WOODS HOLE OCEANOGRAPHIC INSTITUTION

Applied Ocean Physics and Engineering Department

December 19, 2018

Dr. Robert H. Headrick
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Dear Dr. Headrick:

Enclosed is the Final Report for ONR Grant No. N00014-17-1-3019 entitled "Technical Support for J15 Acoustic Source Deployment During ICEX-18," Principal Investigator, Keith von der Heydt.

Sincerely,

Amanda Besaw

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Senior Administrative Assistant II

Enclosure

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Technical Support for J15 Acoustic Source Deployment During ICEX-18

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Abstract

Our work on this grant supported a TACDEV component of the ICEX-18 field program consisting of an ONR funded experiment in cooperation with Arthur B. Baggeroer (MIT) and Jon Collis (Lincoln Laboratories) employing acoustic transmissions to submarine towed arrays. Funding supported the technical aspects of integrating, testing, logistical management, field deployment and operation of a J15-1 acoustic source at the ICEX-18 ice camp north of Prudhoe Bay, AK. The source was deployed from a gantry equipped with an electric hoist to a depth of 550 feet through a hole in the ice within a heated shelter. Seven days time at the ICEX-18 camp were anticipated including 2 days for mobilizing our equipment (approximately 2200 lbs) from WHOI to Deadhorse, AK and out to the ICEX-18 ice camp site. We set up our equipment in a hut over a precut 1 by 2 meter hole in the ice. Due to heavy snow and high winds, flight operations were constrained resulting in our arrival on 18 March at the ice camp 4 days later than expected. After brief time for setup and testing we were fortunate to complete 3 of 4 planned 8 hour J15 transmission cycles. We dismantled and packed our equipment and decamped to Deadhorse on 22 March 2018.

Objectives

There were 4 components to the TACDEV component of our activity at ICEX-18:

1. A light weight deployment and operations package for a J15-1 acoustic projector was configured for use at the ICEX-18 camp at a depth of approximately 550 feet to provide peak source levels of 160dB re 1 μPa in the 100 – 600 Hz band.
2. An existing data logging system was modified to digitally log 4 data channels: 1) the signal applied to the power amplifier, 2) the power amplifier output signal, 3) a source monitor signal from a desensitized hydrophone 1 meter from the source and 4) a depth sensor. The data logging process was driven by a stable, GPS derived timebase to assure precision temporal knowledge of the source signal transmitted.
3. A suite of signals was created using Matlab, converted to wav files, filtered and amplified to drive the J15-1.
4. We supplied technical and logistical expertise to modify, test and configure of equipment and mobilize for shipment from WHOI to the ICEX-18 ice camp in the Beaufort Sea via Deadhorse, AK. K. von der Heydt with salary support from this grant participated in the field and was responsible for the operational aspects of equipment.

Technical Approach

Normally, for a shipboard application, a J15 requires a substantial winch and electro-mechanical faired cable. An ice camp deployment presents logistic restrictions that understandably require compromises related to equipment weight and power requirements. A proper winch and cable alone would weigh at least what we expect for our entire shipping weight, not to mention the power requirement. Additionally, there are environmental aspects of an Arctic ice camp and the J15 having a minimum temperature limit of -10°C due to the fluid filled projector cannot be allowed to cold soak exposed to the open air environment. Hence we required that the ice hole be inside a heated hut. While the J15-1 weighs under 300 lbs in air it is not trivial to manage over a hole in meter thick ice. We used a light weight Spanco aluminum twin A-frame gantry with a trolley on an 8' cross channel to allow the J15 to be attached away from the hole, (Figures 1, 2 & 3). From that we suspended a Tractel Minifor TR30S Electric Hoist which is essentially a small traction winch that is designed to handle any length of .25" steel cable in a controlled fashion whereby it can be bi-directionally stopped and hold the load in either powered or unpowered states. It is compact, relatively light at about 75 lbs. with a rated working load of 660 lbs. The combined wet weight of the J15 plus cables was under 350 lbs. Our deployment scenario depended on having few deploy/recovery cycles as we married the electrical cable to the strength member manually with Tywraps about every 2 meters on deployment. As it turned out, we luckily had only a single deploy/recovery cycle. Both the electrical and steel cable strength member were boxed in figure-8 configuration and managed manually. We had a spare 600' length of both the .25" diameter steel strength member and the electrical cable. Cabling of the wet portion of the system is shown in Figure 4.

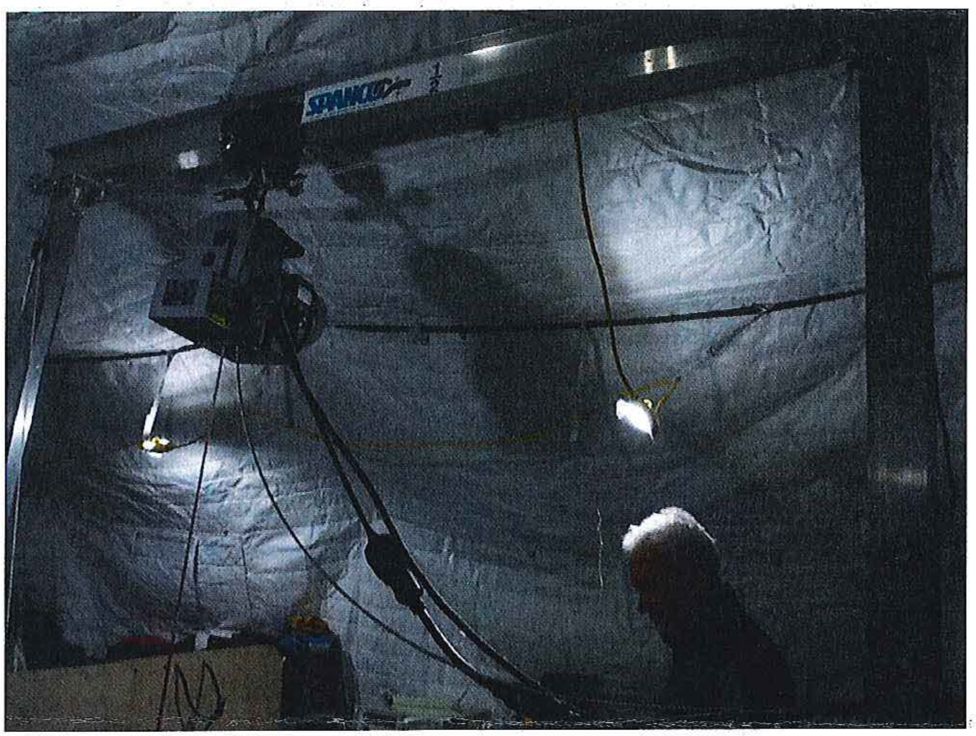

Figure 1, Gantry and Tractel Hoist on Trolley

While we did not "tow" the J15, ice movement relative to the water can amount to a few tenths of a knot hence we planned to minimized cable strum by reversing the spiral direction of the electrical cable approximately every 2 meters as we fastened it to the steel strength member. As it turned out, the wire angle was non-existent so strum was not an issue. The J15 projector was electrically served by 3 twisted, shielded pair of conductors; 1 #16 for J15 power, and 2 #22 for the pressure sensor and the current mode source monitor hydrophone signals.

The J15-1 is a single projector sound source available for rent from NUWC, New London, CT. With a replacement cost of $30,000 and this application having risks similar or worse to shipboard deployments, we did acquire over-the-side insurance. Previous experience with the J15-1 and J15-3 suggest having spare projector is prudent hence we also rented that as well which of course, having it along, was not needed. We possess or can borrow much of the equipment necessary to support work of this nature, in particular a pair of power amplifiers of which one is sufficient to drive a single J15-1 projector, the second being a spare.

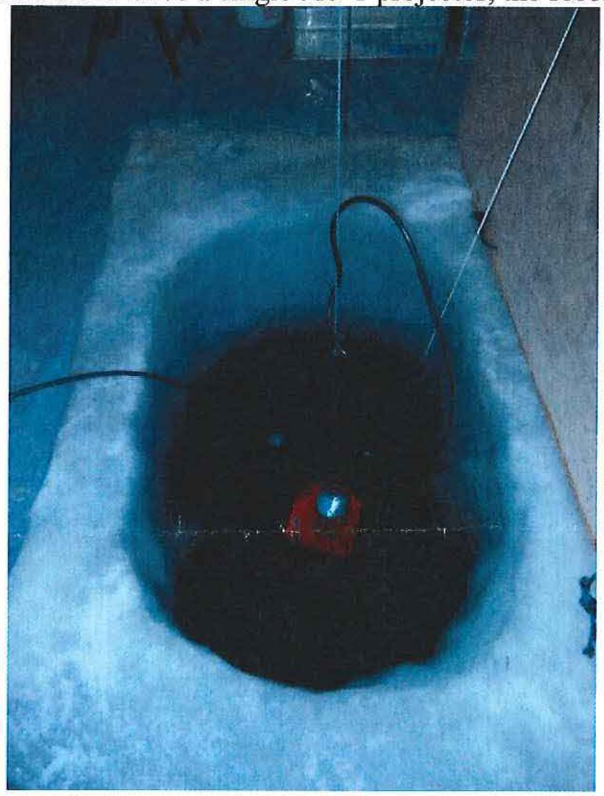

Figure 2, 1 x 2meter opening in approximately 1-meter-thick ice

Figure 3, J15-1

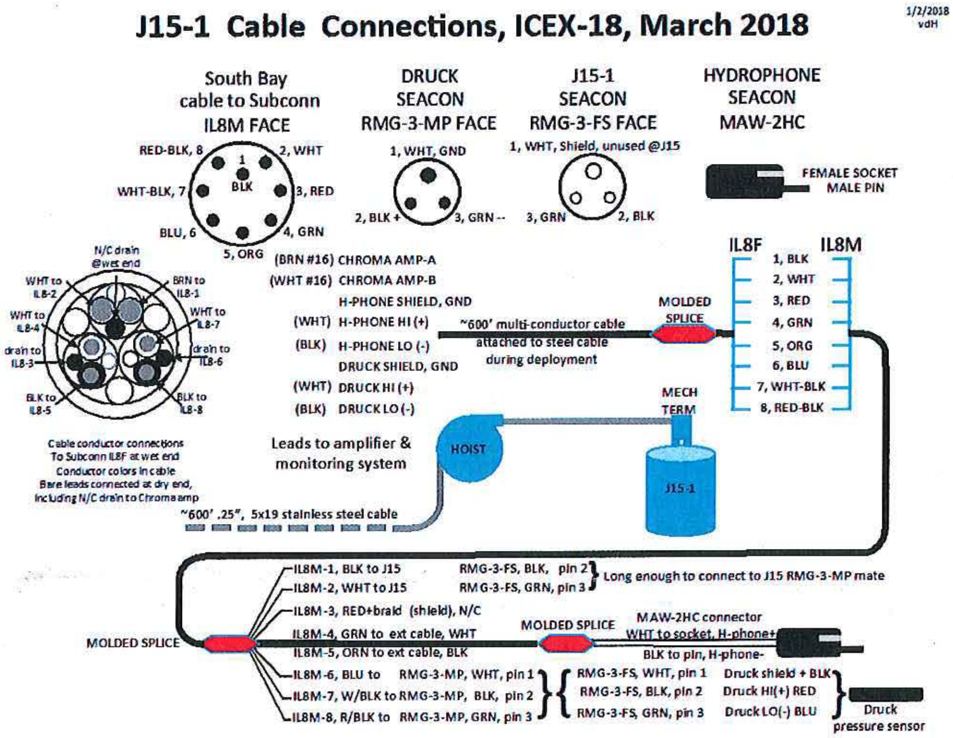

Figure 4, Source Cabling

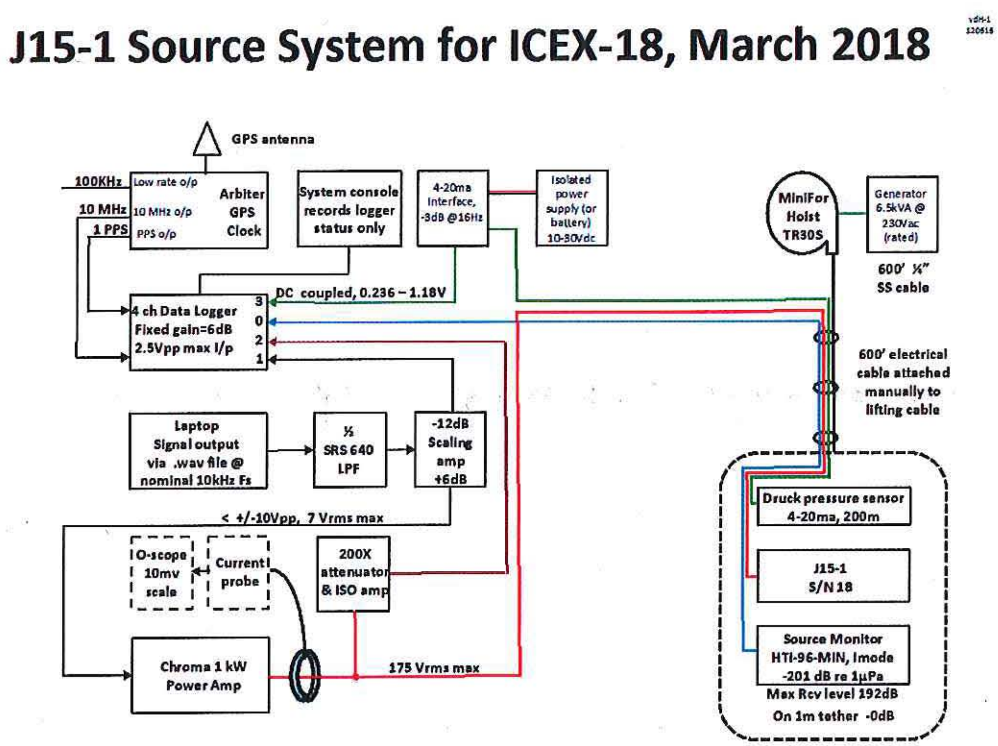

Figure 5, System Schematic Diagram

The topside components of our system are shown schematically in Fig 5. We used a 4-20ma depth sensor (Druck, PTX1830, 0 – 200m depth, absolute) to monitor source depth. A hydrophone with sensitivity -201 dB re 1 μPa (High Tech Inc, HTI-96-MIN, 10–20kHz) was used to monitor the J15 acoustic output level at 1-meter distance from the projector. While this application did not explicitly require synchronization of signal generation to clock time or the timebase of the receiving systems involved, we logged replicas of the wav file, the power amp output and the source monitor hydrophone signal. These signals, along with the depth sensor signal, were simultaneously sampled at a precise rate of 9765.125 kHz derived from a GPS station clock timebase of 10 MHz, and time stamped to +/- 25μs likewise derived from the GPS timebase.

A suite of signals some of which mimicked acoustic communications modulation (thanks to assistance from Sandipa Singh of Lee Freitag's acoustic communications group at WHOI and Jim Preisig, JP Analytics) was synthesized using Matlab into audio wav files at an output rate of 10 kHz. The suite of signals shown in Figure 5, represents exactly 1 hour of playback time. A full 8-hour transmission epoch was created by seamlessly stacking 8 copies of the 1 hour wav file. One additional 1-hour wave file was created for a separately requested transmission comprised of 110Hz CW with 40 ms bursts of 600 Hz at a 5s period.

Note, when played from a laptop as we did, the 10kHz rate is not driven by a precision oscillator, however the logger data was precisely time tagged so the time offset and drift of the signal generation will be a known factor during the processing of the reception data.

Event	Start	-	Finish		Description
1	0	-	100	sec	100 Hz tone
2	100	-	200	" "	125
3	200	-	300	" "	156
4	300	-	400	" "	195
5	400	-	500	" "	244
6	500	-	600	" "	260
7	600	-	700	" "	305
8	700	-	800	" "	343
9	800	-	900	" "	381
10	900	-	1000	" "	428
11	1000	-	1100	" "	476
12	1100	-	1200	" "	525
13	1200	-	1350	" "	Low frequency (175 Hz) pentaline for SNR
14	1350	-	1500	" "	High frequency (425 Hz) pentaline for SNR
15	1500	-	1800	" "	MDL at 100, 200 and 300 Hz
16	1800	-	2100	" "	MDL at 400, 500 and 600 Hz
17	2100	-	2400	" "	MDL at 250, 350 and 450 Hz
18	2400	-	2800		Hadamard codes acomms transmissions
19	2800	-	3200	" "	M sequences channel probe signals
20	3200	-	3600	" "	Convolutional coding transmissions

Figure 6, Signal suite comprising a 1-hour repeatable audio wav file block

Accomplishments

The system with all mechanical and electronic components was configured and tested to the extent possible in a tank at WHOI. Subsequently, the system was packed for common carrier travel to Deadhorse, AK within the schedule specified by the Arctic Submarine Laboratory logistics manager. The J15 was shipped surface from WHOI to Seattle due to its weight then continued on Air Alaska to Deadhorse along with all other boxed gear. The total weight shipped and subsequently returned (less minor expendables) was approximately 2200 lbs.

Arthur Baggeroer, Jon Collis and Keith von der Heydt arrived at Deadhorse, AK on 13 March. Our gear was transported to the ICEX-18 camp on 17 March and we flew to the camp on 18 March. Our objectives were largely met as planned despite a period of un-flyable weather at the ice camp which imposed a compressed schedule. Upon completion of the 3rd 8-hour transmission on 22 March, we dismantled our system, re-packed, loaded the Twin Otter aircraft and were flown back to Deadhorse. Camp backhaul was largely completed by the following day. None of our equipment of any consequence was lost or damaged although normal and expected maintenance was required for a number of items.

Three complete 8 hour epochs of signals as shown in Figure 6 plus the sequence of 110Hz CW with 600 Hz bursts were accomplished. Initial reports confirmed signals were received as planned. The first 2 full 8 hour RUN sequences and the 110Hz CW sequence were transmitted at a depth of 165m. The 3rd and last 8-hour transmission was accomplished while we recovered the source due both to reasoning that it would be beneficial to observe the signal over the deployed depth range.

Data from the logger was stored on compact flash cards that could be easily removed from the data logger for security purposes. We normally use these loggers in pressure tolerant housings for water column deployments but for ICEX, we brought a pair of them without housings.

During J15 transmissions we were able to view the source monitor signal on a spectrum analyzer. Between active episodes of J15 ops, we were able to view segments of the logged data in order to assess the time series and spectra emitted by the J15 and confirm the depth of the projector.

Subsequent to data logging operations during the last of the 3 – 8 hour transmissions at the ice camp, it became apparent that during the transcription of data files from the data logger compact flash to a Linux OS based laptop, the compact flash card in use at that time had become corrupted. The reason for this remains unresolved however such a failure with one of these loggers was unprecedented despite many such copying procedures with machines running Mac OS and Microsoft OS's. The suspicion is that either the variant of Linux OS has some incompatibility with the logger OS FAT32 format that did not manifest itself during the same procedure with data files from Runs 1 & 2, or an error developed on the compact flash media itself.

Upon closer inspection using a low level disk repair software package, we have been able to determine that all data on the compact flash card in question does indeed exist and is recoverable, having so demonstrated by fully recovering the GPS log acquired during RUN 3 and a very small amount of the acoustic/pressure data. The recovery approach with the software on hand by us requires a complete manual rebuild of the File Allocation Table (FAT) for each file which entails more laborious time than we could apply. Our Lincoln Laboratory colleagues however assure us that they are able to employ a more efficient process to recover the RUN3 files, now that they know that the directory information and not the data itself was corrupted.

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