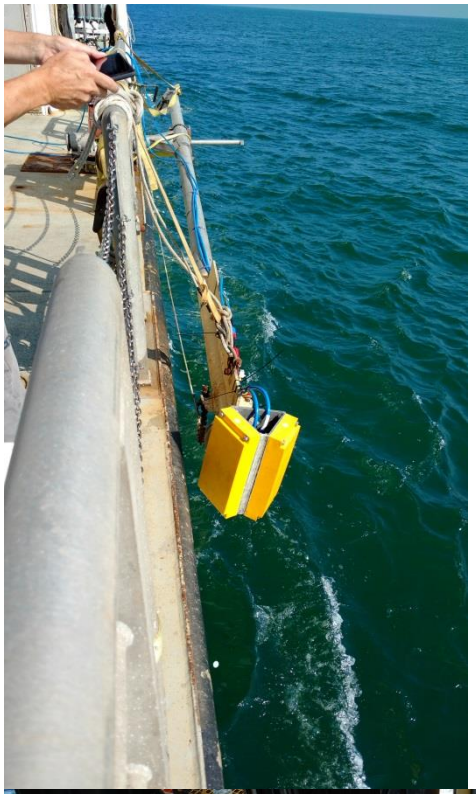
Phase II – Receiver Systems

Bottom-moored Hydrophone waiting to be deployed

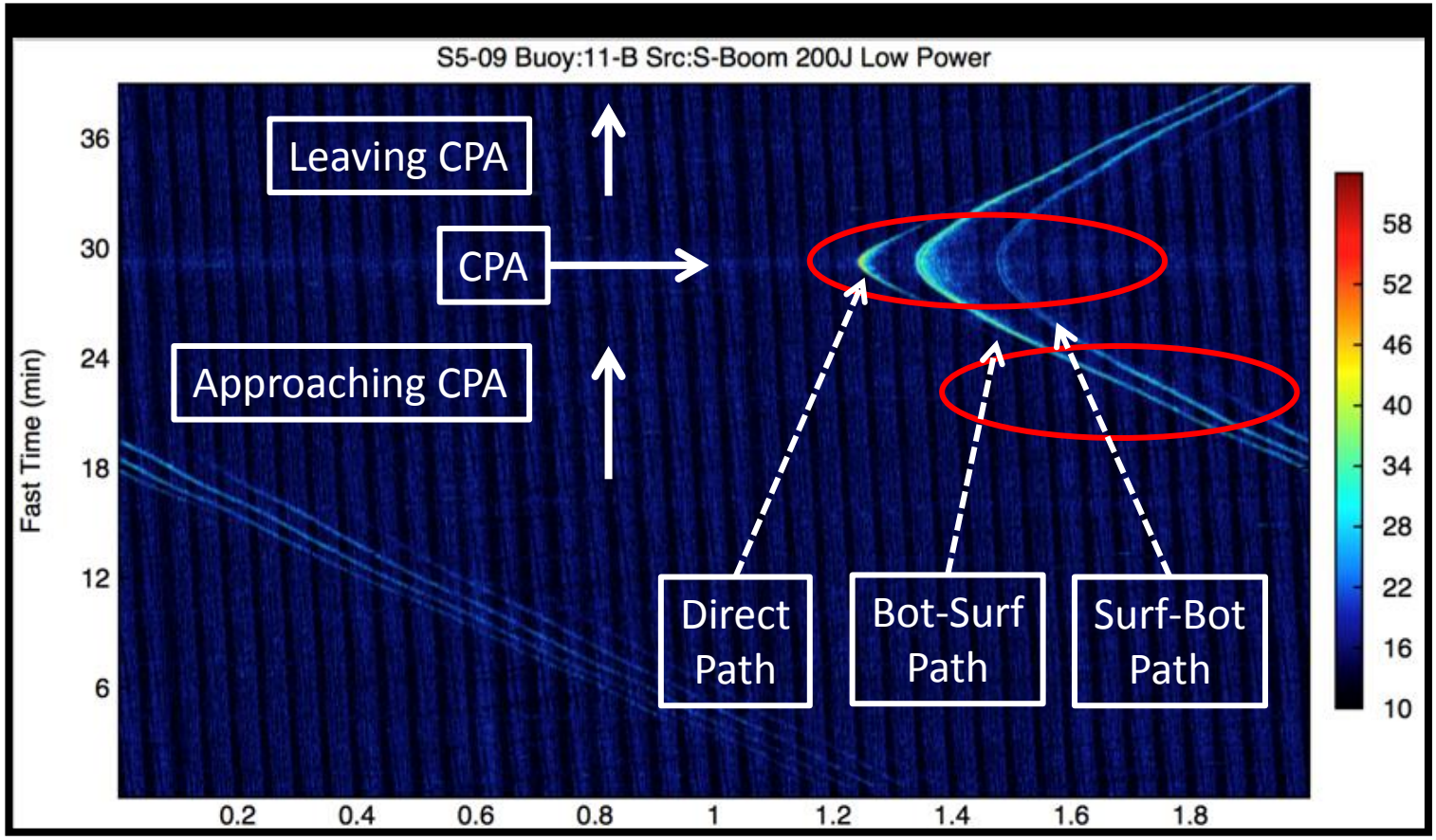
Surface Float Buoy & Anchor being deployed

Phase II – Acoustic Source Systems





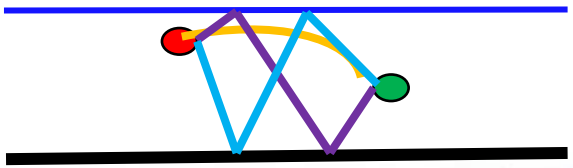
Phase II – Preliminary Results



Approaching CPA:

Orange = Direct Path
Lt Blue = Bot-Surf
Purple = Surf-Bot

At CPA:



Conclusion

Calibrated High Resolution Geophysics (HRG) source data is available now for 19 commonly used source.

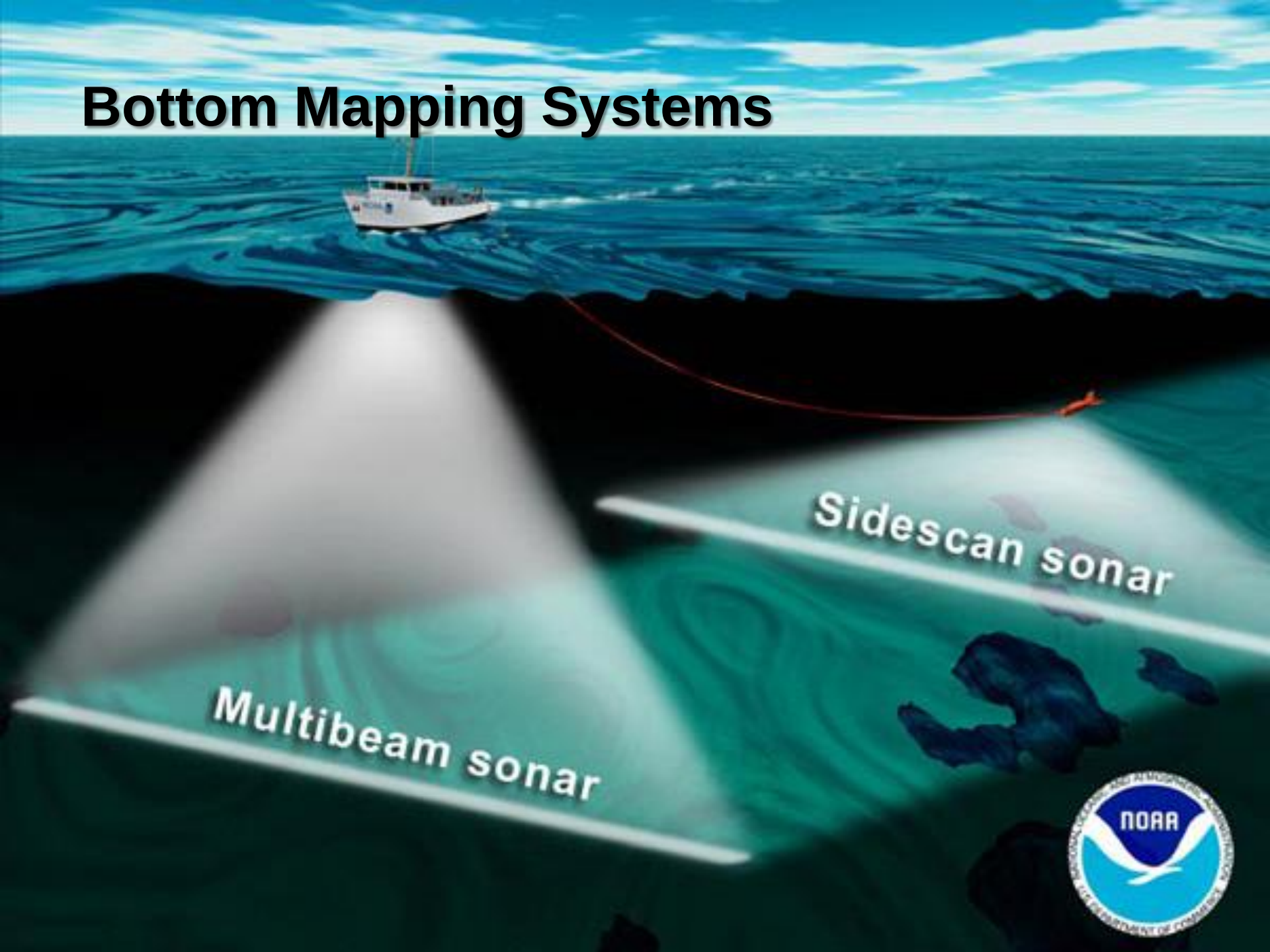
In-situ measured source characterizations of these same sources plus a small GI airgun and sparkers are being analyzed and will be available soon.

The final the phase, analysis and recommendations on modeling these same sources for locations and environments not measured (i.e., predictive modeling), looks to be funded in FY2018.

Requisite Sunset Picture & Questions

Backup Slides

Bottom Mapping Systems



Multibeam Sonar

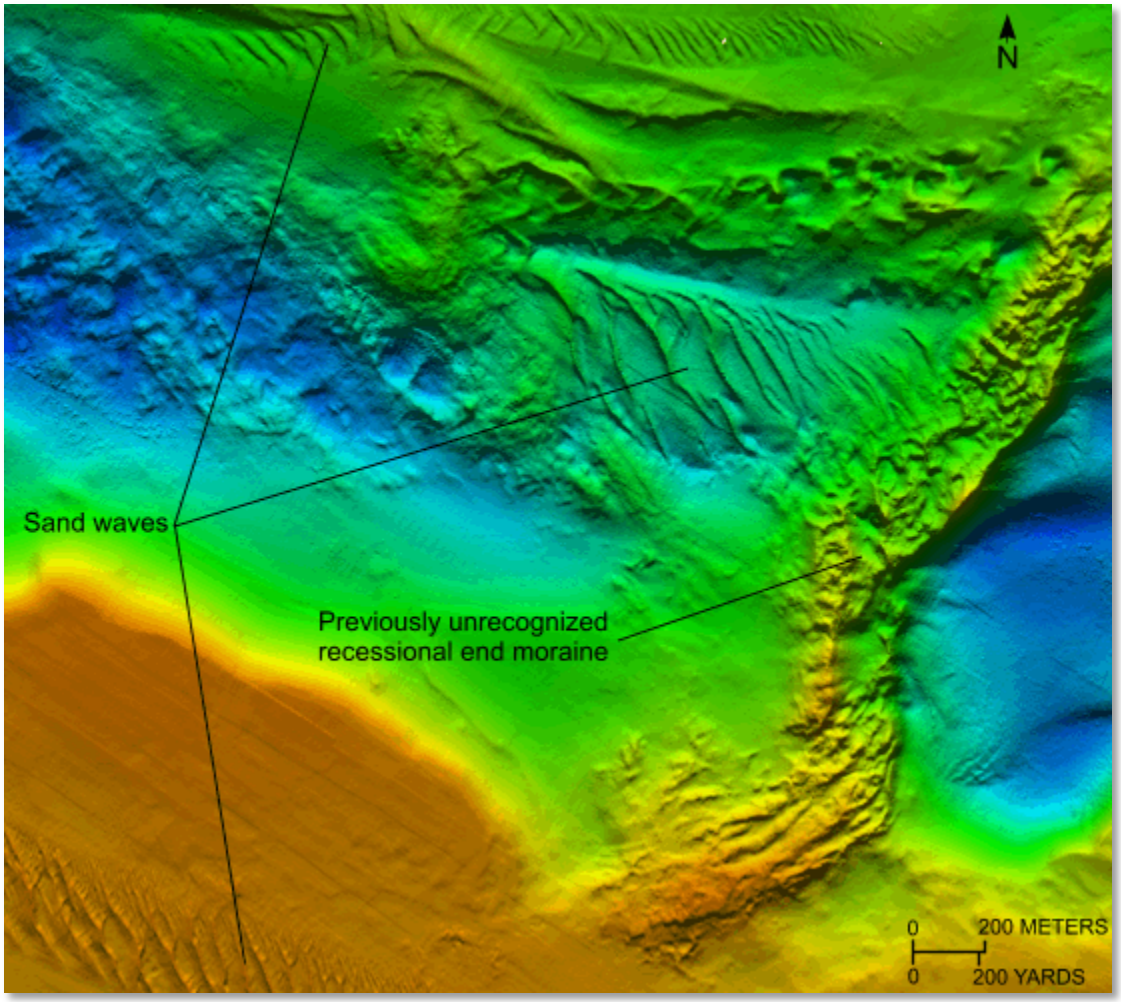
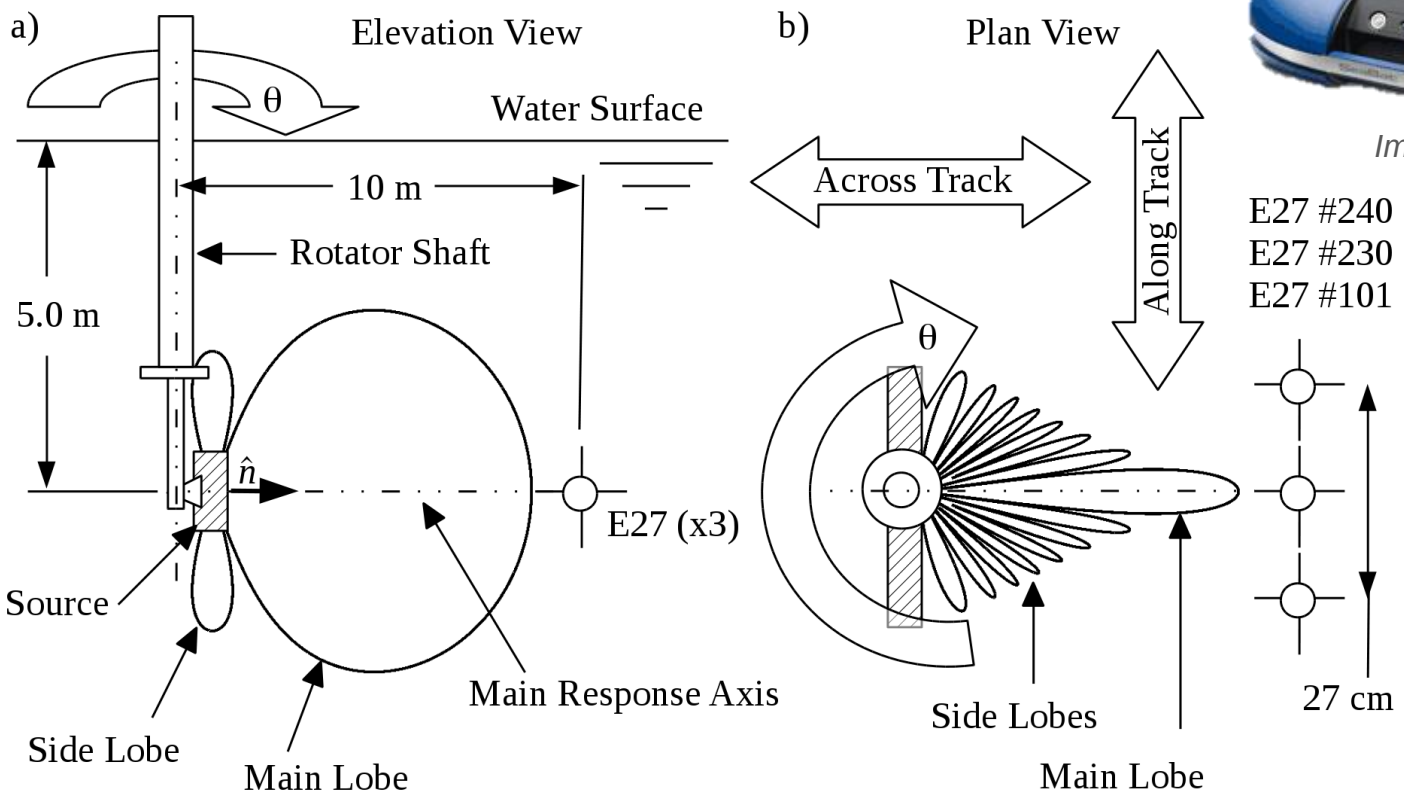


Image: United States Geological Survey

T20P Multibeam Fathometer

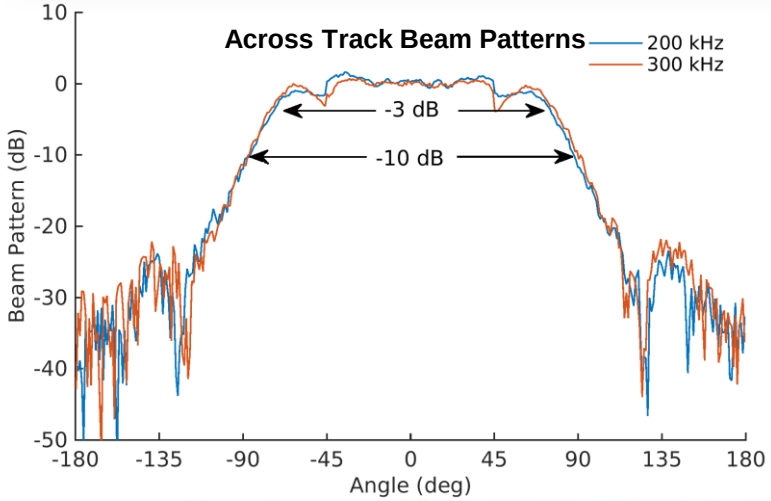
Image: Teledyne Reson

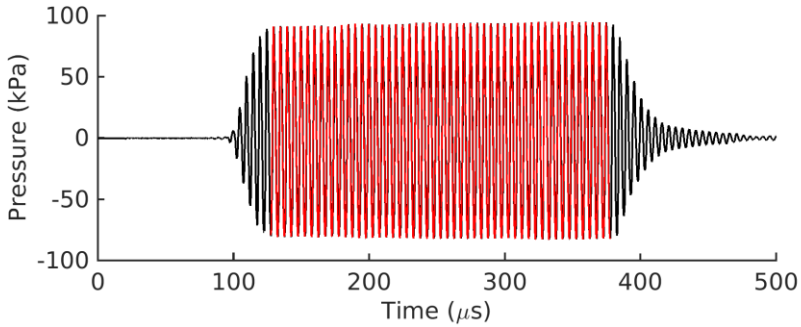


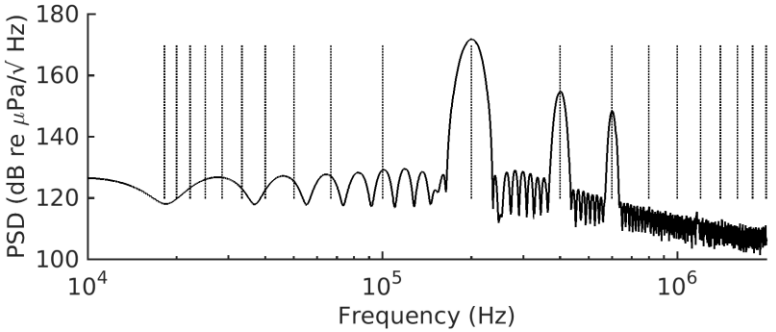
Geometry for measurement of along track beampatterns using closely spaced calibrated reference standards to improve resolution of narrow beam widths.

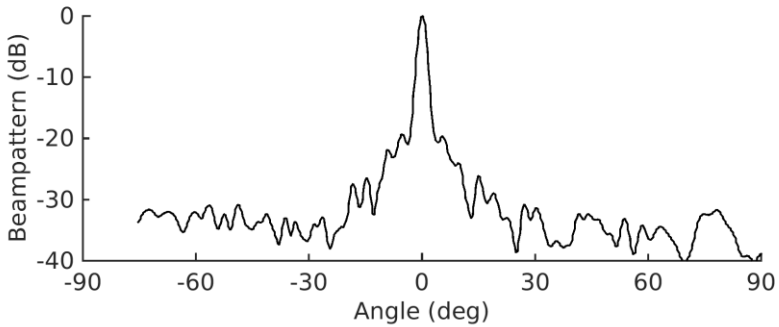
T20P Multibeam Fathometer

Source Settings			Source Level (dB re 1μPa@1m)				Effective Pulse Width (μs)
Freq. (kHz)	Source Level (dB)	Pulse Width (μs)	Pk-Pk	Pk	RMS	SEL	
200	220	300	226	221	218	182	250
200	205	300	213	208	204	168	248
200	190	300	193	187	184	150	254
300	220	300	232	227	221	185	253
300	205	300	215	210	205	169	252
300	190	300	197	191	185	149	254
400	220	300	229	223	220	184	254
400	205	300	214	208	204	168	257
400	190	300	197	191	185	150	269









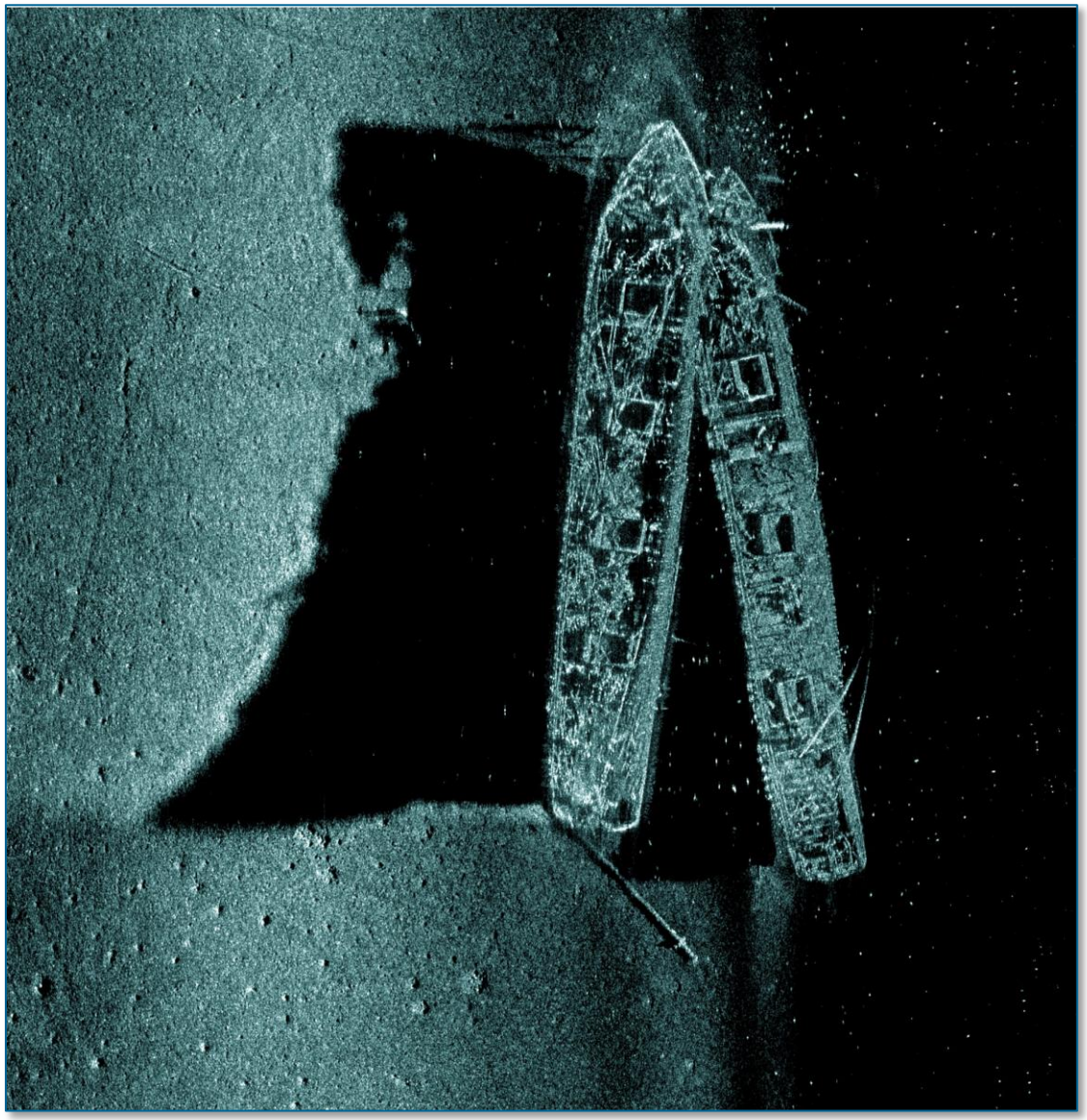
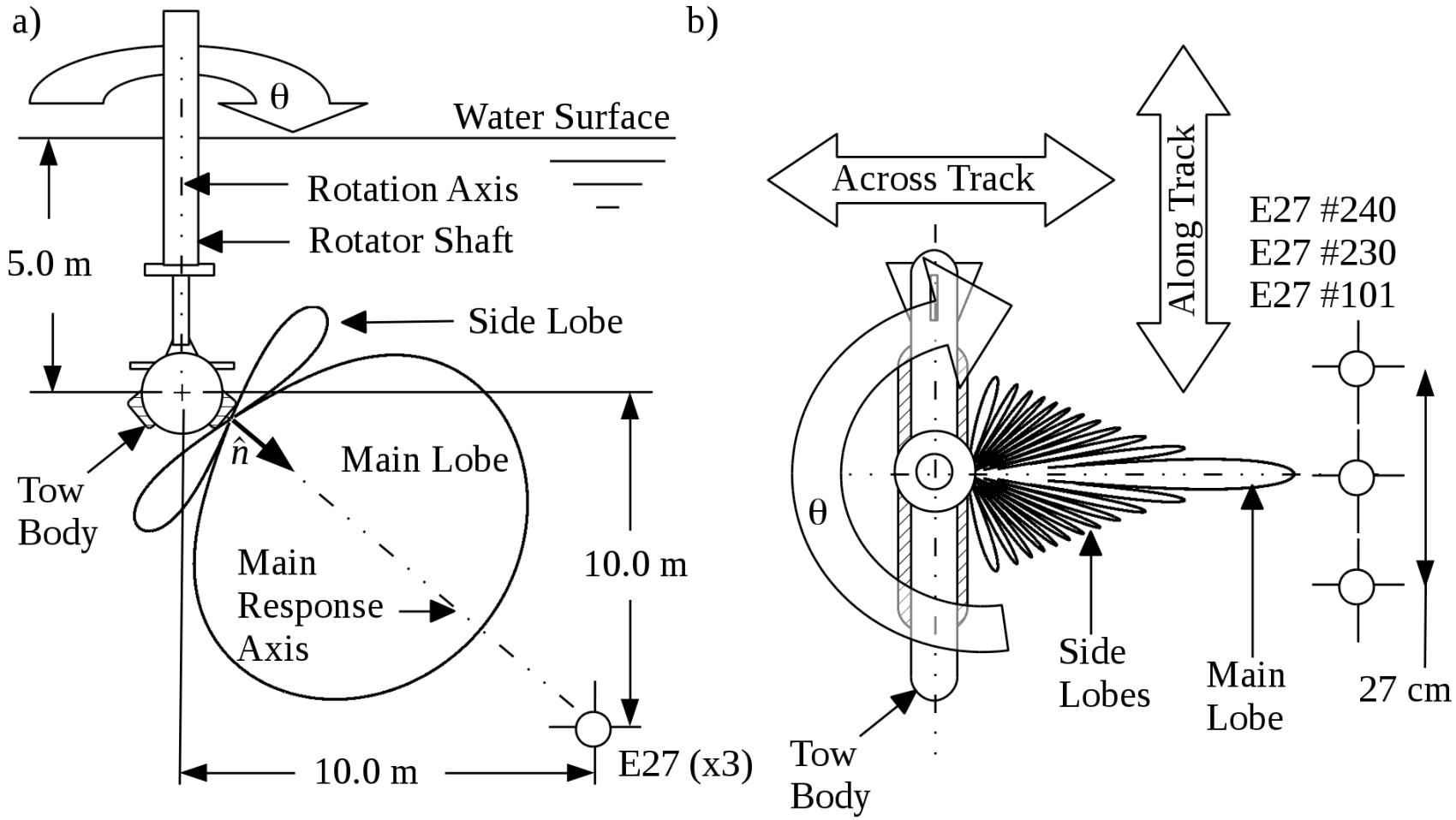


Image: National Oceanic and Atmospheric Administration (USA)

Side Scan Sonar

Klein 3000 Side Scan Sonar



Klein 3000 Side Scan Sonar

Source Settings			Source Level (dB re 1μPa@1m)				Eff. Pulse Width (us)	Main Lobe Width (3 dB) (deg)	Max. Side Lobe	
Freq. (kHz)	Pulse Width (us)	Range (m)	Pk-Pk	Pk	RMS	SEL			Angle (deg)	Level (dB)
132	50	25	229	224	219	176	44	2.4	-16	-10
132	50	50	229	224	220	176	44	2.4	-17	-9
132	50	100	229	224	220	176	42	2.2	-17	-10
132	50	400	230	225	220	176	44	1.9	-17	-10
132	50	600	230	225	220	176	44	2.2	-17	-9
132	100	100	230	224	220	179	81	2.1	-17	-10
132	200	200	230	225	220	182	168	1.8	-17	-10
132	400	400	230	224	219	184	343	1.7	-17	-11
132	400	600	230	224	219	184	343	1.8	-17	-11
445	25	50	233	227	224	177	21	1.2	-5	-16
445	25	600	233	227	223	177	21	0.8	-5	-17
445	100	100	233	227	223	182	88	1.2	-5	-19