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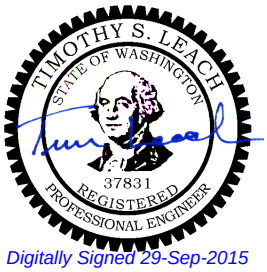

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References

1. *R/V Roger Revelle Trim and Stability Booklet*, The Glosten Associates, Rev. F, 9 July 2013.
2. *Portable Seismic Feasibility Study Deck Gear Arrangement Sketch*, Glosten Drawing 15104-SK-01, Rev -, 25 September 2015.

Summary

Key assumptions have been adopted to determine the maximum feasible size of a seismic survey system for temporary use on the *R/V Roger Revelle* (AGOR 24). One goal of the system is to make it portable. For the purposes of this concept feasibility study "portable" has been defined with the following criteria.

- The system will not interfere with *Revelle*'s existing general oceanography missions,
- Permanent modifications are expected for the *Revelle* to support the Portable Seismic System and correct interferences,
- At least one large compressor will be installed permanently below decks,
- The seismic deck gear will be portable to and from the *Revelle* by using truckable components,
- The entire system is not portable between vessels due to the permanent compressor installation and other modifications.

Under these assumptions it is possible to define a Portable Seismic System with the following key components that meets the *Revelle*'s loadout deck/compartment geometry, power and stability restrictions.

1. One 1800 CFM seismic compressor
2. Two 750 CFM electric drive seismic compressors
3. Two 4 km hydrophone streamers
4. One gun array

This system clearly departs from the notion of reproducing the capability of the *Langseth* in a portable arrangement on the *Revelle*. The final seismic capability of the *Revelle* under these assumptions is much smaller than the existing *Langseth* baseline.

Seismic System

Capabilities of the concept Portable Seismic System are defined by the size of the seismic source and hydrophone streamers, and the shot rate, survey speed and tow loads while surveying. The capabilities of the existing *Langseth* seismic system provide a baseline for comparison:

- 6,600 cubic inch source
- 3,300 CFM compressor capability with 100% redundancy
- Four source sub-arrays with associated umbilicals, rails and overboarding systems
- One 8 km streamer

The Portable Seismic System is limited by compartment space for compressors and deck space to deploy source strings. These restrictions reduce the maximum system size to:

- 3,300 cubic inch source
- 1,800 CFM primary compressor with 1,500 CFM spare capacity through twin 750 CFM deck mount compressors.
- Two source sub-arrays with a 10 second shot rate
- Two 4 km streamers

Source

The seismic source is based on providing the maximum capability that could be installed within the available space, power and stability capabilities of the *R/V Revelle* This source includes a gun array requiring a nominal 1800 CFM air supply. Three compressors are required to meet this air supply with redundancy. The *Revelle* can accommodate three compressors within its current "general oceanographic mission" configuration.

- One LMF 51 electric drive compound compressor supplying 1800 cfm.
- Two LMF 21s electric drive compressors supplying 750 cfm each

In order to support the two source sub-array capability of the *Langseth*, it would be necessary to have two 40 foot containers on the aft deck and a second LMF 51 compressor. Neither of these items fit on the *Revelle* without significant modification to the vessel.

Shot Rate

The seismic gun system is planned to meet a 10 second fire rate for MCS reflection projects.

Streamers

Two 4 km streamers are included in the Portable Seismic System on a pair of waterfall winches. 4 spools of spare streamer cable are stored on deck.

Tow loads

Towing loads are estimated at 7.8 mT while towing an 8 km streamer and four source sub-arrays at 4.5 kts. At the concept level this survey tow load case is assumed to fall within the power capability of the "Transit Normal" electrical load case for the sister-vessel R/V *Thomas Thompson*, AGOR 23. This load case was developed for the *Thompson* mid-life re-fit and includes an integrated propulsion and science load electrical bus. The transit normal case, includes house loads for a full complement and propulsion loads for typical cruising speeds in the 11-13 knot range depending on sea conditions.

Survey Speed

A nominal survey speed of 4.5 knots is planned.

Mission Loadout

The philosophy of the Portable Seismic System is to limit the amount of permanent equipment installed on the vessel by using deck mounted skid and ISO container components where possible. One LMF 51, 1800 CFM compressor is assumed to be permanently installed in the *Revelle*'s Upper Engine Room. Additional permanent modifications and additions include:

- High pressure source-air piping to connect deck mounted 750 CFM compressors to the under-deck 1800 CFM compressor,
- Electrical connections for the deck mounted 750 CFM compressors,
- Noise mitigation for the deck mounted 750 CFM compressors as they are located above accommodation spaces,
- Power and control cabling to deck junctions for the 1800 CFM compressor phase transformer and speed controller in an ISO container on deck.

Source

A containerized source system is installed on the port aft side of the Main Deck. Temporary gun rails, overboarding ramps and winches are installed on a per-cruise basis using the UNOLS bolt-down deck sockets where possible and special foundation bolt patterns if needed.

The bolt-down bulwarks in way of the source container and gun rails must be removed. Safety rails will be included in the gun rail design to replace the bulwarks. Other interferences to be removed or relocated may include valve actuators and personnel access hatches.

Streamer

Two waterfall streamer winches with level-winds are mounted on the UNOLS bolt-down deck sockets near centerline on the working deck. Streamer winch loads may require new temporary foundation structure to interface with the deck and meet the load limits of the UNOLS bolt sockets.

Compressor(s)

One 1800 CFM LMF 51 compressor will be mounted in place of the existing compressors in the Upper Engine Rm on the 1St Platform. Other interferences may include:

- A personnel escape ladderway and hatch to the compartment above, requiring a new location for the ladder and hatch.
- Deck Support stanchions, possibly requiring a modification to the deck structure.
- A future ballast water treatment plant, may need to go in the same space allocated for the compressor.
- The space available for the compressor does not fit the recommended maintenance envelope making it difficult to maintain the equipment.

The electrical drives for all compressors should be specified to match voltage and frequency expected on the vessel (600 VAC, 60 Hz). Some customization of the LMF 51 compressor may be required to align piping and cabling runs within the allotted space

Space for the LMF 51 compressor speed controllers and phase transformers has not been identified below decks on either vessel. These components will be mounted in a 20 ft ISO

container and installed in a designated container location on deck. Permanent electrical deck sockets and junction boxes will be required to connect these compressor components to the LMF-51 compressors below decks.

Two LMF 21S 750 CFM electric drive compressors will be installed in two of the 02 Level forward science lab container locations. Permanent high pressure piping will be installed to the source-air manifold combining output from all four compressors. Permanent circuits with deck sockets and junction boxes will be installed to service the two LMF 21S compressors.

Hydraulic Power Unit(s)

Hydraulic power of approximately 150 GPM at 2000 psi is required to operate the Portable Seismic System deck gear. This capacity may be provided by an electric drive HPU on deck if it is not available from the existing deck gear HPUs.

Control vans

A data recording lab contained in a 20 foot ISO container is mounted on deck in one of the designated ISO container locations.

Navigation Suite

Interfaces between the survey control and Bridge may require installation of a temporary navigation suite on the Bridge to meet the specific requirements of seismic survey.

Cable, Pipe and Hose Management

A temporary installation of the Portable Seismic System will require many cable, hose and pipe runs to interconnect the deck mounted system components. Temporary raised deck grating with cable, hose and pipe supports may be designed to bolt on the UNOLS deck bolt pattern for inboard areas of the Main Deck.

Ocean Bottom Seismometer (OBS) Equipment

The ability to support up to a 100 OBS is included in the suite of *Langseth* seismic capabilities. These units are stored on a dedicated deck on the *Langseth along with additional space on main deck and wet lab*. A much smaller number of OBS frames would be possible to load on *Revelle* together with the Portable Seismic System loadout. The final number of OBS that could be included would require detailed planning to fully utilize smaller, discontinuous deck spaces on the *Revelle* that are accessible so OBS can be deployed.

Lab container space and other supporting systems for OBS work require further deck space that has not been allocated in this feasibility concept arrangement.

Mammal Observing Station

Marine mammal observes require special observer stations providing high visibility during seismic work. This observer station would have to be developed for *Revelle* through additions and modifications to the house structure.

Ancillary Deck Gear

Deck space with overboard access has not been identified for the Passive Acoustic Monitoring (PAM) and magnetometer winches currently used on the *Langseth*. Support for these systems could be investigated in a more detailed phase of design.

R/V *Revelle*: Capability for a Seismic Mission

The following principal characteristics of the *Revelle* frame the capabilities and expected performance on a Portable Seismic System mission.

R/V *Revelle* Principal Characteristics:

Built:	1996	*Speed, cruising:*	11.7 knots
Length:	273 feet	*Speed, maximum:*	15.0 knots
Beam:	52 feet 5 inches	*Speed, minimum:*	Variable from 0 knots, omnidirectional
Draft (maximum):	17 feet	*Motors:*	Two 3,000 hp General Electric
Gross tonnage:	3,180 tons	*Bow thruster:*	1,180 hp azimuthing jet
Displacement:	3,512 long tons	*Propulsion:*	Dual LIPS Z-Drive thrusters
Crew:	21 persons	*Fuel capacity:*	227,500 gallons
Scientific berthing:	37 persons	*Fuel consumption:*	4,400 gallons / day (transit)
Freeboard:	9 feet	*Laboratory area:*	4,000 square feet
Water capacity:	12,000 gallons	*Main work deck area:*	4,070 square feet

Endurance

Endurance: 60 day (limited by provisions)

Endurance: 52 days @ 12 knots (limited by fuel)

Range: 15,000 nm @ 12 knots

Speed and Power

Recent work on the mid-life power upgrades to the *Revelle* sistership *Thompson* provides an example solution for electrical power supply to the Portable Seismic System. These concepts assume that the integrated propulsion/science bus system planned for the *Thompson* would be available on the *Revelle.* Table 1 shows a *Thompson* "Transit Normal" case that could allow a 2100 kW and a 940 kW generator to be dedicated to the Portable Seismic System loads. This capacity could meet the approximate 2500 kW demand of the Portable Seismic System. It is assumed that the "Transit Normal" case would meet the requirements for seismic survey speed and streamer/gun tow loads.

Table 1. AGOR 23 mid-life refit: Integrated Bus Configuration 4: load combinations and spare capacity

Configuration: 4				2 X Caterpillar 3516C @ 2100 ekW					
Installed Power 6080 eKW				2 X Caterpillar C32 @ 940 ekW					
	Load	Gensets Online				Standby Gensets			
Load Case	ekW	Large	Small	Load	GPH	Large	Small	Total	ekW
Transit Full Power	5416	2	1	105%	**384.5**	0	1	1	940
Transit Full Power	5416	2	2	89%	391.4	0	0	0	0
Transit Normal	2475	1	1	81%	179.7	1	1	2	3040
Transit Normal	2475	1	2	62%	182.3	1	0	1	2100
Transit Normal	2475	2	0	59%	**174.7**	0	2	2	1880
On Station Normal	950	0	1	101%	70.3	2	1	3	5140
On Station Normal	950	0	2	51%	74.8	2	0	2	4200
On Station Normal	950	1	0	45%	**69.3**	1	2	3	3980
On Station Normal	950	1	1	31%	76.3	1	1	2	3040
On Station High	1350	0	2	72%	102.8	2	0	2	4200
On Station High	1350	1	0	64%	**95.3**	1	2	3	3980
On Station High	1350	1	1	44%	101.4	1	1	2	3040
On Station High	1350	1	2	34%	107.4	1	0	1	2100
In Port Normal	250	0	1	27%	**20.7**	2	1	3	5140
In Port Normal	250	1	0	12%	28.1	1	2	3	3980
In Port High	400	0	1	43%	**31.8**	2	1	3	5140
In Port High	400	1	0	19%	37.1	1	2	3	3980

It is also assumed that it is feasible to add 600 VAC power subpanels on *Revelle* to supply the Portable Seismic System compressors. Current designs for the *Thompson* include a single spare 600 VAC subpanel rated for 1000 kW. Additional subpanel capacity and installation space would be required.

Stability

The stability of the *Revelle* was investigated with the new mission loadout. Three tankage conditions were investigated for feasibility: (1) load line (fully-loaded to load line), (2) 50% fuel oil (mid-voyage), and (3) 10% fuel oil (arrival). These load conditions were modified from those in the *Revelle* trim and stability book (Reference 1), by replacing the mission loadout and adjusting ballast tank loads. Table 2 shows the mission loadout weights added and subtracted to the mean light operating condition from Reference 1.

Table 2 *R/V Roger Revelle* mission loadout weights

Item No	System	Weight (st)	LCG (ft aft of FP)	TCG (ft stbd of CL)	VCG (ft ABL)
1	Hydraulics/compressor parts-workshop van	9.00	200.00	20.70	30.50
2	Seismic air compressor (750 CFM)	16.00	57.00	6.00	47.00
3	Seismic air compressor (750 CFM)	16.00	57.00	18.00	47.00
4	Seismic air compressor (1800 CFM)	23.00	170.00	-12.00	21.00
6	Compressor phase shift Xfmrs, speed controller	4.00	185.00	-12.00	30.50
7	High pressure manifold and buffer bottles	2.50	187.00	21.00	28.50
8	Recording lab	8.00	155.00	-8.33	64.00
9	Source workshop	9.00	190.00	6.50	30.50
10	Port Source	30.00	215.00	-21.50	30.50

Item No	System	Weight (st)	LCG (ft aft of FP)	TCG (ft stbd of CL)	VCG (ft ABL)
11	Port Gun Rail	4.00	242.00	-21.50	34.50
14	Streamer spares	10.00	242.00	26.00	64.00
15	Streamer winch 1	25.00	210.00	-3.00	31.50
16	Streamer winch 2	25.00	210.00	4.50	31.50
17	HPU's	5.00	177.00	20.70	30.50
	Total Mission Loadout	**186.50**	**176.49**	**-0.21**	**35.72**

It was determined that with the passive anti-roll tank filled to 50%, as per Reference 1, the mission loadout is not feasible in conditions (1) or (3). Therefore, the anti-roll tank was emptied. The anti-roll tank provides a safety margin when at least partially filled, as it can be emptied in the event that the vessel experiences an unforeseen and unsafe decrease in GMt, such as vessel damage or icing. It should be noted that this safety margin will be reduced or lost completely. However, it may be possible to partially fill the anti-roll tank in certain tank loading conditions, if desired.

Figure 1 shows that the required GMt can be met with the new mission loadout and an empty anti-roll tank.

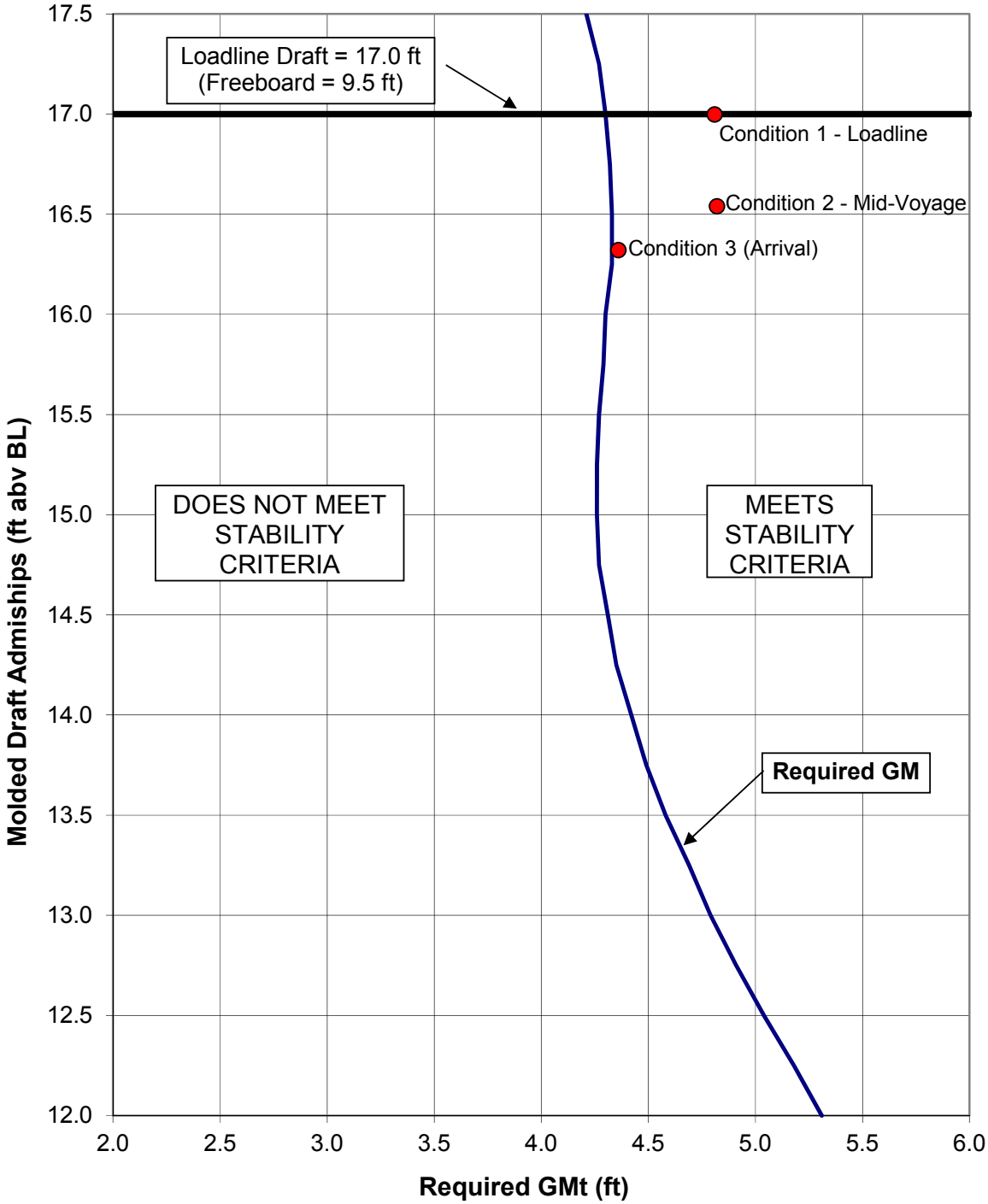
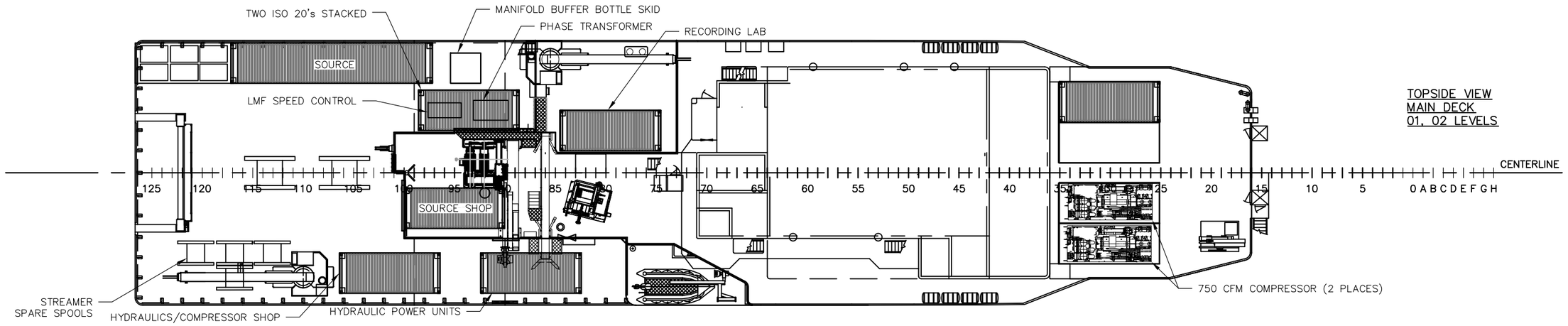


Figure 1 ***R/V Roger Revelle*** **GM required with new mission loadout**

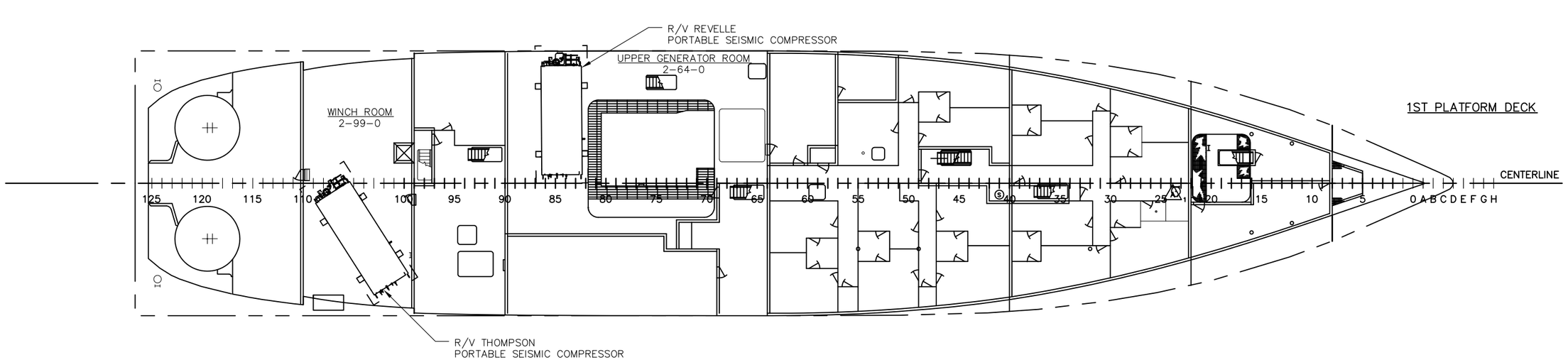
Thompson

As a sistership to *Revelle*, the *Thompson* might be adapted to also meet the requirements of a Portable Seismic System designed for *Revelle* with a few key differences:

1. One 1800 CFM LMF 51 compressor would be mounted in the Winch Room rather than the Upper Generator Room. This compressor would require re-routing the main winch wire with possible modifications to the winch level wind system.
2. Portside midship container locations are not available on the Thompson 02 Level. This could require some re-arrangement of the deck gear layout.



TOPSIDE VIEW
MAIN DECK
01, 02 LEVELS



1ST PLATFORM DECK

LAMONT-DOHERTY EARTH OBSERVATORY
PALISADES, NEW YORI

AGOR 24 CLASS
PORTABLE SEISMIC FEASIBILITY STUDY
DECK GEAR ARRANGEMENT SKETCH

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