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Cruise Report for Seismic Reflection trials from the CCGS Louis S. St Laurent

Thomas Funck and Borden Chapman

2007

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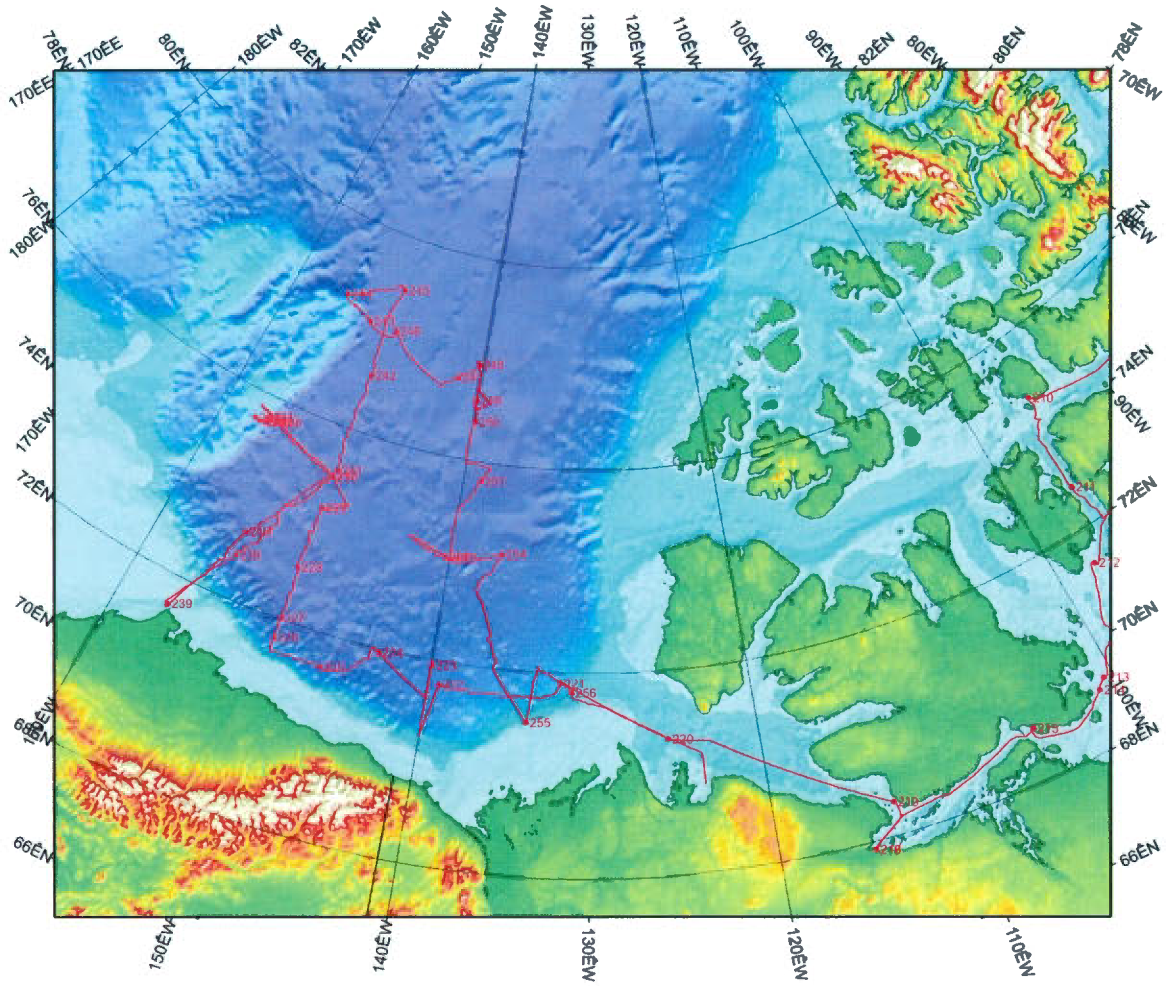

Track plot of the 2006 cruise of the CCGS Louis S. St Laurent

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Report on the reflection seismic work onboard CCGS Louis S. St-Laurent as part of the Canadian UNCLOS project

Halifax, Nova Scotia, to Kugluktuk (Coppermine), Nunavut

July 20 to September 14, 2006

Report prepared by

Thomas Funck

Geological Survey of Denmark and Greenland (GEUS)

Borden Chapman

Geological Survey of Canada (GSC)

The seismic work onboard CCGS Louis S. St-Laurent was joint with:

Joint Western Arctic Climate Study (JWACS)

Joint Ocean Ice Study (JOIS)

Executive Summary

The objectives of the reflection seismic work onboard CCGS Louis S. St-Laurent were to test the newly designed airgun tow sled in Arctic sea ice, and to collect some initial seismic data in Canada Basin that can be used for the planning of future UNCLOS experiments in the Canadian High Arctic. The transit from Halifax to Kugluktuk was used to install the seismic gear on the ship and to do initial deployment tests of the tow sled. The deployment with the two cranes on the quarter deck is difficult and time consuming, but the better-suited A-frame was not ordered in time to have it ready for this cruise. The aging compressor had some downtime, which resulted in the premature end of one seismic line. However, a new compressor will be available for future work.

The airgun tow sled behaved very well in the ice as long as the centre shaft of the shift was not used. When the centre shaft is used, the extra water pressure pushes the sled away from the stern, which increases the likelihood that the tow wires and umbilical cords of the sled get caught by ice, which can pull the entire sled out of the water. The use of the centre shaft is necessary in multiyear ice and in ice ridges, where the ship needs the extra power to break the thick ice. If a camera was mounted on the quarter deck so that the bridge could monitor the sled position, the risk to the gun array could probably be reduced.

Thick multiyear ice impeded CCGS Louis S. St-Laurent when the airgun sled was in the water, because the ship can neither operate at full speed nor can it move backwards. Both techniques are required to go through the 5-m-thick ice that was encountered in the survey area. Hence, the major recommendation for future seismic data acquisitions in the Arctic is to use a second icebreaker that makes a lead for the shooting vessel. The benefits of a two-ship experiment are that the gun array will be at lower risk, the noise levels will be reduced, the speed of the data acquisition can probably be kept close to 4 knots even in multiyear ice, and the ship can stay on the desired track lines.

A total of 405 km of seismic data were acquired during the cruise. In western Canada Basin, sediments were detected down to a depth of 3.5 seconds below seafloor, which implies that a Canadian claim for an extended continental shelf can go out to 350 km from the foot of the slope if UNCLOS' sediment thickness rule is applied. However,

there was no clear indication of basement in the record sections obtained from minimal onboard processing. When the ship sailed through ice, the signal-to-noise ratio was significantly reduced (up to a factor of ten). Two lines were initially shot with three guns and later with one or two guns. The data quality did not change significantly when only one airgun was used. This suggests that the low seismic penetration is more a function of the ambient noise and the streamer than of the airgun source. Hence, it is recommended to use a different streamer and run a short one-day cruise to test the streamer. Some of the streamer options are: 1) a single-channel streamer with better hydrophones (noise cancellation); 2) a longer streamer so that the hydrophones are farther away from the main noise source (the ice-breaking ship) – this would require the development of an appropriate deployment method; 3) a multi-channel streamer. In addition, the shot rate should be reduced to 20 seconds or less (60 seconds in this survey), which should not be a problem with the new compressor. If the guns are operated at a pressure of 3000 psi, the signal will also be significantly stronger than during this experiment (1750 psi).

The lengthening of the leading cable of the streamer from 100 to 306 ft has slightly improved the signal but is still short of the 600 ft used during the USGS seismic surveys in the Arctic. Background noise from the ship (engine, propeller, and icebreaking) was generally below 25 Hz, peak noise levels were below 12 Hz. This is in the same frequency range as the deeper reflections. This suggests that the streamer should be towed as far behind the ship as possible, which is basically determined by a safe deployment technique in the ice.

The test of a sonobuoy was not satisfactory as the signals from the radio transmitter were below the squelch level at a distance of ~8 km, which is too close to observe refractions from deeper sedimentary layers in the water depths of >3500 m. During the test, the antenna on the ship was mounted at a height of 7 to 12 m above sea level. Mounting the antenna higher up on the ship could increase the sonobuoy signal range. The direct wave and the water bottom reflection recorded by the buoy did not have a high amplitude (at least not with the processing carried out on board). This could be due to several reasons: 1) ambient noise from ice, even though the buoy was deployed in an area that was relatively ice-free; 2) the settings on the buoy were not optimal (e.g. hydrophone depth); 3) the energy of the guns is too weak.

Engine problems on the CCGS Louis S. St-Laurent caused the ship to drift for 4.5 days. In 2005, engine problems resulted in a downtime of 6 days. These incidents indicate that the ship is prone to have failures due to its aging technical equipment. If it is decided to use a second icebreaker for future UNCLOS projects in the Arctic, downtime could become a serious financial burden. In addition, the tight deadlines of the UNCLOS program are at risk. Hence, every effort should be made to reduce downtimes at sea and this should be seriously discussed with the Canadian Coast Guard.

This is also the reason that we suggest the use of two tow sleds for the seismic work. This would allow the continuation of data acquisition while one array wasrepaired. Given the high costs for a possible two-ship operation, the investment in a second sled would soon be recovered, as damage to the array cannot be fully prevented in ice-infested waters.

Minor damage to the tow sled occurred at the electric connectors of the air guns and at the fittings of the air hoses. This is caused by the airguns hitting the frame of the sled. Additional protection for the connectors is planned for future experiments (plastic block). Another problem was that the regulator of the anti-freeze system that froze at temperatures around the freezing point. This problem can be fixed by moving the system into the compressor container.

Scientists and crew

onboard CCGS Louis S. St-Laurent from August 5 to September 14, 2006

Scientific staff

Sarah Zimmermann	Chief Scientist (IOS)
Thomas Funck	UNCLOS / Seismic (GEUS) - Scientist
Borden Chapman	UNCLOS / Seismic (GSC) - Technician
Ryan Pike	UNCLOS / Seismic (GSC) - Summer student
Joe Manning	UNCLOS / Bathymetry (CHS) - Hydrographer
Joe Illasiak	Wildlife Observer (Paulatuk, NWT)
Ian Green	Wildlife Observer (Paulatuk, NWT)
Mary Steel	CTD/chemistry (IOS)
Linda White	CTD/chemistry (IOS)
Nes Sutherland	CTD/chemistry (IOS)
Michiyo Kawai	CTD/chemistry (IOS)
Jane Eert	CTD/chemistry (IOS)
Michael Dempsey	CTD/chemistry (IOS)
Hugh Maclean	CTD/chemistry (IOS)
Shigeto Nishino	CTD/chemistry (JAMSTEC)
Kristina Brown	CTD/chemistry (IOS)
Helen Drost	CTD/chemistry (IOS)
Jennifer Jackson	CTD/chemistry (UBC)
Abigail Spieler	CTD/chemistry (LDEO)
Richard Krishfield	Moorings (WHOI)
William Ostrom	Moorings (WHOI)
Kris Newhall	Moorings (WHOI)
Juxin Shi	PRR (Ocean Univ. of China, Qingdao)
Yutian Jiao	PRR (Ocean Univ. of China, Qingdao)
Jennifer Hutchings	Ice observations (Univ. of Alaska, Fairbanks)
Patrick McKeown	Ice observations (Univ. of Alaska, Fairbanks)

Crew

North Crew (updated on August 26, 2006)

Andrew McNeill	Commanding Officer
John Jenner	Chief Officer
Rodney Strowbridge	First Officer
James Ayres	Third Officer
Marian Punch	Third Officer
Don Stortts	Chief Engineer
Robert Lyle	Senior Engineer
Michael Willis	First Engineer
Julien Marceau	Second Engineer
Gerald McDonald	Third Engineer
Norm Robinson	Electrical Officer

Stephen Colp	Electrical Officer
Bill Brocklebank	Logistics Officer
Joe Lucas	Electrician
Rico Amamio	Boatswain
Gary Morgan	Carpenter
Al Jarvis	Winchman
Stephen Archibald	Leading Seaman
Kenneth Baker	Leading Seaman
Ralph Kaiser	Seaman
Daniel B. Maclean	Seaman
Brian MacKenzie	Seaman
Bill May	Seaman
Terry Rhyno	Seaman
William Dobbin	Seaman
Jeff Doane	E/R Technician
Dave Ramsay	E/R Technician
Archie Blanchard	E/R Technician
Raine Jones	E/R Mechanic
Kenneth Pettipas	E/R Mechanic
Wade Mackenzie	E/R Mechanic
Sherry Hudson	E/R Mechanic
Bryant Culhane	E/R Mechanic
Bruce MacDonald	E/R Mechanic
Randy Turner	Chief Cook
Graham Weldon	Storekeeper
Michael Gaudet	Storekeeper
Catherine Munroe	Second Cook
Thomas McMahon	Second Cook
Paul Devlin	Second Cook
Florence Carter	Steward
Larry Royea	Steward
Joe Gurney	Steward
Robin Parker	Steward
Jaimie Mizuik	Steward
Christopher Swannell	Helicopter Pilot
Robert Locke	Helicopter Engineer
Heather Kinrade	Electronics Technician
Scott Payment	Ice Observer
Lori Swain	Medical Officer

The UNCLOS group. From left to right: Joe Manning (CHS), Borden Chapman (GSC), Ryan Pike (GSC), and Thomas Funck (GEUS).

Marine mammal observer Joe Illasiak from Paulatuk, Northwest Territories.

Marine mammal observer Ian Green from Paulatuk, Northwest Territories.

Diary (written by Thomas Funck)

All times in this diary are local / ship time.

Saturday – August 5, 2006

Today was the crew change on the Louis S. St-Laurent (LSSL) and I was allowed to join the charter flight from Halifax, Nova Scotia, to Kugluktuk, Nunavut. A bus shuttle was organized that left the Coast Guard base in Dartmouth at 5.30 am to head for Halifax International Airport. The Coast Guard did not use the airport terminal but the bus drove us to an area that is used for cargo planes. After some waiting time and a cross check of the names we were allowed to enter the Boeing 737 of Canadian North without a security check. The plane started at 7 am, heading towards Churchill, Manitoba. The flying time was ca. 4 hours. People were allowed to leave the aircraft during the refuelling that lasted ca. 30 minutes. After another 90 minutes of flying time, the aircraft arrived in Yellowknife, Northwest Territories, to refuel and for a crew change. After one hour the plane was ready to fly the last segment (60 minutes) to Kugluktuk. The plane was unloaded and the ship's helicopter started to transfer people from the airport to the ship that anchored close to Kugluktuk. The Coast Guard crew was airlifted first, then the scientist, followed by provisions and the baggage. This operation lasted for the rest of the afternoon.

The cabin I got was an indoor cabin on the main deck with no desk. I complained to chief scientist Sarah Zimmermann about this and she organized another cabin for me that had a pullout desk, a telephone and a window. I moved into this cabin the following day.

At 7 pm ship time (Eastern Time), we had the first science meeting in the boardroom, where the science program, the general objectives and the scientists were introduced.

Sunday – August 6, 2006

After consultation with Borden Chapman and Sarah Zimmermann, I decided to set up the SUN workstation for the seismic processing in the board room, where some desk space was available. I brought the wrong power cable for the computer (Danish plug) but Borden had spare cables. Computer and monitor were secured with duct tape and the system booted without any problems.

At 11 am was another science meeting that was also attended by the captain, the chief engineer and the chief officer, to give a brief introduction into the ship's procedures. After I settled in my new cabin, I delivered the SONY video camera to Borden that Ruth gave to me. Borden requested the camera to film the deployment of the airgun array and the behaviour of the array in different ice conditions. I also gave the Fugawi software and two memory sticks to the UNCLOS hydrographer Joe Manning.

Before supper, I got a one-hour familiarization tour of the ship. At the end of this tour, everybody had to try the new Mustang survival suits. After supper, my email account was set up by the ship's technician. There are two daily email exchanges, one at 12.30 pm and one at 10.30 pm ship time. LSSL left Kugluktuk in the afternoon.

Borden was asked by the captain and the chief officer to submit a written guideline on the deployment of the airgun array. These guidelines were to be reviewed by the ship's officers and shall also be used to prepare the deck crew for the deployment. The captain said that the system would not go over the side without these guidelines. Borden worked most of the day on writing the manual.

Monday – August 7, 2006

In the morning we tested the deployment of the streamer, which went without any problems. An evening meeting with the captain and the chief scientist was scheduled to discuss how the seismic work can be best integrated with the oceanographic program. In my opening statement I emphasized that we demand the full 12 days of ship time that UNCLOS was paying for. The captain replied that he got orders prior to the cruise that contradict this request for the 12 days of ship time and that he would not change his view unless he is told so by Martin Bergman. The meeting continued with a discussion on what can be achieved realistically. After the difficulties that were encountered with the deployment of the array on the way up from Halifax to Kugluktuk, one of the main constraints was to minimize the number of deployments. The original plan given to me by GSC senior scientist Ruth Jackson, was to collect data along five priority lines, which were split up into segments between the oceanographic stations. This plan would have required a large number of airgun deployments and retrievals, which is not realistic. Instead, we agreed on a plan to collect data in several segments along priority line 2 in the triangle of the border with Alaska and on some portions of priority line 1. At the end of the cruise, seismic data is to be collected along the remainder of priority line 1 without any interruption by oceanographic work, which means a continuous recording.

I spent the remainder of the day on the preparation of a PowerPoint presentation on the UNCLOS work in the Arctic (this project and the LORITA-1 data collection in the Spring). I hope to get a chance to give this talk to interested people on the ship at a later stage.

At midnight we changed time zone and moved one hour to the west, using Central Time (UTC - 5 hours) instead of Eastern Time. This night people were woken up by a false general alarm.

Test deployment of the streamer.

Tuesday – August 8, 2006

For the afternoon, a test deployment of the airgun array was scheduled. Borden Chapman and Ryan Pike spent the morning with the preparation of the array. They installed four plastic blocks on the cable bundles that the ship's engine department had modified for us over the last couple of days (the diameter of the holes in the plastic blocks were not wide enough and had to be widened).

At 1 pm I had a briefing with the two marine mammal observers Joe Illasiak and Ian Green. Borden and Ryan also attended. The briefing was about Joe's and Ian's obligations during the seismic data acquisition that were outlined in the permissions by the Environmental Impact Screening Committee and by Northwest Territories Environment and Natural Resources Canada. A copy of the permissions was given to Joe and Ian. At the same time, I explained the UNCLOS program to Joe and Ian and afterwards Borden and Ryan showed them the seismic equipment that will be used during the experiment.

LSSL tried all morning to clear some ice for the recovery of a mooring site. However, the ice coverage (8 to 9 tenths) with thick multiyear ice prevented the recovery and it was decided to come back to the site at the end of the experiment. Despite the dense ice cover and thickness, there were a number of seagulls in the area and we also noticed several seals as close as 100 m to the ship. I hope this will not become a problem because during the data acquisition we have to shut down the airguns if there are any marine mammals within a radius of 1 km around the ship. Joe was not surprised to see seals and he expects them throughout the study area. Yesterday, in more open water a total of 24 whales were observed (bowhead and beluga). Joe and Ian observe the wildlife three times during the course of the day (8.30 to 10.30 am, 12.30 to 2.30 pm, and 5.30 to 7.30 pm). All sightings are recorded in a spreadsheet that was given to them by Sarah Zimmermann.

At 2 pm, the test deployment of the airgun array started. The streamer was not deployed in this test and the array was only lifted over the side but not lowered into the water. Ryan Pike was in charge of documenting the deployment with the video camera while Borden coordinated the deployment on the quarter deck with the deck crew and the chief officer. The captain and the chief engineer observed the operation from the deck above. Several trials were made to hoist the array with the winch on the starboard crane. However, the weight of the array (4300 pounds) was only just under the maximum certified weight of the crane (4400 pounds) and all attempts to lift the array over the side failed. After supper at 5 pm, a new technique was tested that proved to be successful. Instead of lifting the array with the crane's winch, the airguns are now lifted by the beam of the crane. During the first leg of the cruise, the lifting of the tow sled with the winch still worked, but the crane would actually bend from the weight. The new method seem to put less strain on the beam and we feel now more confident that the deployment of the array can be done safely and within reasonable time even though the crane is operating at its maximum load. The test was completed shortly before 7 pm.

Successful trial to lift the airgun array over the side of the ship. Note that the array is only lifted by the beam of the starboard crane.

Wednesday – August 9, 2006

Together with Borden I entered the location of the oceanographic stations into the navigation computer (Regulus software) in our seismic laboratory down by the quarter deck. This way we can better follow the ship's operations.

Borden and Ryan prepared the sonobuoys so that we can perform a test during the data acquisition. They also mounted an antenna to the stern of the ship to receive the signals of the sonobuoys.

At 6 pm we had a meeting with the captain, chief officer, boatswain, and our UNCLOS group (Borden, Ryan, Joe Manning, and me) to discuss next day's plan for the first seismic data acquisition. The aim was to move the ship overnight to the southern end of priority line 2 close to station CB-29 at the 2500-m-isobath and start the deployment around 8 am. It was agreed to shoot until 7 pm so that the array can be brought in before 9 pm when the shift of the day deck crew ends. This would also allow to check for the wear and t++++-ear on the array before a new deployment can be made on Friday morning. If the first test is working alright, overnight shooting can be considered.

After the meeting I walked up to "Monkey's Island" to inform Joe Illasiak and Ian Green about our plans for the next day so that they can work out a watch system among themselves to cover the entire seismic acquisition period. They plan to go four hour watches. Longer watches seem to be unreasonable in the cold weather (5°C this evening) and shorter watches would interfere too much with the sleeping pattern.

Thursday – August 10, 2006

At 8 am everybody was on the quarterdeck but the ship had not arrived at the 2500-m contour line yet, the water depth was only 2065 m. The chief officer told us that we may have to wait another couple of hours, lunch time a the latest we should be ready for deployment. Joe Illasiak went to "Monkey's Island" on top of the bridge to start his marine mammal observations, while the rest of the group went into stand-by mode. Ice conditions this morning were very variable. Before breakfast at 7.30 am the sea was ice-free, whereas at 8 am we were into 4 to 5 tenths of ice with fog and a visibility below 1 km. At the science meeting at 11 am we were informed that pink eye infections have occurred on the ship and that we should take extra care in washing our hands.

The LSSL arrived at position (2500-m isobath) around noon and deck crew and the seismic group were ready for deployment. When the captain finished lunch at 12.25 pm we could start the deployment of the array. It was still foggy at that time with less than 1 km visibility. I ensured that the marine mammal observers were on watch. Ice conditions were about eight tenths. The deployment was very smooth; it took ca. 20 minutes until all the equipment was in the water. However, I was not happy with the deployment of the streamer, which was launched into the water before the airgun was deployed. Until the array was in the water, the streamer would swim at the sea surface and the ice would close some 50 m behind the ship. This resulted in some severe bends in the streamer when it was caught between ice blocks. Often the streamer would also be dragged across the ice. Once the airgun is at its towing depth of 36 feet below sea level, the streamer would sink accordingly. This happened some 15 minutes after the streamer went into the sea.

Ryan started the compressor after the array was in the water. After the air pressure had built up to ~1800 psi, shooting began at 1:06 pm ship time (UTC-5 hours). Before the first shot was fired, the marine mammal observers were contacted to get their go ahead and the engine room was informed as well because they wanted to check for any impact of the shots on the ship. According to our permissions, we ramped up the array, starting with one gun and after ca. 15 minutes all three guns were fired. The chief engineer was happy as he could not see any danger for the ship associated with our airgun operation.

The streamer is swimming at the surface until the airgun array is lowered into the water.

One of the first airgun shots fired with the array.

Ice conditions on the run to the north worsened continuously and after one hour of shooting we were into 9tenths + of multi-year ice, the thickness of the ice was up to 5 m and the ship came to a stop several times. After four hours of shooting the ship was incapable of proceeding any farther, just 12 miles after the first shot. Without the array in the water, the ship could have developed enough thrust to break the ice, but with the deployed gun and streamer, the ship cannot move backwards and the shafts can not run at maximum thrust. The seismic array behaved reasonably well in these severe ice conditions. However, several times the sled was lifted out of the water by large pieces of ice, which resulted in a few shots in the air. This happened in particular, when the ship was forced to use the centre shaft, which pushed the tow sled away from the ship where the ice would close behind the ship. Ryan was able to video tape one of these events.

We started the recovery of the airgun array at 5 pm and inspected the array for damage. We noticed that one of the steel bars at the top of the sled (made to attach cables to it) was bent and broken from the frame at one side (see photo). More serious was a puncture in the lead-in cable to the streamer, close to the airgun. Salt water could penetrate into the streamer through the puncture. Despite the damage, Borden was rather pleased with how the array behaved in the severe ice conditions encountered.

Broken steel bar at the top of the air gun sled.

During the acquisition a number of electronic problems were encountered. For the first few shots the hydrophone cable was not connected. Then there was cross-talk in the cables to the guns, which Borden and Ryan could fix. The three guns were not synchronized during the shooting. Borden could not fix this problem even though he carefully followed the manual for instructions. When I looked at the seismic data on the workstation, I noticed that the record length was only 2.5 seconds (+ a delay of 2 or 3 seconds to adjust for the water depth). Borden told me that the setup of the digitizer built by Dave Heffler is a little awkward. If the record length is increased, the sampling rate has to be decreased. I was unaware of this and thought we would have a record length close to the shot rate, which varied between 20 and 60 seconds during our test. We will adjust the record length during future deployments and I will look into the trade-off between record length and sampling rate once I have time to calculate a frequency spectrum of the data.

Bent in the steel bar at the top of the airgun sled.

Puncture in the lead-in cable to the streamer.

Today's data were acquired in the area that is least ice infested in Canada Basin and our conclusions are that it is not feasible to collect data in a single ship experiment. A second ship is required to break a lead. Then it should be possible to collect data with the airgun array that we have available. With today's experience, it is time to look at the options that are available to complete this cruise with the best possible outcome. Borden and I have discussed this with Sarah this evening and afterwards I went with Sarah to the captain to present our conclusions. These conclusions are summarized below and were emailed to GSC scientist Ruth Jackson.

1) Ice conditions are 9tenths + along all five priority lines and after todays experience it is unrealistic to collect any more data on these lines in the near future. Trying to push it at this stage could mean the loss of the array for minimal gain as the

ship has not enough power to go through the ice when the array is in the water.

2) Sarah said that there is some chance that the ice situation might improve in the south in early September. That is why we think it is best to concentrate on this opportunity rather than go to the extreme limits now and risk losing the array. We should keep this option for later if this is desired.

3) We see the benefit of getting some idea of sediment thickness in Canada Basin for next year's program. We plan therefore to carefully monitor the ice situation and if we encounter conditions better than today, we think it is useful to collect data even if it is only for short distances (10 miles). I think, in particular, we may want to look near the outer limit of the 350 nm zone to see if next year's lines need to extend all the way out there or if the sediments are too thin to make a claim there.

4) Another strategy is to look for leads. The captain is willing to use the helicopter to guide the ship if we should find such a lead. This is probably more likely in the northern survey area where we are farther away from the warm water in the south that creates a lot of fog and prevents helicopter flying. Preferentially we would prefer leads in E-W direction because they would provide the best constraint on how far out a possible claim can be made.

5) If we should encounter some open water in a ca. 1 km wide zone we want to deploy the calibrated hydrophone to get a measurement on the far-field signature of the array.

Friday – August 11, 2006

Ruth Jackson called this morning to acknowledge the receipt of yesterday's email. She discussed this with GSC-A director Jacob Verhoef and we got the go ahead to adjust the seismic program according to our suggestions. Jacob also increased our helicopter budget from $10,000 to $30,000 to help the ship's navigation if we find suitable leads to acquire data. Ruth asked me to discuss with the captain if a second icebreaker really helps to increase the speed of data collection if the ice is under compression or if the ice would just close behind the first vessel, thereby gaining nothing. Captain McNeill answered that both ships need to be icebreakers and then it does not matter if the ice is under compression or not. The passage of the first vessel will chop up the ice and this is the important thing for easy passage of the second vessel. He also recommended sending the more powerful icebreaker ahead.

I spent some time in the morning to investigate where on the ship the GPS antenna is located in order to process the navigation data. Heather the ship's technician was very helpful and we found that the antenna is 196 ft from the stern of the ship and 23 ft from the centre of the ship to the starboard side. The gun was towed at a depth of 50 ft from the deck, which corresponds to 36 ft below sea level. The six hydrophone groups (consisting of 14 hydrophones each) were located 100 to 300 ft behind the airguns.

Borden and Ryan spent the day fixing the airgun array. The engineer helped with welding the frame of the array together. The hole in the lead-in cable was vulcanized and covered with tape. Borden also found the reason why the gun synchronization did not work. It was related to a cable that was not connected. I spent the afternoon processing the seismic data on the SUN workstation, also to find out if we can increase the sampling rate on the digitizer to allow for a longer record length. I found that we can probably live with a sampling rate of 8 ms even though some energy above the Nyquist frequency of 62.5 Hz is observed close to the seafloor. When I went with Borden to the seismic lab to enter new values to the digitizing program CGAim (Version 1.4), we found that we could trick the program to get settings that are not allowed according to the menu. However, the way we entered the parameters was not straightforward. We were able to program a sampling rate of 170 Hz and a record length of 2048 samples or ca. 12 seconds. The sampling rate is certainly not a standard rate, but it will allow us to map the sediments down to basement, assuming that the signal-to-noise ratio is sufficient and that the penetration is deep enough. However, the noise levels in the thick ice seem to be high. Borden will now try to get the sampling rate to a more even number like 200 Hz.

Helen wrote a dispatch today on our work for the website at Woods Hole Oceanographic Institution. Both Borden and I came with many corrections to her first draft. Our aim was to be as positive as possible about our first data collection and to emphasize that we have high standards regarding the minimization of the environmental impact of the seismic work.

In summary, the day was used to repair the damage to the array and to fix some other problems that we noticed. We are now ready for another deployment whenever the ice conditions allow for it. However, for the moment we are in the American EEZ and cannot shoot in the otherwise favourable ice conditions.

Saturday – August 12, 2006

Today I have measured the position of the GPS antenna on the ship's plan for a second time because I noticed a discrepancy between the values determined yesterday and the distance when I walked along the deck counting steps. It turned out that the scale on yesterday's plan must have been wrong (it said 1/8 inch on the plan corresponds to 1 ft), maybe because the plan was at a reduced size. In addition, yesterday's distance was obviously not measured to the end of the quarter deck but to the end of the helicopter deck. Today's calculation yielded a distance of 297 ft between the GPS antenna and the stern, and the antenna is offset 31 ft from the centerline of the ship to starboard. With these values, I have started to process the navigation data (see separate processing report) and finalized the onboard processing of the data from priority line 2.

In the evening, scientists and crew gathered at the officer's lounge for a social event. Chicken wings and other food were provided, the captain and other crew members played guitar with many people singing along. At midnight we changed time zone, now we are at mountain time (UTC – 6 hours).

Sunday – August 13, 2006

Today the oceanographers do stations at the south western limit of the survey area close to the coast of Alaska. After the helicopter came back from ice reconnaissance at 10:00 am, Borden and Ryan started to rearrange the bundle with the air and trigger cables. They were assisted by the deck crew who lifted the bundle up on the helicopter deck by crane. The purpose of the exercise is to prevent the cables from sliding too much inside the omni wrap. When they checked the cables, they noticed damage on one air hose beneath one of the four plastic blocks. Borden thinks that this is related to the sliding of the cables in the omni wrap and that the block has shaved the plastic cover of the air hose. In the afternoon, the damaged part of the air hose was repaired by putting tape around it. This was possible because the inner part of the hose was not affected by the abrasion. Joe Manning helped Borden and Ryan with the work on the bundle.

Damaged air hose.

Today I installed the Lexmark Z517 printer to the laptop computer in my cabin. Later I made notes on the processing of the navigation and reflection seismic data.

All four members of the UNCLOS group were invited to the captain's table for dinner. We got a delicious five-course menu with turkey as the main course. This evening was a real treat and our compliments go to the cooks. During the meeting we announced to the captain that we are planning a contest to find an acronym for our airgun sled. We also discussed the issue of using two icebreakers for future UNCLOS work in the Arctic. The captain's favourite solution is to hire a Russian icebreaker. In a Canadian solution, he recommended the Louis S. St-Laurent as leading ship, followed by either one of the Quebec icebreakers or the Terry Fox. The captain also pointed out that the ships should be fully dedicated to the UNCLOS work, with no other interfering scientific programs.

Monday – August 14, 2006

This morning, the repaired bundles were lifted back from the helicopter deck to the quarter deck. This was originally planned for last evening but the invitation to the captain's table prevented this.

Borden and Ryan are still working on downloading the video of the first gun deployment to a DVD or PC. The problem is that the software cannot download directly on the hard disk to PC, but can only write to DVD directly. However, when it attempts to write to DVD, the software says that it cannot recognize the media. Joe Manning found another software package that can bypass these problems.

In the afternoon, Borden initiated his NRCan contest to find an acronym for the towing sled. The contest rules are published on the ship's video channel and entries must be submitted by August 25, 2006. The first price is a 30-$ gift certificate for the canteen.

At 7 pm, Sarah gave a talk on the scientific program of this cruise in the forward non-smoking lounge. The talk was well visited both by scientists, officers and crew. Some people had to sit on the floor.

Tuesday – August 15, 2006

Today, Borden and Ryan got the bundle with the air hoses and trigger cables back in place again after they have worked out the last details. At the science meeting at 11 am, Sarah mentioned that the water will be reasonably ice-free around site CB-4. After the meeting I checked on my map where this area would be (just outside the American EEZ) and went back to Sarah to discuss some possible seismic work in this area. Given the relatively narrow size of the ice-free patch I suggested to conduct the test with the calibrated hydrophone, followed by a test of a sonobuoy which would require ~20 km of continuous seismic profiling. Site CB-4 is the deepest in the survey area and this would be a good test, to check for the maximum penetration of the array. We are estimating that this test would require 6 to 7 hours of ship time. Sarah will coordinate my suggestion with the captain and the overall science program. Most likely the test would happen on Thursday. After lunch I informed Borden on the new plans. We are all hoping for some more data - and work!

In the afternoon Borden and I looked again at the digitizer program and after a lot of trying I was able to enter more reasonable values for the sampling rate than in our earlier trials. This time we entered a sampling rate of 4 ms (250 Hz) and a record length of 15 seconds. With this setting, we can also set the recording delay to zero. This new setup will also allow to send the signal from the sonobuoy through the digitizer because no record delay is used. This will be very helpful, because then we can look at the data onboard. Otherwise Borden would have recorded the data on tape, for which we have no reading software with us.

In the evening, Sarah told me that we will attempt to start the seismic work early tomorrow morning.

Wednesday – August 16, 2006

When we were getting up for breakfast, we were still doing oceanographic work and we were told that we likely would not start our seismic work before 10 am. Shortly after 10 am I had another meeting with Sarah because there were further delays and we discussed alternate plans in case the seismic no longer fit into today's program anymore. We basically came up with the decision that the seismic work should start no later than 3 pm to get the planned tests completed before 9 pm, by which time all equipment has to be on deck again before the deck crew leaves for the night. Borden has changed the sampling rate for the digitizer another time. The new settings are 15 s record length at a sampling rate of 625 Hz (1.6 ms).

At 1.30 pm we eventually arrived in the lighter ice that was identified on the satellite image. At times 1 to 2-km-wide ice-free patches were encountered that felt like lakes in a landscape surrounded by ice. Often it was possible to navigate from one such lake to the next one without going through much ice. The first item on the program was to measure the signal strength of the airgun array at some distance from the ship by means of a calibrated hydrophone ("far-field signature"). For this test only the airgun sled was deployed while the streamer was left onboard. The array was in the water at 2 pm and then the deck crew went to lower the starboard boat that was supposed to bring Ryan and the calibrated hydrophone half a mile away from LSSL. However, the starboard boat would not start and the port boat had to be used instead. A further delay was encountered when it was noticed that the stick to measure the ice thickness (mounted on the port side by the ice observers) was in the way of the port boat. By 3 pm the boat was in the water and could sail away from the Louis. The boat did not have GPS navigation and to determine the distance from the ship, a radar reflector was mounted on the boat. The bridge then measured the distance to the boat by means of the radar at the stern of the ship. We were shooting from 15.16 pm to 16.03 pm, first with one gun, then with two and three guns. The boat was between 4349 and 6991 ft away from the Louis. Ryan initially had some problems with the signals. When he used a gain of 100, the signal was saturated, while at the next setting (gain of 10), he only noticed a weak signal. Consultation with Borden on the radio resulted in a proper adjustment of the settings.

Boat that was used to measure the pressure of the airgun array at distances >0.5 miles away from the Louis S. St-Laurent.

The boat was back at the Louis at 4.30 pm. Before proceeding with the collection of seismic data, the gun array had to be brought back on deck because the hydrophone cable was entangled in the array, probably because the sled twisted. A possible reason for this could have been that the streamer was not deployed and thus some pull on the sled was missing. Due to the supper break, the retrieval of the array had to be postponed until 5.30 pm. The twisting was more severe than anticipated, which made the retrieval of the array rather slow. Finally, at around 7 pm, gun and streamer were in the water again and we could start ramping up the array. The first shot was fired at 7.07 pm. Joe and Ian were on marine mammal watch the entire day but had no observations to report.

At 7.15 pm we were informed by the bridge that the recovery of the array would begin at 7.45 pm, which basically would have made the planned sonobuoy test impossible. Borden said it would be best if we could shoot all night long since it is such an effort to deploy and retrieve the array. After he reconfirmed that he would be willing to stay on watch with Ryan during the night if we got permission to continue, I went to Sarah. She was very positive as she was able to rearrange the oceanographic program so that we could still be at the next mooring site (CB-4) at noon next day. We then went together to the bridge to talk to the captain about our wish to change the research plan for the night. Captain MacNeill rejected shooting until 7 am (start of the day shift of the deck crew) because he feared that their might be problems with the retrieval of the array if there should be an emergency at night. Before we can shoot at night, he would like to introduce an appropriate shift system for the deck crew. However, he was kind enough to give us an extension until midnight, which would allow for the sonobuoy test to be carried out and some more seismic data within Canada's 350-nm zone could be collected.

After this decision was made, Ryan mounted the sonobuoy antenna on the railing of the quarter deck close to the stern on port side. Together with Borden he prepared the sonobuoy and at 20:23 pm, Ryan threw the sonobuoy overboard at the stern while I was recording the position on my handheld GPS receiver (74°20.350'N, 149°38.924'W). The data from the sonobuoy was recorded on the second channel of the digitizer, on which otherwise the filtered seismic data from the streamer is stored. Borden was not able to identify a signal from the streamer on his scope and in the digitizer window. Hence, he decided to throw a second sonobuoy overboard. This happened while I was in the galley. Unfortunately, no position or time was recorded for this second cast (estimated time was 21:25 pm). When no signal was received from this second buoy, Borden changed the receiver and after he increased the gain in the digitizer window, I was able to identify the direct wave received by the sonobuoy. At around 10 pm, the signal from the second buoy was lost. The range probably could have been improved by mounting the sonobuoy antenna higher up on the ship than the ~7 m on the quarter deck.

Ryan preparing for the first sonobuoy deployment.

The sonobuoy antenna at the stern of the ship.

The shooting was carried out with all three guns at a pressure of 1760 psi and a shot rate of 60 seconds. The last shot was fired at 10:15 pm when Ryan had to shut down the compressor during his routine control (carried out every 15 minutes) because of overheating. The bridge was informed to continue steaming in the same direction at a speed of 4 knots but soon after it became clear that the compressor could not be restarted for this experiment. At 10:30 pm it was decided to abandon the line and the array was back on deck shortly after 11 pm. The reason for the overheating was a leak in a coil in the heat exchanger. Borden was very pessimistic about the chances of repairing this at sea because he had no spares.

Thursday – August 17, 2006

Borden and Ryan started to repair the compressor, a rather dirty and unpleasant job because several gallons of anti-freeze fluid had to be removed from the heat exchanger. They were able to find the leak in the coil. The engine room was most helpful with the repair. They produced a plug that could be put in the spiral with the leak. Before building the part back into the compressor, Borden tested it at a pressure of 1500 psi with the remaining compressed air in the storage bottles. This test was successful but it is not a permanent fix. Borden hopes it will hold for the rest of this trip.

Jane Eert gave me the water velocity obtained from an XCTD carried out during yesterday's seismic survey. This can be helpful for the localization of the sonobuoys. The surface water velocity at 73°30'N, 150°01'W was 1429 m/s (see plot). I have started with the processing of the data from yesterday. The signal-to-noise ratio is greatly improved compared to the first line last week, which correlates with the nearly ice-free conditions on this line (I call this line now line 101). During a few segments, the ship also went through ice floes and here the S/N ratio is reduced again. So far I am not able to identify basement on the record section. I was able to extract the sonobuoy data, but I still have to improve the display of the record section and determine the approximate time and position of the sonobuoy deployment.

In the evening I learned the card game cribbage. There is a tournament on the ship and now I can at least follow the games in the forward lounge.

Friday – August 18, 2006

Borden and Ryan continued putting the compressor container together in order to start the first real test of the repaired coil at 2000 psi. This test was positive and now we are ready to collect more data. Borden reminded me that I should tell Sarah that he needs at least a day before we get back to Kugluktuk to clean the three air guns from the saltwater.

I had a meeting with Sarah in the morning to discuss the next seismic data acquisition. We are aiming for a small segment along priority line 5 north of site CB-4, where we likely will have relatively ice-free water. It could be that we get there tomorrow morning. However, at the moment the ship's port shaft is not working due to some electrical problems and this could interfere with the data acquisition, as this would likely mean that the centre shaft would have to be used, which increases the likelihood that the tow sled will be lifted out of the water when hitting ice. The chief engineer is optimistic to get the problem solved.

In the afternoon I looked at little more at the sonobuoy data. The direct wave can be seen to offsets of 8 km, at that point we stopped receiving the signal from the buoy. A suspicious signal with a phase velocity of 6.3 km/s is observed prior to the direct wave, which has several jumps in it. At the position where this signal is, no refraction from the sediments or basement can be expected as a simple ray tracing model has shown. A preliminary conclusion is that it might be some electronic noise that could have been generated by the ship's radio. Further analysis is necessary. At the moment I do not see any obvious refractions from the sediments in the record.

Saturday – August 19, 2006

The Louis S. St-Laurent was drifting during the night with no science going on. The electrical problems could not be solved last evening and the electricians were sent to bed to get some sleep and look at the problems with fresh eyes. The problem is obviously the control unit of the port shaft that does not communicate with the other two control units. Due to the repair work, the heating system was disabled for some time last afternoon. People complained about cold cabins and in some areas of the ship, no hot water was available in the showers.

I used the morning to play a little more with the sonobuoy data and found some display settings that not only would show the direct wave but also the reflection from the seafloor. The ray tracing model indicated that refractions preceding the seafloor reflection can be expected for offsets >8 km. Since this is the distance where the sonobuoy signal went out of range, there is no information from there to determine the sediment velocities. However, a few reflections can be seen behind the seafloor reflection and careful modeling may provide some hints on the velocities.

The electrical problems became more severe during the day. Now none of the shafts can be used anymore because the two other control units for the centre and the starboard shaft experienced the same problem as the port unit. Several technicians ashore are now helping to troubleshoot the problem. In the evening, a polar bear came to the Louis, walked around the ship and left again. This was a big attraction for everybody.

Polar bear (Ursus maritimus) visiting CCGS Louis S. St-Laurent

Sunday – August 20, 2006

The problems in the engine room still persist. At the science meeting at 12.30 pm, Sarah told us that we potentially have to wait a few more days until the ship can sail again. In the meantime are we drifting at a speed of one mile in three hours. The oceanographers use the drift of the ship to do rosette casts and CTD measurements every six hours.

Today I have worked on a track map for the cruise after I got all the navigation data from Borden last night and some additional data from the hydrographer Joe Manning to fill some of the gaps in Borden's data.

Monday – August 21, 2006

During lunch I got a shore call from Ruth Jackson. She wanted to get an update on the engine problems. But there was nothing new, the ship is still drifting while the electricians try to fix the problem.

At 7 pm I gave a talk for scientists, officers and crew on the Canadian UNCLOS work entitled "How Canada could grow by the size of the Prairie provinces". The forward non-smoking lounge was filled, extra chairs were brought in and many people had to sit on the floor. There was a good feedback from the audience with interested questions. I think it was important to give this talk, because now everybody knows the challenges of the data acquisition in the Arctic and the time pressure to get the job done. This will hopefully help to boost our project on the Louis once the ship is operational again. During the talk I also showed some short video sequences of the airgun tow sled when it was caught by the ice. The captain mentioned it could be helpful for the bridge to have a video camera installed on the quarter deck so that the bridge can see how the guns behave. This could help to minimize the number of critical situations for the array.

Tuesday – August 22, 2006

This morning I had a brief conversation with the chief engineer. They found the problem for the burned circuit board in the control unit. It was caused by a loose screw falling out. He also mentioned that other options have to be considered if the ship's crew cannot fix the problem by the end of the day when the engineers will have have tried for four and a half days. This option will most likely be to fly somebody in – there are rumours about an engineer that could be brought in from Singapore. The chief engineer also mentioned that the control unit has an age of about 20 years and that it becomes increasingly difficult to get spare parts and technical support as merchant ships have upgraded to newer systems to avoid expensive downtimes. Coast Guard management is aware of the problems of the aging equipment onboard but does not want to spend money on an upgrade. They hope to keep the ship going until 2017. Two years ago, a blackout on the ship in Lancaster Sound (three miles from shore) caused a loss of the propulsion until the problem was fixed after 16 minutes. Last year, engine problems in the Arctic stopped LSSL for six days.

I used the morning to clip the video footage from our first seismic line down to 12.5 minutes, showing the behaviour of the tow sled in water/ice and the retrieval of the array. Ryan cleaned the compressor container and Borden was thinking about a way to calculate the near-field signature of the airguns from last week's measurement of the far-field signature. However, later he found out that the tape recorder did not work and that we have to repeat the measurement of the far field signature. Borden's preference is to use the waiting time here at 75.5°N and 157°W to redo the test. However, he needs to find a 110 V generator because he would like to do the test with the digitizer installed on the PC to avoid the tape recorder that failed in the first measurement.

Wednesday – August 23, 2006

At our science meeting at 11:00 am, Sarah announced that the captain wants to the see the scientists for a briefing at 01:00 p.m. in the board room (crew was called in for a meeting at 12.30 pm in the crew's mess). At 11.30 am, the ship started moving again. Everybody onboard was very happy about this news. In the briefing at 1 pm the captain explained that the port and starboard shaft are operational again and that it may take another couple of hours to see if the centre shaft can be repaired as well. During the next 48 hours, the science program is conducted in relatively ice-free waters (at our drift position, the ice cover varied between ~ one and five tenths). This way the chief engineer and the captain have time to assess the repair of the control unit before we move into thicker ice farther to the north – or modify our plans if necessary. The captain said further that the Coast Guard was ready to send the icebreaker CCGS Terry Fox for help (to remove people) and that a Siemens engineer was identified who could come to the ship to assist in the repair.

The ship is resuming its science program heading towards the mooring site CB-5A. After that the seismic data acquisition along the ice-free portion of priority line 5 is scheduled as discussed before the engine breakdown. The test of the far field signature of the airgun array is postponed because it is more important to get some seismic data collected. If the ship needs to stop for further repairs, we can still do the measurement of the far-field signature.

Sarah informed me that two divers onboard USCGS Healy died very close to us on the Northwind Ridge. The Healy carried out seismic and geological work but has now returned to Point Barrow in Alaska for further investigations.

Thursday – August 24, 2006

Shortly after 9 am I had a talk with the chief officer. He told me that the centre shaft is in operation again although some adjustments still need to be made. He also said that we will probably start with the seismic work between 5 and 7 pm and that we can shoot during the night until the next morning or until we have technical problems with our equipment – whichever comes first. If there are problems during the night, the ship will be happy to retrieve the tow sled so that we can resume maximum transit speed in order to make up for the lost time during the last five days. I went to Ian and Joe to update them on the plans and that they should prepare for night watch; Borden was attending the conversation with the chief officer. We were reasonably happy because this would be the first test with a continuous shooting of more than 12 hours, which should give a good idea on the wear and tear of the system.

Plans were revised shortly thereafter, when Sarah told at the 11-am science meeting, that the gallbladder infection of the second officer has not responded to medication and that she has to be evacuated from the ship. LSSL will therefore proceed to Point Barrow in Alaska, some 240 nm to the south. At the same time it is planned to airlift the SIEMENS engineer onboard to have a final check on the repair of the control unit. The total delay will be approximately 48 hours. Despite the medical emergency, LSSL proceeded to site CB-4 to deploy a mooring. The ship was stopped there from ~11.30 am to 6.15 pm for the mooring followed by a CTD until 8 pm. No explanation was given as to why the ship did not sail towards Point Barrow immediately.

We were also informed that the Canadian Coast Guard went through their emergency plan and contacted all our next-of-kin to tell them about the engine problems on the LSSL. It was therefore decided that all persons onboard get a 10-minute free call on the Iridium phone in order to talk to their relatives. When I called home to Germany at 1 pm, I learned that the Coast Guard had not contacted my sister yet. Somebody told me that a newscast was planned on our engine problems and that this might have been the reason why the Coast Guard contacted our next-of-kin. Yesterday we had no email exchange and the ship's technician blamed this on the shore station. However, some people on the ship suspected that email did not work to prevent the spread of further information on the engine problems.

Friday – August 25, 2006

The ship sailed all day long towards Point Barrow. The information we got during the science meeting was that the second officer will be flown ashore as soon as the helicopter can safely reach shore. On Saturday, another person (Stephanie the engineer) will be brought ashore to recover from her injury (second degree steam burn of her foot). Around noon on Saturday, we expect the SIEMENS technician and two replacement crew members to arrive in Barrow. Any waiting time will be used for CTD measurements. After arrival of the new personnel, the ship will return to mooring site CB-4 in order to start the postponed seismic work. This will likely be sometime on

Sunday.

Sarah asked for a meeting in the afternoon to discuss how we want to use the remaining research time. However, this meeting did not materialize.

<u>Saturday – August 26, 2006</u>

In the morning, LSSL arrived at Barrow, where she was drifting 3 nm north of town. The second officer was flown from the ship to the airport, but later she was brought back to the ship because her flight out of Barrow would not leave before the afternoon. The SIEMENS technician came onboard in the morning, whereas the two new crew members where not there yet because they missed their flight. During the science meeting at 12.30 pm, Sarah announced that there are two ships (a tanker and a research (?) ship from Vancouver) in the area that have problems with the ice and that we may have to assist them. The two new crew members arrived in the evening without their baggage and the LSSL headed back to the northern study area at around 10 pm.

One positive thing about today's visit to Barrow was that the helicopter brought back a couple of copies of the "Anchorage Daily News", fresh lettuce, vegetables and a total of 140 yoghurt containers. The helicopter pilot just walked to the local supermarket and filled three shopping carts.

Yesterday was the deadline for the contest to find an acronym for the airgun sled. This gave us some work for the day. Ryan typed all the entries into a spreadsheet and then the four of us in the UNCLOS group voted on the best name. The winner was Abigail from IOS, who suggested the name NATASHA (Near Astern Triple Airgun Seismic Hydrophone Array). Ryan made a special winning certificate that was given to Abby together with a 30 $ gift certificate for the canteen.

<u>Sunday – August 27, 2006</u>

At 9.30 am I had a meeting with Sarah to discuss the science plan for the rest of the trip. She presented a revised schedule that would allow for most of the seismic work to be done that was planned prior to the engine breakdown. The first item on the intinerary is to shoot ~12 hours of seismic on priority line 5 and its southern extension as soon as the ship gets outside the American EEZ and into open water. This will likely happen tomorrow morning depending on the speed of the ship. During the night the ship did not move very fast even though there were only minor ice floes in the area (one to two tenths) but later in the morning the ice became more dense (9+ tenths). After the acquisition of priority line 5, the ship will work in the northern area and at the end of the trip we will collect seismic data along a portion of priority line 1. Doing the complete line 1 is not possible due to time constraints. The present schedule is assuming a line from ~40 nm NW of CB-21 up to the 2500-m isobath. Sarah asked me if there are other portions of the line that are more relevant than what she has chosen. I replied it might be more useful to move the segment a little farther to the west and finish the line at the Canadian EEZ. I will discuss this with Ruth.

Sarah mentioned that she is willing to move some of the rosette casts along priority line 1 to the next leg of the cruise, if the extra time is needed. The mooring sites have the absolute priority on this cruise as they are part of a multiyear program. The time schedule still includes allowances for waiting times at the mooring sites. I mentioned to Sarah that it would be helpful to reduce these waiting times as much as possible and that she should ask the captain to be more flexible when it comes to work during night time. With all the delays caused by the engine problems, it would be appropriate for the Coast Guard to make up for some of the lost time. The present schedule has an ETA for Kugluktuk on September 15 or one day later than planned. However, Sarah has not talked with the captain about this and it is unclear if the Coast Guard will extend the cruise given the difficulties in changing the charter flight back to Halifax.

Monday – August 28, 2006

After breakfast, the decision was made to start the seismic program. We were clear of the American EEZ and the ice started to loosen up. Shortly after 8.30 am we started with the deployment of the gun array, which took 18 minutes, not included the time for the deck crew to prepare the cranes and the deck. Shortly after 9 am we started shooting, as usual first with one gun, followed by two and eventually with all three guns. This is to comply with the regulations set out in our permissions. No marine mammals were spotted on this line other than a seal at a distance of 1 km, swimming away from the ship.

The data acquisition went without any problems. Ice conditions were light, with exception of the first hour, the ship could generally find a track that avoided ice floes. The ice cover was one to three thirds.

At 10:40 am we deployed another sonobuoy. Ryan and Joe Manning installed the antenna higher up than last time, because we hoped this might increase the range up to which the radio signals from the sonobuoy can be received. The antenna was mounted on the port side of the helicopter deck close to the refuelling station. However, the maximum range of the radio signal seemed to be similar to last time (around 8 km). Probably we need to have a better antenna and a shorter coax cable that connects the antenna with the receiver.

The deck crew arrived at 7:10 am at the quarter deck and when we fired the last shot at 7:30 pm, we immediately began with the retrieval of the tow sled Natasha and the streamer. This operation lasted until 7:50 pm. Borden and Ryan were pleased with the performance of the sled and the only damage they could find was a dented electric connector at the starboard airgun. It was not obvious against which part of the tow sled the connector hit. Borden assumes it is the middle bar.

Dented electric connector at the starboard airgun.

Tuesday – August 29, 2006

Borden and Ryan repaired the damaged electric connector, basically taping the dents up since we do not have spares onboard. In addition, the repaired connector was moved to a different position. This way, it will experience less strain in the next deployment and we can hopefully prevent a complete breakdown of one air gun. On the other hand, we will likely damage another connector. For future experiments, Borden wants to build some protective cases for the connectors.

I started to process the seismic and navigation data from yesterday. The seismic data on this priority 5 line looks very similar to the previous line 101: essentially horizontal reflections down to ca. 3 seconds two-way traveltime below seafloor. From the plot made on the ship, basement can not be identified. This can have many reasons, some of which are:

1) The basement is not a prominent reflector but just a zone where the general stratified reflectivity disappears.

2) The airgun array is not powerful enough to penetrate down to basement in this deep portion of Canada Basin.

3) The streamer is not suited to record the seismic signals at greater depth and it is potentially exposed to too much ambient noise from the ship (and the ice).

To address the issue whether the streamer or the airgun array needs improvement, Borden suggested to Ruth Jackson and GSC-A director Jacob Verhoef to perform a one-day test cruise. Borden is thinking of using CCGS Hudson at the end of September to run a test line with both the streamer from this cruise and another GSC streamer deployed at the same time.

The sonobuoy data from priority line 5 starts to become difficult to read at offsets of ~4km. This offset is too short to identify refractions. However, at least two reflections following the seafloor can be seen. This might allow for a velocity analysis (NMO) in the uppermost sediments.

Wednesday – August 30, 2006

In the morning, the ship was at 78°N, 150°W and it was the first day where the snow actually accumulated on the deck – a few millimetres. Ice cover was 9 tenths + but most floes were only 20 to 50 m in diameter. This ice was not suitable to perform the scheduled work on ice stations, which upset some of the oceanographers. Flying conditions were not that good either. The ice thickness was mostly < 2 m allowing for a speed of 11 knots. Borden and Ryan did the last fixes to the broken connector at the airgun.

I started to organize all the seismic and navigation data in a meta-directory together with the scripts and programs for the processing of the data, velocity-depth information from a CTD measurement, and GMT scripts for track maps. This way, it will be easier to do the backup at the end of the cruise as there will probably be not much turn-around time between the end of the seismic line and the arrival in Kugluktuk.

Thursday – August 31, 2006

Today the oceanographers started their work on the ice station but it was not a great day for the Woods Hole people, because they lost an anchor on the ice due to some overthrusted ice flows with a void in between.

Ruth Jackson sent us some information on the seismic system of the USGS that was used in the Arctic. I was curious about it because their data on line 93-12rp close to our priority line 5 had a much better penetration even though the seismic source only had a volume of 876 cubic inches compared to 1500 cubic inches of our tow sled. However, Art Grantz from the USGS points out that it is important to keep the streamer far away from the ship to avoid the noise from the engines and the ice breaking as much as possible. The lead-in cable of the USGS streamer was 600 ft long, compared to the 100 ft of our streamer. Borden and I discussed this and we concluded that we should lengthen our lead-in cable for the next test along priority line 1. On that line we will have more ice than on line 101 and on priority line 5. That is why it is important to get something done on the high noise levels. The lengthening of the lead-in cable is a lot of work, because the entire bundle with the cables and air hoses has to be opened. However, since it will take at least a week before we continue with data acquisition, time is not a major constraint. Borden would like to do the work on a day without helicopter operation, because then he can use the helicopter deck rather than the quarter deck where the space is very limited.

Friday – September 1, 2006

Today was the first day of fall and it felt really cold. The wind speed in the morning was 28 knots, ice cover 9 tenths + and we had periods of snow. We are at the northernmost point of the survey, 79°N and 150°W. Fire drill at 12.30 pm, no boat drill due to the cold weather.

Saturday – September 2, 2006

In the morning, the entire deck was covered in snow with a layer of ice underneath. It felt a little like Christmas when I looked out of my cabin window. The modification of the lead-in cable of the streamer had to be postponed again because there were helicopter flights scheduled in the afternoon to find suitable ice for a mooring site. In the evening was a costume party in the forward non-smoking lounge.

Sunday – September 3, 2006

Another blizzard started at around 10 am. LSSL proceeded to the NE survey area and carried out oceanographic work en route. At 1:30 pm, we finally could start with the lengthening of the lead-in cable as the helicopter deck was not used for flight operations. The deck crew lifted the air/cable bundle from the quarter deck to the helicopter deck by means of the starboard crane on the quarter deck. Both Joe Manning and I assisted Borden and Ryan in the extension of the cables because the work had to be done quickly to have the helicopter deck clear again. In addition, it was cold with wind speeds up to 40 knots and nobody wants to work outside for extended periods. Together we got the job done in two hours. It went faster than expected because we did not have to remove the entire omni wrap from the bundle except in one section where the cables were taped together. Once the tape was removed, we were able to pull the spare leading cable from the one end of the bundle to the other end. Borden determined the new length of the extension cable to be 306 ft (before 100 ft).

After this work, the four of us went for supper in the officer's mess instead of the crew's mess where we normally eat. We had turkey dinner and I paid for the wine celebrating my 10th anniversary of moving to Halifax.

Monday – September 4, 2006

Labour Day. Borden and Ryan reconnected all the cables from the bundle so that our seismic system was operational again at the end of the day.

Tuesday – September 5, 2006

The day started with rain and fog in the morning but later it was mostly sunny. Borden and Ryan worked today on the anti-freeze system for the airguns. The anti-freeze injection did not work during the previous seismic lines and today the problem was eventually identified and fixed – one of the valves did not work. For a final test of the anti-freeze system, the compressor was turned on. Now that the temperature dropped below the freezing point, the proper function of the anti-freeze injection system is essential.

During the 11 am science meeting, Sarah mentioned that there are some ice-free patches on our way south along the 140°W meridian (priority line 4). After some discussion with Borden, we decided to modify our plans for the remaining seismic data acquisition. Instead of shooting four 12-hours segments along priority line 1, we want to move one 12-hour block to priority line 4 into the ice-free zone. This will give us a good comparison to priority line 5 to see if the extension of the lead-in cable of the streamer improves the signal-to-noise ratio. In addition, we may get a chance to repeat the measurement of the far-field signature of the airgun array using the calibrated hydrophone and a small boat.

I talked with Sarah about our updated plans and she rescheduled the science program so that we can collect the seismic data on line 4 on Thursday, pending permission from the GSC. An email was sent to Ruth Jackson to obtain her agreement.

Ryan downloaded the remaining videos to the computer in the seismic laboratory at the stern. These sequences show the deployment of the tow sled.

Wednesday – September 6, 2006

During the science meeting at 11 am, Sarah announced that today's plan for finding a site for the ice buoy has to be cancelled because of fog (no helicopter flying). She asked us if we are willing to do some seismic shooting from 1 pm to 8 pm plus some additional shooting the next day to do the calibration test. This way the ship time could be used in the most efficient way. After some discussion we agreed to the plan that was put forward to us, even though we would have preferred to shoot farther south in ice-free waters.

The start of the seismic program was announced for 1 pm, the estimated time for the completion of a repair to the turbo charger. The turbo charger has kept the engine people busy for the last couple of days. After lunch, Borden and Ryan swapped the two connectors on the starboard gun back to their original position. Borden felt more comfortable with this solution, because if the connector gets damaged again we could still shoot just without receiving a return signal from the solenoid.

The repair of the turbo charger was not completed by 1 pm and the oceanographers used this downtime to get some biological samples using bongo nets. At 1:45 pm we were informed that the seismic can start at 2 pm as soon as the biological sampling is completed. When nothing happened at 2 pm, I went to Sarah to complain about the delays and to tell her that at some point the data acquisition is no longer worthwhile, if the captain insists on retrieving the tow sled at 7:30 pm. To discuss these items, Sarah went with me to the captain, who said that the repairs would take another 25 minutes, which I found quite surprising because my information was that the charger was fixed. With respect to all the delays the captain refused to discuss any changes or adjustments of the plans. He essentially said that his priority is the turbo charger and that he does not care much about the seismic program; an attitude that he expressed several times during this cruise. He was rather rude and intimidating and I decided to leave the bridge.

At 2:30 pm, the deck crew arrived at the quarter deck to deploy the gun array. This went again very smoothly in a new record time of 17 minutes. The crew slowly gets used to the system. The deployment of the streamer was a little challenging because there was a lot of drag on the cable and Borden was forced to put the leading cable around a block, otherwise he would have not been able to hold the cable. Ice conditions were 9+ tenths of 1 to 2 m thick ice floes, generally of rather small size (20 to 50 m in diameter) with new ice between the floes. The general impression of the ice was that it was rather "chopped up" and the ship had no problems passing through the ice at 4 knots.

After the deployment of the guns we run into the next problem because the engine could not provide us with cooling water for the compressor. The pump did not work because some filters were clogged, which later caused some valves to break. During the waiting time, we decided to record the ambient noise on the streamer for the six individual hydrophone groups and at different settings for the analog filter. At 4.20 pm we eventually got cooling water, but we had to wait another 6 minutes for the air pressure to build up before we could fire the first shot at 4.26 pm. Shortly thereafter, we had to stop shooting again for 10 minutes (4.37 to 4.46 pm) because the supply with cooling water stopped again.

After all the delays the shooting went quite well and at 6 pm Sarah came to the seismic lab to ask if we would like to shoot during the night, which would allow a greater flexibility for next day's scientific program. Before we made the decision, I made a plot of the first 100 shots to see if the data quality has improved with the extended lead-in cable, otherwise I would have preferred to shoot in the ice-free water the next day. However, the data looked better than during the last shooting in ice (priority line 2), although not quite as good as in ice-free water (priority line 5). With the prospect of getting a reasonably continuous seismic line, I decided that we should continue with our operation during the night. The calibration test was then postponed to Friday, in an area that is ice covered with several larger ice-free pools. The hope is that we can find one of these pools on Friday.

I informed the marine mammal observers that they have to stay watch during night. In the seismic lab, Ryan took the watch until 2 am the next morning and Borden thereafter.

During the evening discussion with Sarah I also mentioned that I would prefer to shoot a longer segment on priority line 1 (24 hours) rather than two or three blocks of 12 hours. This desire comes from the previous experience that it takes a lot of time to get the seismic gear in the water.

The ship's bubbler system was turned off around 10 pm.

Thursday – September 7, 2006

At 6:30 am, the crew came to retrieve the tow sled. This operation was completed by 7:00 am. Ice conditions did not change very much during the night. However, around

6 am Borden noticed thicker ice and he feared that the ship will not get through it. At the southern end of the line we reached the edge of the ice-free water.

Borden went to sleep after this night's adventure and I started to download the seismic and navigation data, followed by the processing (see the processing chapter for more details). The data quality did not change during the profile and it looks like the extension of the lead-in cable has improved the data quality slightly.

Damage to the array was limited to the same electric connector on the starboard gun that obviously hits the frame of the tow sled. In addition, some cables were twisted and one air hose was slightly punctured. Borden and Ryan started with the repair after lunch. In the evening there was a BBQ in the helicopter hangar.

At 7:00 pm, there was a meeting with the captain, the chief mate, Sarah, Rick (mooring operations WHOI), Borden and myself to discuss the science program for the rest of the trip. We all agreed on the following schedule. Late on Friday afternoon or early evening we do the calibration test close to CB-21 and from there we continue towing the sled towards the west along priority line 1. Then we will steam back to CB-21 to deploy a mooring and do a CTD. After that, we tow the airgun array to the east on Saturday night. The eastward line is located slightly north of priority line 1 because we want to head towards an ice buoy that needs maintenance. However, this is not critical as the line will still run perpendicular to the margin.

Friday – September 8, 2006

In the morning, Borden, Ryan and I started the preparation for the calibration test. In particular we tested whether the digitizer works properly in the "free run" mode, which is basically continuous recording. In this mode, one record starts as soon as the previous record ends. We tested this mode with a 150-Hz sinusoid signal as input, the digitizer was set to a sampling rate of 0.5 ms (=2 kHz) and the record length to 1 sec. Longer record lengths were not permitted by the digitizing software. I checked the SEGY file obtained from a short test recording on the work station and could confirm that the recording is indeed continuous.

At 1:00 pm it was decided to cancel the calibration test for today due to bad weather. The temperature was about -3°C with strong easterly winds (30 knots, gusts up to 40 knots) and the captain felt uncomfortable using a small boat for the test. Instead of the calibration, we moved the rosette cast from tomorrow to this afternoon so that there is time for the calibration tomorrow if the weather improves.

The deployment of the airgun array for the westward tow away from site CB-21 started at 5:45 pm and lasted 20 minutes. Ian and Joe were allowed to stand their mammal observation watch on the bridge due to the cold, windy and rainy weather. The rain did freeze on the cold deck and there were many slippery spots. Ian and Joe also decided to go three-hour watches instead of four-hour watches as they did before.

The first shot on priority line 1W (W stands for west) was fired at 6:09 pm with one gun, ramping up the array until 6.21 pm when all guns were in operation (60 sec firing rate at 1780 psi). The ship's track was from site CB-21 to the West. At 8:48 pm, the ship's bubblers were turned off. The digitization program started to cause some problems at 10:08 pm. First Ryan tried to write to a new log-file but the same "access violation error" occurred as before. Then he rebooted the computer, which fixed the problem.

Saturday – September 9, 2006

At 12.51 am, a leak in the starboard gun was noticed; the air pressure was down to 1400 psi. This occurred when Borden came to relieve Ryan from his watch. However, Ryan decided to stay with Borden until the end of the shooting because he did not feel tired enough. The leak was localized in the starboard gun that earlier had problems with the electric connector. This might suggest that the leak was caused by the banging of the airgun against the tow sled. The starboard gun was then turned off at 12:59 am and the shooting continued with two guns and a firing rate of 40 sec (pressure 1850 psi).

At 7:33 am the ship started to turn into the wind at the end of the line but we continued to shoot until 8 am when the deck crew arrived for the retrieval of the tow sled. The system was back on deck and secured at 8:28 am. Ice conditions on priority line 1W were moderate, mostly between six and seven tenths of rather thin ice (generally less than 1 m thick, some floes up to 1.5 m thick). The ice was relatively loose with floe sizes <20 m. Several larger ice-free pools were encountered, for example during he deployment of the array. This was nice because there was no danger that the streamer could get caught in ice.

Borden and Ryan inspected the tow sled after retrieval. The electric connector on the starboard gun was damaged as before and there was a leak at the fitting of the air hose. Borden and Ryan decided to sleep first and start the repairs at 4 pm. In the meantime, I transferred the raw SEGY files and the navigation data from the computers in the seismic lab to the work station and started the processing (see processing report). During the night the temperature was around the freezing point with fog and rain. The regulator of the anti-freeze injection system was frozen even though it was rated down to -10ºC. The first conclusion is that the injection system should be kept inside in a warm place, e.g. inside the compressor container.

In the morning, Borden and I decided to cancel the calibration test (measurement of the far-field signature of the airgun) for several reasons. Although the wind speed has decreased, it was still windy and cold. Then Borden had some concerns with one of the cables used for the test, which in the worst case could mean that the test would need to be run a third time. Time constraints also had some influence on the decision, because the seismic work would probably not start before 7 or 8 pm. With a calibration test at the beginning, the eastern portion along priority line 1 would start rather late. Now the calibration test will have to be conducted either during next year's experiment or during a possible streamer test cruise later this year.

The Woods Hole group finished the deployment of their mooring at 8:30 pm and that was the start signal for the last segment of the seismic work on this cruise. The array was deployed from 8:41 to 9:03 pm in a large ice-free pool so that there was no danger to the streamer. The weather had improved so much that Ian and Joe could stand their mammal observation watch on monkey's island again rather than on the bridge. The first shot with one gun was fired at 9:05 pm, with the full array in operation at 9:17 pm. Ice conditions were similar to last night with rather loose ice. However, during the night the ice conditions worsened and occasionally the ship had to pass through thicker multi-year ice.

<u>Sunday – September 10, 2006</u>

At 2:22 am, the tow sled was lifted out of the water by ice floes. Later at 3:46 am, the amidships gun was turned off because of an air leak and Ryan also noticed an error on the port gun. Ryan called Borden because he was not sure if he should shut the second gun down as well. The port gun was then turned off at 3:59 pm. Around that time I woke up in my cabin and noticed that we were shooting with one gun only and a moment later Borden called to ask what to do. We decided to continue the shooting until the morning, when the deck crew reports for the day shift at 8 am. Waking the crew in the middle of the night was not considered as an option because there was a party in the forward non-smoking lounge last night (hosted by the shipboard scientists). The captain probably would have not allowed waking the crew. More episodes with heavy ice happened at 4:15 and 4:20 am.

The last shot was fired at 8:06 am, followed by the retrieval of the tow sled, which was finished at 8:31 am. Borden and Ryan went for a morning nap while I downloaded and processed the data. Interestingly enough, the data quality hardly deteriorate when only one gun was in operation. The leaks at the port and amidships guns were located at the air hose fittings. This is related to the guns hitting the tow frame. Borden will build a block that protects both the air hoses and the electric connectors. The regulator of the anti-freeze injection system also froze this night.

After supper, Borden and Ryan started to disconnect the electric cables from the guns so that the guns can be moved to the helicopter deck on Monday.

Monday – September 11, 2006

Borden and Ryan continued with the packing of the seismic equipment, while I started to organize all the files for data backup. This includes the raw and processed seismic and navigation data, UNIX scripts that were used for the processing, CTD data from one site, plot files, video footage from the gun deployment/operation, photos and the cruise report.

One seaman had chest pain and was diagnosed with a heart attack. The ship proceeded immediately towards Tuktoyaktuk, Northwest Territories, to evacuate the patient who was in a stable condition. The helicopter returned to the ship at 6:00 pm. Ryan spent the evening downloading the remaining videos from the camera onto the computer in the forward lab (hydrography).

Tuesday – September 12, 2006

This was another day of packing for Borden and Ryan. They were assisted by Joe Manning in carrying some of the heavy items, as Borden had some back pain. The main job was to open and clean all the airguns from the saltwater. During this operation, Borden noticed that the guns have an inset in the chamber that reduces the volume to 520 cubic inches. Removing the inset would probably increase the chamber volume to around 600 cubic inches. Borden wants to find out more about this option. The packing was finalized in the afternoon.

I spent most of the time with editing the video footage of the deployment of the tow sled. The resulting video is 5 minutes long compared to 20 minutes of the original material. I also made a clean set of all relevant plots to give to Ruth Jackson. We have arranged for a debriefing in Halifax on Friday. I also made two color track maps for the marine mammal observers who will leave us tomorrow by helicopter when the ship is passing by their community (Paulatuk).

The work schedule of the LSSL included the last mooring site of the Woods Hole group and at 4:30 pm the ship started to return to Kugluktuk, Nunavut. In the evening was a farewell party with two free drinks for everybody courtesy of WHOI.

Wednesday – September 13, 2006

In the morning I got the last navigation data from Joe Manning, which I added to the cruise track. After that I was ready to burn all the data on DVD, with a second copy on the laptop computer that will be returned to Ruth Jackson. After completion of the backup, I packed the SUN workstation and brought it to the storage room. Borden will ship the computer back to GEUS once the LSSL has returned to Halifax in November.

The two marine mammal observers (Ian and Joe) left the ship at 9:00 am by helicopter and returned to Paulatuk, N.W.T. Before they left, we had a science group photo on the foredeck.

Thursday – September 14, 2006

In the morning, LSSL arrived in Kugluktuk where she anchored. At 8:30 am, the ship's helicopter started to transfer the scientists, the baggage and eventually the crew to the airport in Kugluktuk, Nunavut. The Boeing 737 of Canadian North left for Halifax via Yellowknife and Churchill at 2:30 pm. Arrival time in Halifax was 1:30 am the next morning, which was 30 minutes late due to delays in Yellowknife (90 minutes waiting time). In Halifax, there was bus transportation from the airport to the Coast Guard base in Dartmouth (arrival 2:15 am).

Onboard data processing

Navigation data

The ship's navigation was made available through the ship's network and Borden stored the raw-navigation files on a PC in the seismic lab at the stern of the ship. These raw navigation files are named *Lake[JulianDay][a/b].06E*. They contain the ship's position (obtained from the Global Positioning System, GPS) for every two seconds (positions are stored in the string with the tag "$GPGGA"). In general, several readings of the ship's heading can be found between consecutive position tags. The heading strings are marked by the tag "$HEHDT" and do not have a time stamp. Later, the names of the raw files started with *Loui* instead of *Lake*.

In a first step, the FORTRAN program *get-xyh-from-gps.f* reads all "$GPGGA" strings, from which the time and the position were extracted. In addition, the program adds the heading from the most recent "$HEHDT" string prior to the "$GPGGA" string. Time, position and heading were written into the file *day[JulianDay][a/b].nav*.

In a second step, the script *get-time-from-segy.cmd* was executed to extract the shot times from the trace headers in the SEGY files. These shot times were saved to the file *shottimes-[line-identifier].dat*. The shot times are synchronized with the GPS clock.

The third step was to run the FORTRAN program *calc-cmp-position.f* to calculate a table with the shot times, the heading and the geographical coordinates of the common mid-point (CMP) for each shot, using the output files from the two previous steps as input file. To calculate the CMP position, the offset between GPS antenna and the airgun array was measured. The GPS antenna is located 297 ft forward of the airgun array and 33 ft away from the centre line of the ship towards starboard. The lead-in cable of the streamer was 100 ft long; the active streamer length was 200 ft. This means that the CMP is 100 ft astern of the airgun array. The output file is *cmp-[line-identifier].dat*. Note: later during the survey, the lead-in cable of the streamer was extended from 100 to 306 ft (starting with priority line 4) and the program *calc-cmp-position-cable2.f* was used instead.

Finally, the distance between the first CMP on each line and all subsequent CMP's were calculated using the script *offset.cmd*. Output files: *offset-[line-identifier].z*.

Seismic data

The incoming data from the streamer were digitized and stored in SEGY files with the names

Seismic_Raw_Benthos_[YYYY_DDD_HH_MM_SS].SGY

Seismic_Filtered_Benthos_[YYYY_DDD_HH_MM_SS].SGY

for priority line 2; for all other lines the following names were used

RawData_[YYYY_DDD_HH_MM_SS].SGY

K-HFiltereddata_[YYYY_DDD_HH_MM_SS].SGY

with YYYY_DDD_HH_MM_SS being the year, Julian day, hour, minute, and second of the first shot time in the SEGY file (time in UTC). One set contains the raw data (unfiltered), while the other data are filtered (analog band-pass filter from 10 to 120 Hz). At each full hour, a new SEGY file is created.

For the onboard processing, a workstation Sun Blade 150 and the seismic software package Seismic Unix (Release 34) were used. In addition, the process *project* in the Generic Mapping Tools (GMT) version 4.0 was used to calculate distances between two points.

The first step in the data processing was to merge all the individual raw SEGY files into a single file. Corrections were applied to compensate for the recording delay thus that each seismic trace in the resulting SEGY file begins at shot time. For this purpose, the script *merge-static.cmd* was used. The output was stored in a temporary file in Seismic Unix format.

The next script (*make-final-segy.cmd*) produced the final SEGY file. This script included the following processing steps:

1. Application of a static correction of 15 ms to introduce sea level as reference. This correction follows from a streamer and airgun depth of 36 ft and an assumed water velocity of 1500 m/s.
2. The geographical coordinates of the CMP positions were written into the trace headers (header words "Source Coordinate"). Before this was done, the coordinates were multiplied by 10000.
3. The distance to the first CMP (in meters) was added to the trace headers (header word "Offset").
4. Field record number (fldr) and CDP ensemble number (CDP) were numbered consecutively for each line, starting with one for the first shot/CMP.
5. EBCDIC headers were added to each SEGY file to describe the processing and experiment. Final SEGY files are stored in *final-[line-identifier].sgy*.

The processing was carried out on the unfiltered raw data. However, the extra identifier "*filt*" in the final SEGY files indicate that the file was produced from the analog-filtered raw data.

For the final display of the record sections, data were filtered. High amplitudes for frequencies below 20 Hz seem to be mostly associated with noise from the ship and the sea ice. Deconvolution (spike and predictive) was applied to plot the data but the deconvolution parameters can still be improved. A mute at the seafloor was applied. Plots jobs are named *plot-[line-identifier].cmd*.

Line	Profile length (km)	First and last CMP number in final SEGY file with data	
Priority 2	32.331	64	376
101	20.426	11	212
Priority 5	76.859	1	641
Priority 4	101.192	1	850

Priority 1W	97.159	1	1046
Priority 1E	77.114	1	1157

Total length of profiles: 405.081 km.

Comments on the data

Priority line 2

Julian Day 222 = August 10, 2006 - Shooting direction from the south to the north

First shot

CMP 1

Year 2006 Julian Day 222, 18:12:33 UTC

Position 139.998550°W 71.644447°N

Last shot

CMP 444

Year 2006 Julian Day 222, 22:47:21 UTC

Position 140.000290°W 71.809158°N

During the first 63 shots, the streamer was not connected to the digitizer and no meaningful data were recorded. Therefore, the first good shot is

CMP 64

Year 2006 Julian Day 222, 19:25:23 UTC

Position 140.004028°W 71.706612°N

At the northern end of the record section, the reflectivity disappears. The last shot, where a reflection from the seafloor can be recognized, is

CMP 376

Year 2006 Julian Day 222 21:54:51 UTC

Position 139.996704°W 71.800598°N

This is probably the time when the retrieval of the airgun array started. For some reason, the recording must have continued during the retrieval phase.

Between shots 340 and 341, the two-way traveltime to the seafloor jumps by some 30 ms. The reason for this is not determined. Either it is some error in the recording unit or a fault at seafloor. The record length on this line was 2.5 seconds at a sampling rate of 2.5 ms (400 Hz). The delay of the recording was

Shots/CMP 1 through 64: 2003 ms

Shots/CMP 65 through 444: 2703 ms

Reflectivity can be recognized down to ca. 1.5 seconds below the seafloor, which corresponds to the end of the record length. Basement could not be identified and probably lies below a two-way traveltime of 5.2 sec (end of record).

Line 101

Julian Day 229 = August 17, 2006 - Shooting direction from the SW to the NE

Shots on line 101:

Julian Day 229 at 01:07:32 UTC first shot with a shot interval of 20 seconds (1 gun).

Julian Day 229 at 01:13:29 UTC first shot with a shot interval of 40 seconds (2 guns).

Julian Day 229 at 01:18:42 UTC first shot with a shot interval of 60 seconds (3 guns).

Air pressure: 1760 psi

The SEGY file for this line has a total of 212 traces.

CMP 1	JD 229 01:10:12 UTC	no data (hydrophone not connected)
CMP 11	JD 229 01:14:49 UTC	first good trace (hydrophone connected)
CMP 16	JD 229 01:18:42 UTC	first shot with three air guns

CMP 68	JD 229 02:10:41 UTC	heading into ice (before mostly ice-free)
CMP 81	JD 229 02:23:41 UTC	ship out of last ice patches
CMP 193	JD 229 04:15:39 UTC	last good shot before compressor failed
CMP 212	JD 229 04:34:39 UTC	last record in SEGY file (digitizer off)

All shots were recorded with a sampling rate of 625 HZ, a record length of 15 s and without a recording delay.

The record section shows a series of horizontal reflections that can be seen down to a depth of 7.5 s two-way travel time (TWT). In some areas, also deeper reflections can be recognized, for example at the western end of the profile where reflectivity can be seen down to 8.5 s. Basement cannot be clearly identified as it does not show up as a high-amplitude reflector with variable shape. Either basement lies below the maximum penetration of the airgun array or it is located between 7.5 and 8.5 s TWT, where the horizontal reflectivity disappears. The maximum sediment thickness on line 101 is at least 3.3 s TWT.

The area along line 101 was mostly ice-free and often the ship could circumnavigate smaller ice floes. Occasionally, the ship had to go through ice, as for example at CMP 68, where the signal-to-noise ratio decreases significantly.

Priority line 5

Julian Day 240 = August 28, 2006 - Shooting direction from the south to the north

Shots on priority line 5:

Julian Day 240 at 14:56:08 UTC first shot with a shot interval of 20 seconds (1 gun).

Julian Day 240 at 15:05:50 UTC first shot with a shot interval of 40 seconds (2 guns).

Julian Day 240 at 15:13:08 UTC first shot with a shot interval of 60 seconds (3 guns).

Julian Day 241 at 01:30:58 UTC last shot.

Air pressure: 1780 psi

The first shot after the digitizer was enabled was at day 240 at 15:00:06 UTC. However, the digitizer did not work properly and the software had to be restarted. The first shot thereafter was at 15:01:24 UTC.

The analog filtered streamer data was disconnected from the digitizer between 16:20 and 18:40 UTC on day 240. During this time, the raw sonobuoy data was digitized on the channel labeled "K-HFiltereddata[time].SGY", although no analog filter was applied to the sonobuoy data.

The SEGY file for this line has a total of 641 traces.

CMP 1	JD 240 15:01:24 UTC	first recorded shot (one gun)
CMP 13	JD 240 15:05:50 UTC	first shot with two guns
CMP 23	JD 240 15:13:10 UTC	first shot with three guns
CMP 641	JD 241 01:30:58 UTC	last record in SEGY file (digitizer off)

All shots were recorded with a sampling rate of 625 HZ, a record length of 15 s and without a recording delay.

The record section shows a flat seafloor at ~5.2 s TWT. All reflectors are horizontal and the deepest reflector that can be correlated across the entire line is at 7.8 s TWT. Some deeper reflections can be recognized down to 8.2 s TWT.

The ship was able to bypass most ice floes in the. Areas with ice or increased engine thrust can be recognized in the record by increased noise levels, in particular during the first 20 CMPs.

Priority line 4

While we were waiting for cooling water for the compressor, we started to record the ambient noise at the streamer for the six individual hydrophone groups. We also changed the settings of the analog filter. Here a summary of the settings during the recording.

Julian Day 249 = September, 2006 - Shooting direction from the north to the south

21:05:00 UTC Analog filter 10 to 150 Hz, recording every 20 sec (15 sec windows) of the summed streamer channels.

21:14:00 30-150 Hz analog filter

21:16:00 recording only channel 1 of the streamer

21:16:40 recording only channel 2 of the streamer

21:17:34 recording only channel 3 of the streamer

21:18:28 recording only channel 4 of the streamer (**THIS CHANNEL IS DEAD!**)

21:19:02 recording only channel 5 of the streamer

21:19:52 recording only channel 6 of the streamer

21:20:38 all channels connected again

Shots on priority line 4:

Julian Day 249 at 22:26:35 UTC first shot with a shot interval of 20 seconds (1 gun).

Julian Day 249 at 22:31:09 UTC first shot with a shot interval of 40 seconds (2 guns).

Julian Day 249 at 22:36:37 UTC first shot with a shot interval of 60 seconds (3 guns).

Julian Day 250 at 12:28:21 UTC last shot.

At JD 249 22:33 UTC, the analog filter was changed from 30-150 Hz to 10-150 Hz.

A breakdown of the supply with cooling water forced the temporary shut down of the shooting. The last good shot was fired at 22:37:37 UTC and shooting resumed at 22:46:37 UTC. The digitizer digitized ambient noise for the missing eight shots (corresponding to CMP 22 through 29 in the final SEGY file).

One raw SEGY file containing the shots for JD 259 00:28:34 and 00:29:34 UTC could not be read by the processing software, and, hence, these two traces are missing in the final SEGY file.

The record section shows a flat seafloor around 5 sec TWT with two minor steps around 50 ms. Although noisier than the previous line in the ice-free water, some horizontal reflectivity can be correlated down to a depth of 8.1 sec, maybe even up to 8.5 sec between CMP 800 to 850. Some reflectivity around CMP 300 at depths between 8.5 and 9.0 sec seems to dip in contrast to the otherwise horizontal strata. If this is real and not noise, this could be the basement (?).

Priority line 1W

Shooting direction from the east to the west.

Shots on priority line 1W (Julian Day 252 = September 9):

Julian Day 252 at 00:09:36 UTC first shot with a shot interval of 20 seconds (1 gun).

Julian Day 252 at 00:14:36 UTC first shot with a shot interval of 40 seconds (2 guns).

Julian Day 252 at 00:21:47 UTC first shot with a shot interval of 60 seconds (3 guns).

Julian Day 252 at 06:59:07 UTC down to two guns with a shot interval of 40 seconds.

Julian Day 252 at 13:59:38 UTC last shot.

Air pressure: 1780 psi with three guns, 1850 psi with two guns

The Khron-Hite analog filter was initially set to 10-150 Hz but changed to 30-150 Hz at 01:02:47 UTC.

CMP 1:	1 gun, 20 seconds shot interval
CMP 14:	2 guns, 40 seconds shot interval
CMP 24:	3 guns, 60 seconds shot interval
CMP 171:	The ship's bubbler was turned off
CMP 251:	Last shot (JD 252 04:08:43 UTC) before a short recording break due to a problem with the digitizing software.

CMP 252: First recorded shot (JD 252 04:12:42 UTC) after the problem with the digitizing software was solved. A total of three shots were not recorded.

CMP 414: Last shot with three guns, air pressure temporarily at 1400 psi.

CMP 415: Firing rate 40 seconds, with two guns, 1850 psi.

CMP 1006: End of line, ship starts to turn while the shooting continues.

CMP 1046: Last shot

The seafloor is gently dipping from 4.8 s TWT in the east to 5.1 s in the west. Horizontal reflectors can be identified down to 8 s. Farther below, reflectors become more interrupted. Between CMP 650 and CMP 1046 some weak horizontal or westward dipping reflectors can be seen at a depth of 9.5 to 10 s but it is unclear if this is caused by sediments or by basement.

Priority line 1E

Shooting direction from the west to the east.

Shots on priority line 1E (Julian Day 253 = September 10):

Julian Day 253 at 03:05:41 UTC first shot with a shot interval of 20 seconds (1 gun).

Julian Day 253 at 03:10:28 UTC first shot with a shot interval of 40 seconds (2 guns).

Julian Day 253 at 03:17:34 UTC first shot with a shot interval of 60 seconds (3 guns).

Julian Day 253 at 09:46:28 UTC down to two guns (starboard and port) with a shot interval of 60 seconds.

Julian Day 253 at 09:59:45 UTC down to one gun (starboard) with a shot interval of 20 seconds.

Julian Day 253 at 14:06:37 UTC last shot.

Air pressure: 1780 psi with three guns, 1780 psi with one gun

The Khron-Hite analog filter was initially set to 30-150 Hz at 01:02:47 UTC. The gain on the filtered channel was increased by 20 dB at 10:10 UTC.

From the start of shooting, no signal or only a poor quality return signal was received from the starboard gun. This is why the synchronization for this gun was set to manual. However, the return signal improved shortly thereafter and at 3.27 UTC, the gun was put into auto mode again.

Heavy ice was noticed at 06:00, 08:09 and 10:15 UTC. The gun sled was out of the water at ~8.22 UTC.

CMP 1:	1 gun, 20 seconds shot interval
CMP 13:	2 guns, 40 seconds shot interval
CMP 23:	3 guns, 60 seconds shot interval
CMP 412:	2 guns, 60 seconds shot interval
CMP 425:	1 gun, 20 seconds shot interval
CMP 1157:	last shot

The seafloor is gently dipping from 4.6 s TWT in the east to 4.8 s in the west. The data quality (signal-to-noise ratio) does not change significantly across the profile despite the fact that only one gun was used for CMPs > 425. The reflectivity is horizontal but amplitudes decrease significantly below a prominent high reflector band between ca. 5.5 and 6.0 s. It could be that these reflectors have high reflection coefficients, which could explain the decrease in amplitude for deeper horizons. At 7.7 to 8.0 s TWT, some wavy reflectivity can be recognized between CMP 340 and 500. If real, this could be a basement high. However, a verification would need a more careful interpretation and improved processing/plotting.

Sonobuoy on line 101

The first sonobuoy was deployed at JD 229 02:23:20 UTC at 74°20.350'N and

149°38.924'W. The data from this sonobuoy could not be received. The second sonobuoy was thrown overboard at an unknown time and position (no record was made). For the first few shots, no signals were received either. When the receiver was replaced with the spare receiver, a signal was received. For the calculation of the offset, an approximate deployment position was assumed but still needs to be corrected.

Up to an offset of ~1 km, no signal can be seen on the plot (receiver problem). For larger offsets, the direct wave can be seen that has a velocity of 1430 m/s, compatible with the CTD measurement of the water velocity in the area. At around 5 s, the seafloor reflection can be observed followed by at least one deeper sediment reflection.

Sonobuoy on priority line 5

The sonobuoy was deployed at JD 240 16:40:17 UTC at 74°45.117'N and 150°34.055'W. The position was taken with a handheld GPS receiver (GARMIN geko 201) right next to the person who threw the buoy overboard (indicated accuracy of position was 5 m). The buoy had the serial number B4, transmitted on channel 75 and the depth of the hydrophone was set to 300 m. The radio signal from the buoy was recorded until 18:40 UTC when the buoy was ~12 km away from the ship. The recorded shots correspond to CMP 111 through 229 on the reflection seismic line.

At offsets of ~4 km, the recorded signal starts to become successively more noisy and this is presumably a problem with antenna system and the long coax cable between the antenna and receiver. The direct wave and the seafloor reflection can be easily identified. Two other reflections from sedimentary layers can be observed as well. This may allow for some velocity analysis (NMO) in the uppermost sediments.

Measurement of the pressure of the airgun signal

On August 16, 2006 (Julian Day 228), the pressure of the airgun array was measured at some distance away from the Louis S. St-Laurent by using a calibrated hydrophone deployed from a boat at ~74°19'N, 149°59'W. The pressure was recorded on tape. Below the shot sequence is described and the distance to the boat is given (using the RADAR at the ship's stern).

21:16:15 UTC	1 gun	First shot
21:17:10 UTC	1 gun	Second shot
21:19:10 UTC	1 gun	Start shooting at 20 sec shot interval
		Distance to boat: 4349 ft
21:24:50 UTC	2 guns	Start shooting at 40 sec shot interval
		Air pressure 1800 psi
21:37:00 UTC		Distance to boat: 6144 ft
21:40:50 UTC	3 guns	Start shooting at 60 sec shot interval
		Air pressure 1750 psi
21:51:00 UTC		Distance to boat: 6570 ft
21:53:26 UTC	2 guns	Start shooting at 40 sec shot interval
		Air pressure 1750 psi
21:58:56 UTC	1 gun	Start shooting at 20 sec shot interval
22:03:00 UTC		Distance to boat: 6991 ft
		Guns shut off

Serial numbers of the airguns

There were three 500 cubic inch G-guns at the tow sled. The serial numbers of the guns were:

Starboard:	#6873
Amidships:	#6874
Port:	#68710

Cruise Report: Technical

GSC (A)/ UNCLOS
Equipment Trials from the Quarterdeck of the CCGS Louis S. St. Laurent, Summer 2006

Submitted by: C Borden Chapman cet,
Ryan Pike, NSCC

Equipment Trials from the Quarterdeck of LSSL Summer 2006

Our 2006 Summer Mandate:

Canada's participation in the United Nations Convention of the Law of the Sea requires our country to survey large marine expanses in the western Artic. The challenge to carry out this task was jointly passed to Natural Resources Canada (NRCan) and Department of Fisheries (DFO), both science organizations being based from the Bedford Institute of Oceanography in Dartmouth Nova Scotia. The science program was conducted on board the CCGS Louis S. St. Laurent.

The future data set collected as a result of a multiyear survey by the two Departments, will form part of the submission to be made to the United Nations.

This summer, on board the CCGS Louis S. St. Laurent, a newly designed seismic acquisition system was put through its paces. On board the vessel, safe equipment handling methods had to be developed while repeated towing trials were carried out to ensure dependability and longevity of the equipment during future seismic operations. Seismic data quality was assessed and recommendations for future surveys made. This part of the science program was conducted by personnel from Natural Resources Canada, GSC (A).

Also, during the summer program on LSSL, a new Knudsen 320 dual frequency echo sounder was tested and the performance of this equipment was documented. This part of the program was completed under the direction of the DFO Canadian Hydrographic Service personnel.

Vessel operations were evaluated by both organizations and recommendations from a science perspective, are to be made to Canadian Coast Guard.

Science Objectives:

The purpose for conducting this scientific program on board the CCGS Louis S. St. Laurent during the summer of 2006 was to determine if the geophysical equipment, as designed and configured, would provide the data set of the quality required for Canada's UNCLOS submission. By testing the equipment in the actual proposed survey area, performance was evaluated and recommendations for modification will be made. It also allowed the technical staff to evaluate the performance of the vessel and develop suitable "over the side" handling techniques for the seismic towed system.

Bathymetry:

Department of Fisheries and Oceans (DFO), Canadian Hydrographic Service (CHS), was responsible for testing the newly installed Knudsen 320MB dual frequency echo sounder and collecting bathymetric data along the vessel transit from Dartmouth, NS, CCG base, through the Northwest Passage, en route to the survey area, in the Beaufort Sea. During science operations,12 kHz bathymetry data was continuously collected. While the vessel was operating in heavy ice, some data was lost as a result of sea noise around the vessel transducer. However during the seismic survey operation, even while breaking ice at reduced speed, the sounder performance was judged satisfactory. Several bar checks were conducted during the cruise to confirm proper sounder calibration. XCTD data was used to supply sound velocity corrections throughout the program.

Seismic operations:

The equipment required to collect the seismic data was provided by Natural Resources Canada, Geological Survey of Canada Atlantic. The common techniques of collecting seismic data have been employed by researchers and industry for many years. The only difference from a normal GSC (A) marine survey and the operation from the deck of the CCGS Louis S. St. Laurent was the need for the equipment function in heavy ice conditions where up to 9/10 multi year ice coverage was possible.

The design challenge faced by GSC (A) engineer and staff centered mainly on the ability of the towed equipment to withstand the enormous stresses resulting from sea ice impact. To reduce the possibility of ice impact the towed system was designed to "fly" directly behind and below the vessel.

The hydrophone receiver was affixed to the towed sled and concerns about how to couple the receiving system to the seismic source were evaluated and addressed.

In this system design it was necessary to keep the source tight to the stern, within several meters of the ship's rudder and centre propeller. To accomplish this task, a tow sled was fabricated using an old 16 inch artillery shell filled with 3000 lbs. of lead. (See Figure: 1).

Figure 1: Tow Sled on its cradle

A tow sled cradle was fabricated to carry the 16" shell casing. Below the cradle three "I" beams were attached. Three 520 Cubic Inch Sercel G guns were fitted, one to each "I" beam. The distance between each gun was just over 1 meter, as recommended by the gun manufacturer.

At the top of the shell casing a balanced pull point was chosen. At this pull point a 1 inch steel cable was affixed. The inboard end (or dry end) of this cable was attached to the bollards located at the mid point of the quarterdeck. This cable served as the main pull wire while the tow sled was in the water. Total length of cable was 73.5 feet. This cable length was chosen to place the tow sled just below the ship's keel. By keeping the sled slightly below the keel, it was thought that there would be some reduction in the turbulence caused by the centre propeller. Actual tow depth was 34 feet below the surface. Running the sled at this depth also reduces the chance of ice impact.

Air and electrical lines were bundled together and attached to the pull cable using specially designed clamps. The clamps allowed free rotation of the bundle about the tow cable. (See Figure: 2). A total of four clamps were fitted to the pull cable at 12 foot intervals starting at the tow sled (outboard cable end).

Figure 2: Bundle Clamp affixed to Tow Sled Pull Cable Showing "break out eye"

The tow cable was fitted with four "break out eyes" made from ½" steel wire (See Figure: 2). The "break out eyes" were fitted to the 1" pull cable starting at the pull point on the top of the tow sled and then at 12 foot intervals. The fourth "break out eye" was just at the ship's deck level. The "break out eyes" served to aid in the handling and the recovery of the tow sled.

The cable bundle consisted of 3- ½" Synflex air lines, three solenoid and three shot sensor electrical cables, the hydrophone electrical cable and a fourth air hose that was used as a guide for a ¼" steel support cable.

All of the cables within the bundle were wrapped inside a product called OmniWrap. This provides excellent protection for the umbilical system and also reduces operator risk while handling the air and electrical lines. The OmniWrap is extremely rugged and thus protected the bundle from damage when in contact with the ice.

As noted above, there was a "support cable" added to the bundle after initial tow trials. The outboard end of this ¼"steel support cable was clamped to the top of the tow sled. The inboard end of the ¼" cable was clamped to the 1" tow cable close to the bollard (vessel tow point). The purpose of this support cable was to prevent the bundle from sliding through the bundle clamps. This minor addition to the bundle reduced the looping effect that occurred as the bundle slid lower towards the top of the tow sled. By reducing the looping effect the chances of the bundle becoming caught by a piece of ice was reduced. Next season two additional bundle clamps will be added to the tow cable/ bundle to better control the bundle while the sled is being towed.

Acoustic Sources:

Three -520 cubic inch Sercel G guns were mounted approximately 24 inches below the tow sled "I" beams using ½" grade 80 -chain. Six foot electrical and air cables were run in a looped fashion, secured at the guns and to specially constructed nylon "break-out" blocks mounted above the guns on the "I" beams.

The G guns were chosen for several reasons. Firstly the acoustic signature was deemed to be within the parameters required for the necessary sea floor penetration; secondly the gun durability was far above industry average and thirdly there was little gun recoil when fired. (See Figure: 3)

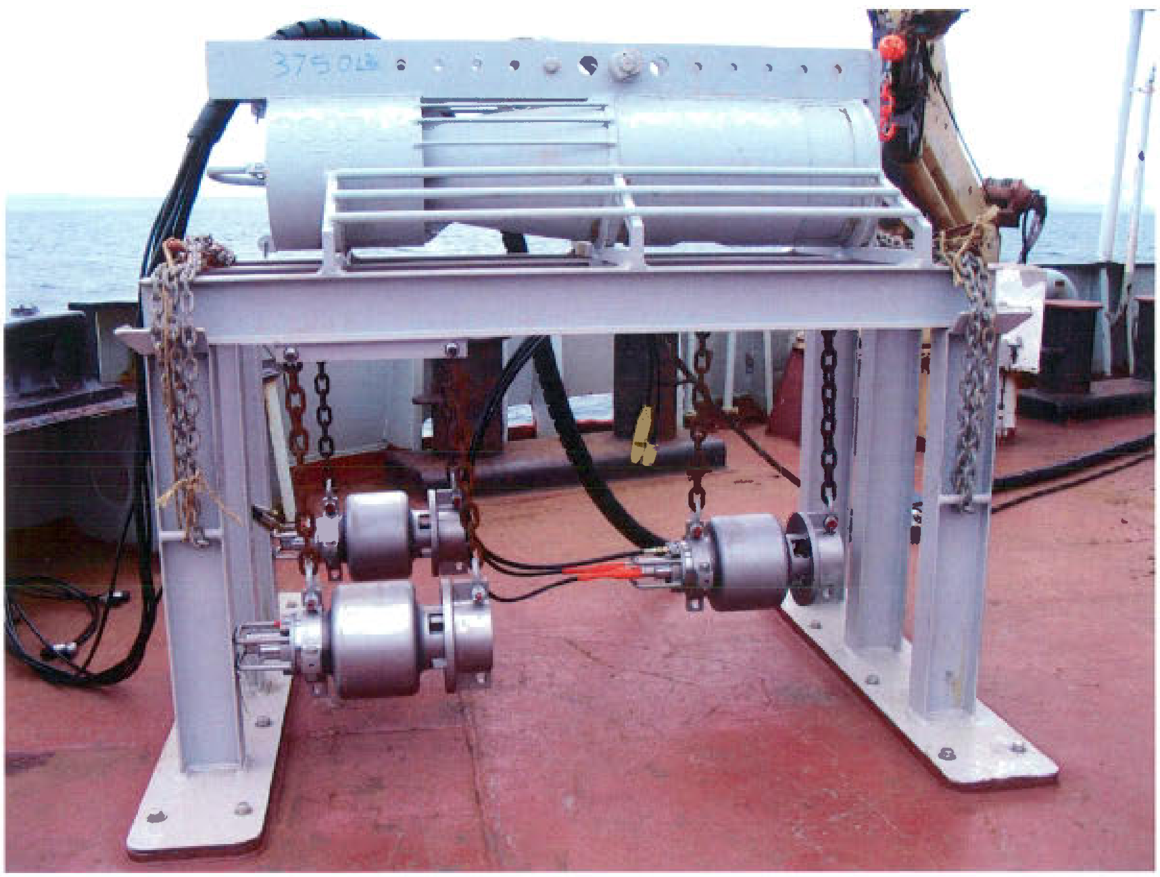


Figure 3: Tow Sled with G-Guns fitted

During the tow tests there was more gun recoil than expected. This problem caused damage to one electrical connector on the starboard gun. It appeared that the gun was repeatedly striking the end of the "I" beam, hitting this electrical connector. Oddly enough it appeared that this was the only gun that was being damaged. However, when dismantling the system at the end of the program, there was evidence of damage to other connectors indicating that the port gun was also hitting the support structure. For future operations additional precautions will be taken to ensure this damage is minimized.

Hydrophone Streamer:

The 200 foot hydrophone streamer was received from the refurbishment shop only days prior to the ship leaving port. The streamer was constructed using existing GSC (A) equipment that was supplied to the refurbishment shop. The firm was asked to rebuild the array using these parts.

Configuration and layout of this streamer was similar to that of the Teledyne streamer GSC (A) uses as its principal seismic streamer. Hydrophone spacing and grouping was identical to the Teledyne streamer. Inside the LSSL streamer there were a total of 84 Benthos AQ-1 hydrophones, clustered in six groups of 14 phones, nested into groups 1 and 4, 2 and 5 and 3 and 6. The output of each group is coupled to the seismic signal amplifier through isolation and impendence matching transformers. The signals are summed together and produce a single analog signal which is then sent to the filter/ graphic recorder and the data logger, GSC (A) Dig.

Initially the streamer was towed 30 meters behind the tow sled. A measurable amount of prop noise was realized at this distance and so an additional 70 meters of cable was added to allow a total of 100 meters of layback. This improved the signal to noise ratio somewhat. It was felt that increasing layback of the streamer even more would improve the seismic signal.

The general performance of this streamer was disappointing. It is believed that the streamer sensitivity was too low and this was due to the performance of the AQ-1 hydrophones. Future consideration must be given to a better array design. The design must take into consideration the potential for damage due to ice contact, the difficulty in the handling and deployment of a longer array, total element count for increased sensitivity, analog or digital configuration and processing of the received signal.

Data Logging:

During the seismic program a GSC (A) Dig was used to log the seismic streamer data. This unit produces a SEG Y format for ease of processing.

Because of the deep water in the work area and our requirement to have a "look window" exceeding the six second digitizing rate, setting up the digitizing parameters were a bit tricky. The current digitizing software will not allow logging times in excess of six seconds. When opening the software, GDAim, by entering trial sample rate and interval times in their respective windows, the operators were able to extend the digitizing rate to 15 seconds. This allowed the digitizing of the water column and thus we could use the same GSC (A) Dig to log the sonobuoy data along with the G gun seismic data.

Additional program development should be undertaken to correct this GDAim software "glitch" for future year's surveys.

Longshot Firing system:

G Gun synchronization and firing control was accomplished using the Real Time Systems' LongShot Firing Control System.

Each G gun is equipped with a shot sensor which produces a shot return pulse when the gun is fired. The time interval between the firing of the gun electronically and the actual release of the acoustic pulse is therefore known to the system. The system averages these time intervals and adjusts the three gun fire pulses to allow the acoustic pulses to leave the three guns at the same time, thus maximizing the acoustic energy.

The setup of the LongShot, and the actual performance of this system through out the program was judged as satisfactory with no real problems encountered. Gun synchronization was kept within acceptable limits of >.2 milliseconds during the shooting program.

Firing Interval Control:

Due to the limitations of capacity for the electric air compressor, the shot interval for firing the three guns was set at sixty seconds. Air pressure was consistently regulated at 1800 PSI using a Fisher flow control valve.

Firing pulses were produced using a small control system and laptop. This control system is commonly called the "Frydecky Box". This "box" attaches to the parallel port a PC (or laptop) and runs a DOS based program. Additionally, a serial navigation string can be connected to the PC to allow the shot or trigger pulse to be generated for a "fire on distance" mode of operation. During the LSSL program this option was not employed and so the internal PC clock was used to produce the time interval trigger pulse for the LongShot system. No difficulty was realized using this system except that there was minor clock drift in the PC clock.

Regulus Navigation:

During the transit from the Dartmouth CCG base in Nov Scotia to the Canada Basin region in the western Artic and throughout the subsequent science program, GSC (A) logged navigational data on a PC running Regulus software. Initial PC setup was somewhat different than the usual installation as the data feed for the PC came in a different format, a simulated serial feed on a network broadcast from the bridge of the LSSL. In order to accommodate this different format a small program called "GPSGate" had to be run on the Regulus PC. What this program does essentially, is to produce a virtual serial port on the PC, converting the Nav feed from the vessel network into a virtual comm. port within the PC. This virtual port can then be selected as the originator of the nav data source for Regulus.

Initially a daily reset occurred. After some troubleshooting it was discovered that the "Windows Automatic XP Update" was turned on. This caused the PC to try and access the vessel network for links to Microsoft causing the GPS Gate software to crash. Once the Auto update was turned off the nav feed and Regulus software performed well.

Price Compressor:

The Price electric air compressor was employed during the seismic survey on the LSSL. This compressor generated the 1800 PSI of compressed air at approximately 185 SCFM for the three G Guns on the seismic tow sled. The Price is an electrically operated compressor. A soft start variable speed electronic drive controls the speed of the 200 HP electric compressor drive motor and is located within the 20 foot container where the compressor is located. This variable speed drive can control the RPM of the Price compressor and hence the compressor air volume output. A Fisher flow control regulator valve is located in the container. This valve regulates the discharge pressure from the compressor by dumping excess air.

While the compressor is in operation, a log is kept to record the system pressures and temperatures. Readings are taken every 15 minutes. At one point during the readings, student, Ryan Pike, realized there was an antifreeze leak in the system. On inspection it was discovered that there was a high pressure air leak inside the fourth stage heat exchanger (or intercooler). The machine was immediately shut down and the tow sled equipment was recovered. Next day the intercooler was disassembled and a small leak in one of the cooling tubes was repaired.

Once the equipment was re assembled, the compressor functioned well for the rest of the program. The intercooler will need replacement this winter.

Tow Sled performance:

As part of the initial equipment testing, a pitch, roll, and yawl package was affixed to the tow sled. Our intentions were to evaluate the sled performance on initial deployments. Testing at various tow speeds and steerage conditions would provide data regarding optimal tow speeds etc.

The small tow sled underwater attitude package was mounted to the port side of the tow sled in a suitable pressure case. The attitude package consists of a Honeywell module comprising a compass, X and Y roll sensors and A to D converters. The data from these sensors were converted to a RS485 serial string and fed to a cable from the underwater package to a logging PC. The manufacturer supplied a software program that allowed the data to be plotted on the PC in real time and also stored in Xcel format.

Following a series of speed and turning maneuvers, the Xcel data from the tow sled sensor package was plotted to show the sled performance. (See Figure 3)

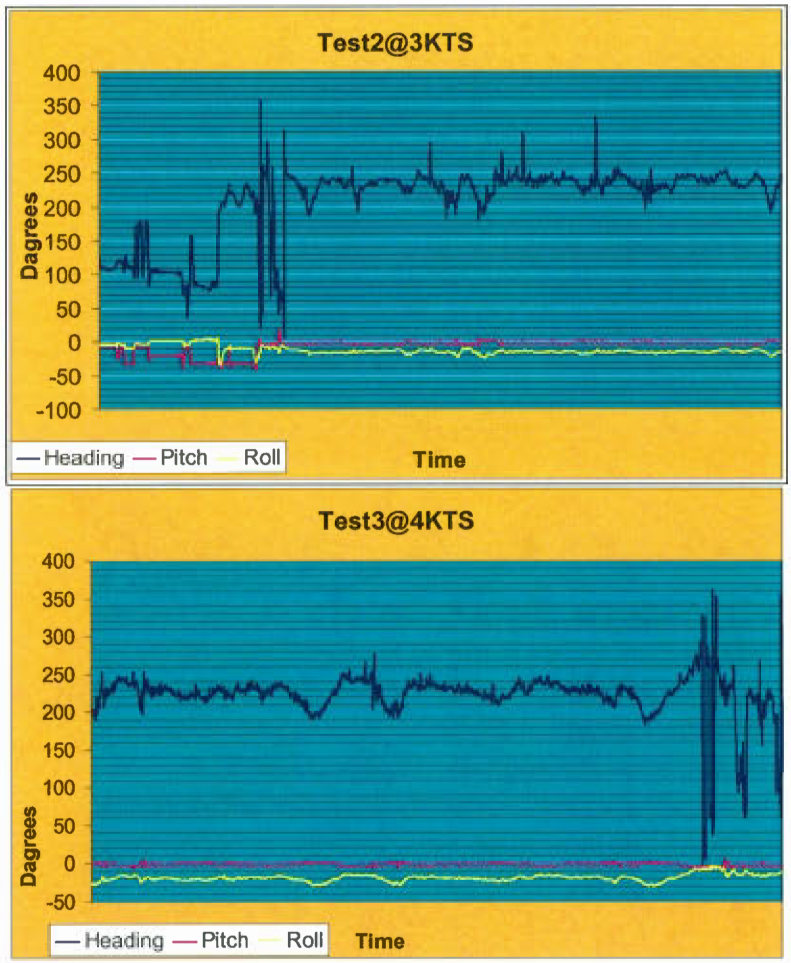


Figure 3: 4 knot Tow sled towed parameters

The data shows little change in the pitch or roll attitude of the tow sled from 3 to 4 knots. This leads us to believe that acceptable data can be collected at ship speeds up to four knots. Also note a positive 2- 4 degree pitch to port and also a 5 degree yaw to port. These results were consistent over the various tow speeds and these effects could not be reconciled except for the possibility that a "twist" in the 1" pull cable produced a rotation at the tow fish.

One of the tests involved stopping the ship until dead in the water and then applying full vessel power to all three propellers. During this test the tow sled, which at speeds of up to four knots, remained near vertical, went almost completely horizontal and at the maximum measurable horizontal limit for the attitude package. It was also during this test that a large pan of ice was pushed into the prop's wake and literally shot astern by the prop wash. This ice lodged between the vessel and the tow sled and the tow sled was pulled completely out of the water, over the top of the ice flow and dragged across the ice into the water as the ice moved astern. There was almost insignificant damage to the tow sled due to this action. (See Figure 4 and 5)

Figure 4: 3- 520 G Guns fire in air!

Figure 5: Tow Sled does a 360 flip!

Another test, conducted in some heavy ice proved interesting. The vessel was traveling at four knots with the sled deployed. A fairly substantial pressure ridge was encountered. This ridge stopped the vessel dead. Increased power was applied to the propellers to overcome this ridge but the vessel was unable to proceed through the ice ridge. Again, as shaft power was increased the tow sled rose to near horizontal. The equipment had to be recovered to allow the vessel to come astern and then full shaft power was applied to break through this ridge.

Tow Sled Deployment Issues:

Prior to leaving CCG Dartmouth base, CCG crew did lift testing on the two cranes located on the quarterdeck of the LSSL. The starboard crane was to be used for the deployment and recovery of the tow sled. The runner winch on the crane is a Pullmaster winch with maximum lift capability of 4500 pounds. The tests certified this winch to its manufacturer's specifications. The crane boom was, however, capable of handling more weight, the limit was on the winch.

The maximum combined weight of the tow sled and guns was certified at 4350 pounds, just below the maximum winch capacity.

Initial lift trials at sea showed that the winch could handle the weight, but later on, as ambient temperatures fell, the winch could not lift the tow sled off the support frame. At this point the deployment of the sled was in jeopardy. After several attempts a new method was developed proved to be more efficient and actually safer. The cable from the Pullmaster crane winch was removed from the crane's lift point. A fixed hook was then placed on the outboard eye of the boom. Using a predetermined boom extension (scope) of 40 inches, the crane was able to boom down to the first lift eye on the tow sled pull cable and by booming up, lift the tow sled off the cradle. Keeping the boom length fixed, the crane was then sluffed to starboard and this positioned the tow sled out over the stern, clear of the vessel fan tail. Then, by booming down, the tow sled was moved amidships where the tugger winch took the tow sled load from the crane's hook. Once the tugger winch had the full weight, the fixed hook on the crane boom was disconnected from the first recovery eye on the pull wire. The tow sled was slowly lowered over the stern. (See Figure 6).

Figure 6: Tow Sled being lifted from the cradle

As the tugger winch lowered the tow sled into the water, the small port side crane was used to aid in handling the bundle, keeping personnel clear of the equipment as the sled went into the water. The small port crane lifted the pull wire/ bundle at the second and third recovery eyes lowering the bundle/ pull wire over the stern at the same rate as the tugger winch lowered the tow sled. Once the towing depth was reached, the full load weight of the tow sled was on the pull wire and the small port crane hook was disconnected for the lift eye. The tow cable and bundle was rested into the large sheave block located amidships over the stern. See Figure 6.

The recovery procedure was the same in reverse.

This proved to be an optimal method of deployment for the ship and equipment, as fitted. It also proved to be quite time consuming, taking up to one hour on each deployment and recovery. There is always a danger in handling equipment weighing this much, especially at sea, and being so close to the maximum specifications for the handling equipment.

The Chief Officer, Bosun and crew should be congratulated on devising this deployment and recovery method. The fact that no one was injured was a testimony to their abilities alone.

Sonobuoy operations:

GSC (A) purchased 20 sonobuoys and two VHF receivers prior to Dartmouth departure. The receivers were supplied with a small Omni-directional antenna and 200 feet of coaxial lead in cable. The receiver frequencies were programmable using a software program supplied with the equipment. During the trials the sonobuoys were deployed from the stern of the vessel, port side, aft. The antenna was mounted to the starboard side rail at a height of 7 meters above the water.

Sonobuoy transmitter frequency and the programmed deployed depth of the sonobuoy hydrophone are set on the side panel of the instrument prior to dropping it into the water. After the buoy is deployed, the "red hat" VHF antenna is released and floats to the water surface. A salt water switch turns on the unit and the instrument will continue to transmit the hydrophone signal back to the vessel for up to 8 hours.

Unfortunately the limiting factor using the buoys was the "line of site" propagation of the VHF signal. After approximately 5 km the receiver was squelching off as the signal got weaker. In order to improve the receiver performance, and thus increase the usefulness of the buoys, an improved antenna system needs to be purchased. Because the buoys use VHF frequencies the receiver height needs to be greatly increased, possibly using a balloon to place the antenna to 1000 feet or more.

One other point; during the construction of the sonobuoys, an attenuator was added to the hydrophone amplifier to reduce the gain. This was thought to be useful due to ambient ice noise in the work area. However this proved to be a problem for data quality also. The remaining buoys should have the amplifier gains returned to maximum prior to next season's use.

Data Quality:

Approximately 400 km of seismic data was collected during the 39 day program. There were several deployments, each lasting 12 to 18 hours. Besides the actual data collecting phase there were numerous deployments to conduct the pull and seep trials.

The designated work area was in 2500 to 4000 meters water depth. Ice conditions were from open water to 9/10 ice coverage.

The acquired data set showed sub bottom acoustic penetration to a depth of 3.5 to 4 seconds. No strong reflectors to indicate basement were observed. During towing operations in ice, background noise levels increased a measured 12 fold, reducing data quality to an extent where the data was considered unusable.

It is believed that a better receiving array will improve data quality. As this first season was a trial for the tow system, the streamer was considered a "disposable" item and GSC (A) intention was not to fit an expensive streamer to the tow sled as it may be immediately lost or damaged. Since the tow sled trials were successful, it is now our intension to investigate and purchase a better, perhaps multi channel array, for subsequent field programs.

Conclusions:

The principal results from the 2006 summer operations on the LSSL can be itemized as follows:

(A) The CCGS Louis S. St. Laurent is a vessel that can be used to tow seismic equipment.

(B) The vessel cannot simultaneously tow seismic equipment and break through ice ridges and multi year ice. Our test results demonstrate that there will be a need for a second vessel to break ice or employ a different shooting vessel while the LSSL breaks ice.

(C) The current design of the tow sled will serve to support the G Guns and receiving streamer.

(D) There will be a need to service the tow sled every 18- 24 hours, thus proving that a second, duplicate system is required to minimize downtime and the added cost associated with ice breaker/ ship time.

(E) Improved streamer/ eel receiver is required, with 3 units necessary.

(F) New air compressor will allow increase in shot density.

(G) A better sonobuoy antenna/ receiving system is required.

(H) Better laboratory space facilities are required than the rope locker used on this experiment.

(I) Navigational data from the GPS receivers to the lab spaces are needed for "shoot on distance" operations

(J) Better handling equipment on the stern of the LSSL is needed. An "A frame" must be fitted.

(K) Better telephone/ intercom systems for the quarterdeck and bridge should be fitted.

(L) Additional CCTV systems for the bridge to monitor quarterdeck operations are required.

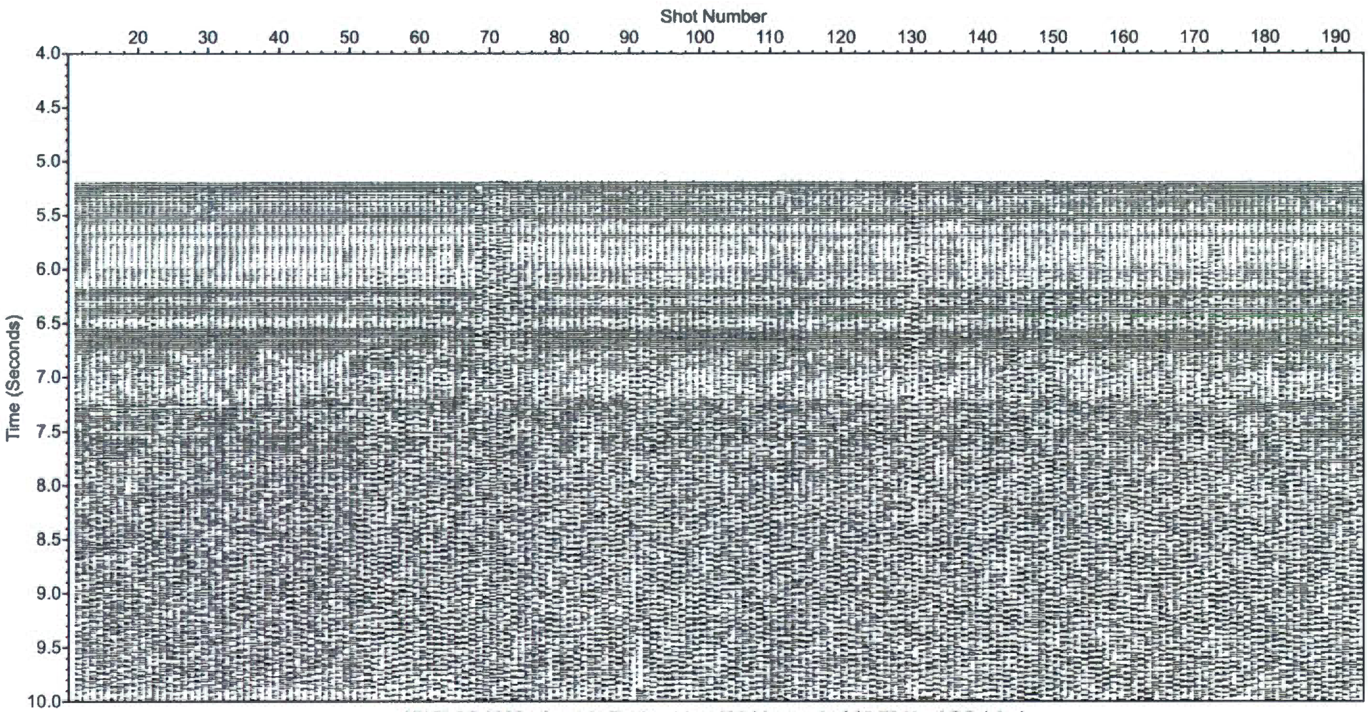
Acknowledgements:

Much credit for the success of this program lies with the crew of the CCGS Louis S. St. Laurent. This type of seismic operation was "new" to almost all of the ship's company. A sharp learning curve was necessary. New ways of handling the equipment were developed "on the fly". Without the ingenuity of the C/O and deck crew the program would not have gone off with the level of success that it did.

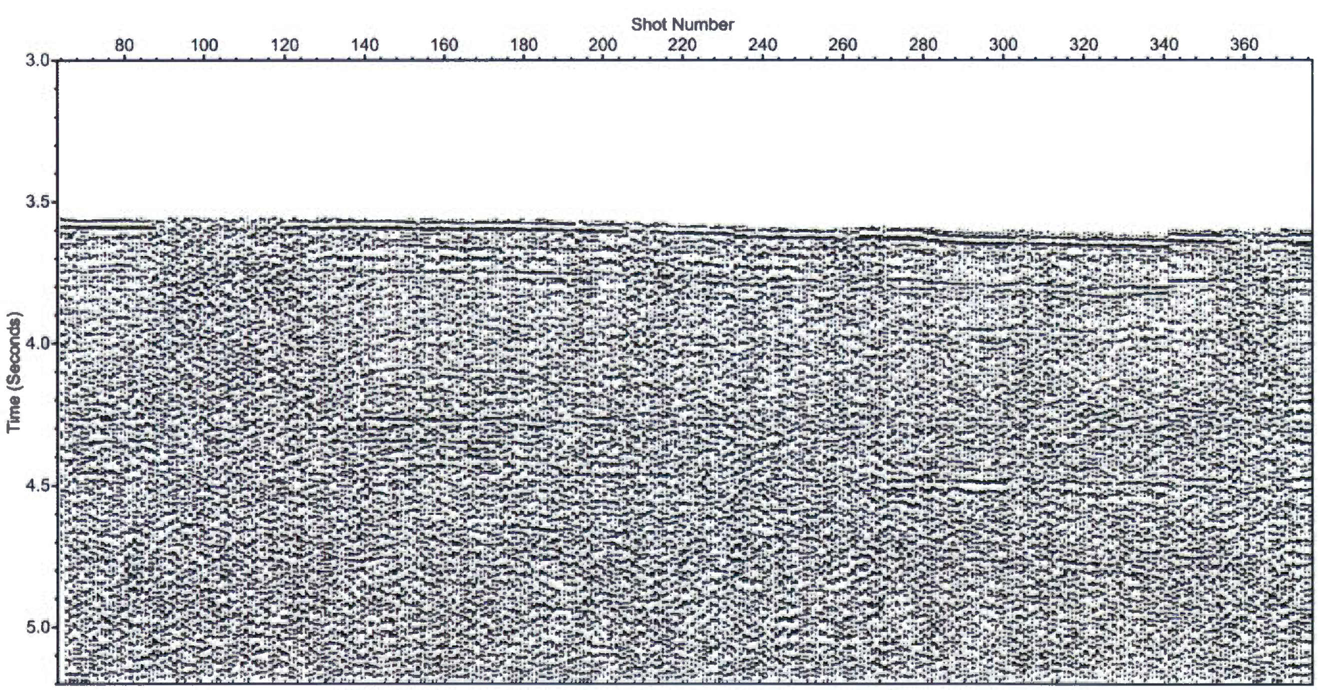
Also the author would like to especially thank Dr. Thomas Funck of the Danish Geological Service for his guidance and advice throughout the LSSL program. His knowledge and enthusiasm were greatly appreciated.

Finally to the cooks of the LSSL, thank you. Enough said!

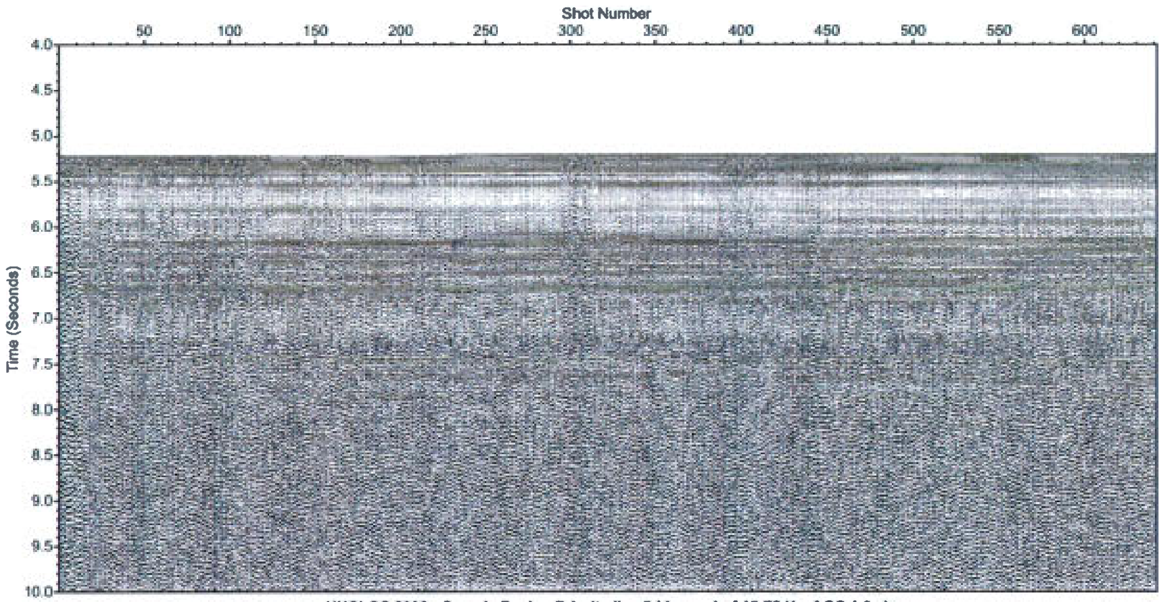
Examples of data:



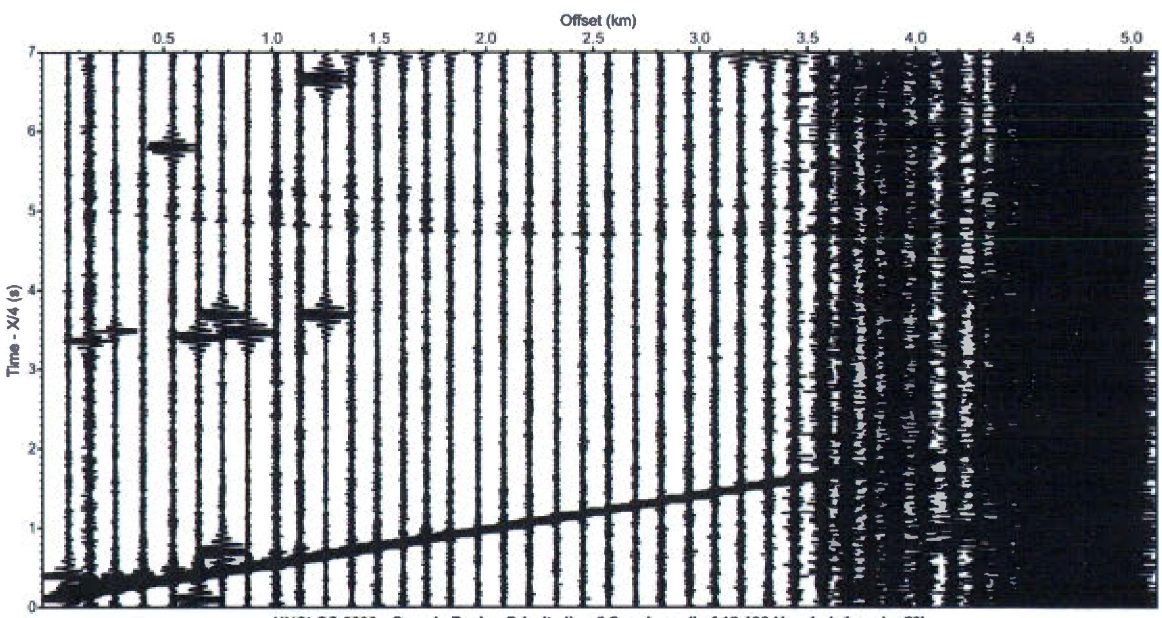
UNCLOS 2006 - Canada Basin - Line 101 (decon, bpf 15-72 Hz, AGC 1.0 s)



UNCLOS 2006 - Canada Basin - Priority line 2 (spike decon, bpf 20-72 Hz, AGC 1.0 s)



UNCLOS 2006 - Canada Basin - Priority line 5 (decon, bpf 15-72 Hz, AGC 1.0 s)



UNCLOS 2006 - Canada Basin - Priority line 5 Sonobuoy (bpf 15-130 Hz, pbal=1 scale=50)

Location of seismic reflection profiles:

Location of priority line 1

col: 1 Trace Index
col: 2 CDP ensemble number
col: 3 Source X coordinate
col: 4 Source Y coordinate

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