ANADARKO PETROLEUM CORPORATION
1201 LAKE ROBBINS DRIVE • THE WOODLANDS, TEXAS 77380
P.O. BOX 1330 • HOUSTON, TEXAS 77251-1330

February 26, 2024

Jolie Harrison, Division Chief
Permits and Conservation Division, Office of Protected Resources,
1315 East-West Highway, F/PR1 Room 13805,
Silver Spring, MD 20910

RE: LOA Application, G&G Permit - VSP Seismic Survey
Mississippi Canyon, MC Block 216

Dear Ms. Harrison:

Please find the attached request for an incidental take authorization under section 101(a)(5) of the Marine Mammal Protection Act of 1972 (MMPA), as amended, for the potential take of marine mammals incidental to conducting a VSP Seismic Survey (referred as "Orange VSP") in "Mississippi Canyon" area, in block 216.

The Horn Mountain Field general area has been covered in the past by WAZ (Wide Azimuth) multiclient streamer surveys. Those surveys combined provide a good regional image, however, they lack the resolution and high frequencies that could be provided by a more targeted downhole survey. Further, the regional seismic representation of the geology needs to be referenced ("tied" in geological parlance) to the depth observed at the well bore. The industry standard to provide such tie is to record a 1D Vertical Seismic Profile (1D VSP). The new proposed 1D VSP at Orange (Well MC 216 #001) would provide an accurate estimation of the stretch factor between geological depth and the time at which surface seismic techniques record events. This referencing is essential for any further operation in the block, and would help Anadarko optimize further activities, hence reducing environmental impact in the long run.

Anadarko is planning to conduct **a zero offset VSP.** No dedicated source vessel would be in use. The seismic source would be suspended at 5m of water depth with a crane on the side of the drill ship. The source would be either a 6-element, 1,500 cubic inch airgun array, referenced as the "hyper cluster", or a 12-element, 2,400 cubic inch airgun array, referenced as the "dual Magnum". The expected source activity duration for this configuration is less than 3 days.

Anadarko's upcoming VSP survey is subject to the provisions of the MMPA and the Regulations Governing Taking Marine Mammals Incidental to Geophysical Survey Activities in the Gulf of Mexico (50 CFR § 217, Subpart 5); therefore, we are requesting issuance of a Letter of Authorization for the proposed activities.

Anadarko is requesting the LOA be issued with an effective period from May 15, 2024, to November 15, 2024. The expected commencement date of the survey is May 20, 2024.

In support of this request, please review the attached Letter of Authorization Application and copy of Anadarko's VSP Ancillary Activities Permit/Plan with all supporting documentation, submitted to BOEM on 2/26/2024.

If you have any questions, please contact me at 713-557-9453 or e-mail at Debbie_Malbrough@oxy.com.

Sincerely,

DocuSigned by:

F4013CDF08CA45C...

Deborah "Debbie" Malbrough
Consultant Regulatory Sr.
GOM Regulatory Affairs

Letter of Authorization Application – Addendum to G&G Permit Application

Short Form – Assumes proprietary materials of BOEM G&G application are provided to NMFS

A. Type of Survey:

Please indicate which type of survey will be used in the proposed activity
_X__ Deep Penetration Seismic (greater than 1,500 in^3 total airgun array volume) • 2D Seismic-towed Streamer • 2D Seismic-Seafloor Cable or Nodes • 3D Seismic-towed Streamer • 3D Seismic-Seafloor Cable or Nodes • NAZ • WAZ • 4D (Time Lapse) • Vertical Cable • Borehole Seismic (VSP) **_X__ Shallow Penetration Seismic (less than 1,500 in^3 total airgun array volume)** • Surface Vessel • Surface Vessel and AUV/ROV • Borehole Seismic (VSP) **___ HRG Surveys (no airguns used)** • Surface vessel • AUV/ROV • Both **___ Other** Describe (if Other):

B. Survey Area and Operational Plan:

Question:	Response
Overall Duration of the Activity (days):	4-8 days
Areal extent of the survey area: (in OCS lease blocks or km^2) (Attach GIS file(s) of survey lines and/or survey area perimeter)	Survey centered around Mississippi Canyon block MC-216 Source area, 1 OCS blocks. Receiver area, 1 well. All receivers downhole. See map inserted in Section F.
G&G ITR/PEIS Modeling Zone(s) in which the activity will occur (1-7):	Zone 5 (Central GoM in slope water around 6,150 ft)
Number of days during the overall activity period on which the sound source(s) listed in Section C will operate: (If the activity will occur in more than one Modeling Zone, provide the number of operating days within each modeling zone.)	3 days

C. Sound Sources:

- List the same sound sources provided in response to question #3 in "Section D Proprietary Information Attachment" to the G&G Permit Application and indicate their Duration of Use.

Only one energy source of the two types of equipment listed below will be selected.

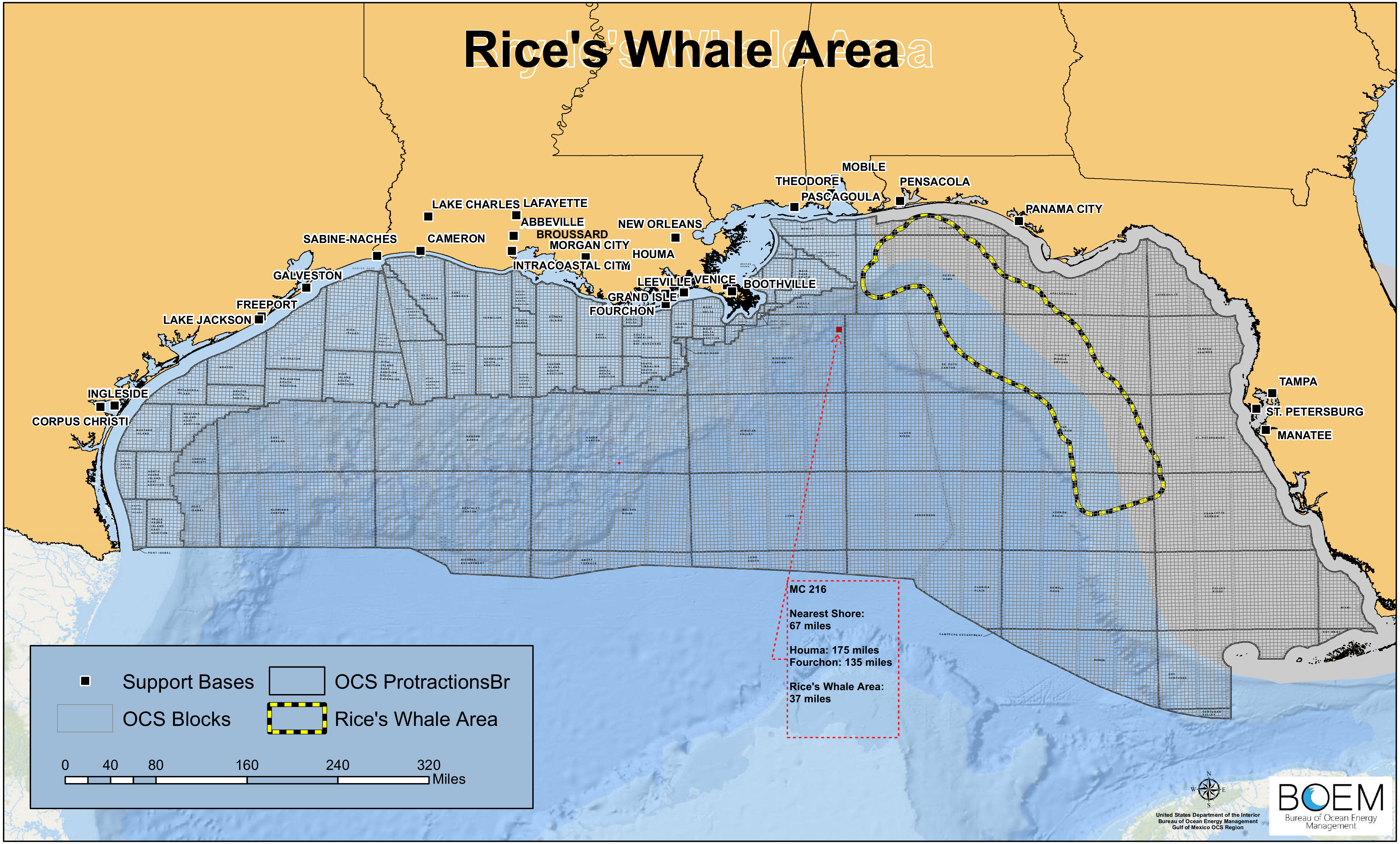
Energy Source	**Manufacturer & Model**	**Duration of Use** (Number of Days or Percent of Active Sound Source Days)
Dual Magnum 2,400 cu.in.	Sercel G Gun, 12 guns, total volume 2,400 cu. In., 2,000PSI	Less than 3 days
Hyper cluster 1,500 cu.in.	Sercel G Gun, 6 guns, total volume 1,500 cu. In., 3,000PSI	Less than 3 days

D. Take Estimate:

Summary of Exposures in support of LOA application:

E. Mitigation and Monitoring Efforts:

Question:	Response:
Please indicate which set of monitoring and mitigation measures from the ITR apply to the planned activity:	All monitoring and mitigation measures in the ITRs applicable to Deep Penetration Airgun Surveys with a total volume >1,500 cu in will be followed. BOEM NTL 2016-G02 revised 6/19/2020 Appendices A, B, and C to NMFS 2020 BiOp for the GoMex Oil and Gas Program
Confirm that you will apply this set of monitoring and mitigation measures during the activity:	Yes, we will apply these measures during this VSP survey.



Office of Leasing and Plans, Mapping and Automation Section | MAS202000234 | 21 April 2020

Gulf of Mexico Seismic Survey Exposure Calculator

Compute estimated marine animal exposures based on user-defined seasonal schedule, survey configuration, and location.

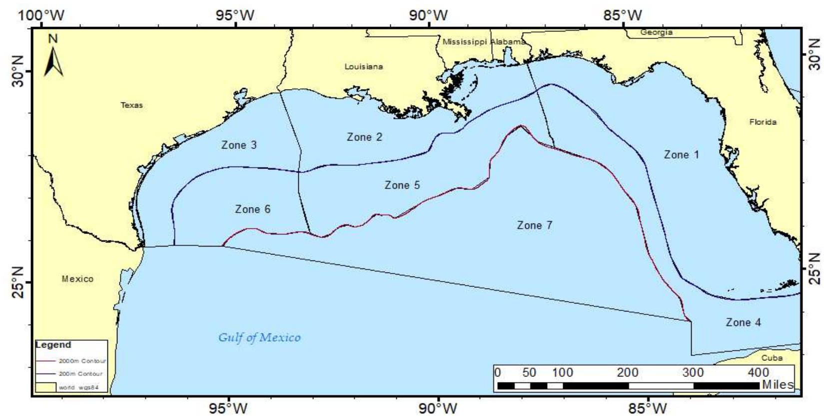
Instructions:

- Select the survey type and zone number (2-7, operations in Zone 1 are not covered by the incidental take regulations) from the drop down lists (click in the cell to see the dropdown arrow)

- Type in the number of days of acquisition per season in the "Schedule" section (Winter: December - March, Summer: April - November)

Report tables are automatically updated based on user selections.

Zone Map:



Parameters	
Survey Type	*2D*
Zone Number	*5*

Schedule	
Season	**# days**
Summer	8
Winter	

Level A Color Legend:	
	Level A SEL
	Level A Peak

*If no color highlight, both level A peak and SEL are <0.01

Exposures by Metric	Summer	Winter	Total
Level A			
Low-Frequency Hearing Group			
Bryde's whale	0.01	< 0.01	0.01
High-Frequency Hearing Group			
Kogia (dwarf, pygmy sperm whale)	2.14	< 0.01	2.14
Level B			
Low-Frequency Hearing Group			
Bryde's whale	5.87	< 0.01	5.87
Mid-Frequency Functional Hearing Group			
Beaked whales (Cuvier/Blainville/Gervais)	1,474.91	< 0.01	1,474.91
Bottlenose dolphin	997.25	< 0.01	997.25
Short-finned pilot whale	109.18	< 0.01	109.18
Sperm whale	284.62	< 0.01	284.62
Atlantic spotted dolphin	381.53	< 0.01	381.53
Clymene dolphin	595.86	< 0.01	595.86
False killer whale	121.35	< 0.01	121.35
Fraser’s dolphin	64.51	< 0.01	64.51
Killer whale	3.89	< 0.01	3.89
Melon-headed whale	377.44	< 0.01	377.44
Pantropical spotted dolphin	2,703.95	< 0.01	2,703.95
Pygmy killer whale	76.28	< 0.01	76.28
Risso’s dolphin	177.30	< 0.01	177.30
Rough-toothed dolphin	175.31	< 0.01	175.31
Spinner dolphin	724.53	< 0.01	724.53
Striped dolphin	232.73	< 0.01	232.73
High-Frequency Hearing Group			
Kogia (dwarf, pygmy sperm whale)	98.61	< 0.01	98.61

Total take, including Level B Scaling (where appropriate)		
Summer	Winter	Total
5.8815406	< 0.01	5.88
1474.91	< 0.01	1474.91
997.25	< 0.01	997.25
109.18	< 0.01	109.18
284.62	< 0.01	284.62
381.53	< 0.01	381.53
595.86	< 0.01	595.86
121.35	< 0.01	121.35
64.51	< 0.01	64.51
3.89	< 0.01	3.89
377.44	< 0.01	377.44
2703.95	< 0.01	2703.95
76.28	< 0.01	76.28
177.30	< 0.01	177.30
175.31	< 0.01	175.31
724.53	< 0.01	724.53
232.73	< 0.01	232.73
100.75	< 0.01	100.75

Created for NOAA by JASCO Applied Sciences (USA) Inc.: 05/07/2021

Information relative to BOEM G&G Permits
(BOEM-0137 & BOEM-0138)
in support of
NOAA/NMFS Letters of Authorization and 1D (Zero Offset) VSP

1. Expected Commencement Date: May 15, 2024

   Expected Completion Date: May 18, 2024

2. The activity will be conducted by: Schlumberger
   Contact information: A. Martinez
   Address: 6350 West Sam Houston Pkwy N, Houston, TX 77041
   Telephone: 346-275-8377/ 281-284-4584
   Email: ammartinez@slb.com

   The activity will be conducted for: Anadarko Petroleum Corporation
   Contact information: Deborah Malbrough
   Address: 1201 Lake Robbins Drive, The Woodlands, TX 77380
   Telephone: 832-636-2321
   Email: Debbie_malbrough@oxy.com

3. Individual in charge of the field operation:
   Contact information: Williams Adeyemi
   Address: 6350 West Sam Houston Pkwy N, Houston, TX 77041
   Telephone: 985-297-1316
   Email: WAdeyemi@slb.com

4. Vessel(s) to be used in the operation is (are):
   Vessel Name(s) | Vessel model | Registry Number(s) | Radio Call Sign(s) | Registered Owner(s)

   Ocean BlackHawk | Drillship | 9618898 | V7AS9 | Diamond Offshore Drilling

5. Briefly describe the navigation system (vessel navigation only):
   DGPS on the vessels; dynamic positioning using Geosynchronous satellites and on-board receivers operating in conjunction with the global positioning system.

6. Proposed Operation: Vertical Seismic Profile
   a. Acquisition method (OBN, OBS, Streamer): Downhole Receivers
   b. Type of Acquisition: (High Resolution Seismic, 2D Seismic, 3D Seismic, gravity, magnetic, CSEM, etc.) This survey will be a 1D VSP also known as check shot.

   See attached Plat.

7. List all energy source types to be used in the operation(s): (Air gun, air gun array(s), sub-bottom profiler, sparker, towed dipole, side scan sonar, etc.). Air gun

8. Explosive charges will ____will not X _be used. If applicable, indicate the type of Explosive and maximum charge size (in pounds) to be used:

   Type NA Pounds NA Equivalent Pounds of TNT NA

9. List each energy source to be used (e.g., airgun, airgun array(s), sparker, towed dipole, side scan sonar, sub bottom profiler, etc.). Indicate the source's manufacturer, model, Source Level (SL) in dB re 1µPa @1m in water (RMS) and if applicable, Source Level (SL) in dB re 1µPa @1m in water (Peak to Peak) and ping rate. If the manufacturer does not provide a peak-to-peak level (many side scan sonars, etc.), please enter N/A. Additionally, provide the operational frequency ranges.

Energy Source	Manufacturer	Model	Array or Airgun Size (cu. in.)	Source Level (SL) in dB re 1uPa@1m in water (RMS)	Source Level (SL) in dB re 1uPa@1m in water (Peak to Peak)	Frequency (Hz, kHz range)	Ping Duration/ Cycle	Ping Rate
Airgun	Sercel	G-Gun	2400	228	252	0 to 1,000 Hz	0.4s	0.083Hz
Airgun	Sercel	G-Gun	1500	228	251	0 to 1,000 Hz	0.4s	0.083Hz

For air guns/air gun arrays (excludes multibeam bathymetry, high frequency sub bottom profilers, and side scan sonar systems), provide the maximum distance from the sound source to the 190, 180, and 160 dB in RMS dB levels: (Required for Alaska region, GOM region only requires this information for surveys in the GOM that will use simsource during acquisition; Not required for Atlantic permits).

dB Level	Maximum Distance from Source
190 dB	
180 dB	
160dB	

10. State the shot frequency of the source array(s) as shots per minute or shots per linear mile (statute): One shot every 12 seconds.

11. List the towing depth (ft/m) of the source array(s): 5m (hung from crane off side of drillship).

12. If applicable, list the towing depth (ft/m) of the receiver(s):
    NA. The receivers will be down hole in the well.

13. CSEM, OBN, Magnetotelluric, and OBC surveys: Describe the receiver deployment and retrieval procedures. Indicate the number and spacing of any ocean bottom receivers, cables, and anchors. If anchors will not be retrieved, provide their physical composition and rate of decomposition.

    Not applicable

14. List the navigation/positioning system or method used to position shotpoint locations and/or ocean bottom receivers: Industry-standard seismic navigation software.

15. Proposed areal extent (in OCS blocks) for 3D surveys or total number of line miles for 2D surveys: 1D VSP is punctual; source at ~250 feet from well head.

16. Provide the company identification name of the proposed survey (e.g., Deep Six Survey) and list all proposed initial and final processed data sets that will result from survey acquisition:

    Orange 216 VSP. Deliverables: 1D, vertical profile for well tie.

17. State the estimated date (month and year) on which initial and final processing will be available for all proposed processed data sets:

    Intermediate dataset: ~June 15, 2024; Final ~July 30 2024.

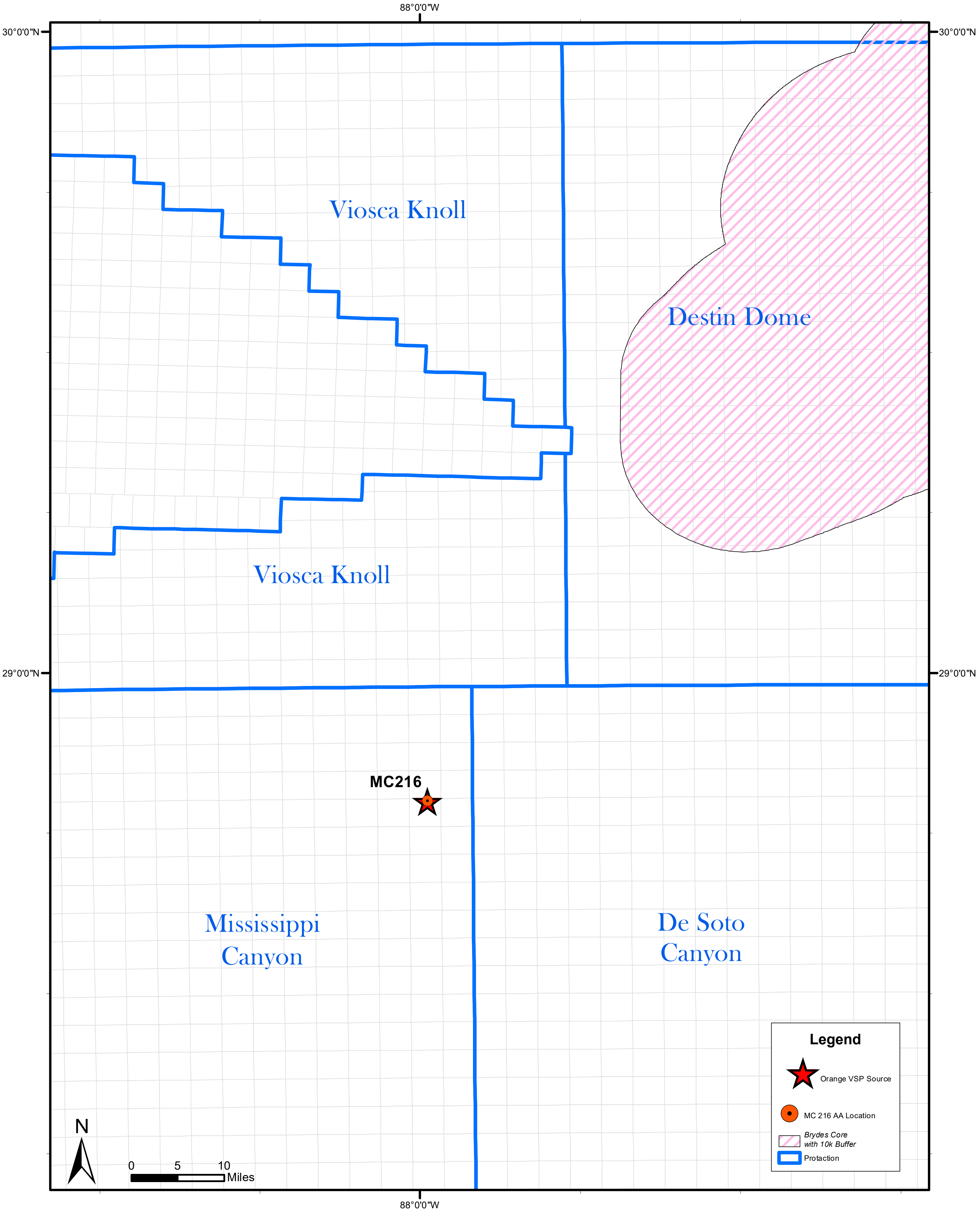
18. Attach map(s), plat(s), and chart(s) (preferably at a scale of 1:250,000) and an electronic version of same showing latitude and longitude, scale, specific protraction areas, OCS boundary/3-mile limit, block numbers. The map, plat or chart should be submitted at a sufficient size and scale to make out all details of the activities shown. The map should be labeled "Proprietary" For 2D data acquisition provide specific track lines with line identifications with the total number of line miles proposed or a representative polygon and total number of blocks for 3D surveys. Along with the hardcopy map, submit on CD or flashdrive (subject to security screening), the necessary ArcGIS shape files to reproduce the map for 2D track lines including individual line names in the attribute table. For 3D surveys provide a representative polygon as an ArcGIS shape file. You must provide a shapefile data set of the latitude/longitude location for all track lines, shot lines, and node placements. This can be submitted at a later time but must be received before activities can take place.

BOEM-0327 Section A – General Information (Attachment A-3)
Orange MC 216 Check Shot (1D VSP)

The Orange Check Shot (1D VSP) geophysical survey will use the 1D Vertical Seismic Profile (1D VSP) technique. For this survey, a borehole tool equipped with seismic sensors will be lowered into the Orange well (MC 216 001) while a seismic source will be operated in the water, outside of the well. The source will be craned in the water from the “Ocean BlackHawk” drillship and will be stationary. The seismic source be located within a radius of 250-ft from the well head, using rig's crane to deploy it and keep it stationary.

No aircraft are expected. Protected Species Observers will monitor exclusion zone and shut-down source if marine mammals /turtles or any protected species are observed in zone.

The stationary seismic source ~~vessels~~ will generate a sound source that is created by an air gun array. There are no scientifically proven lasting adverse effects on marine life. In an effort to minimize excessive sound in water, we have chosen to utilize the lowest sound volume possible that would still allow for the geophysical objective to be achieved.


88°0'0"W
30°0'0"N
30°0'0"N
Viosca Knoll
Destin Dome
Viosca Knoll
29°0'0"N
29°0'0"N
MC216
Mississippi Canyon
De Soto Canyon
Legend
Orange VSP Source
MC 216 AA Location
Brydes Core with 10k Buffer
Protaction
N
0 5 10 Miles
88°0'0"W

Ocean BlackHawk

GENERAL DESCRIPTION

Design……………………………...…...…………….......... Gusto P10,000 DW

Year Entered Service………………...……………….…………………… 2014

Classification. ABS, +A1, Drillship, Helidk, +AMS, +ACCU, +CDS, + DPS-3, SH-DLA, GP

Dimensions…... 757 ft long x 118 ft wide x 59 ft deep

Draft…………………..……………………..…....... 36 ft operating and transit

Displacement…………...……………………...............……. 70,333T operating

Variable Deck...……..………...………………....…….....…. 34,896T operating

Transit Speed………………...………...…...…………….……... up to 12.5 knots

Water Depths…………....….....……...... 12,000 ft designed / 10,000 ft outfitted

Drilling Depth…………………....…………………………….…… 40,000 ft

DRILLING EQUIPMENT

Derrick	NOV Dual Bottleneck, 210 ft high with 80 ft x 60 ft base, combined hook load capacity of 4,000 kips
Drawworks	(Main): NOV / AHD 1250, six AC electric motors, 9,000hp total, 1,250T with sixteen 2 1/8” drilling lines
	(Aux): NOV / AHD 750, five AC electric motors, 5,750hp total, 750T with fourteen 1 ¾” drilling lines
Compensator	Active Heave Compensating Drawworks and Passive Heave CMC (Main) - 500 ST at 25ft stroke
Rotary Table	(Main): NOV RST 75 ½” hydraulic, 1,375T static
	(Aux): NOV RST 60 ½” hydraulic, 1,000T static
Top Drive	(Main): NOV TDX-1250, 1,250T with 7,500 psi
	(Aux): NOV TDS-8SA. 750T with 7,500 psi
Tubular handling	2 x NOV MPT ‘Hydraulic Roughneck’ for tubular range 3 ½” to 9 ¾” + 2 x NOV HR IV-ER
Mud Pumps	5 x NOV 14-P-220, 2,200hp, 7,500 psi

POWER EQUIPMENT

Main Power	6 x Himsen diesel engines rated 4,300kW, each driving 5,375 kVA AC generators
	2 x Himsen V-type diesel engines rated 8,700kW, each driving 10,875 kVA AC generators
Emergency Power	V-type Cummins diesel engine rated 1,900kW driving 1 x STX engine rated 1500kWAC generator

STORAGE CAPACITIES

Liquid Mud………………………………………….……………..… 15,204 bbls

Base Oil……………………………………….............................… 7,209 bbls

Brine………………..…………………………….………….…..... 13,175 bbls

Drill Water…………………..………………………………….... 18,593 bbls

Potable Water………………………….………………………..... 8,834 bbls

Bulk Storage…...............… 16,513 ft³ (barite + bentonite) + 15,891ft³ (cement)

Sack Storage……...………………………..……...……..……… 6,000 sacks

CRANES

Knuckle-boom	1 x 100 ton + 2 x 85 ton knuckle-boom
AHC Subsea	165 ton Active Heave Compensation knuckle-boom

SUBSEA EQUIPMENT

Diverter	Vetco CSO 21¼” 500 psi diverter with 1 x 20” flow line + 2 x 16” overboard diverter lines
BOP Stacks (2)	Hydril 18 ¾” 15,000 psi seven-ram preventer
	2 x Hydril 18 ¾” 10,000 psi annular preventers
	APIS53 compliant
C&K Manifold	3 1/16”, 15,000 psi
Marine Riser	Vetco HMF Class H 21”, 75 ft long per joint
Tensioners	16 x 225 kips NOV wireline riser tensioners. Total capacity 3,600 kips with 50 ft of wire travel
Moonpool	73 ft x 42 ft

STATION KEEPING / PROPULSION SYSTEM

Thrusters	6 x Thrustmaster, 5,000kW azimuth thrusters with fixed pitch variable speed propellers
DP System	Kongsberg K-POS

OTHER INFORMATION

Dual Activity	Yes
Accommodation	210 people
Helideck	Sikorsky S-61 & S-92, CAP 437 compliant
MPD	Fully integrated Managed Pressure Drilling (MPD) system (Q4 2023 installation)

DIAMOND
OFFSHORE

These specifications are intended for general reference purposes only, actual equipment may vary upon the contract situation and customer needs.

BOEM-0327 Section D

Proprietary Information Attachment

Anadarko Petroleum Corporation

Attachment D-1 - DualMagnum_5m_2400cuin_2000psi

GUNDALF array modelling suite - Array report

Gundalf revision AIR8.1n, Date 2018-03-30, Epoch 2018-03-30

Fri Mar 08 11:37:34 Central Standard Time 2019 (ASayed2)

Report pre-amble

Author: Ali Sayed

Author Organisation: Schlumberger

250 cu-in cluster inter-gun spacing = 90 cm; 150 cu-in cluster inter-gun spacing = 60 cm; inter-cluster spacing = 2.0 m;

Contents

Signature filtering policy

For marine environmental noise reports, Gundalf performs no signature filtering other than that inherent in modelling at a sample interval small enough to simulate an airgun array signature at frequencies up to 50kHz, and any requested marine animal weighting functions.

For all other kinds of reports, Gundalf performs filtering in this order:-

- If a pre-conditioning filter is chosen, for example, an instrument response, it is applied at the modelling sample interval.
- If the output sample interval is larger than the modelling sample interval, Gundalf applies appropriate anti-alias filtering. (This can be turned off in the event that anti-alias filtering is included in the pre-conditioning filter, in which case Gundalf will issue a warning.)
- Finally, Gundalf applies the chosen set of post-filters, Q, Wiener and band-pass filtering as specified, at the output sample interval. If none are specified, (often known as unfiltered), only the above anti-alias and/or pre-conditioning are applied.

In reports, when filters are applied, they are applied to the notional sources first so that signatures, directivity plots and spectra are all filtered consistently. The abbreviation muPa is used for microPascal throughout.

Finally note that modelled signatures always begin at time zero for reasons of causality.

Anti-alias and pre-condition filtering

In this case, no pre-conditioning filter has been applied.

In this case, no anti-alias filtering was necessary.

Post filtering

Details of the post-filtering used in this report follow. Post filters are applied at the output sample interval after any pre-conditioning and anti-alias filters have been applied.

Q filtering

No Q filtering performed.

Wiener filtering

No Wiener filtering performed.

Band-pass filtering

No band-pass filtering performed.

Some notes on the modelling algorithm

The Gundalf airgun modelling engine is the end-product of 15 years of state of the art research. It takes full account of all air-gun interactions including interactions between sub-arrays. No assumptions of linear superposition are made. This means that if you move sub-arrays closer together, the far-field signature will change. The effect is noticeable even when sub-arrays are separated by as much as 10m.

The engine is capable of modelling airgun clusters right down to the 'super-foam' region where the bubbles themselves collide and distort. It has been calibrated against both single and clustered guns for a number of different gun types under laboratory conditions and accurately predicts peak to peak and primary to bubble parameters across a very wide range of operating conditions.

In many cases, the predicted signatures are good enough to be used directly in signature deconvolution procedures.

Array summary

The following table lists the statistics for the array quoted in various commonly used units for convenience. Note that the rms value is computed over the entire modelled signature. Conservative error bounds for the main signature characteristics of peak to peak, primary to bubble and bubble period are also shown. These represent 95% confidence intervals for the Gundalf model against its calibration data.

Array parameters ...	
Number of guns	12
Total volume (cu.in).	2400.0 (39.3 litres)
Peak to peak in bar-m.	39.5 +/- 0.571 (3.95 +/- 0.0571 MPa, ~ 252 db re 1 muPa. at 1m.)
Zero to peak in bar-m.	24.8 (2.48 MPa, 248 db re 1 muPa. at 1m.)
RMS pressure in bar-m.	2.61 (0.261 MPa, 228 db re 1 muPa. at 1m.)
Primary to bubble (peak to peak)	18.8 +/- 5.24
Bubble period (s.)	0.167 +/- 0.0115
Maximum spectral ripple (dB): 10.0 - 50.0 Hz.	4.41
Maximum spectral value (dB): 10.0 - 50.0 Hz.	206
Average spectral value (dB): 10.0 - 50.0 Hz.	206
Total acoustic energy (Joules)	110046.6
Total acoustic efficiency (%)	20.3

Array geometry and gun contribution

The following table lists all the guns modelled in the array along with their characteristics. The last column is completed only if the array has actually been modelled during the interactive session and contains the approximate contribution of that gun as a percentage of the peak to peak amplitude of the whole array. Please note the following:-

- The peak to peak varies only as the cube root of the volume for the same gun type so that even small guns contribute significantly. This is particularly relevant to drop-out analysis.
- The peak to peak can also be depressed due to clustering effects as reported by Strandenes and Vaage (1992), "Signatures from clustered airguns", First Break, 10(8).

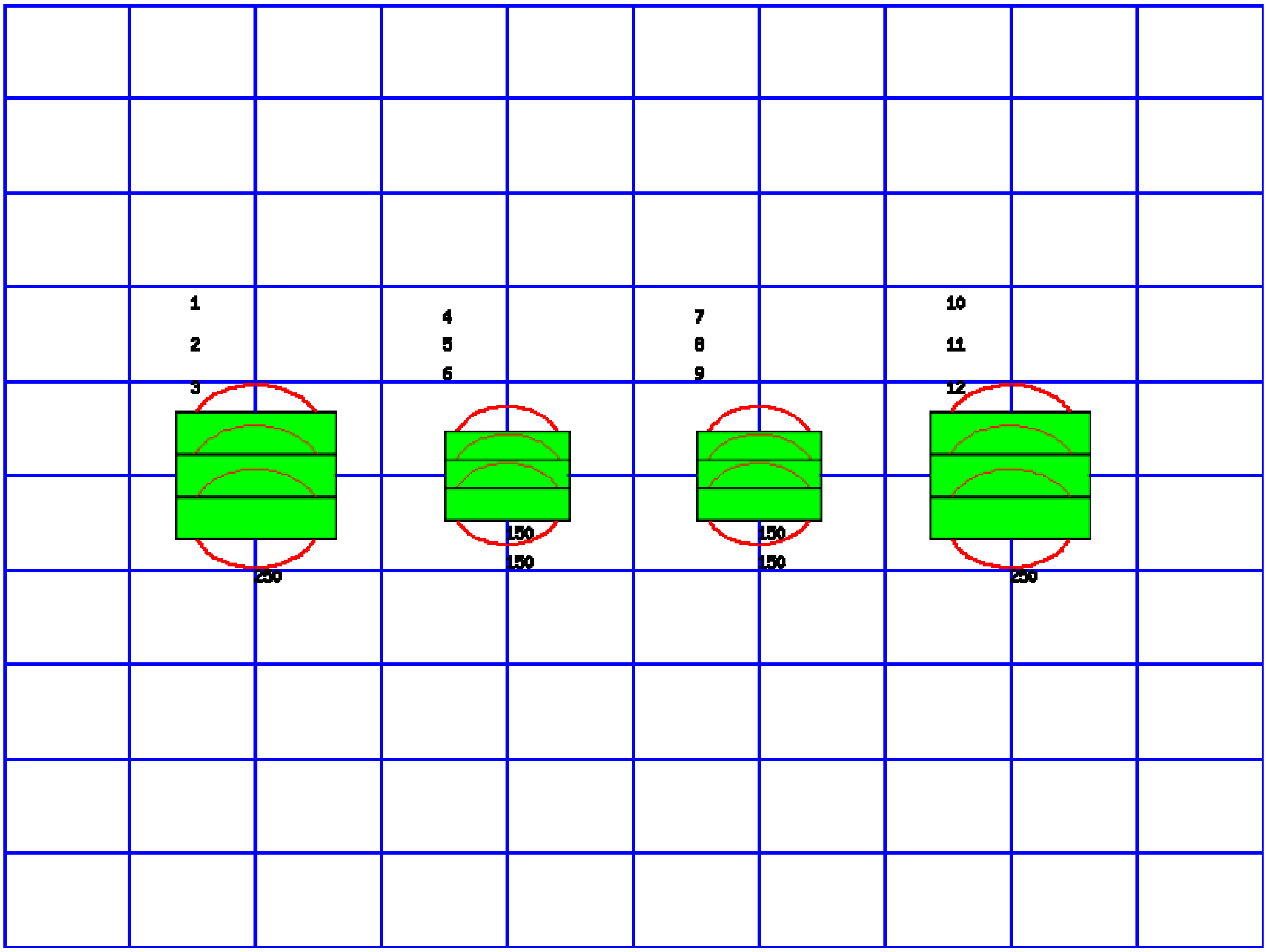
Gun	Pressure (psi)	Volume (cuin)	Type	x (m.)	y (m.)	z (m.)	delay (s.)	sub-array	p-p contrib (pct.)
1	2000.0	250.0	G-GUN	0.000	-0.450	5.260	0.00000	1	8.9
2	2000.0	250.0	G-GUN	0.000	0.000	4.480	0.00000	1	8.6
3	2000.0	250.0	G-GUN	0.000	0.450	5.260	0.00000	1	8.9
4	2000.0	150.0	G-GUN	2.000	-0.300	5.170	0.00000	1	7.9
5	2000.0	150.0	G-GUN	2.000	0.000	4.650	0.00000	1	7.8
6	2000.0	150.0	G-GUN	2.000	0.300	5.170	0.00000	1	7.9
7	2000.0	150.0	G-GUN	4.000	-0.300	5.170	0.00000	1	7.9
8	2000.0	150.0	G-GUN	4.000	0.000	4.650	0.00000	1	7.8
9	2000.0	150.0	G-GUN	4.000	0.300	5.170	0.00000	1	7.9
10	2000.0	250.0	G-GUN	6.000	-0.450	5.260	0.00000	1	8.9
11	2000.0	250.0	G-GUN	6.000	0.000	4.480	0.00000	1	8.6
12	2000.0	250.0	G-GUN	6.000	0.450	5.260	0.00000	1	8.9

Note that some guns in this array depart from the median depth of the array by at least 0.5m.

The array is shown graphically below.

Hydrophone position: Infinite vertical far-field

<----- Direction of travel ----- --, 1 m. grid, plan view



The red circles denote the maximum radius reached by the bubble. Please note that pressure-field interactions take place over a much larger distance than this, (typically 10 times larger). However when bubbles touch or overlap, super-foam interaction can be expected. In this zone, significant peak AND bubble suppression will normally be observed.

Note also that a green rectangle represents a single gun and an orange rectangle indicates that the gun is currently dropped out. Where present, a yellow rectangle represents a vertical cluster (V.C.) of guns. Please see the geometry table above for more details. The small number to the above left of each gun is its reference number in this table. For clusters of guns, these reference numbers mirror the symmetry of the cluster.

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Array centres and timing

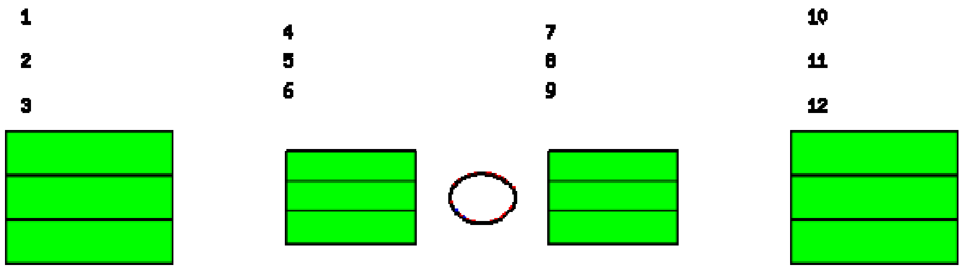
The following diagram shows the array geometric centre, the centre of pressure and the centre of energy defined as follows:-

- The array geometric centre is defined to be the centre of the rectangle formed by the largest and smallest x and y values of the active guns (non-active guns are ignored). This is shown as a blue circle.
- The centre of pressure is defined to be the array centre when each active gun position is weighted by its contribution to the overall peak to peak pressure value. This is shown as a red circle.
- The centre of energy is computed by weighting the coordinates by the self-energy of the active gun at that position. In an interacting array this may be a long way from the centre of pressure as some guns may absorb energy giving a negative self-energy. This is shown as a black circle.

Depending on how first breaks are calculated, these can be used for first break analysis.

Dropped out guns are shown as orange rectangles whilst live guns are shown as green rectangles.

Array centres



The geometric centre is at (3, 0, 4.87)

The centre of pressure is at (3,0.000568, 5)

The centre of energy is at (3, 0.00533, 5.45)

Note that Gundalf by default uses the deepest gun to define time zero for the vertical far-field and it uses the nearest gun to the observation point to define time zero if an observation point is specified. This means that if one gun is accidentally run deep, this will cause the bulk of the signature to appear to be delayed. It is still a research question how an airgun array should be timed. There are several candidates as defined above but it is not currently clear which if any is appropriate in complex scenarios such as Ocean Bottom Deployment.

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Array directivity

The following tables show the inline and crossline directivity of the array in both (angle-frequency) and (angle-amplitude) form and optionally, the azimuthal directivity (theta-phi) form.

Note that the effects of cable ghosting if present are not shown in Gundalf directivity displays although source ghosting is included. This matches common practice in such displays.

For inline directivity displays, the x-axis is the inline angle from the vertical with the word fore indicating the end nearest the boat. For crossline directivity displays, the x-axis is the crossline angle from the vertical with the word port indicating the port side.

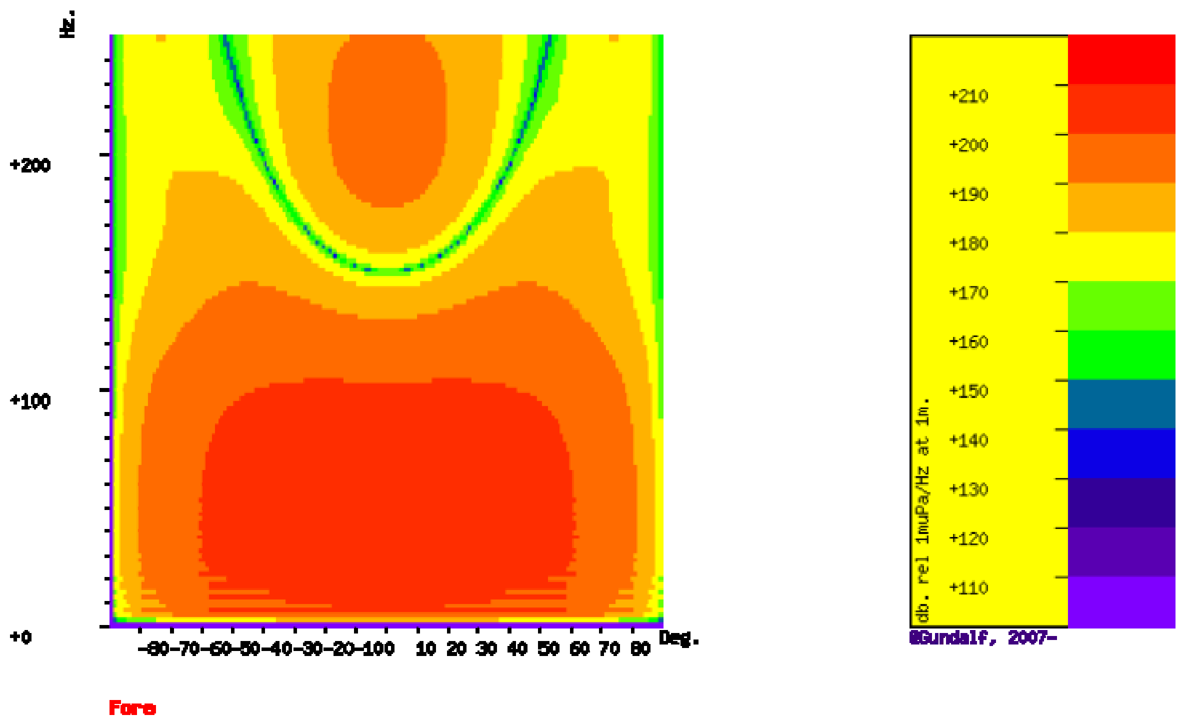
Note that *inline* is used nominally to mean any angle within +/- 45 degrees of the boat direction (which corresponds to a bearing of zero degrees). Similarly, *crossline* is used nominally to mean any angle within +/- 45 degrees of the perpendicular to the boat direction which is measured as a bearing of 90 degrees, (i.e. starboard). The nominal inline and crossline angles can be set by the user in the report options. The values used are indicated in the diagram titles below as bearings.

Where shown, the azimuthal plots show contours at four chosen frequencies as a function of phi (angle from the x-axis, opposite to the boat direction) and theta (the angle from the vertical). A bearing of zero degrees corresponds to a value of phi of 180 degrees.

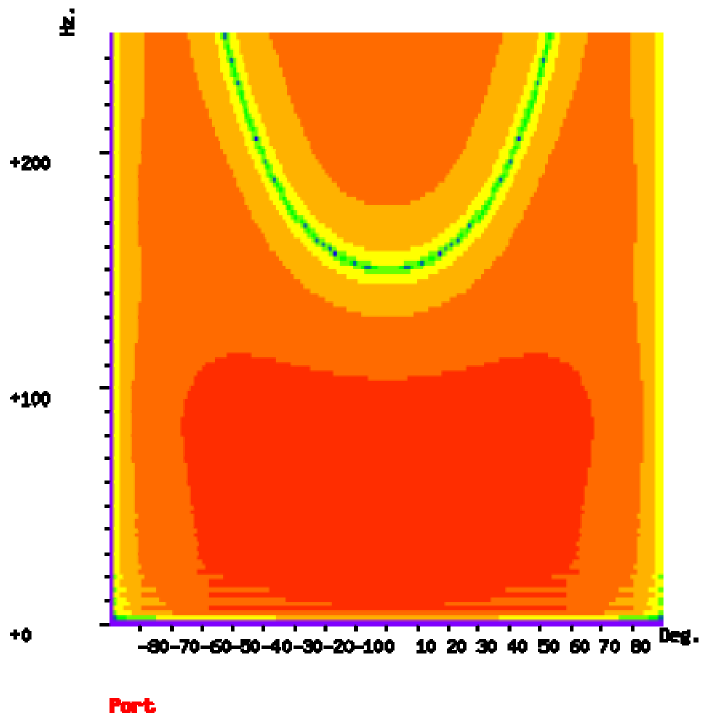
Angle-frequency form

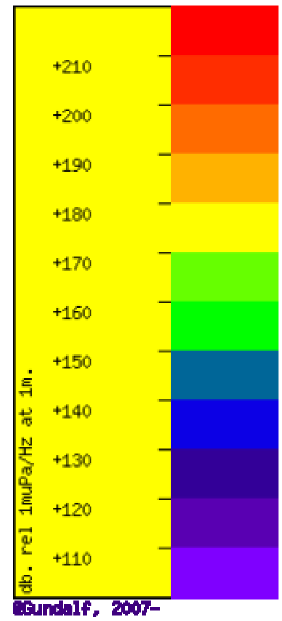
The following tables show the inline and crossline directivity of the array in (dip angle-frequency) form. Both plots are scaled as dB. relative to 1 muPa. per Hz. at 1m.

Inline directivity, bearing = 0 degrees



Crossline directivity, bearing = 90 degrees

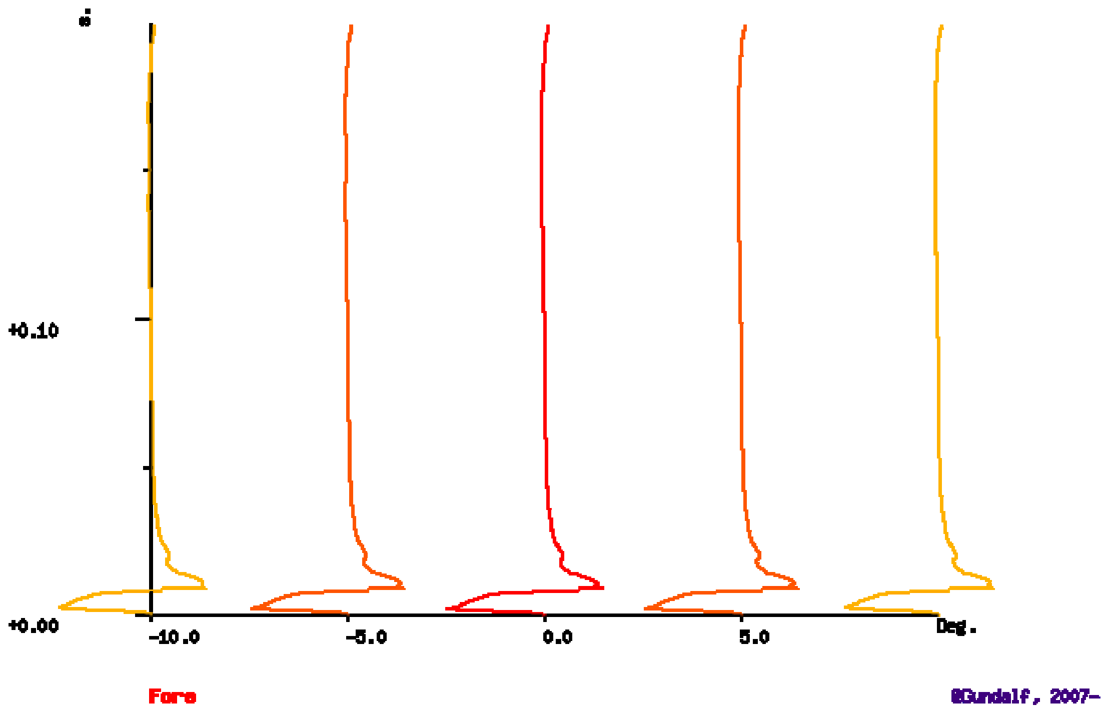




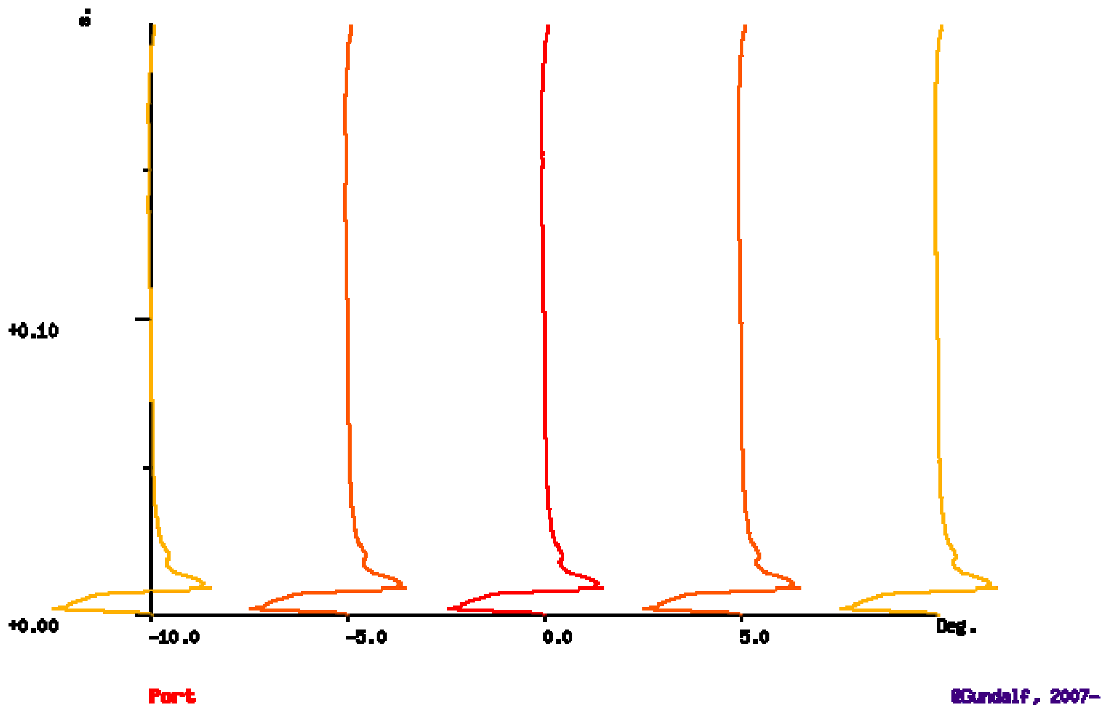
Angle-amplitude form

The following tables show the inline and crossline directivity of the array in (dip angle, amplitude) form. The computed signature (or under option the amplitude spectrum) for each angle is shown in colour varying form with red signatures shown in the centre, shading to blue at the furthest angles computed. The vertical scale indicates the type of plot, time or frequency. Both types of plot are individually scaled and plotted with the same units as the corresponding plots in the Signature Characteristics section.

Inline directivity, bearing = 0 degrees



Crossline directivity, bearing = 90 degrees



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Signature characteristics

The following tables show the signature parameters, the signature and the amplitude spectrum of the modelled signature.

The amplitude spectrum is shown in units of dB. relative to 1 muPa. per Hz. at 1m.

The position of the bubble by default is determined internally but can be overridden by interacting with the modelled signature using the right hand mouse button to determine the start of the bubble.

Signature and statistics

The following table includes error bounds for the primary characteristics of an airgun signature: peak to peak, primary to bubble and bubble period.

Airgun modelling programs like Gundalf must be calibrated against real data and no computational model is any better than the quality of that calibration. Calibration datasets however are themselves subject to experimental error so Gundalf is calibrated to best fit the various datasets which are used across the extensive range of volumes, pressures and depths available.

In practice, such experimental errors arise for a variety of reasons including

- Depth inaccuracies. These are usually around 3-5% even in the best facilities particularly if there is sea surface movement.

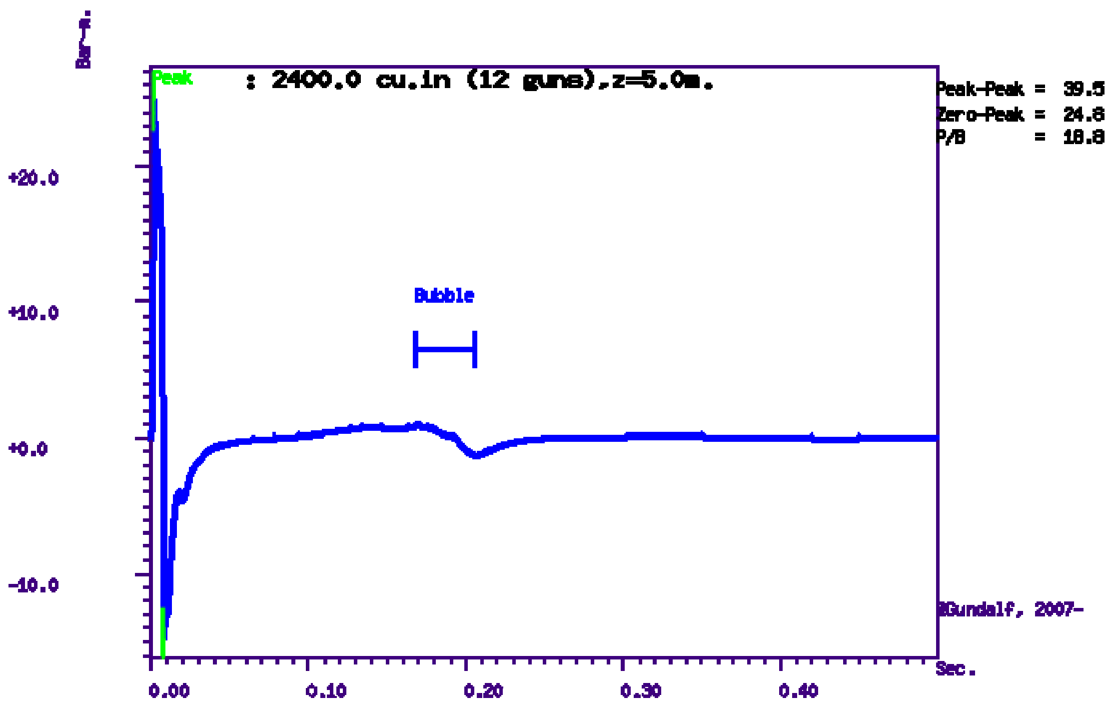
- How frequently the gun is being cycled during measurement. This is rarely recorded but a warmed up gun might be 50deg C warmer than the sea, changing its normal peak-to-peak and other parameters by 5-10% compared with when it is first fired.
- Filtering differences. Filtering is recorded but filtering errors are still more frequent than we would like and analog filter v. digital filter differences are also sometimes a factor.

As a guideline, typical individual errors across different measurement datasets for the best-calibrated guns are of the order of 5% for peak to peak, 15% for primary to bubble and 2% for bubble periods.

Individual gun errors are calculated from the data shown in Help -> Calibration (which themselves accumulate gun data from different sources) and the resulting array error bounds are calculated by accumulating these errors for each gun in the array. The error bounds are calculated as 95% error bounds and for simplicity assume that errors are non-correlated although in practice some are systematic. The total error bound is always greater than any of the individual error bounds and is strongly influenced by the largest gun contributions.

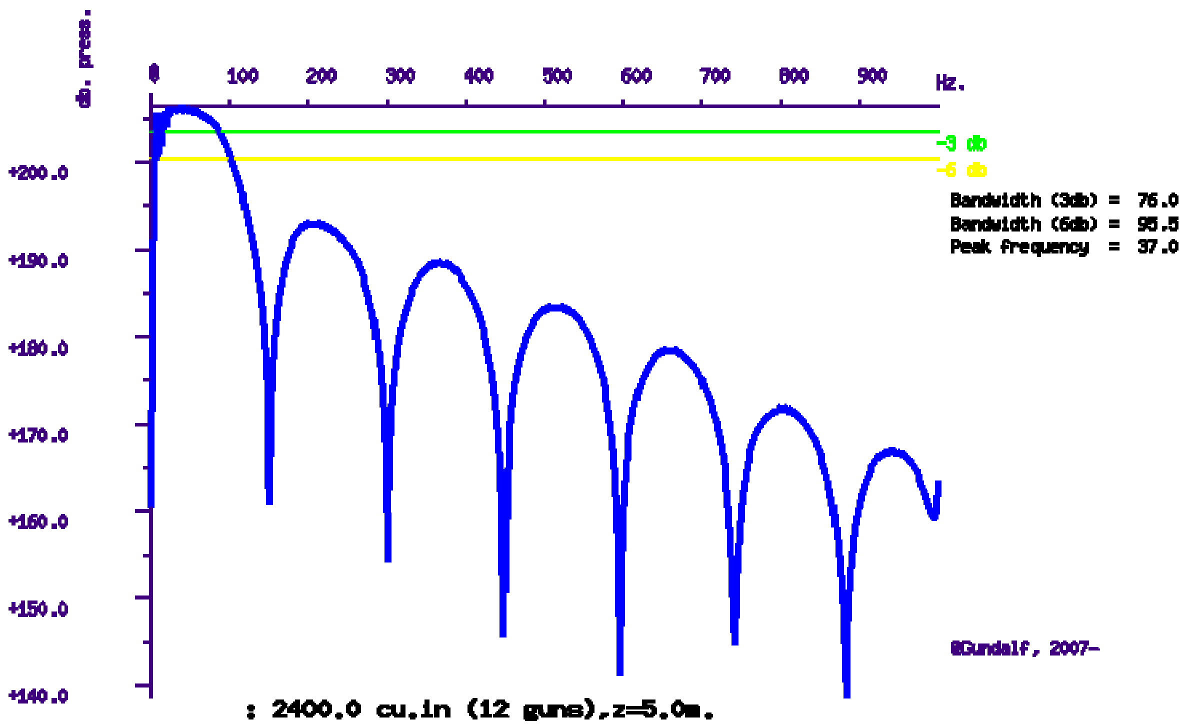
The error bounds simply mean that *it is very likely that the true values for these primary characteristics will be within the ranges shown, but it is not possible to be more precise.* If other comparison data or models indicate values outside this range, this means that those data or models are very likely to be *incompatible* with Gundalf's calibration data. This may be due to several causes as described above. For more on calibration see Gundalf's calibration Help pages.

Peak to peak in bar-m.	Zero to peak in bar-m.	Primary to bubble (peak to peak)	Bubble period (s.)
39.5 +/- 0.571	24.8 +/- 0.285	18.8 +/- 5.24	0.167 +/- 0.0115

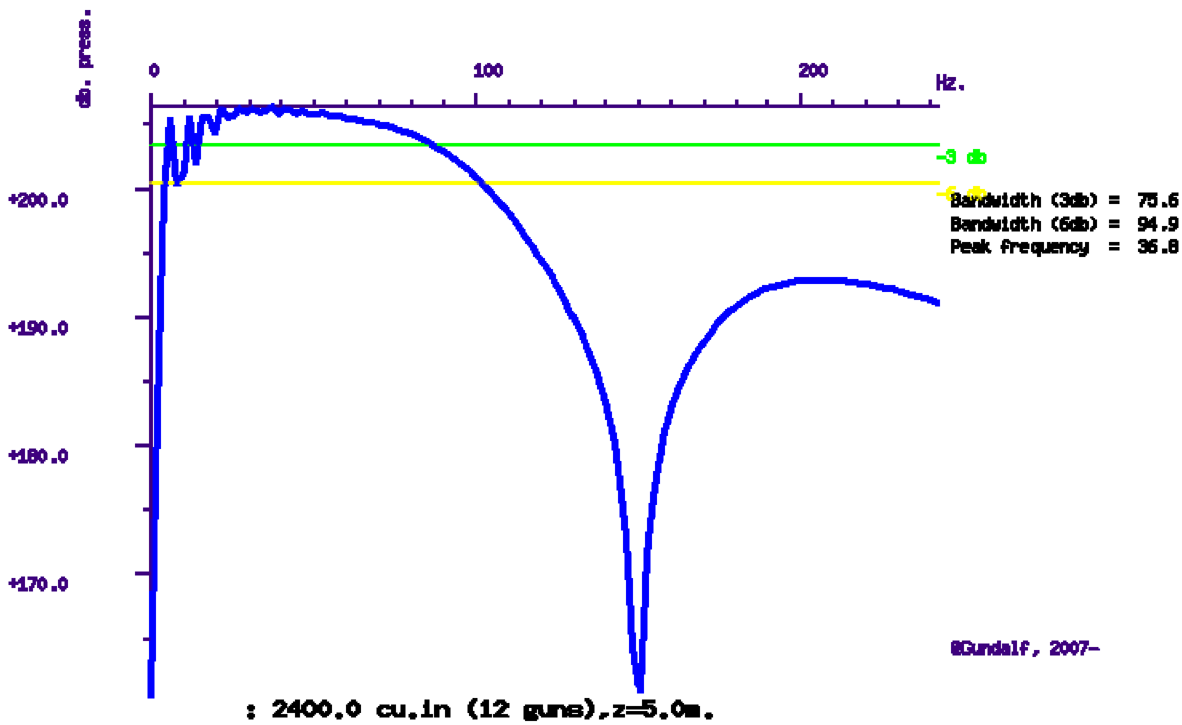


Filtered amplitude spectrum

Amplitude spectrum. Amplitude Units are dB. relative to 1 muPa / Hz. at 1m.



Close up of amplitude spectrum



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Modelling summary

The following table lists the modelling parameters for the array quoted in various commonly used units for convenience.

Signature parameters ...	
Output sample interval (s.)	0.0005
Number of samples in signature	1000
Duration of signature (s.)	0.500
Modelling sample interval (s.)	0.0005
Observation point	Infinite vertical far-field
Bubble search start time (s.)	0.04 (Auto)
Filter parameters ...	
Signature filtering details	OFF
Q filtering	OFF
Wiener deconvolution	OFF
Sea Surface parameters ...	
Source ghost	ON
Reflection coefficient	-1.00
Source ghost estimation method	Direct
Streamer 1 ghost	OFF

Streamer 2 ghost	OFF
Physical parameters ...	
Sea temperature (C)	10.0
Velocity of sound in water (m./s.)	1496.0
Expected dominant frequency in signature (Hz)	20.0
Observed wave height (m)	0.0
Gun controller parameters ...	
RMS gun controller variation (s.)	0.0

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Acoustic energy characteristics

The following table lists the individual gun contributions to the acoustic energy field in joules. A negative value means the gun is actually absorbing energy. This is very common in interacting arrays. It does not however mean that the gun is damaging the array performance. Rather it is acting as a catalyst to allow the other guns to perform more efficiently. The total acoustic energy gives the true performance of the array as a whole. See Laws, Parkes and Hatton (1988) Energy-interaction: The long-range interaction of seismic sources, Geophysical Prospecting (36), p333-348 and 38(1) 1990 p.104 for more details. Note that internal energy is not included in the data below. The true acoustic efficiency of airgun arrays is typically < 5% of the total initial energy.

Overall acoustic energy contribution

Total acoustic energy output (j.)	Acoustic energy output due to energy-interaction (j.)	Total potential energy available in array(j.)	Percentage of total potential energy appearing as acoustic energy
110046.6	5785.5	542833.9	20.3%

Individual acoustic energy contributions

Volume (cuin)	x (m.)	y (m.)	z (m.)	Acoustic energy contribution (j.)
250.0	0.00	-0.45	5.26	8296.5
250.0	0.00	0.00	4.48	-33072.1
250.0	0.00	0.45	5.26	8724.8
150.0	2.00	-0.30	5.17	26828.7
150.0	2.00	0.00	4.65	17025.2
150.0	2.00	0.30	5.17	27167.0
150.0	4.00	-0.30	5.17	26812.7
150.0	4.00	0.00	4.65	17008.5
150.0	4.00	0.30	5.17	27152.5
250.0	6.00	-0.45	5.26	8350.2
250.0	6.00	0.00	4.48	-33020.5
250.0	6.00	0.45	5.26	8773.0

The red entries denote guns which are catalysing the array by absorbing energy.

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Drop-out characteristics

Information not requested

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Inventory usage

Information not available

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Gundalf calibration details

All modelling software requires calibration against convincing experimental data. Gundalf provides accurate modelling of airguns across a wide range of gun types, gun parameters and operating environments, however, we do not expect you to take this simply on trust. It is therefore our policy to keep users of Gundalf aware of its latest calibration status and up to date information is available under Help -> Calibration.

The latest information, including technical references can be found here.

For sales enquiries please contact: Gundalf sales.

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Product code : GDF8.1Optimiser

Licenced to : asayed2@slb.com

Organisation : Western Geco

Maximum users : 1

Attachment D-1 - HyperCluster_5m_1500cuin_3000psi

GUNDALF array modelling suite - Array report

Gundalf revision AIR8.1n, Date 2018-03-30, Epoch 2018-03-30

Fri Mar 08 15:39:08 Central Standard Time 2019 (ASayed2)

Report pre-amble

Author: Ali Sayed

Author Organisation: Schlumberger

250 cu-in cluster inter-gun spacing=90cm; inter-cluster spacing=1.5m

Contents

Signature filtering policy

For marine environmental noise reports, Gundalf performs no signature filtering other than that inherent in modelling at a sample interval small enough to simulate an airgun array signature at frequencies up to 50kHz, and any requested marine animal weighting functions.

For all other kinds of reports, Gundalf performs filtering in this order:-

- If a pre-conditioning filter is chosen, for example, an instrument response, it is applied at the modelling sample interval.
- If the output sample interval is larger than the modelling sample interval, Gundalf applies appropriate anti-alias filtering. (This can be turned off in the event that anti-alias filtering is included in the pre-conditioning filter, in which case Gundalf will issue a warning.)
- Finally, Gundalf applies the chosen set of post-filters, Q, Wiener and band-pass filtering as specified, at the output sample interval. If none are specified, (often known as unfiltered), only the above anti-alias and/or pre-conditioning are applied.

In reports, when filters are applied, they are applied to the notional sources first so that signatures, directivity plots and spectra are all filtered consistently. The abbreviation muPa is used for microPascal throughout.

Finally note that modelled signatures always begin at time zero for reasons of causality.

Anti-alias and pre-condition filtering

In this case, no pre-conditioning filter has been applied.

In this case, no anti-alias filtering was necessary.

Post filtering

Details of the post-filtering used in this report follow. Post filters are applied at the output sample interval after any pre-conditioning and anti-alias filters have been applied.

Q filtering

No Q filtering performed.

Wiener filtering

No Wiener filtering performed.

Band-pass filtering

No band-pass filtering performed.

Some notes on the modelling algorithm

The Gundalf airgun modelling engine is the end-product of 15 years of state of the art research. It takes full account of all air-gun interactions including interactions between sub-arrays. No assumptions of linear superposition are made. This means that if you move sub-arrays closer together, the far-field signature will change. The effect is noticeable even when sub-arrays are separated by as much as 10m.

The engine is capable of modelling airgun clusters right down to the 'super-foam' region where the bubbles themselves collide and distort. It has been calibrated against both single and clustered guns for a number of different gun types under laboratory conditions and accurately predicts peak to peak and primary to bubble parameters across a very wide range of operating conditions.

In many cases, the predicted signatures are good enough to be used directly in signature deconvolution procedures.

Array summary

The following table lists the statistics for the array quoted in various commonly used units for convenience. Note that the rms value is computed over the entire modelled signature. Conservative error bounds for the main signature characteristics of peak to peak, primary to bubble and bubble period are also shown. These represent 95% confidence intervals for the Gundalf model against its calibration data.

Array parameters ...	
Number of guns	6
Total volume (cu.in).	1500.0 (24.6 litres)
Peak to peak in bar-m.	35.4 +/- 0.722 (3.54 +/- 0.0722 MPa, ~ 251 db re 1 muPa. at 1m.)
Zero to peak in bar-m.	21.4 (2.14 MPa, 247 db re 1 muPa. at 1m.)
RMS pressure in bar-m.	2.42 (0.242 MPa, 228 db re 1 muPa. at 1m.)
Primary to bubble (peak to peak)	29.6 +/- 3.1
Bubble period (s.)	0.189 +/- 0.0103
Maximum spectral ripple (dB): 10.0 - 50.0 Hz.	4.43
Maximum spectral value (dB): 10.0 - 50.0 Hz.	206
Average spectral value (dB): 10.0 - 50.0 Hz.	205
Total acoustic energy (Joules)	159677.3
Total acoustic efficiency (%)	31.4

Array geometry and gun contribution

The following table lists all the guns modelled in the array along with their characteristics. The last column is completed only if the array has actually been modelled during the interactive session and contains the approximate contribution of that gun as a percentage of the peak to peak amplitude of the whole array. Please note the following:-

- The peak to peak varies only as the cube root of the volume for the same gun type so that even small guns contribute significantly. This is particularly relevant to drop-out analysis.
- The peak to peak can also be depressed due to clustering effects as reported by Strandenes and Vaage (1992), "Signatures from clustered airguns", First Break, 10(8).

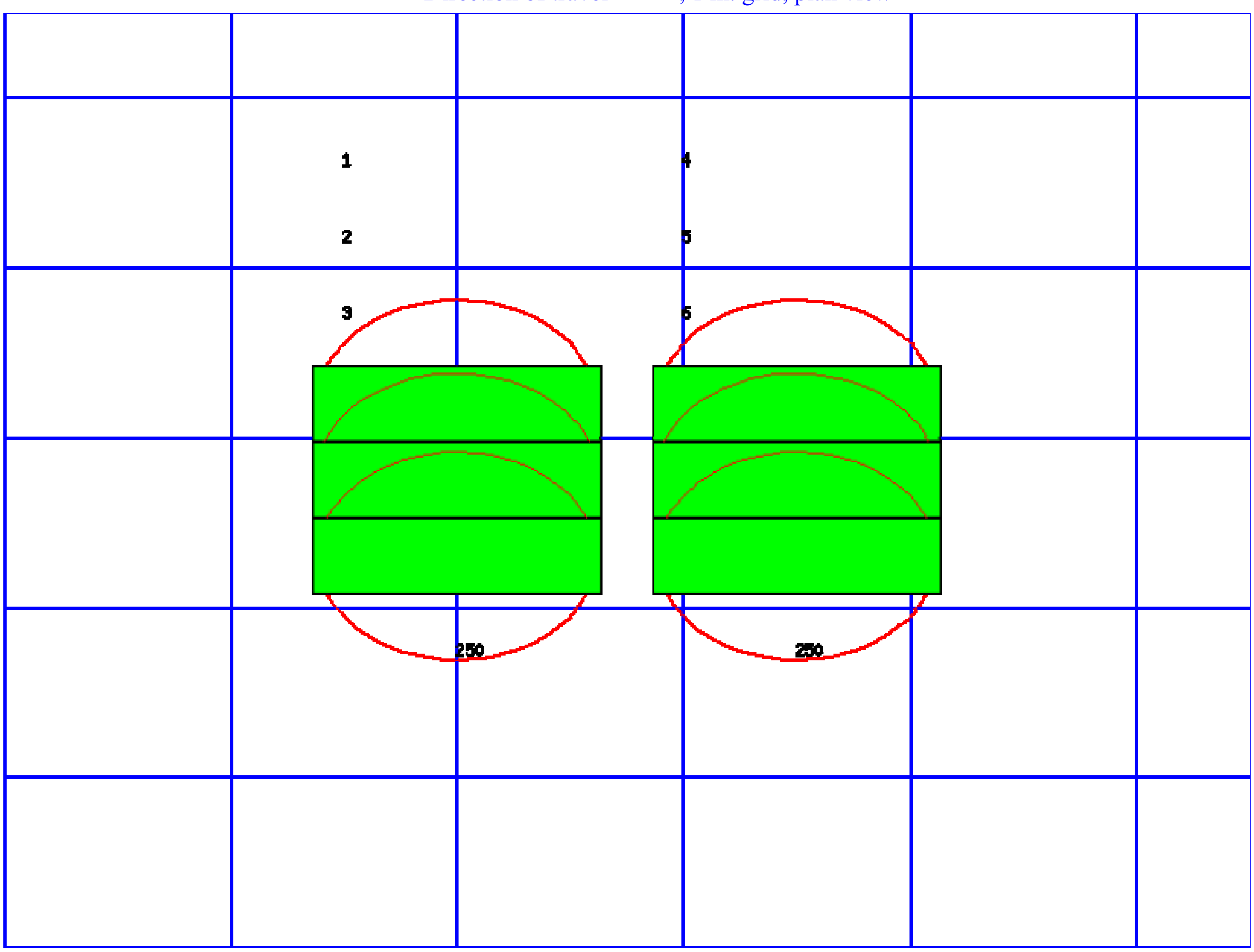
Gun	Pressure (psi)	Volume (cuin)	Type	x (m.)	y (m.)	z (m.)	delay (s.)	sub-array	p-p contrib (pct.)
1	3000.0	250.0	G-GUN	0.000	-0.450	5.260	0.00000	1	16.8
2	3000.0	250.0	G-GUN	0.000	0.000	4.480	0.00000	1	16.2
3	3000.0	250.0	G-GUN	0.000	0.450	5.260	0.00000	1	16.9
4	3000.0	250.0	G-GUN	1.500	-0.450	5.260	0.00000	2	16.8
5	3000.0	250.0	G-GUN	1.500	0.000	4.480	0.00000	2	16.3
6	3000.0	250.0	G-GUN	1.500	0.450	5.260	0.00000	2	16.9

Note that some guns in this array depart from the median depth of the array by at least 0.5m.

The array is shown graphically below.

Hydrophone position: Infinite vertical far-field

<----- Direction of travel ----- --, 1 m. grid, plan view



The red circles denote the maximum radius reached by the bubble. Please note that pressure-field interactions take place over a much larger distance than this, (typically 10 times larger). However when bubbles touch or overlap, super-foam interaction can be expected. In this zone, significant peak AND bubble suppression will normally be observed.

Note also that a green rectangle represents a single gun and an orange rectangle indicates that the gun is currently dropped out. Where present, a yellow rectangle represents a vertical cluster (V.C.) of guns. Please see the geometry table above for more details. The small number to the above left of each gun is its reference number in this table. For clusters of guns, these reference numbers mirror the symmetry of the cluster.

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Array centres and timing

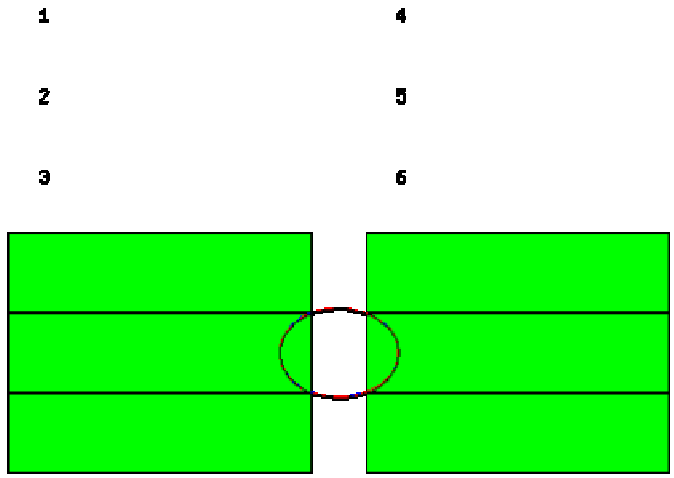
The following diagram shows the array geometric centre, the centre of pressure and the centre of energy defined as follows:-

- The array geometric centre is defined to be the centre of the rectangle formed by the largest and smallest x and y values of the active guns (non-active guns are ignored). This is shown as a blue circle.
- The centre of pressure is defined to be the array centre when each active gun position is weighted by its contribution to the overall peak to peak pressure value. This is shown as a red circle.
- The centre of energy is computed by weighting the coordinates by the self-energy of the active gun at that position. In an interacting array this may be a long way from the centre of pressure as some guns may absorb energy giving a negative self-energy. This is shown as a black circle.

Depending on how first breaks are calculated, these can be used for first break analysis.

Dropped out guns are shown as orange rectangles whilst live guns are shown as green rectangles.

Array centres



The geometric centre is at (0.75, 0, 4.87)

The centre of pressure is at (0.751, 0.00107, 5.01)

The centre of energy is at (0.753, 0.00493, 5.41)

Note that Gundalf by default uses the deepest gun to define time zero for the vertical far-field and it uses the nearest gun to the observation point to define time zero if an observation point is specified. This means that if one gun is accidentally run deep, this will cause the bulk of the signature to appear to be delayed. It is still a research question how an airgun array should be timed. There are several candidates as defined above but it is not currently clear which if any is appropriate in complex scenarios such as Ocean Bottom Deployment.

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Array directivity

The following tables show the inline and crossline directivity of the array in both (angle-frequency) and (angle-amplitude) form and optionally, the azimuthal directivity (theta-phi) form.

Note that the effects of cable ghosting if present are not shown in Gundalf directivity displays although source ghosting is included. This matches common practice in such displays.

For inline directivity displays, the x-axis is the inline angle from the vertical with the word fore indicating the end nearest the boat. For crossline directivity displays, the x-axis is the crossline angle from the vertical with the word port indicating the port side.

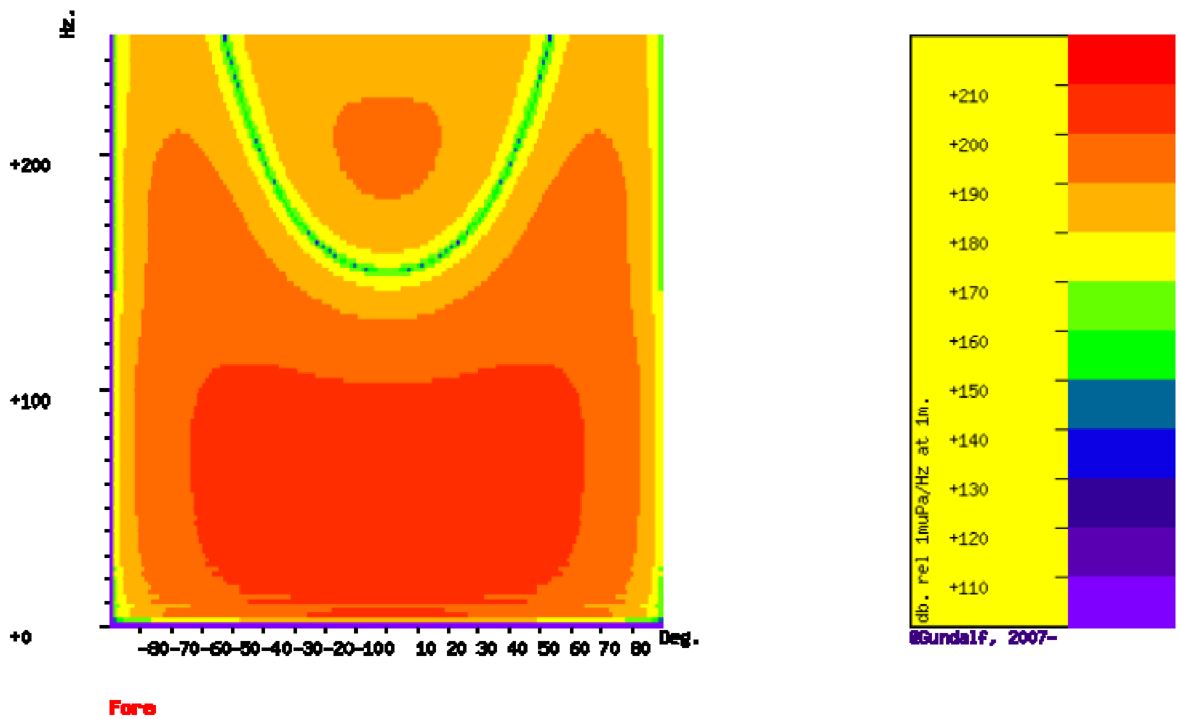
Note that *inline* is used nominally to mean any angle within +/- 45 degrees of the boat direction (which corresponds to a bearing of zero degrees). Similarly, *crossline* is used nominally to mean any angle within +/- 45 degrees of the perpendicular to the boat direction which is measured as a bearing of 90 degrees, (i.e. starboard). The nominal inline and crossline angles can be set by the user in the report options. The values used are indicated in the diagram titles below as bearings.

Where shown, the azimuthal plots show contours at four chosen frequencies as a function of phi (angle from the x-axis, opposite to the boat direction) and theta (the angle from the vertical). A bearing of zero degrees corresponds to a value of phi of 180 degrees.

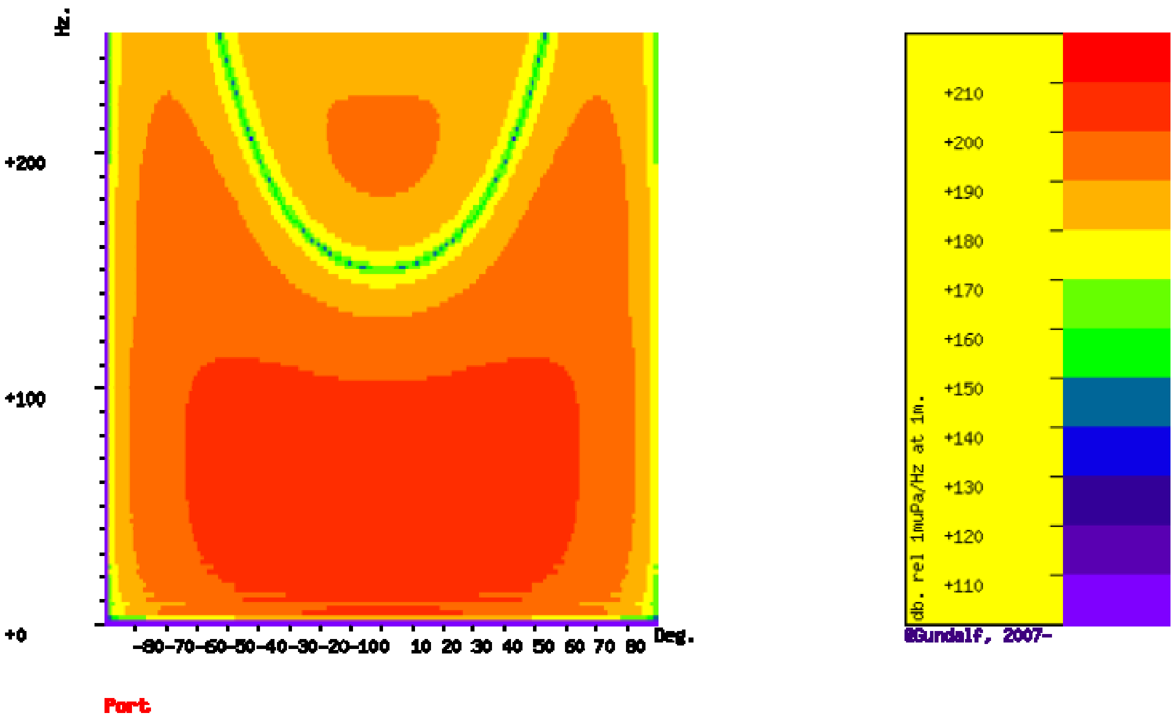
Angle-frequency form

The following tables show the inline and crossline directivity of the array in (dip angle-frequency) form. Both plots are scaled as dB. relative to 1 muPa. per Hz. at 1m.

Inline directivity, bearing = 0 degrees



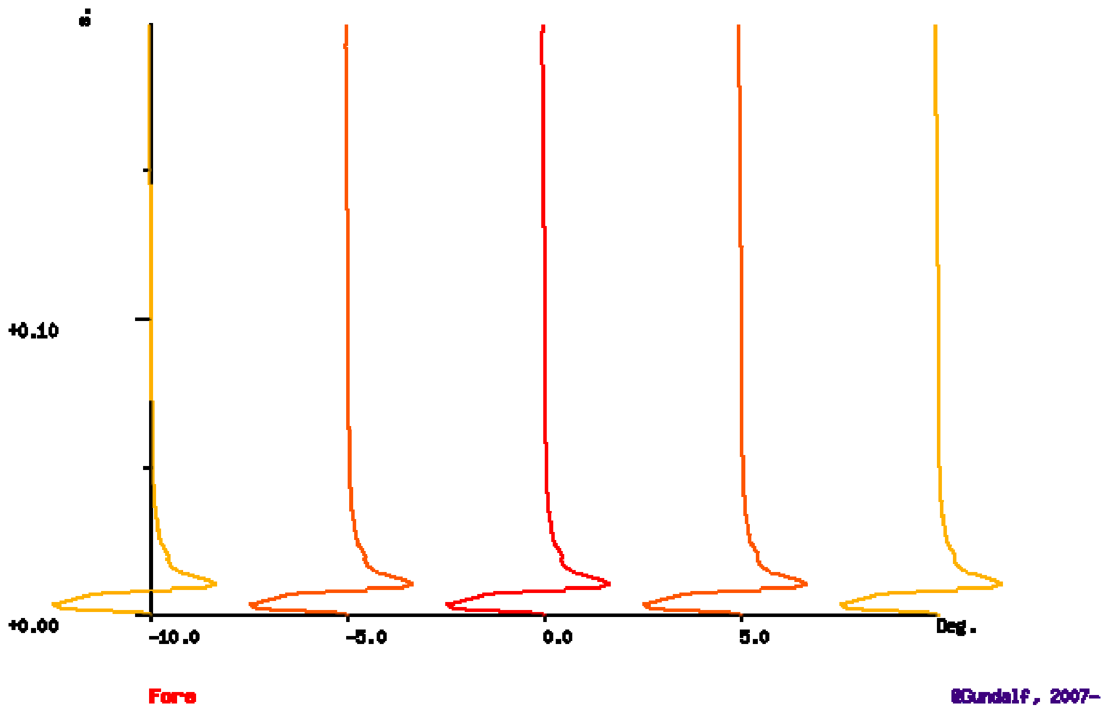
Crossline directivity, bearing = 90 degrees



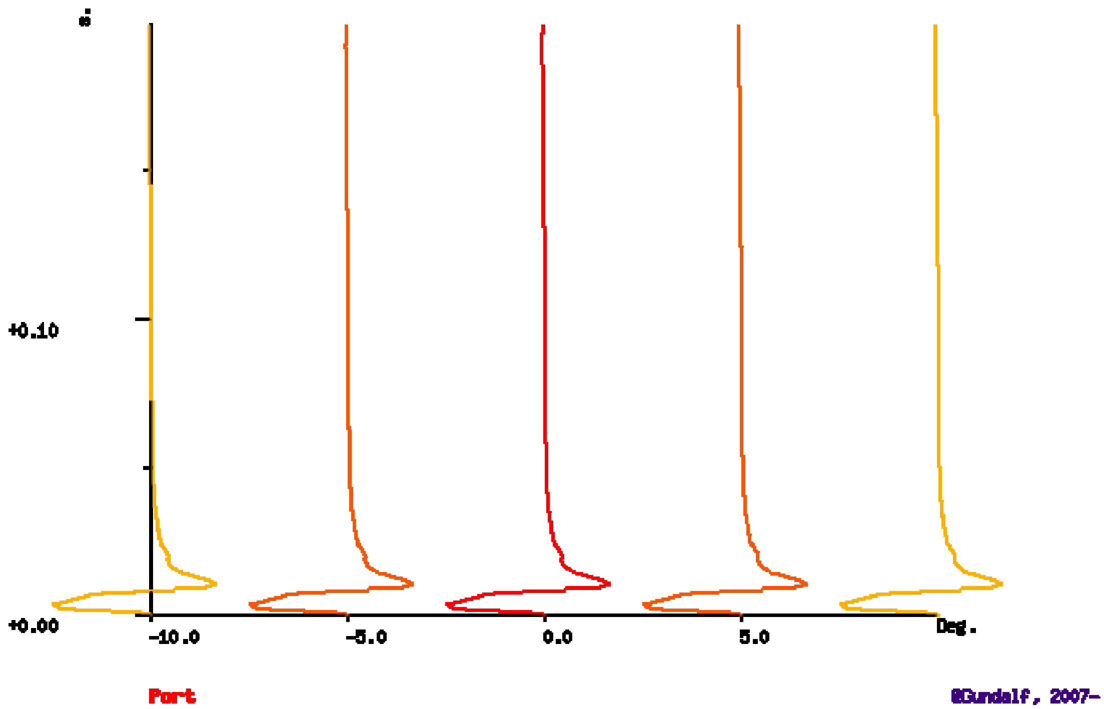
Angle-amplitude form

The following tables show the inline and crossline directivity of the array in (dip angle, amplitude) form. The computed signature (or under option the amplitude spectrum) for each angle is shown in colour varying form with red signatures shown in the centre, shading to blue at the furthest angles computed. The vertical scale indicates the type of plot, time or frequency. Both types of plot are individually scaled and plotted with the same units as the corresponding plots in the Signature Characteristics section.

Inline directivity, bearing = 0 degrees



Crossline directivity, bearing = 90 degrees



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Signature characteristics

The following tables show the signature parameters, the signature and the amplitude spectrum of the modelled signature.

The amplitude spectrum is shown in units of dB. relative to 1 muPa. per Hz. at 1m.

The position of the bubble by default is determined internally but can be overridden by interacting with the modelled signature using the right hand mouse button to determine the start of the bubble.

Signature and statistics

The following table includes error bounds for the primary characteristics of an airgun signature: peak to peak, primary to bubble and bubble period.

Airgun modelling programs like Gundalf must be calibrated against real data and no computational model is any better than the quality of that calibration. Calibration datasets however are themselves subject to experimental error so Gundalf is calibrated to best fit the various datasets which are used across the extensive range of volumes, pressures and depths available.

In practice, such experimental errors arise for a variety of reasons including

- Depth inaccuracies. These are usually around 3-5% even in the best facilities particularly if there is sea surface movement.

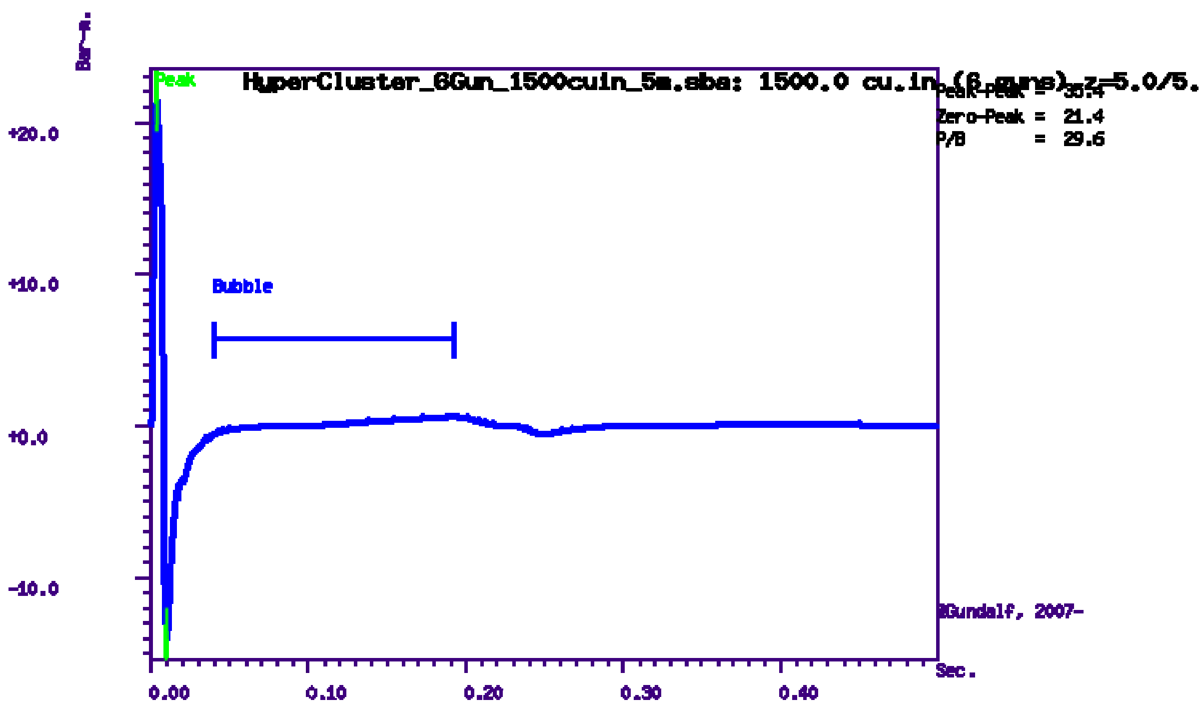
- How frequently the gun is being cycled during measurement. This is rarely recorded but a warmed up gun might be 50deg C warmer than the sea, changing its normal peak-to-peak and other parameters by 5-10% compared with when it is first fired.
- Filtering differences. Filtering is recorded but filtering errors are still more frequent than we would like and analog filter v. digital filter differences are also sometimes a factor.

As a guideline, typical individual errors across different measurement datasets for the best-calibrated guns are of the order of 5% for peak to peak, 15% for primary to bubble and 2% for bubble periods.

Individual gun errors are calculated from the data shown in Help -> Calibration (which themselves accumulate gun data from different sources) and the resulting array error bounds are calculated by accumulating these errors for each gun in the array. The error bounds are calculated as 95% error bounds and for simplicity assume that errors are non-correlated although in practice some are systematic. The total error bound is always greater than any of the individual error bounds and is strongly influenced by the largest gun contributions.

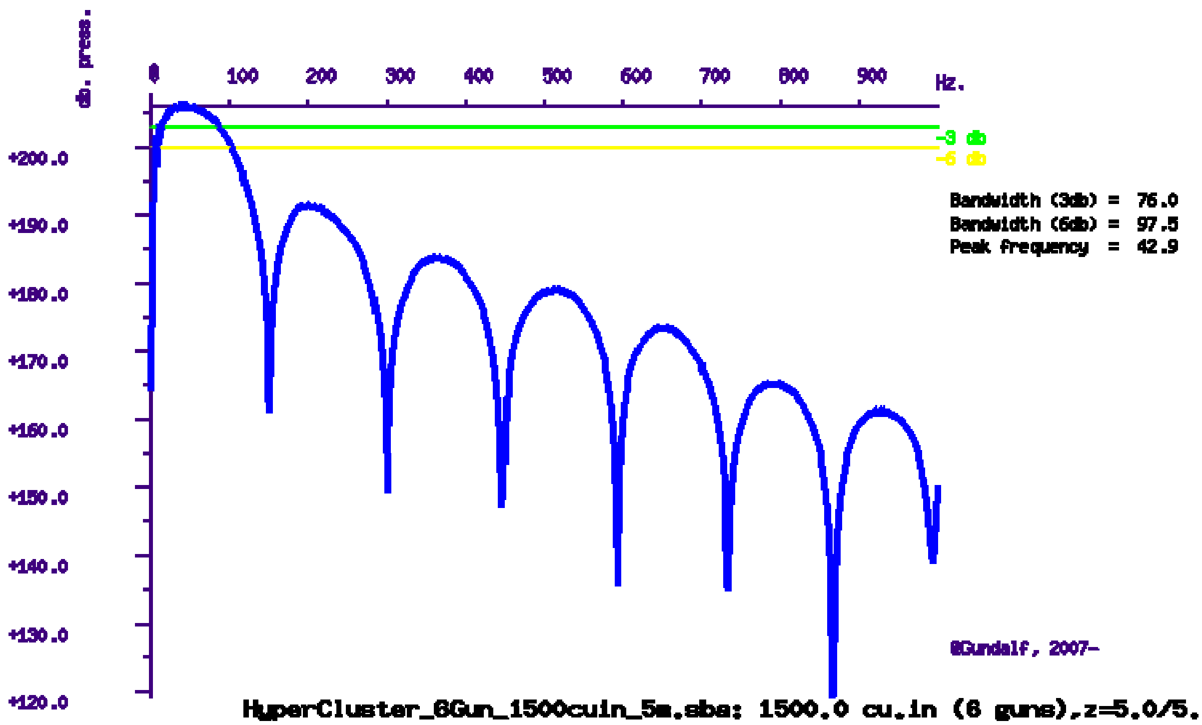
The error bounds simply mean that *it is very likely that the true values for these primary characteristics will be within the ranges shown, but it is not possible to be more precise.* If other comparison data or models indicate values outside this range, this means that those data or models are very likely to be *incompatible* with Gundalf's calibration data. This may be due to several causes as described above. For more on calibration see Gundalf's calibration Help pages.

Peak to peak in bar-m.	**Zero to peak in bar-m.**	**Primary to bubble (peak to peak)**	**Bubble period (s.)**
35.4 +/- 0.722	21.4 +/- 0.361	29.6 +/- 3.1	0.189 +/- 0.0103

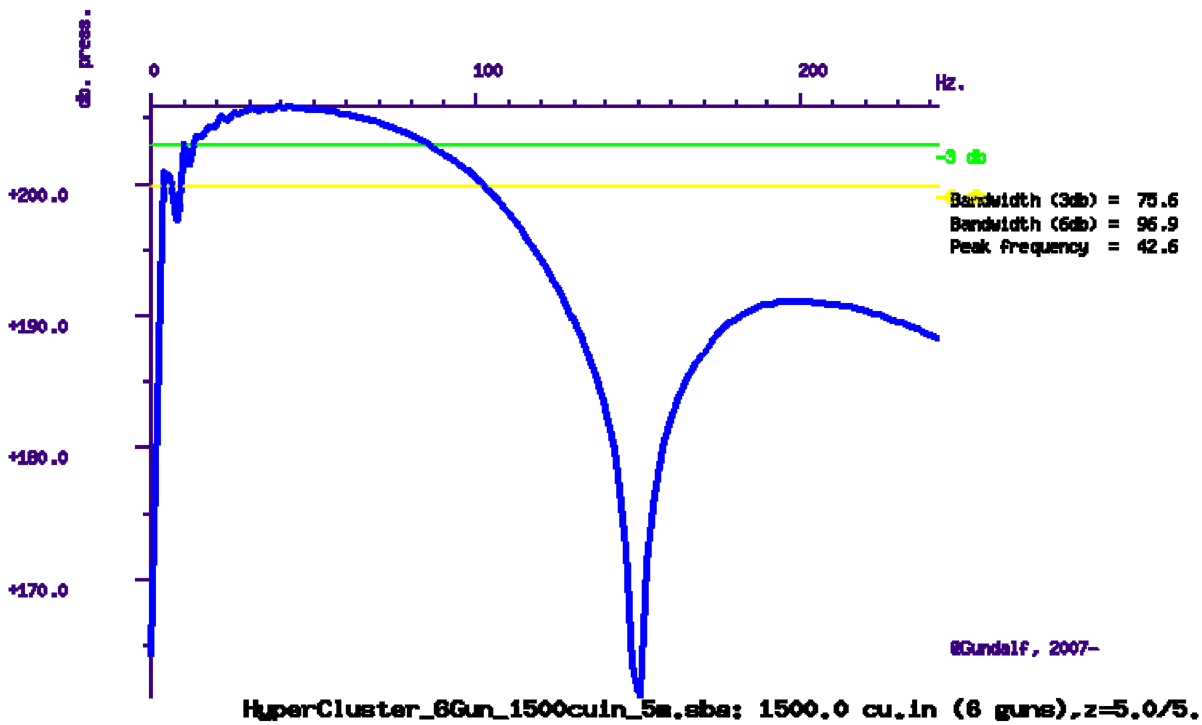


Filtered amplitude spectrum

Amplitude spectrum. Amplitude Units are dB. relative to 1 muPa / Hz. at 1m.



Close up of amplitude spectrum



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Modelling summary

The following table lists the modelling parameters for the array quoted in various commonly used units for convenience.

Signature parameters ...	
Output sample interval (s.)	0.0005
Number of samples in signature	1000
Duration of signature (s.)	0.500
Modelling sample interval (s.)	0.0005
Observation point	Infinite vertical far-field
Bubble search start time (s.)	0.04 (Auto)
Filter parameters ...	
Signature filtering details	OFF
Q filtering	OFF
Wiener deconvolution	OFF
Sea Surface parameters ...	
Source ghost	ON
Reflection coefficient	-1.00
Source ghost estimation method	Direct
Streamer 1 ghost	OFF

Streamer 2 ghost	OFF
Physical parameters ...	
Sea temperature (C)	10.0
Velocity of sound in water (m./s.)	1496.0
Expected dominant frequency in signature (Hz)	20.0
Observed wave height (m)	0.0
Gun controller parameters ...	
RMS gun controller variation (s.)	0.0

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Acoustic energy characteristics

The following table lists the individual gun contributions to the acoustic energy field in joules. A negative value means the gun is actually absorbing energy. This is very common in interacting arrays. It does not however mean that the gun is damaging the array performance. Rather it is acting as a catalyst to allow the other guns to perform more efficiently. The total acoustic energy gives the true performance of the array as a whole. See Laws, Parkes and Hatton (1988) Energy-interaction: The long-range interaction of seismic sources, Geophysical Prospecting (36), p333-348 and 38(1) 1990 p.104 for more details. Note that internal energy is not included in the data below. The true acoustic efficiency of airgun arrays is typically < 5% of the total initial energy.

Overall acoustic energy contribution

Total acoustic energy output (j.)	Acoustic energy output due to energy-interaction (j.)	Total potential energy available in array(j.)	Percentage of total potential energy appearing as acoustic energy
159677.3	9320.0	508906.8	31.4%

Individual acoustic energy contributions

Volume (cuin)	x (m.)	y (m.)	z (m.)	Acoustic energy contribution (j.)
250.0	0.00	-0.45	5.26	47265.9
250.0	0.00	0.00	4.48	-15858.0
250.0	0.00	0.45	5.26	48114.9
250.0	1.50	-0.45	5.26	47443.7
250.0	1.50	0.00	4.48	-15631.8
250.0	1.50	0.45	5.26	48342.5

The red entries denote guns which are catalysing the array by absorbing energy.

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Drop-out characteristics

Information not requested

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Inventory usage

Information not available

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Gundalf calibration details

All modelling software requires calibration against convincing experimental data. Gundalf provides accurate modelling of airguns across a wide range of gun types, gun parameters and operating environments, however, we do not expect you to take this simply on trust. It is therefore our policy to keep users of Gundalf aware of its latest calibration status and up to date information is available under Help -> Calibration.

The latest information, including technical references can be found here.

For sales enquiries please contact: Gundalf sales.

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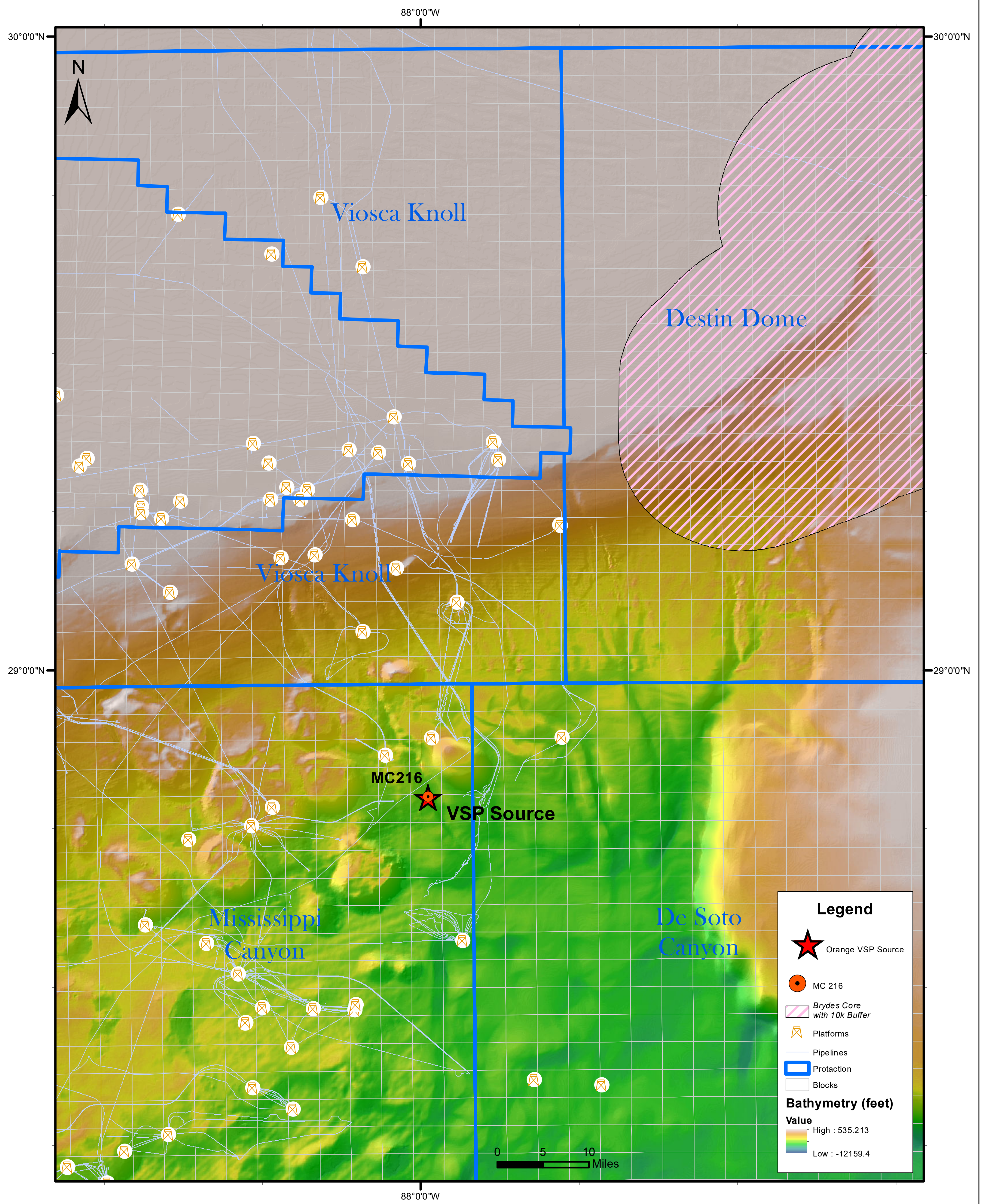
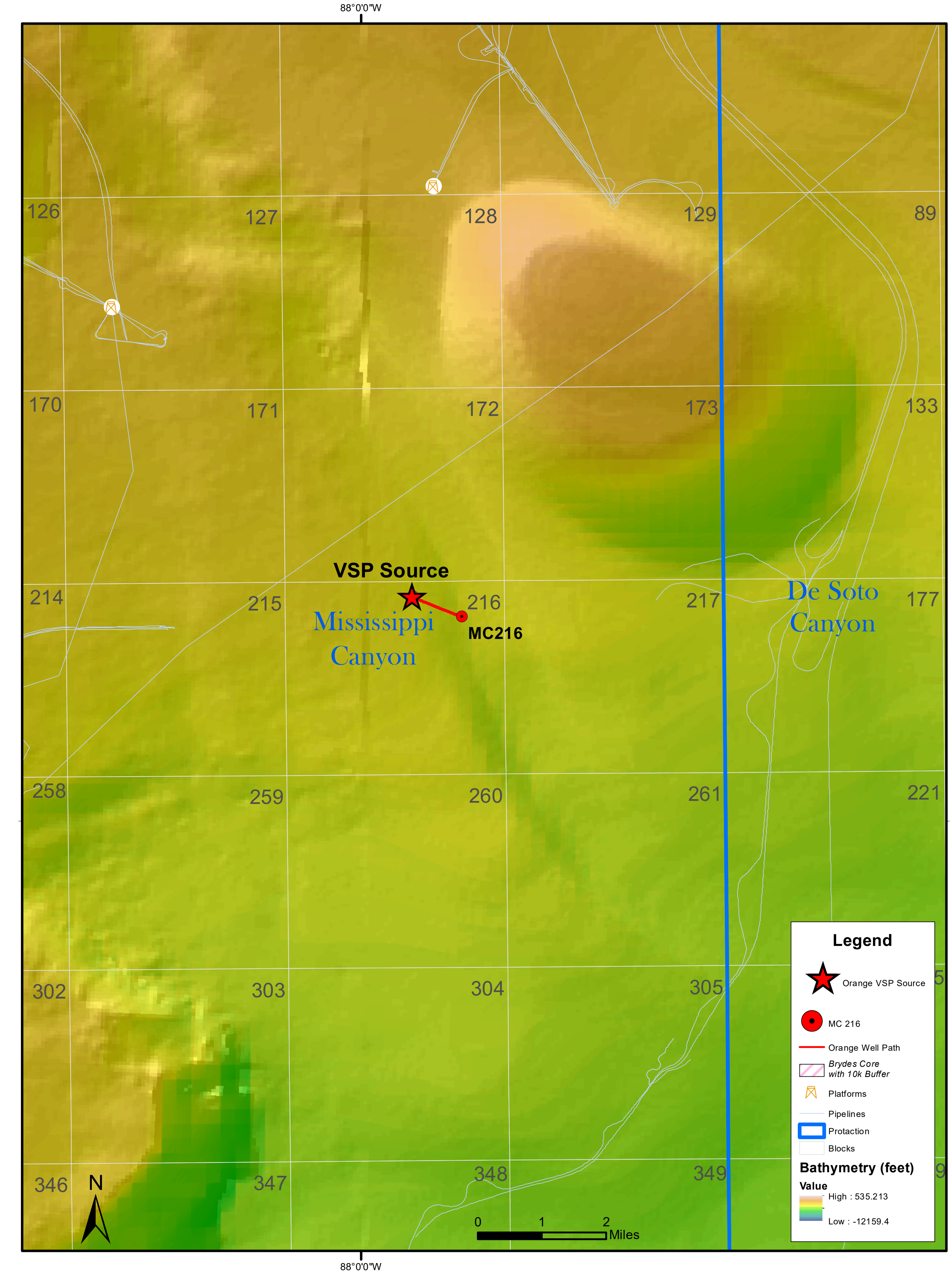


88°0'0"W
30°0'0"N
30°0'0"N
N
Viosca Knoll
Destin Dome
Viosca Knoll
29°0'0"N
29°0'0"N
MC216
VSP Source
Mississippi Canyon
De Soto Canyon
0 5 10
Miles
Legend
Orange VSP Source
MC 216
Brydes Core with 10k Buffer
Platforms
Pipelines
Protaction
Blocks
Bathymetry (feet)
Value
High : 535.213
Low : -12159.4
88°0'0"W


88°0'0"W
126
127
128
129
89
170
171
172
173
133
VSP Source
214
215
216
217
177
Mississippi Canyon
MC216
De Soto Canyon
258
259
260
261
221
302
303
304
305
346
347
348
349
N
0
1
2
Miles
88°0'0"W
Legend
Orange VSP Source
MC 216
Orange Well Path
Brydes Core with 10k Buffer
Platforms
Pipelines
Protaction
Blocks
Bathymetry (feet)
Value
High : 535.213
Low : -12159.4

Anadarko – Borehole Seismic Technology Info for Permitting

Alejandro Martinez – Geophysics Domain Champion

Shujaat Ali – Geophysicist

January, 2023

Elements for Permitting

Schlumberger:

- ***Depending on Job Objectives and Risk Management: Modeling of Alternate Geometries (ZOVSP)***
- Seismic Source Specs (permit all sources)
- Estimated Operating Time
  - ZOVSP within 30hrs (within 500 shots)

- Description of Operation

Operator & MMO:

- *Day/Night Operations (MMO, PAM)*
- *Soft Start Procedure*
- *Silence, Shutdown Procedure*
- *Exclusion Zone (i.e., obstructions, block limits, etc.)*
- *Protected Species*

Seismic Sources

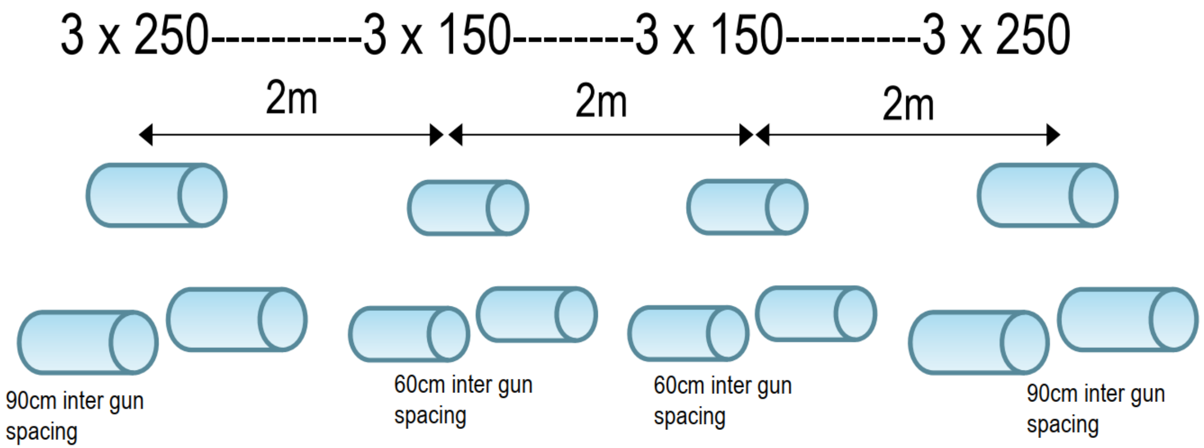
To be used in ZOVSP

VSP Marine Airgun | Dual Magnum

- 2,400 cu in volume (6 x 150 + 6 x 250 cu in G-guns)
- Operates at 2,000psi

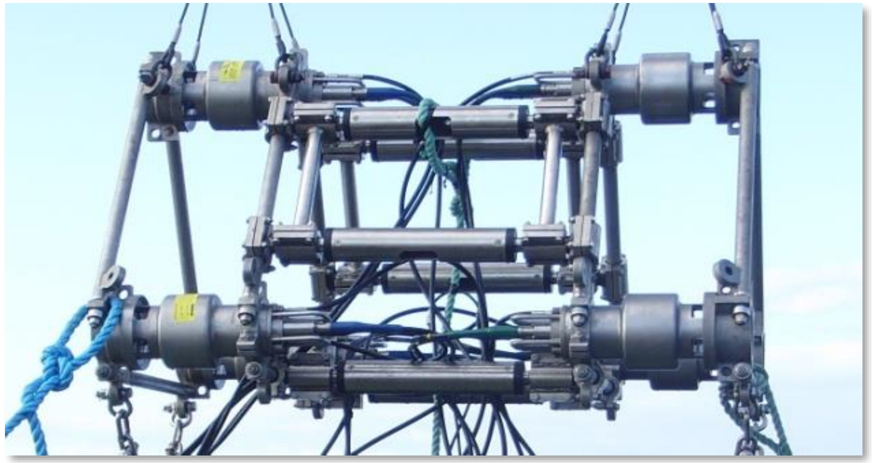
Elements for Permitting

- 12 x G-Guns
- Peak to Peak output: 47 +/- 0.678 (4.7 +/- 0.0678 MPa, ~ 253 db re 1 muPa. at 1m.) (15' depth)*
- RMS Pressure in bar-m 3.3 (0.33 MPa, 230 db re 1 muPa. at 1m.) *
- SEL (Sound Exposure Level) 154.1 dB re 1muPa^2-s (Mxx) (10Hz - 25 kHz) 148.1 at 500 M*
- Total Volume 2400 in3 / Firing Pressure 2,000 PSI



* Modeled output using Gundalf software-Marine mammal noise impact report (0-25,000 Hz)

VSP Marine Airgun | HyperCluster

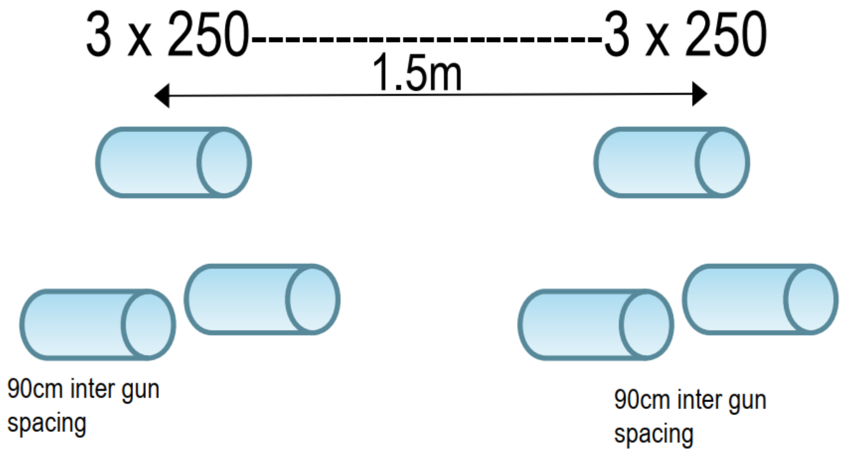


- Floatable & Compact, 20sec between shots
- 1,500 cu in volume (2 x 3 x 250 cu in G-guns)

- Operates at 3,000psi
- Extended low frequencies

Elements for Permitting

- 6 x G-Guns
- Peak to Peak output: 36 +/- 0.734 (3.6 +/- 0.0734 MPa, ~ 251 db re 1 muPa. at 1m.). (15' depth)*
- RMS Pressure in bar-m : 3.05 (0.305 MPa, 230 db re1 muPa. at 1m.) *
- SEL (Sound Exposure Level): 156.2 *dB re 1muPa^2-s (Mxx) (10Hz - 25 kHz)* at 500 M*
- Total Volume 1500 in3 / Firing Pressure 3,000 PSI



* Modeled output using Gundalf software-Marine mammal noise impact report (0-25,000 Hz)

Downhole Acquisition

Downhole Tools | ZOVSP

VSI:

- **Length:** 231 ft
- **Max OD:** 3.625”
- **Weight in air:** 937 lbs
- **Max temp**: 350DegF. **Max Pressure** : 20/25KPsi
- **Acquisition of 4 seismic levels per station / 100’s of Shots**
- **Logging time : hours**

Source:

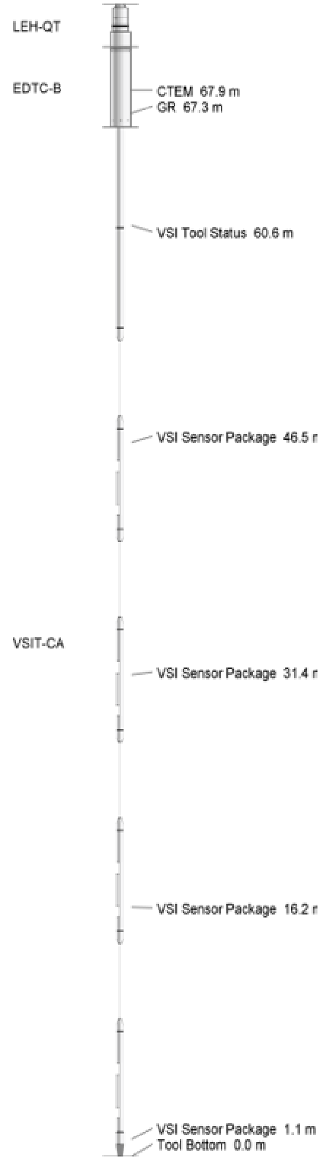
Dual Magnum 2,400cu.in (2,000psi) / HyperCluster 1,500cu.in (3,000psi)

Source Controller:

2 x TRISOR

Air Supply:

1 x Compressor / Gas Rack



Dual Magnum Cluster

Air Compressor

Gas Rack

DAS Equipment

Parameters

- **Spatial Resolution:** 1.5 m
- **Cable Length:** 11km

Equipment

- **At the rig**
- Weight: Server 60 kg, Instrument 30 kg
- Dimensions: 22"(W) x 9.6"(H) x 37.6"(L)
- Supply Voltage: 110 – 240 V, 50 – 60 Hz
- Operating/Storage Temperature: 0-50ºC / 20-70ºC

https://www.slb.com/reservoir-characterization/surface-and-downhole-logging

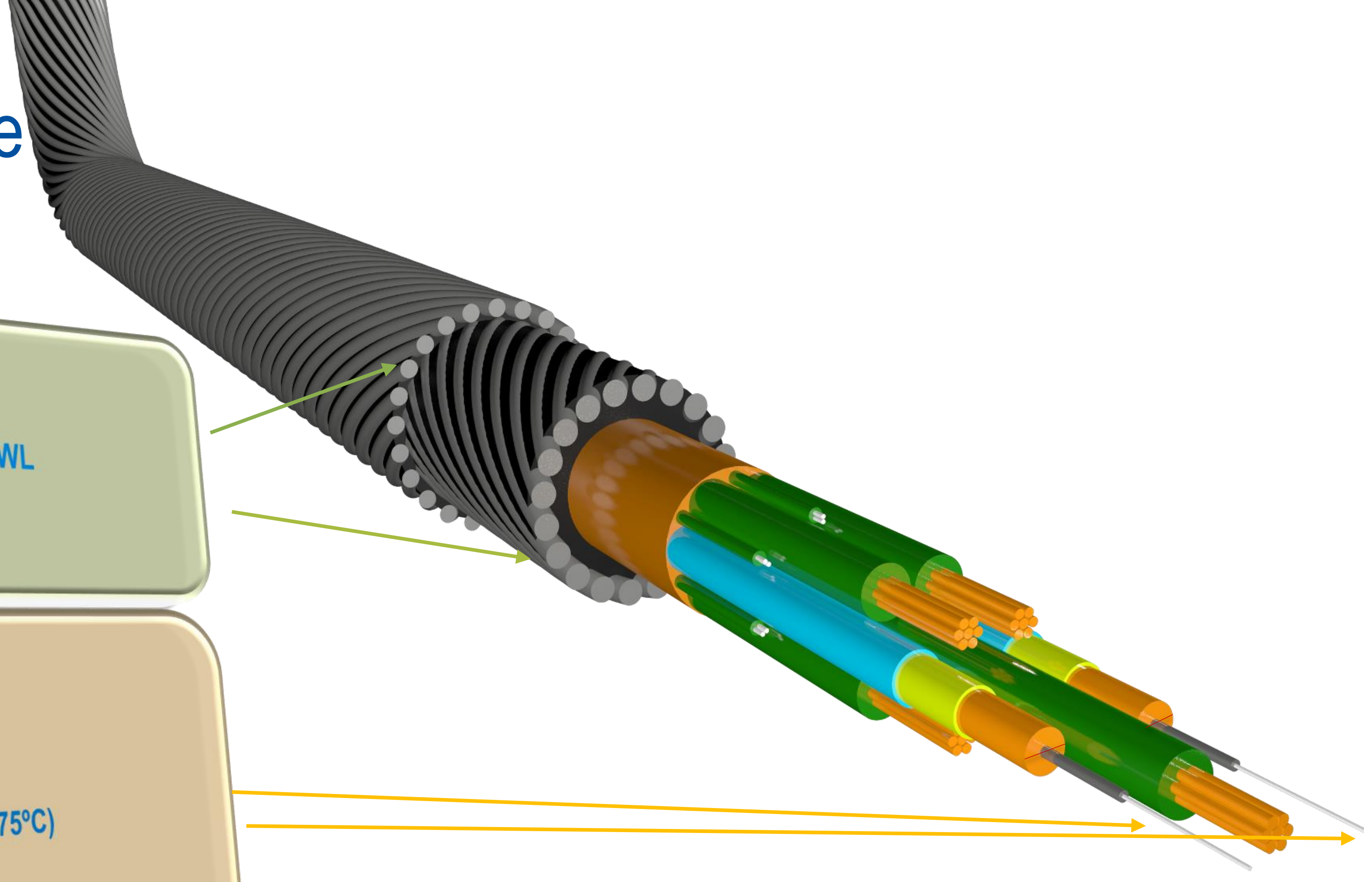
Hybrid Fiber Optic Logging Cable

Armor Matrix with Intermediate Jacket

- TuffLINE NOVA: 18k lbf SWL

Fiber Optic Conductors

- 2 x Single-mode Fibers (175ºC)

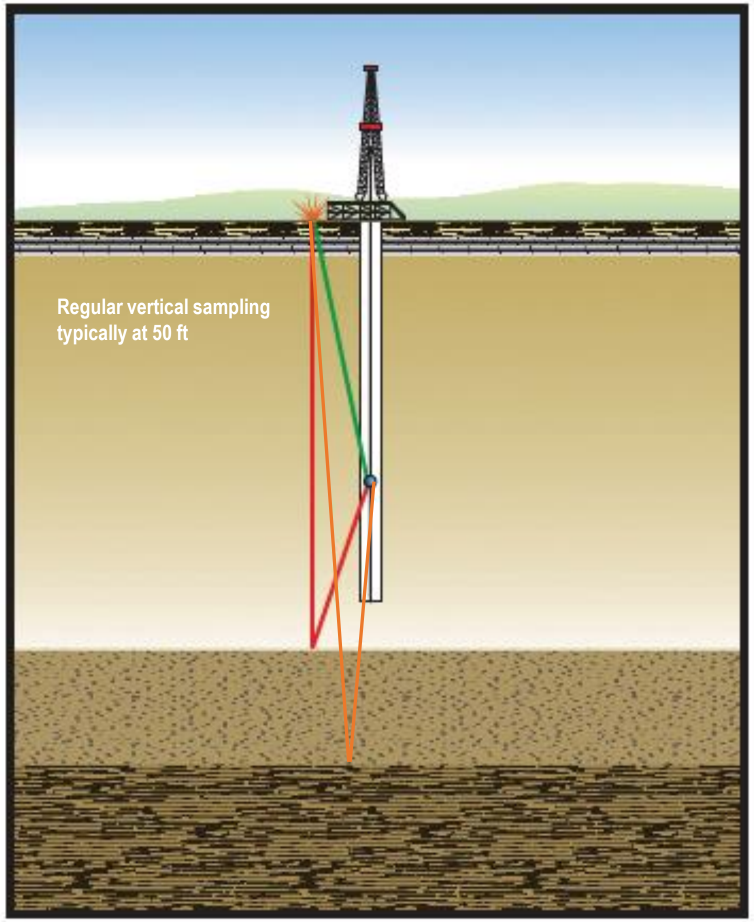


https://www.slb.com/reservoir-characterization/surface-and-downhole-logging

Survey Types / Description of the Operation

Zero-offset VSP (ZVSP)

- Most common types of borehole seismic surveys
- Energy source is placed close to the wellhead, and receivers are usually located at depths that are evenly spaced in the well.
- The regular spacing would normally extend up the hole to a point above the shallowest reflector of interest, and then a few, more widely separated levels (checkshots) would be planned to the surface for velocity control.
- Travel times can then be used to correct sonic logs for dispersion and hole conditions.
- Zero-offset VSP data can be processed for upgoing wavefield, showing the reflection response of the subsurface, and the response beyond TD can be used for prediction ahead of the bit (i.e. distance to a drilling hazard or to the target reflector).
- Q, Multiple analysis, phase matching, and depending on conditions Shear and 2D-images.
- The standard output from a zero-offset VSP is the corridor stack.



VSI
Versatile Seismic Imager

Applications

■ Integrated processing for interpretation of boreholeand surface-seismic data

■ Images for reservoir definition

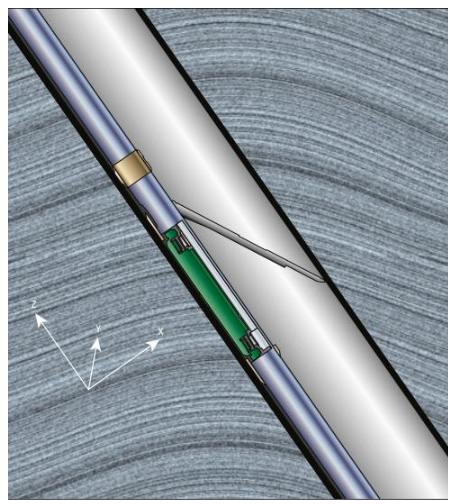
■ Images ahead of the bit

■ Three-dimensional (3D) vertical seismic profiles (VSPs)

■ Pore pressure predictions

■ Planning for placement of future wells

■ Simultaneous surface- and borehole-seismic recording for high-definition images



Benefits

■ Wellsite delivery of answer products for real-time decisions

■ Schlumberger answer products with high-fidelity shear and compressional wavefields

■ Fast and efficient acquisition Features

■ Three-component (3C) borehole-seismic data acquisition

■ Small sensor package with 3C omnitilt geophoneaccelerometers

■ Excellent signal-to-noise ratio and tube wave rejection on 3C wavefields

■ Acoustically isolated sensor package

■ Relative bearing measurement on each shuttle

■ Configuration using 1 to 40 shuttles

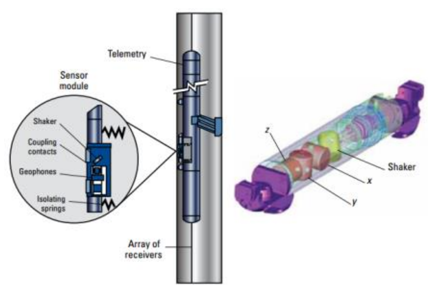
■ Shaker in each sensor package

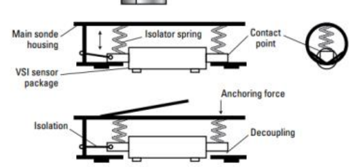
■ Shuttle spacing adjustable using standard logging cable

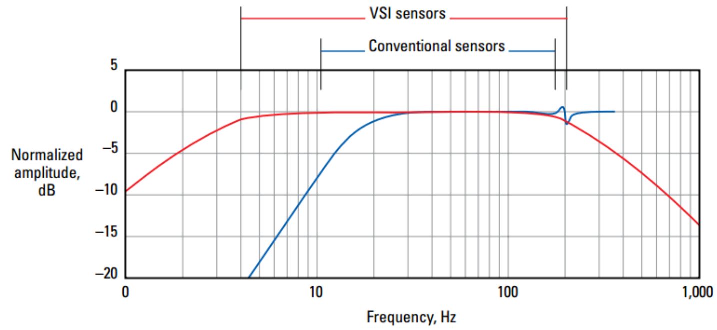
■ Integrated wellsite acquisition software for quality control (QC) and field processing

■ Combinable with mostwireline tools

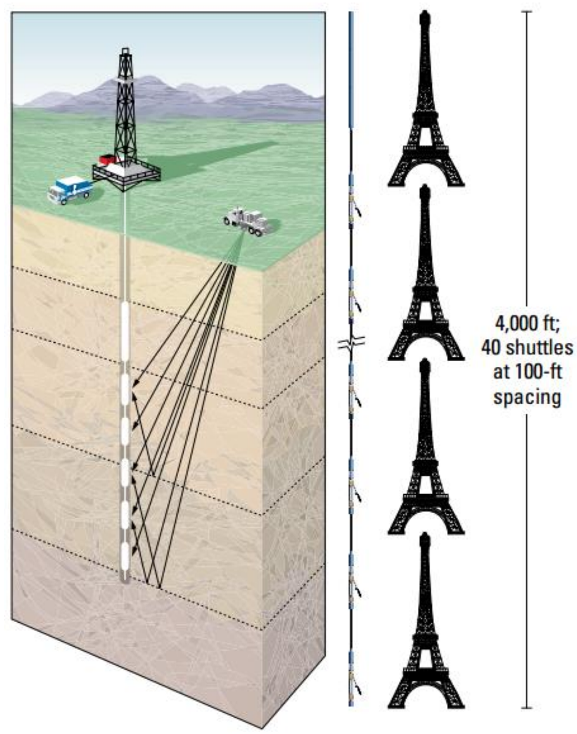
■ Choice of tool conveyance

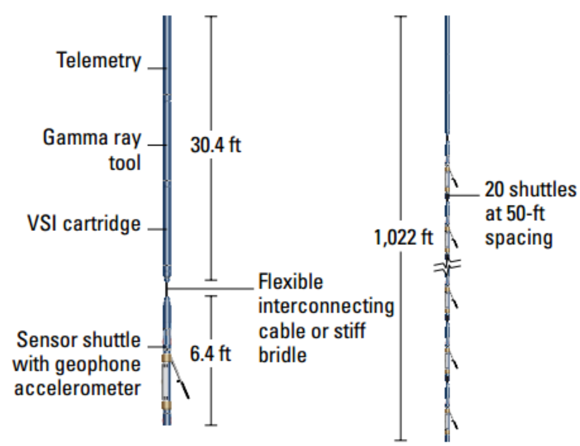






Max. number of shuttles	20; 40 in newest series
Max. temperature	350 degF [175 degC]
Max. pressure	20,000 psi [1,360 bar], standard; 25,000 psi [1,700 bar] for high-pressure version
Tool OD	3⅜ in [85.7 mm] standard; 2½ in [63.5 mm] for slimhole version
Anchoring hole size	3½–22 in [88.9–558.8 mm]
Intershuttle spacing	8–100 ft, 150 ft in special applications
Sampling rate	1, 2, and 4 ms, 0.5 ms in special applications
Combinablilty	Gamma ray and casing collar locator, standard; all other wireline tools by special switch
Cartridge length	20.9 ft [6.37 m]
Cartridge OD	2½ in [63.5 mm] 2.6 in [66 mm] for 25,000 psi [1,700 bar] high-pressure versions
Shuttle makeup length	6.4 ft [1.96 m]
Cartridge weight	190.8 lbm [86.5 kg]
Shuttle weight	70.6 lbm [32 kg]
Sensor package	Three omnitilt geophone accelerometers; one shaker
Sensitivity	> 0.5 V/G ± 5%
Natural frequency	20-Hz flat bandwidth in acceleration: 2–200 Hz
Dynamic range	> 105 dB (at 36-dB gain)
Distortion	< 0.15%
Digitization	24-bit ADC
Length	11.4 in [290 mm]
Weight	6.4 lbm [2.9 kg]
Coupling force	63.9 lbf ± 11.0 lbf [284.4 N ± 49.0 N]
Coupling force-to-sensor weight ratio	10:1
VSI sonde mechanical strength	
Standard compressive	5,000 lbf [22,241.1 N] standard; 10,000 lbf [44,482.2 N] with TLC* tough logging conditions stiffener
Standard tensile	18,000 lbf [80,068 N]
VSI cartridge mechanical strength	
Standard compressive	10,000 lbf [44,482.2 N]
Standard tensile	43,000 lbf [191,273.6 N]
Well deviation	No limitation
Stiff bridle spacing	49.61 ft [15.12 m]
Stiff bridle OD	2½ in [63.5 mm]
Stiff bridle mechanical strength	
Standard compressive	8,000 lbf [5,585.8 N]
Standard tensile	40,000 lbf [177,928.9 N]





Schlumberger

ONYX™

sensing unit

Features and Technical Specification

SINTELA

ONYX™ sensing unit

Features and Technical Specification

Next Generation Distributed Fiber Sensing System

ONXY™ represents the next step in the evolution of Distributed Fiber Sensing; it provides distributed acoustic data over long fiber lengths with a high detection sensitivity and a low false alarm rate in a compact, low power unit.

ONYX™ has been designed to address three key aspects:

- Performance
- Usability
- Cost

ONYX™

A new approach to Distributed Fiber Sensing

Building on over a decade's worth of experience, the team at Sintela are focused on providing Next Generation Distributed Fiber Sensing solutions.

- **Standard 100 km range:** Each ONYX™ Sensing Unit contains a unique optical module capable of simultaneously interrogating two sensing fibers - each up to 50 km to 65 km (depending on applications) in length. This represents 130 km range for one unit. This long-range capability results in significantly less equipment being required and lower cost per kilometre of monitoring.

- **Quantitative Measurements:** ONYX™ makes coherent quantitative measurements over 100 km. This enables the implementation of sophisticated signal processing techniques - significantly improving the detection and classification of events, thereby improving the probability of detection whilst reducing the nuisance alarm rate. This also allows machine learning algorithms to be used reliably on the system.

- **Integrated Design:** A single ONYX™ Sensing Unit integrates the optical sensing components, processing hardware and engineering displays into a single 3U enclosure. This considerably reduces the space, weight, and power requirements as well as simplifying system setup. Furthermore, the ONYX™ Sensing Unit has been designed with an internal modular design, allowing for quick and easy maintenance for individual modules and components.

- **Distributed Architecture:** The ONYX™ system has been designed from the outset to be entirely distributed. This distributed architecture results in no single point-of-failure, minimizing downtime and increasing system availability. Administration and control functions are distributed throughout the ONYX™ Sensing Units, providing the system with a high degree of fault tolerance.

- **Class 1 Laser Safety:** Class 1 lasers are defined as being eye-safe under all operating conditions, which makes the ONYX™ system inherently safe for use, lowers the HSE burden for end clients, and increases the life span of the optical components. This also eliminates the need for costly interlock safety switches and physical keys to operate the equipment.

- **Automatic Setup with integrated OTDR:** The ONYX™ has an integrated OTDR [Optical Time Domain Reflectometer] capability and automated installation process, simplifying the setup, commissioning and testing stages of system implementation. This results in lower manpower costs and simplifies maintenance and administrative tasks for support by local engineers; specialist engineers are not required as often for straightforward tasks. The integrated OTDR enables the fiber health to be monitored and is extremely useful in mitigating faults caused by engineering works carried out on the telecoms network.

Features

Measurement type: Quantitative [3]

Number of fibers: Two (simultaneously monitored)

Standard operating wavelength:
1550.12 nm [ITU-CH34, 193,400 GHz]

Performance specification

Performance measured according to SEAFOM MSP-02:
Measurements taken using a 6.4 m Gauge Length, using a standard SMF with a one-way insertion loss of 0.2 dB/km

Sensing range:
Standard range up to 50 km per fiber (100 km in total)
Longer ranges possible depending upon the application

Minimum detectable signal:
-80 dB Rad.Hz-½ at the front of a 5 km fiber
-60 dB Rad.Hz-½ at the front of a 50 km fiber

Dynamic range:
155 dB @ 1 Hz | 135 dB @ 10 Hz | 115 dB @ 100 Hz

Crosstalk isolation: > 80 dB

Linearity Harmonic distortion typ. < -40 dB

Minimum gauge length: 3.2 m

Minimum sample interval: 1.6 m

Acoustic Frequency Range:
Min: 1 mHz [Arbitrarily selectable]
Max: 10 kHz @ 5 km | 1 kHz @ 50 km

Sensing fiber requirement specification

Standard fiber types:
SMF-28e, ITU-T G.652, G.654 or G.655

Maximum acceptable loss budget: 20 dB

Maximum acceptable back reflection: < 2 %

Processing capability

Fully integrated processing using NVIDIA Volta™ architecture with 512 NVIDIA CUDA cores and 64 Tensor cores

Connection Interface

Power: 2x IEC 320 C14 sockets (Dual redundant power supply)

Data: 1x SFP@1 Gbit/s | 1x USB 3.2 Gen 1 (USB C)

Trigs: Up to eight available via LEMO connector and Trigger Interface Unit (application specific)

GNSS Antenna: SMA connector, up to 300 m 50 Ω – coaxial cable

Fiber: 2x Diamond E2000-PS APC (single mode)

Size, Weight and Power

Height:	3U – 133 mm
Width:	483 mm (for 19” rack)
Depth:	453mm
Weight:	<17 kg
Power:	100 W

Environmental characteristics

Storage Temperature: -40 °C to +70 °C

Operating Temperature: -5 °C to +50 °C

Operating Relative Humidity 10% to 85% (non-condensing)

Ingress Protection: IP50 (Protected against dust)

Conformity

Class 1 Laser

FCC, CE, UKCA and RoHS compliant

ONYX™

The all in one solution

The new ONYX™ system delivering a clear smaller size and cost advantage

A clear size and cost advantage

The smaller, lighter, lower power design of the ONYX™ Sensing Unit simplifies shipping, setup and commissioning, reducing the time and cost required to get the system fully operational.

SINTELA

For more information contact:

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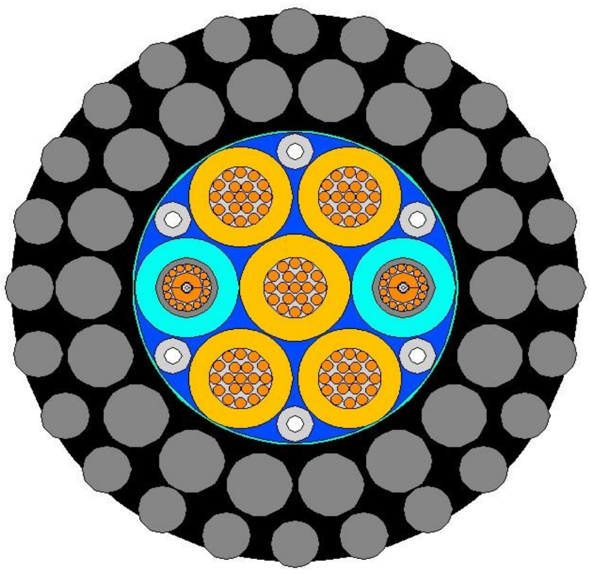
www.sintela.com

SINTELA

PDM #:	104341312D
Rev:	AC
Date:	15-Jul-22

A-Sheet: 7-53AKZ-US-FH-SSC, NOVA-F 18K

A seven conductor, hybrid electro-optical logging cable. Cable contains 2 #18AWG reinforced electro-optical conductors with single mode fibers and 5 #16AWG SBC conductors insulated with PFA. The cable core is jacketed with layers of high-temperature PEEK Tape and extruded carbon fiber reinforced Tefzel jacket. The core is armored with ultra-strength galvanized improved plow steel armor wires and an intermediate jacket of carbon fiber reinforced Tefzel between the armor layers.



Conductor 1,4 - Helical FO		0.097 in	2.464 mm
#18 AWG SBC & 125/250 SMF			
125/250um CMTDA Single Mode Fiber			
Copper Halves, Serve and Cladding - 0.058"			
Tefzel and PEEK Insulation			
Conductor 2, 3, 5, 6 - Helical		0.097 in	2.464 mm
#16 AWG SBC			
19 strands, 0.0117" SBC - 0.0585"			
PFA insulation			
Conductor 7 - Center		0.103 in	2.616 mm
#16 AWG SBC			
19 strands, 0.0117" SBC - 0.0585"			
PFA insulation			
Core Assembly			
PFA-extruded glass yarn filler rods, 0.035" OD			
EPDM non-conductive filler material			
Tape, PEEK		0.302 in	7.671 mm
Armor Package			
Inner Armor - 18 wires, 0.062" US GIPS 350-380ksi			
Outer Armor - 24 wires, 0.046" US GIPS 350-380ksi			
Cable Diameter		0.536 in	13.614 mm
Diameter Variation	±	0.005 in	0.123 mm

Cable Properties

Optical Properties - on shipping drum			Maximum	
SMF Attenuation	1310 nm		0.14 dB/kft	0.45 dB/km
	1550 nm		0.09 dB/kft	0.30 dB/km
Electrical Properties			Maximum, Minimum**	
DC resistance (68 degF/20 degC)	#18AWG - Helical FO		6.5 Ohm/kft	21.3 Ohm/km
	#16AWG - Helical		4.6 Ohm/kft	15.1 Ohm/km
	#16AWG - Center		4.4 Ohm/kft	14.4 Ohm/km
	Armor		0.96 Ohm/kft	3.1 Ohm/km
Insulation Resistance	at 500 VDC **		15,000 MOhm.kft	4572 MOhm.km
Capacitance (1 kHz)	Helical FO		48 pF/ft	157 pF/m
	Helical		42 pF/ft	138 pF/m
	Center		42 pF/ft	138 pF/m
Voltage / Current Rating	Helical FO vs Armor	1131 Vdc	800 Vrms	1.65 A
	Helical vs Armor	1100 Vdc	778 Vrms	2.60 A
	Center vs Helical	1881 Vdc	1,330 Vrms	2.60 A
Mechanical Properties				
Calculated Weight	in Air		485 lb/kft	722 kg/km
	in Fresh Water		387 lb/kft	576 kg/km
Temperature Rating	8 hours		375 degF	191 degC
	Unlimited		350 degF	177 degC
	Minimum Temperature		-40 degF	-40 degC
Cable Safe Working Load			**18,000 lbf**	**80 kN**

Do not use CMTD. Premature damage of the armor matrix and optical damage will occur
Recommended to use TDL device and Minimum sheave diameter to prevent fiber damage 36"

All values are subject to change without notice . Contact InTouch for the latest
Values are calculated values and subject to verification through testing

Schlumberger