TECHNIQUES AND INSTRUMENTATION EFFORT FOR
WHALE MIGRATION TRACKING

May 1975

by

R. M. Goodman, FIRL
K. S. Norris, UCSC
and
L. Hobbs, UCSC
R. J. Gibson, FIRL
E. Dougherty, FIRL
J. Palladino, AII

Prepared for
The National Aeronautics and Space Administration
Ames Research Center, California

NASA Contract No. NAS2-8013

Reference: Program Code 178-56-12-02-00

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ABSTRACT

Effort prior to and during the January - February 1974 Expedition is presented. Resulting data obtained from an instrumented Gray Whale is analyzed and commented. Recommendations for follow-on effort are made.
CREDITS

The work and results described in this report are the products of an interdisciplinary effort involving many people and several organizations. In addition to the authors already listed we recognize the contributions and participation of the following people:

NASA - Paul Sebesta
         David Winter
NOAA - David Wallace
NMFS - George Rees
CONACYT, MEXICO - Bernado Villa Ramirez
           Louis Fleischer
MEXICO - Sr. Serrano, Lopez Mateos
         Sr. Armas, Port Captain, San Carlos
MEXICAN FISHERIES
SCHOOL SYSTEM - Jose Costello
SCRIPPS - J. Kooyman
         Sigmund Rich
         Roger Gentry
         Tom Dohl
FIRL - John Price
       Earl Sonnie
TRAWLER LOUSAN - Tim Houshar (skipper) and crew
AIL SYSTEMS - O. J. Hanas
              E. Haines
INTRODUCTION

The period of this contract ran from 1 December, 1973 through 30 November, 1974. At the outset of the period, extremely energetic efforts were carried out by the biology team under Dr. Norris at the University of California at Santa Cruz and the technology team under R. M. Goodman at The Franklin Institute Research Laboratories. These efforts were directed to completion of equipment and preparation of facilities, plans, various gear and logistics for the field expedition to take place at Baja California Sur, Mexico in mid-January of 1974.

Everything was completed in time by virtue of the unstinting efforts of all staff members involved. On 24 January, 1974 the UCSC and FIRL teams were joined at San Francisco and later that day arrived at La Paz, Mexico. On 25 January, after a 255 km overland trip, they were on site at Lopez Mateos. The trawler LOUSAN arrived that afternoon. Field activity initiated the next day.

In the course of our work in Mexico we met with both successes and disappointments. We acquired unique data on capture techniques, learned much about the responses of equipment to hostile environments, evolved detailed expedition safety codes as regards personnel safety and animal safety and made rewarding friendships with some of the people of Lopez Mateos and with Dr. Bernardo Villa-Ramirez. Senior Scientist and Professor (University of Mexico). We are happy to report that we obtained over four days of continuous diving activity data from a gray whale in its natural environment - a major achievement.

Part of our effort was to be related to the "bread-boarding" of an expendable transmitter, a device which is key to our ultimate system. As part of such a system, these transmitters will permit the acquisition of fiduciary fixes along the migration path. The transmitter design approach was related to the requirements of the Nimbus-F satellite system; being a representative RAMS system. This course was taken because enough problem similarities presently exist in transmitter design for use with any RAMS satellite. The funds necessary to support the transmitter design effort, as well as for support of parts of the biology team work, were placed in the contract through the good offices of The National Marine Fisheries Service of NOAA. Unfortunately, the transfer of these funds was delayed by administrative circumstances and our subcontractor, ATI Systems, was forced to pursue the development under a most severe time constraint. Nevertheless, useful bread-boarding was completed and the insights the study was to evolve have been recognized and assimilated.
Because of the multi-faceted efforts involved in this long-term program, which involves a step-wise development of a system to make possible the tracking of the great whale species over their full migration routes, the Principal Investigators have decided to include the first two quarterly reports of this present effort within the Final Report. We feel the inclusion will provide the reader with a deeper insight as to the status of the overall effort and to details of importance.
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CONTINUATION OF TECHNIQUES DEVELOPMENT FOR
WHALE MIGRATION TRACKING

Period: 1 December 1973—28 February 1974

R. M. Goodman
K. S. Norris

Prepared for
National Aeronautics and Space Administration
Ames Research Center
Moffett Field, CA 94035
ABSTRACT

Completion of harnesses, flotation gear and instrument pods is discussed.

Preparations for the January-February 1974 field expedition are described; a preliminary reporting on the expedition is disclosed.
CREDITS

The authors are grateful for the support and cooperation of the entire scientific party and ship's complement in the work described; José Castello of Mexico, who came to observe and photograph, became a dedicated team member and helped in innumerable ways.

We want particularly to mention the remarkable courage and selfless efforts contributed by P. Sebesta of ARC and the understanding kindness and help of Dr. Bernardo Villa of Mexico who arranged for hot water in our showers, commandeered an aircraft so he could "count heads" to be certain that all hands were OK when the ship grounded, helped the men whose visas were lost with the ship as well as the crew whom he led through the intricacies of legal and language barriers in a country to which they were visitors and whose language they could not speak—all of this while suffering a broken sternum acquired just after ship grounding.

The authors were aided directly in the preparation of this report by R. Gibson of FIRL and R. Gentry and L. Hobbs of UCSC.
INTRODUCTION

For approximately twelve weeks prior to 1 December, 1973, the cooperative research team, made up of one group under R. H. Goodman (P.I.) at FIRL and a second under K. S. Norris (P.I.) at UCSC worked at full speed to develop and fabricate the protocols, devices and gear essential to the January-February 1974 field expedition.

On 1 December, 1973, the work continued under Contract NAS2-8013 and this present report is a record of effort activity and preliminary findings for the period of 1 December 1973—28 February 1974.

The goals desired under this present contract are as follows:

1. To complete fabrication of first model expansible (Mark II), instrument-pack-bearing harnesses (two each) for the juvenile whale, January 11, 1974 - Design to be furnished to FIRL by Ames Research Center.

2. To modify and fabricate a minimum of two (2) and up to five (5) if time permits of the 1973 model (limited expansible) gray whale harnesses.

3. To complete the design, construction and tests of two (2) P/T (water) instrument pack for application to the juvenile gray whale in the January/February 1974 expedition. Tests will be done by FIRL in pressure chambers simulating 72 foot depths which is 12 fathoms (36 PSI) or 200% of expected in-lagoon field conditions.

4. To carry out in-lagoon, behavioral field studies with a minimum of two instrumented whales for periods of one week. Studies are time dependent on erosion rates of harness release bolts. Therefore, the week study may be plus or minus up to 3 days. Studies are dependent on availability of animals. Therefore, the numbers of animals cannot be assured; however, a minimum of 2 are desired. If there is a release of equipment causing a short week study and another animal can be captured, a third study will be done.

5. To carry out pure following-track studies with a minimum of two (2) and up to three (3) instrumented whales at sea for periods of up to two weeks. Instrumentation is only the tracking
transmitter and Xenon flasher. The third study is only in event of an early harness release by one of the previous two tests. All studies are possible only if animals are available through the natural course of events.

6. To acquire behavioral data on individual activity and interpersonal activity on the whale mother and juvenile for inclusion in concept and design planning for the 3-6 month migration study in our next major field expedition.

7. To breadboard and perform laboratory evaluation on the performance of the expendable tracking transmitter.

8. To process and analyze the pressure/temperature data from the January/February 1974 expedition.
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1. WHALE HARNESS AND GEAR

Testing and final production of harnesses and associated gear continued as scheduled prior to the field portion of the program.

1.1 THE INSTRUMENT HARNESS

A prototype of the modified girdle-type harness, used successfully in the 1973 captures, was tested on our whale model and found satisfactory with minor modifications and alterations indicated.

A backplate was designed and fabricated, in the UCSC shop, to incorporate appropriate harness attachments and receptacles for securing a radio tracking transmitter and the FIRL MK I instrument pod. Polyurethane flotation needs were calculated and units with hard, exterior fiberglass shells were molded. These are essential to protect and float the entire harness assembly upon its release from the whale.

Five such harnesses were fabricated for use in the field.

1.2 EXPANSIBLE HARNESS

In consultation with R. Mancini (NASA/ARC), a design for an expansible-contractible harness was completed. It incorporated springs and a "sandwich" backplate which could accommodate a tracking transmitter, a Xenon flasher and a depth-of-dive recorder.

The specially fabricated linear-expansion springs introduced a constant tension of approximately 20 pounds (9 kg) to be maintained during the expansion and compression experienced by the young whales during diving and resurfacing behavior.

Polyurethane flotation with a hard, fiberglass shell was also fabricated to the necessary volume and configuration for these harnesses.
1.3 RELEASE MECHANISM

Extensive laboratory testing of magnesium corrosible release bolts produced uncertain results and ocean tests were deemed necessary. These latter tests showed performance which appears reliable for periods up to one week and less reliable, but useful for up to two weeks.

We were thus able to design bolts with appropriate diameters for use in the field studies. A variety of bolts were fabricated to provide a range of release times. Specific bolts used in the field were to be selected from this supply.

1.4 TRACKING TRANSMITTER

An extensive survey of commercially available radio tracking units was carried out. It was finally decided to use the Model PT-219 radio tracking transmitter manufactured by the Ocean Applied Research, Inc. of San Diego.

The PT-219 transmitter is characterized by the following improvements: it has a greater transmission range than previously available, it mounts a specially flexible transmitting antenna considered to be highly desirable for our purposes and utilizes the newly available lithium fluoride batteries to provide necessary transmitter power and long life.

The unit works well and is compatible with the ADF 210 gear also made by OAR, Inc. This latter equipment will be used in the field work to track all animal packages and expansible harnesses.

1.5 XENON FLASHER

The addition of Xenon flashers to the harnesses was considered a usefully redundant location method—particularly because of possible damage to the tracking transmitter through the whale’s activity.

General Oceans, Inc. of Florida, undertook the production of a flasher for our purposes. The resultant device was however, too large and heavy and, in our judgement, could have caused the floating harness
(after release from the animal) to become hydrodynamically unstable.
In addition, we were concerned that their concentrated mass might introduce a behavioral aberration in the whale's general activity.

With certain redesign and modification these units may be useful in the future.
2. INSTRUMENTATION

2.1 COMPLETION OF UNITS FOR USE IN THE FIELD

2.1.1 The Subminiature Recorder

Two recorders were completed and tested exhaustively for tape drive capability and recording and playback.

Recorder (Serial No. 2) was stepped through more than 300,000 increments and numerous records were made of the 40,960 word test pattern. These were played back and evaluated by visualization via the laboratory oscilloscope.

Recorder (Serial No. 3) was stepped through more than 2,900,000 increments and was similarly evaluated for record and playback capability. These recorders now appear as in Figure 2-1.

Then both units were loaded with approximately 210 feet (64 m) of 1/4 mil, polarized tape for use in the field. Prior to loading, all heads were cleaned and tape snubbers reset. As a final check, at least one test pattern (40,960 words) was recorded on each recorder and played back for visual analysis.

2.1.2 Sensors

2.1.2.1 Temperature Sensor

These units were electrically connected to the circuitry and zero balance rechecked prior to closing the units.

2.1.2.2 Pressure Sensor

Same as 2.1.2.1
Figure 2-1. Microminiature Recorder—Top View
2.3 ELECTRONICS

All testing of the electronics circuit boards was completed and the supporting metal structure to hold the boards was also completed. The complete instrument package was then assembled including the recorder, electronics and battery supply. See Figures 2-2 and 2-3.

It will be noted from the Figures that the package becomes a single, integral unit with the exception of the transducers which are necessarily mounted on the pod casing.

Figure 2-2 shows clearly the aperture through which both the power and test switches are accessible as well as the red filter behind which the Test LED is located.

The total instrument package fits precisely into a polyurethane foam receptacle shown in Figure 2-4. This Figure is a photograph of the underside of the pod. Figure 2-5 shows the instrument package inserted into the foam-filled pod. In this latter Figure, a thin metallic cover has been emplaced over the test and power switch aperture to prevent intrusion of the thin foam (pre-cut) blanket, which normally is inserted between the instrument package and baseplate.

Both pod enclosures were sprayed with Emerson and Cuming shielding material Type ES; notes offering a reward for return of the pods (English and Spanish) were attached to the surface and the entire surface then was covered with a polymer gel coat. The only exception was at the lip of the cover where electrical connection was to be made to the baseplate. Figures 2-6 and 2-7 show the pod mounted on the baseplate. In Figure 2-7 the bonding lead from pod to baseplate can be seen clearly.

2.3.1 Testing

Both field units were powered up and key circuits and functions tested via the LED procedure which was detailed in our Report No. P-C3748.

Both units performed satisfactorily. Power was shut down and the instrumented pods were fastened to their respective baseplates with stainless nuts and bolts (thumb tight only).
Figure 2-2. Pod Instrument Assembly—Top View
Figure 2-3. Pod Instrument Assembly—Bottom View
Figure 2-4. Pod—Internal Foam Padding
Figure 2-5. Pod—With Instrument Assembly In Place
Figure 2-6. Pod Assembled to Baseplate—Rear View
Figure 2-7. Pod Assembled to Baseplate—Leading Edge
2.3.2 Instrument Transport Packs

Two special boxes were designed and fabricated in which to transport the whale pods, miscellaneous tools, spare parts and the like. Each pod was multiply-wrapped in bubble plastic so that mechanical shock would not be transmitted to it. Packages were then screwed shut.
3. FIELD PREPARATIONS

Field preparations proceeded rapidly at both UCSC and FIRL after 1 December 1973. Considerable communication on this effort took place between the two parts of the team, and coordination of all matters which we could control directly was excellent.

3.1 PERMITS

Applications for permission to capture juvenile Gray Whales had been filed well in advance with both the United States' and Mexican Governments. However, for reasons beyond our control, immediate action was substantially delayed.

The permit from the Government of Mexico was approved the week prior to the departure for the field (approval received during the week of Jan. 14, 1974). The necessary approval from the U.S. Government was received by telephone notification after our party had already reached our operations base in Mexico.

3.2 CAPTURE BOAT CHARTER

A final contract was negotiated with Swordfish Inc. to charter their 45 foot fishing vessel Louson, Timothy Koushar, Captain.

The charter cost for whale capture and tracking included the vessel, captain (who has previous experience in marine mammal capture) and a crew of three. Also included in the charter arrangements was an added rider to the extant vessel insurance coverage to bring the overall policy up to standard charter requirements of the University of California—which includes protection from vessel grounding or loss.
3.3 FIELD EQUIPMENT

3.3.1 Food, Supplies, Boat Gear

All field equipment, capture gear, assembled harnesses, water barrels and stocked food containers were consolidated at Santa Cruz and shipped to San Diego which was the departure point for the vessel *Louson*. Food supplies for the expedition were procured in San Diego and stowed with the field gear aboard the *Louson*.

While in San Diego, the ADF equipment to be used in the field was reconditioned and adjusted at the factory.

3.3.2 Instrument Pod Gear

Special carrying containers were fabricated for the two instrument pods. The design was such that the units fit under commercial aircraft seats which meant that they could be carried aboard by member of the party.

Arrangements were made to by-pass normal airport X-ray and magnetometer checks because of potential damage to our gear.
4. TRAVEL ARRANGEMENTS

Travel arrangements were coordinated through the UCSC group. The main scientific party met at San Francisco (from Santa Cruz and Philadelphia) and then proceeded to La Paz, Mexico. The following day, they continued on to Lopez Mateos by bus.

José Castello was kind enough to provide the party with a fisheries' school bus from Villa Constitucion to Lopez Mateos. This gracious gesture made our last lap remarkably easier and more comfortable.

The remainder of the total party arrived by car and boat for a rendezvous at Lopez Mateos on 25 January.

No difficulty was experienced in by-passing the X-ray checks at the airlines by the group from FIRL. This was essential because of the fear that the pulsed X-rays might damage the CMOS integrated circuits in the instrument pods. Excellent arrangements were made for us with United Airlines and Hughes Air West by Mr. David Moore, FIRL Security and Mr. Paul Sebesta of Ames (ARC), NASA.

The only untoward event which occurred in this regard was when a helpful Air West personnel carried Instrument Pod A through a magnetometer before we could stop him. Our concern was over the fact that our data-tape recorder uses pre-polarized tape which could conceivably be erased.
5. PRELIMINARY FIELD REPORT

The objectives of this year's Gray Whale instrumentation and tracking effort were sixfold:

a. To gain additional experience in the capture and handling of young whales and in fitting them with harnesses and instrument packages.

b. To test new instruments and housings in the marine environment when mounted on a whale.

c. To learn more of the factors which lead to harness abrasion and to check the animal for possible chafing from the harness.

d. To measure the total volumes and respiration profiles in young Gray Whales.

e. To carry out a short sea track from which to gain experience with the logistics necessary to such an effort.

f. To study the distribution, numbers and behavior of whales in the channels of Boca de Soledad and northern Magdelena Bay, Mexico.

Most of the objectives were attained although under difficult circumstances. The abrasion and chafing studies were incomplete and no sea track was carried out due to the loss of our collecting vessel Louson.

5.1 CAPTURE AND HANDLING OF YOUNG WHALES

During the first capture a young whale was lost. This was due to a malfunction of the capture gear which resulted in a line being attached only to the tail instead of both head and tail. An autopsy was performed and the entire procedure immediately reviewed. Procedural changes in technique were incorporated to minimize the possibility for recurrence of such an accident. In addition, all capture operations were halted until proper authorities were notified of the circumstances and occurrence. No further capture activity was carried out until permission was received to proceed five days later (See Appendix for log of Field Activities for 27 Jan. 1974).
Three additional captures were made subsequent to receipt of permission to proceed. Two resulted in the placement of harnesses and instrument pods with subsequent tracks and one was released when the mother animal was not seen for a time during the capture. With regard to this latter animal, it was felt that the additional time required to take the animal ashore, attach a harness and release it might increase the difficulty of reunion between mother and young. Hence the juvenile was released and seen to rejoin its mother.

Before these captures were carried out an unmarked juvenile was noted alone in the shallows along the sand dune coast near the fishing village of Lopez Mateos. It was examined, acoustical recordings attempted of heartbeat, physical measurements taken—including the crucial one of chest expansion during breathing, a measurement needed for harness design. A series of measurements of breathing profiles were made using a specially constructed instrument designed to be held in place over the blowhole. The very high rate of expiration of 200 l/s was obtained. The animal was then directed into deeper water and is presumed to have reunited with its mother since it was not seen again in the restricted confines of the channel system around Lopez Mateos.

The young animal that was released (see above) associated itself, for a time, with the collecting vessel Louson and it was only with some difficulty that the vessel was able to move away from it. This and other events will be described more fully below.

5.2 INSTRUMENTS AND HOUSING TESTS

Both instrument pods were powered up, taken through the built-in-LED-indicated checkout procedure and then sealed with double vellumoid gaskets coated with Permatex No. 2 sealant. The pods were attached to stainless steel baseplates as part of the sealing procedure.

On completion of sealing, the pod baseplates were then attached to the harness baseplates with four 1/4/20 bolts. The complete harness package consisted then of an instrument pod, a tracking transmitter and a protective flotation casting. The two completed units were named KNUTE
and PATTI respectively. Both the instrument pods and the flotation castings were marked in both English and Spanish with identification information so that retrieval of the units from persons other than our own party would be enhanced. In this latter regard, we learned that even when markings were covered with a fiberglass gel coat, it was not sufficient to prevent the abrasive action of water-carried sand from grinding through. Future packages will be marked by deep engraving on the stainless steel baseplate to ensure its longevity.

The first instrumented harness (KNUTE) was fitted with a 4-day corrosible release bolt. It floated off the animal on 5 February and was recovered by a beach party searching for it on 6 February (the day after the loss of the Louson). On return of this unit the sealed pod was removed from the harness baseplate and the recorder-stepper-drive "click" could be heard through the fiberglass enclosure so that we knew it was still operational. It was not until the night of 7 February in La Paz that we opened the unit, shut off the power and determined that it had retained its seal. Visual inspection seems to indicate normal function. The unit was returned to FIRL on 9 February.

With regard to the second pod (PATTI), it is presumed that it came free of its host sometime around 9—10 February. However, since the animal was in the Pacific and we no longer had either a ship or ADF gear it was beyond our capability to retrieve the package. We can only hope that the notices of "reward, etc." stay legible on the package and that some fisherman will find it and return it to us.

5.3 HARNESS ABRASION AND CHAFING

These tests were not completed. It was originally planned to recapture one of the harnessed whales (No. 2) prior to automatic harness release and to examine the animal for chafing. The loss of the collection vessel precluded this effort.

The information retrieved in this area was obtained from inspection of a jettisoned harness and instrument pack (KNUTE) recovered at the mouth of Boca de Soledad. The modified harness design, planned to
correct for abrasions noted on harnesses used in the first year's tests, appeared to function well since no abrasion was noted. No visual evidence of chafing or other related problems were noted from our shipboard observations of the harnessed animals moving freely in the inland channels. The harnesses did not appear to vibrate or flap in the water as the whale swam and they seemed firmly in place over the pectoral fins at all times. No lateral slippage was noted.

5.4 RESPIRATION MEASUREMENTS

Two sets of quantitative measurements of the sequence, rate and volume of inhalation and exhalation were made. These represent the best such data from whales to date.

One long series of measurements, as mentioned above, were taken from the young whale found partially stranded on the lagoon beach. Another shorter set of measurements was made from the second animal to be harnessed.

Photographic observations of respiration were made which show that most exhalations start while the blowhole is still under water and that a considerable part of the "spout" is undoubtedly sea water.

5.5 SEA TRACK

The loss of the chartered collection vessel Louson at the entrance to the lagoon made it impossible to carry out our plans for a two week sea track. We plan to attempt to test tracking systems during the year—using porpoises since whales will be absent.

5.6 DISTRIBUTION, NUMBERS AND BEHAVIOR OF WHALES AT LOPEZ MATEOS

A census was made of whales, porpoises and sea lions within the inland waters near Lopez Mateos. We also made a cursory survey of their occurrence near San Carlos in upper Magdalena Bay.

Two hundred and five whales, thirty-one bottlenose porpoises and two California sea lions were counted in the Lopez Mateos area. Whale
pairs were found to be abundant in upper Magdalena Bay though no count was attempted. Whales proved to be scattered rather uniformly in the channel at Lopez Mateos, mostly in mother-young pairs; a few smaller lone animals, assumed to be males, were seen and some three-whale groups were noted.

Mating was observed in the lagoon entrance (Boca Soledad) and two chases were noted inside the lagoon in which pairs of adults raced in the channel, or thrashed in remarkably shallow water. In one instance such a chasing pair was accompanied by a newborn young (assumed to be the calf of one of the adults) which seemed able to keep up with the adults even though the chase was rapid.

It is suspected however, that abandoned young so commonly seen in these lagoons—especially Scammon's to the north—may result from such events in areas of complex tidal channels. The Lopez Mateos region is a single, simple channel which occasionally broadens into somewhat larger bays, but no complexity such as exists at Scammon's is to be found. At Lopez Mateos we believe that abandoned young have an excellent chance of recontacting their mothers when such chases are over.

Defensive reactions of mother-young pairs were observed and studied. They seem stereotyped and composed of simple behavioral components: (a) lifting of the young animal by the mother or by pairs of adults; (b) tail thrashing; (c) incidental (perhaps) pressure of adult against young; and (d) evasive swimming and diving maneuvers. Even though capture places the vessel close to mother-young pairs with a man suspended about ten feet over the pair (he is on the bow pulpit), no attempt was made by the adult to direct an attack at either the man or the boat.

Thigmotaxis, the tendency of an organism to contact with a surface, appears to be a dominant feature in the behavior of the young animals. They constantly rub, or press against attending adults, sliding this way and that over the swimming animal (possibly with the aid of the adult) and when separated from an adult, seem to seek another surface to satisfy this behavioral need. In one instance, a juvenile assumed
a position alongside the collecting vessel, pressing against it and making what appeared to be attempts to nurse at various points along its length (at overboard discharges, rudder, etc.). We are even led to consider that the persistent behavior of abandoned young to beach themselves is a related phenomenon. In the case observed, the juvenile sought contact with a beach and persistently returned to it even though repeatedly pushed into deeper water.

5.7 BRIEF FIELD CHRONOLOGY

Jan. 24  Scientific party arrived at La Paz after receiving preliminary permit from the Marine Mammal Commission; R. Gentry and G. Kooyman arrived at Lopez Mateos by car.

Jan. 25  Took bus to Villa Constitucion and received final permission from the Marine Mammal Commission by phone there; arrived in Lopez Mateos in the late afternoon and located ourselves near the fish cannery's laboratory; prepared radio gear in the evening.

Jan. 26  Set up and tested radio tracking gear on Louson; extensive discussion in the evening about duties, procedures, and responsibilities during capture and harnessing scheduled for the following day.

Jan. 27  Set to capture and harness two whales, but first animal died during capture; shock, autopsy, and official report.

Jan. 28  K. Norris and R. Goodman made official accident reports by phone from V. Constitucion to all appropriate authorities; those remaining in Lopez Mateos worked at photography and hydrophone recordings in the lagoon; evening meeting and preliminary recording analysis.

Jan. 29  One group of the party walked the beach from Boca de Soledad to Lopez Mateos in search of skeletal parts—found *Mesoplodon* skull; the rest of the party did a census of the whales in the lagoon; awaited word from the Marine Mammal Commission concerning continuance.

Jan. 30  Excellent early morning photography; found stranded calf and took measurements and measured respiration with G. Kooyman's flow meter.

Jan. 31  Received permission to proceed with captures; captured large calf and successfully placed instrumented pack "Knute" and harness on animal No. 1; no respiration tests were taken on this animal; 24 hour ADF tracks maintained.
Feb. 1  8 chases, but no whales captured; broke line on whale with two adults; last whale noosed fouled the propeller with the capture line.

Feb. 2  K. Norris left for the States; successfully captured, harnessed with instrumented harness, and released animal No. 2; respiration data was collected by G. Kooyman; relocated animal No. 1 near devil's bend (ADF & visual).

Feb. 3  Animal No. 2 went out through the Boca during the early morning; took Louson to Colina Coyote and put a party ashore to locate the animal on the ocean side with a hand-held RDF; photographed animal No. 1 with the pack in place and then tracked him north to the Boca; it went south inside the lagoon during the night watch.

Feb. 4  Propeller fouled as we left anchorage; found animal No. 1 south of the cannery and followed him north to the Boca where we observed the remainder of the day.

Feb. 5  Hobbs and Fleischer observing behavior from sandhill south of Colina Coyote; "Knute" harness released in the morning and Louson was abandoned at 1830 and went down with the tide; K. Norris was notified by 'phone of the accident.

Feb. 6  Found radio pack "Knute" on the beach 4 miles north of the Boca in excellent condition; Captain Housher and crew went to San Carlos to report the boat sinking and then on to La Paz.

Feb. 7  Remainder of party departed for meetings with K. Norris and D. Winter in La Paz.

Feb. 8  K. Norris, D. Winter and R. Gentry returned to Lopez Mateos for an on-site inspection; others left for their home laboratories.

Feb. 9  D. Winter and K. Norris reviewed capture techniques and sites and then returned to La Paz in the evening.
6. POST EXPEDITION ACTIVITY

6.1 BEHAVIORAL STUDY DATA

Behavioral information was obtained by direct observation, by ciné photography and by still photography. In the latter instance, a motor-drive attachment was used so that sequential records were obtained of features such as respiration, swimming patterns, harness and instrument pack placement and effects, capture, strandings, thigmotaxis and association patterns and distribution of whales in the lagoon.

6.1.1 Observational Data

The vessel *Louson* was an excellent platform from which to carry out observations. Use of the crow's nest—some 30 feet above water level—permitted observers to look or photograph downward on nearby animals. By careful handling of the ship, animals engaged in activities of interest could be brought very close aboard. In this way, complete sequences of swimming and respiratory behavior were obtained. This same vantage point was useful for observing the effects of the harness and instrument pack upon the mother-young pairs.

Counts of respirations versus time of mother-young pairs were made prior to, during and after capture from the *Louson*. In this manner, a baseline was obtained against which any aberrations caused by harnessing could be noted. None were observed. Respiration, like that of all whales is irregular, consisting of breaths taken rapidly at the surface as the animal arcs upward and descends below the surface again. Breath-holding is predominant and of variable interval. Normally, in undisturbed animals engaged in swimming, dives varied from 10 seconds to about 2 minutes in length—and tended to be bunched. That is, a series of breaths separated by short dives was typically followed by one or two (deeper)
longer dives which were then followed by another series of shorter breaths. Once pursuit and capture were begun, dives became shorter and the tendency for bunching lessened. When the tail line and head net were in place, the animal spent most of the time at the surface with blows still occurring irregularly, but rapidly—varying from a few to about 45 seconds in interval. When the captured juvenile was returned to its mother and thereafter undisturbed, the respiration patterns returned to a format indistinguishable from those observed on undisturbed animals.

Most of the activity of young whales in the company of mothers (when undisturbed) seems to be in maintaining contact of body or snout against the mother, in nursing and in short sorties away from the parent. During the census taking effort, six young whales were observed for which no accompanying adult could be seen. Often adults stayed below the nearby opaque water for longer periods than the young so we presume they may have been nearby. Nonetheless, the young do move some distance from the adults as a matter of course. As previously mentioned, truly abandoned young have also been noted and likely result from male-female chases in which the young animal is simply not able to keep up.

An attempt was made to plan for more detailed observations of undisturbed whales in subsequent years. A site was located at a large sandhill, called Colina Coyote, on which an observer can occupy the top of a 75 foot high sand bluff that falls off directly into the channel occupied by numbers of whale pairs. The channel is deep enough close to shore so that an observer can look almost directly down into the water and whale pairs—and their behavior—should be clearly visible. A camp is planned at this site next season so that two weeks can be spent (prior to capture) observing whale behavior in the lagoon. We hope these continuous observations will provide a more realistic baseline for natural behavior and its meaning than we now have.

The two successful harnessings resulted in radio tracking data containing some new information. The first animal was harnessed on 31 January 1974. It was netted, using a headline only; and beached at the north end of "Big Bay" somewhat to the north of Colina Coyote. It proved
to be a male, 560 cm in total length. It was harnessed about 35 minutes after being beached and released to the waiting mother. The pair proceeded north up the channel and then circled around and moved back down toward Colina Coyote where they stayed for three days. On the afternoon of 3 February, *Louson* tracked the pair from Colina Coyote north to Boca de Soledad. During the night of 3 February, the animals passed *Louson* (anchored at Lopez Mateos) heading south. The pair turned again, going to the Boca the following day and this time staying in the vicinity of Boca de Soledad. On the morning of 5 February, the *Louson* moved in pursuit of the pair. The harness was jettisoned from the young whale at about 0900 on that day. It was recovered from the beach, four miles north of the lagoon entrance, on 6 February.

The movements of this animal pair were reminiscent of the intention movements of birds, which point and move in the direction they will follow during migration, but prior to movement. It will be interesting to see if future animals exhibit such movements.

The second animal to be harnessed was caught on 2 February at 1450. It proved to be a very large, young female, 578 cm in total length. That same night, it moved past the anchored *Louson* out of the lagoon entrance and southward along the outer side of the sand bar barrier between the lagoon and the sea. It was tracked across the dunes as far as Colina Coyote. A shore party, with a hand-held RDF went ashore on the dunes and crossed to the Pacific side. From a position about 6 meters above sea level, the tracking signal came in over an angle of about 270°±20 true. Using 8 power binoculars an attempt was made to correlate whale blows with signal occurrence. This was carried out in a slow sweep over a 40 minute period. No correlation could be made and we assumed that PATTI was at least beyond binocular resolution range. The horizon, with an observer 20 feet above sea level, is at about 5 miles. The party returned to the *Louson* and signals were subsequently lost. We presume that the harness and pod are lost since the release bolt was set to go at eight days. The entrance channel of Boca de Soledad out of which these animals passed, turns southward so this direction of initial movement was to be expected. Whales leaving and entering the lagoon were
seen to stay close to the edges of the tidal channel that transects the entrance sand bar. Thus, their normal course becomes southward prior to reaching the open sea. However, the continuance of this pair southward, at least to Colina Coyote (15 miles to the south from the Boca) was unexpected. Because of these varying observations, behavior of whales about to make the long swim north holds much interest.

6.1.2 Ciné Photography

Complete records of capture, beaching, harnessing and releases were made. Records of the behavior of whale pairs subsequent to harnessing were also made. Two full sets of films were made; one by Thomas Dohl of UCSC and the other by José Castello of the Dirección General de Educación en Ciencias y Tecnología de Mar. These are presently being edited to produce a comprehensive film of the research effort and of natural behavior of whales in the lagoon at Lopez Mateos.

6.1.3 Still Photography

All aspects of the expedition were photographed including capture, harnessing, natural behavior, respiratory experiments, personnel, the local scene, the autopsy, equipment and its preparation and certain other subjects such as the skull of a rare beaked whale (Mesoplodon) found by a beach party. This photo will allow identification of the rare find; the skull was lost with the Louson.

6.2 REVIEW OF CAPTURE TECHNIQUE

The first year's flawless capture performance was not duplicated in this year's effort—largely due to some small and seemingly innocuous changes in gear. Difficulty was experienced—in certain parts of the operation, but was ultimately corrected in the field to allow two successful captures to be made.

Capture is achieved by following a whale pair with the capture vessel, with a man stationed in the pulpit about 35 feet out from the bow. This
man wields a capture noose and net. First, as the vessel brings him up upon a pair of animals and the attending speedboat distracts them, he waits for them to surface beneath the pulpit. He then places a noose of line over the young animal's head. This line is designed to slip back to the tail stock and cinch tight there. The line in contact with the animal is a soft braided line to minimize abrasion to the animal. Then the young animal is allowed to run free a short distance from the vessel while another hoop with a head net attached is brought to the man on the pulpit. The ship is then positioned closer and closer to the animal and finally the pulpit is again over it. Then the head net is placed, both head and tail lines taken ashore and the animal beached in shallow water.

We found two flaws in the procedure when it was compared to what occurred on the first expedition. First, the tail noose was mounted (this time) in a strong stainless steel hoop instead of an aluminum one. The noose is held to the hoop by ties of fine, weak twine designed to break loose under the stress of capture. The effect of the change in materials was that the stainless hoop resisted bending as it circled the animal and the tail line was scraped free at about the point of the pectoral fins. Because of the pliable skin of the young whale, the line sometimes cinched tight there and would not slip to the tail. This meant that the animal was held only at mid-body and subsequent placement of the head net was impeded because the "tail line," now under the placed head net, had the effect of loosening and causing it to be thrown off. The problem was solved by spreading the stainless hoop until it was considerably larger than the girth of the young whale; subsequent placements were uneventful in this regard. The second problem was in the use of a head net that proved some inches too shallow. When placed over the animal's head it failed to pass the pectoral fins and hence, sometimes failed to lock in place and slip off forward. This was solved by construction, on shipboard, of a deeper net. The head net is not designed to "hold" the animal by itself, but merely to place a noose at the proper level of the animal's body. A result of these problems was that on the first capture the head net fell free as the animal was being brought onto the beach. The animal had taken out considerable line and was far off the
beach when this happened and hence difficult for the shore party to see in detail. This meant that the animal was being towed ashore by the tail. Old porpoise capture techniques, using a "tail grabber" have been used in various places, especially in Florida, but have been notorious for causing occasional "drownings" of animals. The animal struggles against a force pulling its tail upward and hence its head is caused to dip, making breathing difficult. Unless this is being watched for, death can result.

Another problem in the beaching operation was inadequate communication from ship to shore. Even though the problem with the first capture was noted instants after the head net fell free, the crew ashore did not understand what had happened until a man could be sent from the ship to inform them. By that time it was too late and the animal could not be revived in spite of heroic efforts to do so. Correction of this problem was accomplished by establishing radio communication between two assigned individuals—one on the boat and one ashore.

Problems also occurred because most members were assigned two or more tasks to perform and when difficulty occurred, some tasks were abandoned in favor of others.

We also faced the problem of adoption of the ship by young whales. Concern was felt for these animals as the ship attempted to maneuver away because of danger to the animal from the screw. While no such injuries occurred, steps must be taken to preclude them. Also, any vessel moving in the nursery area is a similar potential hazard.

A final problem was presented by the characteristics of the mouth of the lagoon. The entrance is treacherous. Because it is narrow, currents are swift and the channel is unmarked. Tidal changes make this an even more difficult situation.

Consideration of these problems has suggested the following changes for future field plans:

1. The use of a tail line appears to be unnecessary as has been shown by the many captures of whales at sea using only a head net and by the capture of animal No. 2 on this expedition. Since the tail line has been demonstrated to introduce a hazard we
recommend the use of a head net only. The head net, placed as it is, just posterior to the pectoral fins, pulls the animal sideways and upward; it is always possible for the animal to breathe.

To compensate for the loss of one line, additional men will be placed on the remaining line and a gasoline-operated net gurdy provided as a source of additional power.

2. Communication between ship and shore was markedly improved by using citizens' band radio. However, all communication aspects of future expeditions will be further reviewed and steps taken to assure coverage of both situations and personnel.

3. Organizational changes will be made in expedition operation. It is planned to assign specific tasks to the scientific crew; timing of respiration to two members, measurements of body and changes in diameter with breathing to another pair, a harnessing team of three people will be designated, the veterinarian will monitor the well-being of the animal and a photographer will operate without disturbance. In addition, a shore coordinator will see to it that various functions are carried out.

4. The site of operations will be moved to the region of San Carlos, Upper Magdalena Bay. This is also the site of the Baja-California Fisheries School. José Castello, a member of the central administration for this group (located in Mexico City) has suggested that we may be able to involve students from the school in our operations. We feel they could provide manpower for beaching the whale thus leaving the scientific crew free to carry out its duties.

5. To avoid injuring whales in proximity to the collecting vessel, we plan to equip it with a basket over the screw and to similarly outfit skiffs we may use. We feel this source of danger so serious to the whales that a requirement for safety baskets on ship and boat screws should be made on all vessels entering the nursery area.

6. The problem of passage out of Boca de Soledad will be avoided by shifting operation to Upper Magdalena Bay in the vicinity of San Carlos. Many whales were seen on our reconnaissance of the area and mangrove flats are available for beachings. The channel to the sea is deep and miles wide. These factors combined with access to the fisheries school make this an attractive alternative.

6.3 REVIEW OF SAFETY PROTOCOLS

While most safety protocols in past work seem adequate there are certain changes that will be made in future work. In the past, the number of people placed aboard the collecting vessel has been large and they have
had to remain in areas where they would not interfere with the activities of the crew. More freedom of action is deemed both necessary and desirable for those performing functions vital to the collecting operation. The remaining members of the team may be deployed by skiff some distance from the collecting vessel awaiting the netting of an animal. Only key personnel will be permitted on board: the party chief, the photographer, the instrument personnel, logistics personnel and those concerned with obtaining and recording respiration and behavior data.

Though none have been needed to date certain basic equipment will be placed in all small powered boats in future work. These items include: oars, first aid supplies, flashlight, flares and a walkie-talkie.

Communication call-in arrangements will be established for all groups which may leave the main group in the course of their work and related channels will be monitored.

A check-off list of safety precautions for both the vessel and shore operations will be prepared.

6.4 MAGNETIC TAPE DATA

Work is under way to link the subminiature recorder to the PACER-100 computer. A disk file and magnetic tape input-output system for the PACER is expected by 15 April, 1974 and it will be tied in to the computer on delivery.

While awaiting the computer peripheral gear we are attempting to debug the linking amplifiers to the computer. This work is progressing slowly.

Although a final decision has not yet been made, it is likely that we will print a duplicate of the data on the pod tape. To date, that tape has not been run and will not be until the decision to copy it has been made.
Appendix

LOG OF FIELD ACTIVITIES OF 27 JANUARY 1974
At 10:15 on the morning of January 27, 1974 a mother-young pair of California Gray whales was sighted off "Zum Shell Mound", south of Lopes Mateos, Baja California, Sur, Mexico. The young animal was judged to be about 14 feet long and suitable for expandable harness test which would be carried out wholly within the lagoon. The pair was followed at a distance of approximately 150 yards in order to check respiration cycles. Timings were made of dives and a count taken of blows. These usually consisted of two or three blows in rapid succession (3-10 seconds apart) followed by a dive which often exceeded 8 minutes in duration.

After about 30 minutes of observation it was decided to attempt capture. Accordingly capture gear was rigged and pursuit begun. The speed boat was lowered to assist in herding the whales toward the pulpit area on the bow plank of the collecting vessel Louvon. In rather short order, the first loop was placed on the animal's tail at 11:14 AM. The pair swam off together, now staying more consistently at the surface. The young was allowed to swim on a nearly slack line for approximately 22 minutes in order to bring it close to shore and to tire it gradually. It was then brought again under the pulpit and the head net was quickly put in place. The animal then went off, tethered head and tail, as has proven a successful method in previous captures.

The line men went ashore and began to tow the young animal onto the beach, with the adult in
attendance, sometimes crossing back and forth over the lines. Shortly the captain noted that the head net was no longer in place but had slipped free. The head net serves the function of allowing the men ashore to pull on both head and tail simultaneously, thus breaking the normal swimming pattern of the animal and allowing it to be brought in quickly without disruption of normal respiration.

As soon as the slippage was noted a boat was sent ashore to notify the shore team. About this time this boat arrived the line crew noted a lessening of resistance from the captive. The animal was towed in as soon as it could be seen clearly it was decided that it was in trouble. Several members rushed out in waist deep water to the animal and found it lying quietly, sputtering, but regular respiration was absent.

It was taken quickly to shallow water and attended by Dr. Sigmund Rich, DVM, who found eye and skin reflexes absent and was unable to detect a heartbeat. Under his direction resuscitation efforts were initiated, first by mouth to mouth methods and shortly thereafter by use of a hand operated air pump. Periodic pressure was applied to the thoracic region by two members of the scientific crew to expell air. These efforts were continued for approximately 20 minutes when air was noted issuing from the angle of the mouth, indicating the air was no longer reaching the trachea but because of displacement of the arytenoid extension of the larynx which normally crosses the esophagus and allows breathing in whales and porpoises.
to reach the trachea during resuscitation by reaching down the throat, but this failed due to the small diameter of the esophagus and the long distance to the trachea. The animal was determined to be dead shortly thereafter, by Dr. Rich.

This is the first serious capture problem which has been encountered in efforts of this sort on young whales by us or by other investigators who have taken these animals during similar studies.

The principal investigators determined immediately the following course of action.

1) No further capture would be undertaken until consultation with both Mexican and American authorities.

2) A thorough autopsy would be performed to determine the cause of death, with samples and procedures to be examined performed by both Dr. Rich and a representative of the Mexican scientific community, if possible.

3) Appropriate authorities in the Mexican and US governments would be informed as soon as possible.
Today being Sunday no contacts can be made until tomorrow morning.

Since it is impossible to preserve the animal intact Dr Rich was requested to sample important organs for later pathologic examination. These are to be preserved in the ship's refrigerator.

On analysis of the occurrence described above it is clear that the occurrence can be avoided by use of a heavier head net or larger mesh (6") that will slip over the pectoral fins and prevent slippage. Such a net has been constructed by the Captain of the 

It will permit said completion of our scientific experiments.

We firmly believe that continuation of the gray and other species depends upon leaving their migration routes and hence numbers, upon which rational management must be based. The methods we are developing represent the only present effort to develop non-lethal means by which such data can be gathered. It is our fervent hope that the unfortunate accident which occurred today will not prejudice the continuance of these essential efforts, which will, we hope, extend to threatened species around the world.

The principal investigators speak for the entire scientific party and the crew of the 

Recently an international permit for the 

...
of 100 grey trout was issued for scientific studies to the National Marine Fisheries Service and this quota has not expired. It is hoped that this animal may be included in that quota, to which both the Mexican and American governments were signatories.

_Extra: It is essential to our effort to be allowed to continue within a week or so, for the following reasons:

1) The work can only be done in the Mexican lagoons and the animals will leave in a short time.

2) Data packs have been activated and sealed and must be used within one week or they will be expedited. These instruments represent a design this effort by the Franklin Institute of approximately two years duration.

3) The vessel _Lassen_ is on charter which cannot be extended and will have to leave if work cannot be completed within the time stated above.

We sincerely hope that our request to continue this important work can be submitted given quickly.
CONTINUATION OF TECHNIQUES DEVELOPMENT FOR
WHALE MIGRATION TRACKING

Period: 1 March 1974—31 May 1974

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K. S. Norris

Prepared for
National Aeronautics and Space Administration
Ames Research Center
and
National Oceanographic and Atmospheric Agency
Washington, D.C.
ABSTRACT

Status of effort at UCSC in the period is discussed. Work at FIRL is covered including data reduction, the subminiature recorder and initial efforts related to expendable transmitter circuitry design.
CREDITS

The authors were aided directly in the preparation of this report by L. Hobbs of UCSC and R. J. Gibson and E. Dougherty of FIRL.
INTRODUCTION

The period which this quarterly report covers has been spent primarily in working on data reduction and assessing problem areas uncovered by our experience in the field.
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1. WORK AT UNIVERSITY OF CALIFORNIA AT SANTA CRUZ

1.1 BEHAVIORAL PHOTOGRAPHIC DATA, CINÉ

A motion picture was put together from the film shot during the January-February field work. The film runs for about 20 minutes and records various aspects of behavioral data and capture techniques. It will be studied and reported on in the annual report.

1.2 BEHAVIORAL PHOTOGRAPHIC DATA, STILL

Analyses of these films will be made in correlation with field notes and reported in the annual report.

1.3 EQUIPMENT EVALUATION

Preliminary evaluation of the harness and associated gear recovered from the first instrumented animal shows remarkably little wear. Further comment on these will be reported later and will detail some design changes to avoid capture of sand which can reduce chances of gear recovery.
2. WORK AT FIRC

2.1 THE PACER 100 COMPUTER

The computer was fitted with peripheral input-output magnetic disc memory and drive plus magnetic tape capability. A number of initial debugging efforts was involved and has finally been completed.

It should now be possible to read the entire recovered recorder data (from whale pod) onto a disc for analysis.

In the interim while awaiting completion of the debugging effort, we have been sampling data from the tape and working out processing programs to preclude apparent errors caused by playback irregularities. As a matter of fact, these irregularities have led to certain redesign considerations appropriate for the subminiature recorder.

Original data on the tape were sampled at high frequency such that a number of computer bits was generated for each original bit. We then devised a program to condense the samples to obtain an approximately bit-to-bit correspondence. Teletype printout provided a binary-coded replica of the original data. Where drop-outs appeared, the time sequence could be used to fill in the gaps. A readout of 23 hours of continuous data (2 February 1974, 0245 to 3 February 1974, 0140) was completed. These data were fully corrected and comprised about 500 pages of data containing about 33,000 seven-bit words. The points were entirely translated, corrected and plotted. Dive data for this period are included in the Appendix to this brief report.

Over 250 dives were plotted and their occurrence times, within the total trip from onset: 1500, Jan. 31, 1974, were indicated within 1—2 minutes. Actual relative time and duration of each dive is known to within 5 seconds. Absolute time of day is known to within about 2 minutes.
Some statistical analyses of dive data are now under way and will be reported and commented on by both the biologists and physical scientists involved.

Most dive data seen so far are in the range of 8—12 feet (2.4—3.7 meters), the deepest being 29.3 feet (8.9 meters). We note parenthetically that the charts indicate the deepest channel depths to be on the order of 35 feet (10.7 meters). There were periods up to 40 minutes during which no dives were made. Recorded dives should be accurate to within a foot (.305 meters).

Apparently water mixing within the lagoon was relatively complete. Our temperature recordings show differences on the order of 0.5°F. (.22°C) with dives and mean temperatures of about 63°F. (17.2°C) Tidal currents in the lagoon reach velocities on the order of 5 knots and thus one can expect fairly complete mixing in the relatively constricted volume involved. The least count of our temperature/recorder system was 0.156°F. (.087°C)

2.1.1 Effort in the Next Period

We expect to transpose the entire pod-tape to a single disc memory unit, clean up irregularities in data and produce:

1. a compressed activity record vs. time for the full 4 day, 19 hour trip
2. a detailed temperature/pressure record showing dive profiles for the full trip
3. activity frequency distribution analyses
4. biological insights to the data.

2.2 THE SUBMINIATURE RECORDER

Detailed data analysis brought to light several areas for improvement in the recorder. These problems are primarily mechanical in nature and are correctable. The first deals with the fact that incremental stepping was non-uniform. This was known prior to the field trip and was not considered a detriment for our first operation. However, in long runs, it will be essential for accurate .001 inch (.025 mm) steps. The second
problem was more serious and showed up as tape skewing in the playback mode. It was not possible to check this prior to the expedition because of the compressed work-time scale and the fact that computer interface gear was not yet built.

Several approaches to correcting the difficulty were worked out and we decided to prototype them insofar as present budgeting would allow.

The tape drive was redesigned in such a manner that the tape is driven on the return stroke of the magnetic motor, rather than on the powered stroke. The advantages are several: the power stroke which produces a spring tensioning produces maximum force at the end of the stroke at the maximum spring tension; this maximum tension is then available at the beginning of the tape drive stroke where it is needed. Further, tape drive on the return stroke can be controlled very precisely and movements of .025 mm will be attained. In this configuration the tape motor is mounted horizontally rather than vertically to permit improved fixing by clamps. In this position, simple removal, if desired, is also achieved. Design effort on this part of the system is about 80% complete.

The recording heads are now rigidly mounted in dovetailed slides on a separate baseplate. This permits total removal and accurate replacement where necessary. It also permits simple micrometer, head adjustment for channel interlacing—a chore which in the past was painstaking at best. This effort is about 60% complete. Another attribute of this separate mounting arrangement allows for straightforward tape threading.

The capstan gear drive was redesigned to permit partial disassembly without requiring total disassembly. This arrangement simplifies adjustment. In addition, the capstan is now captured between two bridges instead of being hung from a single bridge. This effort has been completed.

The tape guidance system has been redesigned, but not yet built. Tape will now be guided across the heads by three static posts and the capstan will no longer double as a tape guide. These changes are expected to minimize skew.

2.3 Packaging marking

Because of the high sand content caused by fast tidal currents in the lagoon, wear on the outer pod surfaces is substantial. About five days of such exposure was almost sufficient to scour off the "reward"
notes on the outside of the package. These notes were mounted on the pod surface and covered with a gel coat.

In the future, critical markings and notations will be engraved on stainless steel plaque or the baseplate for permanence.
3. WORK AT AII SYSTEMS

3.1 THE EXPENDABLE TRANSMITTER CIRCUITRY

Work performed thus far has concentrated in the area of a high efficiency 401 MHz amplifier. Problems encountered have been with transistors capable of a 2-watt output with an 8-volt supply. The present design is a three-stage amplifier with the last stage operated in a Class C mode. The transistor presently being tested is a CTC B2-8Z type. Preliminary test results are encouraging.

Studies have been performed on crystal oscillator designs which would exhibit the required stability of one part in $10^8$ per fifteen-minute periods without the use of an oven. The most promising approach appears to be to use a high quality TCXO mounted to the outside wall of the transmitter. The wall of the transmitter will act as a constant temperature heat sink by dissipating the heat into the ocean.

3.1.1 Planned Tasks

Within the next six weeks a breadboard design and implementation of the transmitter will be completed. The breadboard model will be tested and evaluated. The transmitter will be designed to operate for 48 hours with a 2-watt output using lithium batteries for power. The duty cycle will be one second of transmission and 59 seconds off. During the one second of transmission, the format will be .36 second of CW, two 8-bit synchronization words, one 14-bit identification word and four 8-bit data words.
Appendix

DIVE DATA COVERING THE PERIOD FROM
2 FEB. 1974, 0245 HRS.
TO
3 FEB. 1974, 0140 HRS.

ORDINATE: 0.891 x depth number = feet
ABSCISSIA: 100 seconds/inch
(25 minutes across full sheet)
TECHNIQUES AND INSTRUMENTATION EFFORT FOR
WHALE MIGRATION TRACKING

May 1975

Prepared for

The National Aeronautics and Space Administration
Ames Research Center, California

NASA Contract No. NAS2-8013
1. DATA ANALYSIS

The instrument pod recovered from the juvenile gray whale sensed water pressure and water temperature each five seconds. The designed temperature sensing range was 55°F (12.8°C) to 75°F (23.9°C) with a least count of 0.16°F (.09°C). Temperature data is recorded in binary form with "zero" being 12.8°C and "127" being 23.9°C. In a similar manner, pressure is sensed over the range of 0 - 50 psi, referenced to atmospheric pressure. The system was usable to 60 psi. The least count was 0.39 psi or .89 feet (.305m).

Data taken each five seconds were accumulated on the magnetic tape of the subminiature recorder. In each five second period, from the initiation of the experiment, a data-group count (0 - 127), a water temperature and a water pressure were recorded. Thus, in an estimated recording period of 4 d 19 h, about 248,000 data were accumulated. Of these, there are about 83,000 each of temperature and pressure (depth).

The following sections describe the software developed to obtain the data from the tape, cleanup problems which originated because of tape skew in the recorder and the like. Further, the simple form of data presentation from the computer is described and a preliminary biological analysis of the data presented.

We note here that most of the problems which complicated the software effort, to date, are not expected to be encountered in the future. These occurred primarily because of certain mechanical design aspects of the recorder which became apparent as a result of this study — a situation created by the telescoped time-scale within which the effort was undertaken. Corrective measures are known and future recorders will be far easier to work with in this regard.
1.1 MANUAL DATA REDUCTION

In the early stages of the development of the software to permit data readout from the miniature recorder magnetic tape we obtained a numerical readout of approximately one day's data. (See Sample X-1, Figure 1-1). From this numerical readout exact timing information could be obtained. Since a pressure, temperature and data group count was recorded each five seconds exactly, and this was printed out in this type listing, the dives could be plotted with exact duration and relative timing. This was done and is shown in Sample X-2, Figure 1-2. In Sample X-1, Figure 1-1, the count can be seen progressing from 115 to 127, next count 0 and there through 15. Since a great deal of information was present in this printout, ambiguities if any, and missed bits, if any, could be corrected, interpreted or inserted without error.

Dives each had their characteristic shape and on later analog traces of the full experiment could be identified. The timing from Sample X-2, Figure 1-2 was used to calibrate the analog write-out (see Sample X-3, Figure 1-3) for time. Approximately 500 computer data pages of 3 columns of 29 lines each was manually interpreted and plotted. Sample X-1, Figure 1-1 shows part of page 79, all of page 80 and part of page 81. On page 80, counts 126 through 8 show a dive which lasted, from surface to surface, a time equal to 10 intervals of 5 seconds, or a duration of 50 seconds. The pressure count went to a maximum of 14. The conversion factor relating count to pressure and pressure to depth is 0.891 counts/foot. Hence, the maximum depth of dive was 0.891 x 14 equal to 12.47 feet. The constant 0.891 was determined by

\[ K = a \frac{P}{d} \text{ feet/count} \]

\[ p = \text{full scale pressure gage} = 50 \text{ psi} \]
\[ c = \text{full scale count} = 127 \text{ counts} \]
\[ d = \text{density sea water} = 63.63 \text{ lbs/ft}^3 \]
\[ a = \text{constant} = 144 \text{ in}^2/\text{ft}^2 \]

The dive on page 80 (Sample X-1, Figure 1-1) is the numbered dive D27 shown in graph #2, line 3 in Appendix of Quarterly Report Q-C3799-02. This is shown again in a small sample as Sample X-2, Figure 1-2.
Figure 1-1. Sample X-1
Data Sample X-2
Scale Horz. 1 div = 5 sec
Vert. 1 div = 0.891 Feet (1 count)

Figure 1-2.
Figure 1-3. Sample X-3C
The temperature varied very little and there was some difficulty in interpreting the temperature as the 2nd bit from the left (= 32) did not always appear when it should have. The 7th and 8th bits from the left are always the same and are the least significant bit (= 1). The temperature shown on page 80 is then read as 62.69°F (17.05°C) for 00100011 where the missing bit is inserted to give 01100011. This binary number then is read as 1 + 16 + 32 = 49 decimal. The temperature is determined from:

\[ T^\circ(F) = 55 + 0.157 C \]

Then

\[ T = 55 + 0.157 (49) = 50 + 7.69 \]

\[ = 62.69^\circ F (17.05^\circ C) \]

This changed to 1 count less during the dive giving 62.54°F (16.97°C). The other bits were considered reliable and since the 2^4 bit did not disappear, this is believed to be the true state of affairs. That is that the temperature was remarkably uniform at all depths. Tidal currents on the order of 5 knots contributed to this mixing as well as the animals' motion. In addition the ship's water thermometer observed over a period of several days varied less than 2 degrees F. (1.1°C)

1.2 COMPUTER DATA REDUCTION

1.2.1 Methods

Programs were written and debugged (see Section 1.3) to provide a signal suitable for digital-to-analog conversion. These data were then processed through a D/A converter and plotted at various speeds on a strip chart recorder.

Three time bases for the analog records were chosen: a slow speed (approximately 11 seconds real time/mm) to reveal fine detail in each dive and detail of dive intervals, a faster speed 5 times the slow speed (~55 sec. real time/mm) and very fast speed approximately 25 times the slow speed. The two "faster" records were made to allow a visual comparison of the dive density and to be able to see the complete track in a few feet of record. Calibration and discussion of these three analog records is discussed in the next section.
1.2.2 Results

Three analog records were produced where the time base is at three different speeds. These three speeds give the following real time bases of the track and may be used to compute the dive duration, dive intervals, etc.

\[
\begin{align*}
1 \text{ mm} &= 11.074 \text{ sec.} \\
1 \text{ mm} &= 55.37 \text{ sec.} \\
1 \text{ mm} &= 276.5 \text{ sec. (}4^{36.5}\text{)}
\end{align*}
\]

For all time bases:

- The temperature calibration starts at 55°F (12.8°C) and increases upwards by 0.47°F (.26°C) each mm.

- The pressure calibration starts at zero feet and increases downwards by 0.62 feet per mm.

- Because of the computer capacity limitation the total run was broken into four sections labeled W1 through W4. The start and end of each section is labeled and time at end of W1 is the time at beginning of W2, etc.

- W4 data is not useful.

- Portions of data at each of the three time bases are shown in Sample X-3a, b, c. Time in day, hours, minutes and seconds is given for the beginning of each "W" section and for a number of intervals throughout each section.

- The absolute local time of any point on the readout can be determined by adding to one of the marked times the product of the number of mm after that time, times the time-base for that particular chart. Any time on the chart is probably accurate to within two minutes from start time and is usually much better. Small time differences up to a few hours are probably accurate to a few seconds.

- Complete analog records have been made for both FIRL and UCSC for further analysis.

- Certain parts of the record contain erroneous output due to the computer readout. These are crossed out in red and should be disregarded; time continues through these sections, however.
The analog readout by the computer had its problems. Occasionally the computer would mistake a temperature, or a record number (not shown) for a dive depth or vice versa. Also because of skewing of the data on the tape, many of the dive profiles are not exact on the analog readout. The marked dives D1, D2, etc. were plotted by hand from a digital readout and corrections made for this skewing. The depths and contours and times on the manually reduced data are exact, probably 99% of the time. The analog data, however, is precise in its timing and separation of dives with the possible omission of a dive with about the same error.

For both temperature and pressure (depth) the values are digitized and should be smoothed. Pressure transducer response was instantaneous and so only sharp corners should be smoothed. Temperature response was on the order of 5 secs. and lags true temperature change by approximately this time.

The time of entrance into water and the time when whale started swimming are both estimated, but are believed to be accurate to within a few minutes. Time when whale was released set at Jan 31 15h 00m 00s.

Data on section W4 (starting Feb 4d 16h 50m 18s and thereafter) was not recoverable due to problems with tape and computer readout. This amounts to about the last 7 or 8 hours of data which was not recoverable depending on exactly when the harness released from the whale.

The dives from Feb 2d 02h 45m 00s on the hand-reduced (large scale) data are numbered. These same dives are numbered on the analog record (11.074 sec/min).

These records can be used for analyses involving total activity, periodicity of activity and the like. One the other hand, we believe, the set of manually reduced data, which are included in the Appendix to the joint Quarterly Report No. Q-C3700-02, are more representative of detailed dive activity including the dive profile itself.

1.3 COMPUTER SOFTWARE

Several computer programs were written on FTRL's PACER 100 computer to test and read data from the miniature data recorder. This section deals with the development and use of these programs.
1.3.1 Recorder Tests

The testing procedure included prerecording patterns on the tape via a specially designed pattern generator. The test patterns were such that they represented the worst-case conditions for the miniature recorder. For example, one pattern was alternating 1's and 0's. Two methods of evaluating the miniature recorder were used. One method involved oscilloscope viewing and the other the PACER 100 computer.

The first method simply used an oscilloscope to monitor the output channels of the miniature recorder. This provided information on the shape of the data pulses, duration, height, noise and the relative position of one channel to another. Based on the observations of this display, adjustments to the mechanics or electronics could be made.

The computer method read the 8 channels of prerecorded data into the computer. The computer, programmed to know what was prerecorded on the tape, was then able to count the number of errors and store up to 500 error words. At the end of the run the computer would print out the number of errors and, at the discretion of the user, would print out up to 500 of the erroneous data words.

The tests were expected to reveal that each channel would be played back with very little skewing and that each channel would be coincident with the other (as shown in Fig. 1-4).

It was expected that the time between pulses ($T_2$) and the pulse widths ($T_1$) would be constant. While $T_1$ and $T_2$ did prove to be acceptably consistent, skewing was much greater than anticipated. In fact, the skew was so great at times as to have bits of one data word overlap into the next data word (see Figure 1-5). Fortunately, the skew was fairly consistent so that once the skew pattern was established, it varied very slightly during the run and could therefore be corrected.

Because the expedition had to adhere to a tight time schedule, the mechanical cause of the skew was not corrected and thus the computer was programmed to compensate for the skew.
Figure 1-4. Expected Relative Position of Channels

Figure 1-5. Example of Extreme Skewing
1.3.2 Data Recovery Programs

The objectives of the programs to read the field data were to correct for skewing, separate the three types of data (time, temperature and pressure), store the data on disk and magnetic tape, plot the data vs. time on the strip chart recorder and perform statistical analysis on data (e.g. mean-time between dives). Except for the statistical analysis, all of the above were performed with reasonable success.

The statistical analysis was not undertaken because of lack of funds.

Three types of programs were written. The first type read the 8 channels of data from the recorder and transferred the data on the PACER's disk memory. The second type of program was used to display the data from the disk on a teletypewriter. The third type plotted the data in analog form on the strip chart recorder.

The programs to read the data from the miniature recorder were real-time, assembly language programs. Because the recorder plays back at high speed and is essentially free running, the programs could do very little processing other than read in the data. Therefore, no skewing corrections were attempted with these programs. Because of the skewing, the program sampled the tape outputs as shown in Figure 1-6. The sampling rate was such that at least two samples were taken during each data pulse. The program condensed the sampled data by performing a logical OR on groups of the samples and by writing the condensed samples into a buffer in the computer's memory (see Figure 1-7). Once the buffer was filled, the contents of the buffer were written on the disk. Because of finite time is required to write onto the disk and because the miniature recorder is free running, some samples were missed every time the buffer was filled. The time lost each time the buffer was filled was a small percentage of the total sampling time and did not significantly deteriorate the information content of the data. The lost samples were minimized by creating two buffers in the computer. Because the PACER has direct memory access, one buffer could read from the miniature recorder while the other was writing onto the disk. Another method of minimizing
Figure 1-6. Data vs. Sampling Rate
Figure 1-7. Condensing of Sampled Data
the importance of the lost data is to make the buffers as large as possible; this will reduce the number of data gaps. Through further programming refinements, the data gap can be completely eliminated.

The second type of program, printed out on the teletype the whale data as stored on the disk. Through observation of these data, methods were developed to correct for skew, to condense the data and to separate the three types of data. These methods were programmed, applied to the data on the disk and the results printed on the teletype.

After many iterations of this sort, final programs were written to plot the data on a strip chart recorder. These programs applied the algorithms developed earlier in the project. The programs read the raw data from the disk, corrected the skewing, condensed the samples and, through the computers digital to analog converters, supplied the analog signals to the strip chart recorder. One channel of the strip chart recorder displayed the temperature; the other channel displayed the pressure. The program displayed the pressure as a negative value to give the visual effect of a dive.

1.3.3 Summary

The computer software described in this section represents some 15 assembly language programs to test and retrieve data from the miniature tape recorder.

The development of the software was a larger effort than anticipated. The major reason for this was the necessity to correct for recorder skewing.

The software and experience gained under this project are expected to prove valuable in future efforts. Details of the various programs developed will be found in the Appendix to this report.

1.4 PRELIMINARY ANALYSIS OF DIVING DATA

Our original plan was to obtain data on diving rhythms and behavior from two sources: (1) from the five-second records of pressure acquired by the instrument pod harnessed to the animal and (2) from data observed on shipboard of the tracking transmitter signal originating on the animal.
Only the instrument pod record from the first animal, was recovered and available for analysis. The second animal, left the lagoon before it jettisoned its harness and the instrument pod is assumed lost. The tracking transmitter, mounted on the ventral part of the harness, transmits only when the antenna (a vertical whip) breaks the water and hence the received signal is available only when the animal is essentially surfaced. From such information, crude correlations between recorded pressure data and occurrence of transmitter signal should be possible. Unfortunately, the transmitter data were lost with the collecting vessel LOUSAN.

Animal No. 1 carried the instrument pod for over four days. The patterns of diving indicated from its taped records are of three kinds. First, very frequent shallow dives of 1 - 2 feet; second, extended periods when the young animal remained within a foot (approximately the least count of the sensing system) of the surface; and third, clusters of deep dives, many nearly as deep, or as deep as the bottom of the channels in the lagoon.

1.4.1 Shallow Dives

It is surmised that these frequent and strikingly uniform depth dives by the young animal represent swimming around its mother and may also relate to nursing activity. They seem to occur at all times of the day and their average frequency is 3.91 dives/hour. They are all short in duration, ranging from 5 to 55 seconds and with an average duration of 16 seconds. Nevertheless, there is a fluctuation in occurrence frequency noted with the periods of greatest frequency centered at early morning and mid-afternoon. Figure 1-8 illustrates this frequency distribution versus the 24-hour day.

From visual observations of mother - young pairs in the calving lagoons it was not common to identify behavior that is clearly nursing. Often, the young animal can be seen diving near its mother and sometimes is seen diving under her body. We can only guess that nursing may be occurring at these times. However, because of the rapid growth rate evidenced by the young whales, it is clear that considerable effective
Figure 1-8. Shallow Dives
nursing is occurring - and very likely during these dives around the mother. These observations provide some confidence that some of the recorded short dives, in the range indicated, represent nursing.

1.4.2 "Surface" Periods

The record recovered from the data pack carried by animal No. 1 contains many extended periods during which the dorsal surface of the young animal was within a foot of the water surface - showing up as data "zero" or "no dive". These periods are scattered throughout both day and night where the indications are that the animal stayed at or very close to the water surface. Simultaneously we note that the temperature record indicates no sharp changes such as those which might be anticipated were the data pack and its temperature transducer free of the water and subject to evaporative cooling. Since equipment analysis indicates no obvious malfunction, we can only assume that the animal swam in the surface layer during these periods.

While our visual observations of whale pairs indicate the young animals to be at the surface around the mother frequently, it is our impression that such behavior (where the dorsal area has actually broken the water surface) is generally of fairly short durations. Also, even though radio transmission records were lost, it is our impression that transmissions were always intermittent and never constant for more than a minute or two. One may deduce then, that the young animal typically submerges its dorsal surface with this frequency. It follows then, that only if the excursions between actual surfacings are spent in very shallow submergences can our two sets of observations be reconciled.

Figure 1-9 illustrates the occurrence and duration of these "surface" periods.

1.4.3 Deep Dives

Deep dives apparently occurred in bouts during each of which several dives generally would be taken. These often reached bottom, or near bottom. The deepest of these correspond closely to the depths shown on
Figure 1-9. Surface Periods Over 45 Minutes
our navigational charts for the area. Further, since the recorded dives do not exceed these chart depths, we have additional confidence in the validity of the recorded data. A histogram of dive depths is presented in Figure 1-10.

Dives ranged in duration from 15 seconds to $2^m 35^s$ and bouts of several dives range from $15^m$ to $6^h 5^m$. The dives appear only slightly related to time of day, being somewhat more frequent in the early morning, late afternoon and near midnight than at other times. The lowest frequency of occurrence is at 0400 hours. Figure 1-11 illustrates dive frequency versus time of day.

Diving bouts also show little correlation to time of day. However, there is more activity in the morning and around midnight than at other times, correlating somewhat with dive frequency. The diving bouts are given in Figure 1-12.

Other information available to us suggests that during migratory swimming, Gray Whales often dive near the bottom, even at sea. Some observers suggest that this behavior may be related to the acquisition of navigational cues in terms of depth and bottom features.

1.5 THIGMOTACTIC BEHAVIOR

A striking characteristic of mother-young behavior was the amount of bodily contact between the two. The young animal was usually in physical contact with the mother, both when the pair was swimming slowly, or when resting. Often when the mother surfaced to breathe, the baby would be observed draped across her rising body. This contact occurred along the full length of the mother's body from tail to head and the young animal appeared to be relatively limp as it was being supported. During the pursuit phase of capture, this thigmotactic behavior increased in intensity.

Two additional examples of this apparent predilection for physical contact by the young animal were observed. In one instance a stranded young animal made contact with the collecting vessel. For perhaps a half
Figure 1-10. Number of Dives vs. Depth
Figure 1-11. Deep Dives
hour it rubbed against the vessel, especially at the stern and amidships adjacent to the overboard discharge of engine cooling water. Attempts were made to move the animal away from the ship by pushing it gently and by making loud noises in the nearby water. Only after the most skillful maneuverings of the vessel by the skipper were we able to free ourselves of the young animal. One of our concerns about this animal being close to the ship involved the danger of it being wounded or killed by the screws. In cases of pursuit of mother-young pairs, the mother often lifted the young animal from the water with her back or tail. In one case, a 14-15 foot young animal was actually thrown completely free of the water by the adult; such lifting behavior was noted particularly during collection.

Young animals lost or for some unknown reason stranded from the mothers, and apparently healthy, were observed at the beach in contact with the bottom. All attempts by us to steer the young into deeper water, where it could swim easily, proved futile. We suspect that again we were observing a thigmotactic need as the young animal pressed its body against the bottom in the shallow water.

1.6 WATER TEMPERATURE DATA

The temperature data, as recorded in the instrument pod recovered from animal No. 1 showed little in the way of variation. Temperatures appeared to range between 17.0°F and 17.7°C with the lower figure correlating with dives.

These data correspond well with water temperatures in the lagoon because the water is well mixed by the very strong tidal currents. The temperature distribution is almost uniform from the surface to the bottom.

We noted earlier that the temperature records do not show evaporative cooling occurring - which one might have expected when the animal broke the water surface. On analysis, we realize that the thermal sensor is shielded from above by the thick layer of the syntactic-foam float; it would be almost impossible for the sunlight to reach it and evaporative
cooling would, in any case, have considerable lag. In the underwater situation however, the sensor was in constant contact with the water streaming by.
2. THE EXPENDABLE TRANSMITTER STUDY

2.1 SYSTEM DESCRIPTION

For the purposes of this initial effort, the system is directed toward the use of the Nimbus-F satellite which is equipped with a random access measurement system.

The problem of tracking (in the case at hand, of obtaining fiduciary fixes) an animal which is submerged most of the time has been solved by virtue of a sequence of releasable buoy packages, each being a RAMS-compatible transmitter. Periodically, at times predetermined by a clock internal to the instrument package, one of the buoys is to be released. It is electronically activated after it reaches the water surface. The transmitter for this package has been bread-boarded by AII Systems.

To bring the requirements for the transmitter package into focus, we must first examine the nature of the Nimbus-F satellite and its inherent measurement and communications capability. The satellite is in a near polar orbit at an inclination of 100° and its orbit is approximately circular at an altitude of 965 km. Visibility to any ground transmitter, from the satellite, is restricted to a range of roughly 2100 miles (3379 km). The time duration of an orbit is 108 min. The satellite receives signals from transmitters within its visibility region as it orbits the Earth. Signals transmitted to it are acquired by an internal Doppler measurement system and the frequency characteristics of the transmitting unit are derived and recorded together with received data also transmitted from the ground. Figure 2-1 illustrates the configuration of the Nimbus-F system. The satellite eventually passes over a ground station to which Doppler and other data, previously recorded, is transmitted.
2.2 RAMS CHARACTERISTICS

The RAMS system is a Doppler measurement system which operates at a carrier frequency of 401.2 MHz. The design of the animal platform for operation with that system consists of a data buffer, oscillator, modulator, transmitter and antenna as well as the battery pack to power the package. Compatibility with the RAMS system requires that the animal platform transmit for one second of each minute during a satellite overpass.

A comparison of the bread-board developed, with the Random Access Measurement System as presented in Table 2-1.

2.3 OVERALL BLOCK DIAGRAM

The bread-board unit block diagram is shown in Figure 2-2. The signal path consists of a crystal oscillator which is amplified and multiplied to a frequency of 416* MHz. The signal is then applied to a modulator which feeds the final power amplifier, delivering two watts. Control logic, which operates from a 1 KHz clock, controls both B+ switching to conserve power and provides data modulation to the modulator in the signal path. The B+ switching conserves power when the expendable unit is not operating.

*Authorized by FIRL for this study only
Table 2-1. RAMS and Breadboard Specifications

<table>
<thead>
<tr>
<th></th>
<th>RAMS</th>
<th>BREADBOARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier Frequency</td>
<td>401.2 MHz</td>
<td>416.0 MHz*</td>
</tr>
<tr>
<td>Power Output</td>
<td>2W</td>
<td>2W</td>
</tr>
<tr>
<td>Antenna Gain</td>
<td>0 dB</td>
<td>N/A</td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear</td>
<td>N/A</td>
</tr>
<tr>
<td>Osc. Stability</td>
<td>$1 \times 10^{-8}$ in 15 min.</td>
<td>$1.9 \times 10^{-8}$ in 15 min.</td>
</tr>
<tr>
<td></td>
<td>$0.5 \times 10^{-6}$ in a year</td>
<td>$0.5 \times 10^{-6}$ in a year</td>
</tr>
<tr>
<td>Modulation</td>
<td>PSK, 60° phase shift</td>
<td>PSK, 60° phase shift</td>
</tr>
<tr>
<td>On Time</td>
<td>1 sec</td>
<td>1 sec</td>
</tr>
<tr>
<td>Duty Cycle Interval</td>
<td>60 secs</td>
<td>60 secs</td>
</tr>
<tr>
<td>Preliminary Demodulated Interval</td>
<td>.36 secs</td>
<td>.36 secs</td>
</tr>
<tr>
<td>Bit &amp; Frame Sync Words</td>
<td>Two 8 bits each</td>
<td>Two 8 bits each</td>
</tr>
<tr>
<td>Mode ID</td>
<td>2 bits</td>
<td>2 bits</td>
</tr>
<tr>
<td>Platform ID</td>
<td>14 bits</td>
<td>14 bits</td>
</tr>
<tr>
<td>Information Words</td>
<td>Four 8 bits each</td>
<td>One 8 bits*</td>
</tr>
<tr>
<td>Total Bits</td>
<td>64</td>
<td>40</td>
</tr>
<tr>
<td>Bit Rate</td>
<td>100 bps</td>
<td>25.3 cu. in.</td>
</tr>
<tr>
<td>Volume</td>
<td>N/A</td>
<td>10 oz. (circuitry)</td>
</tr>
<tr>
<td>Weight</td>
<td>N/A</td>
<td>168 mw. avg.</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

2-3
Figure 2-2. Whale Tracker Overall Block Diagram
Individual units in the block diagram are discussed in subsequent sections regarding their electrical, mechanical and physical specifications.

2.4 THE CRYSTAL OSCILLATOR

This is a 52 MHz unit utilizing a 2N2857 transistor in the common-base configuration. The base, however, is not directly grounded nor normally bypassed. The crystal, a series-resonant type, is placed in the base to provide grounding at the crystal frequency; at other frequencies, the base is essentially open-circuited. External feedback is provided around the 2N2857 to ensure start-up conditions and stable oscillation. The schematic of the crystal oscillator appears in Figure 2-3. This unit provides about +3 Dbm of output power at 52 MHz.

The 52 MHz crystal was used in our breadboard only because it was readily available and delivery on an optimum (for our purposes) 200.6 MHz unit was prohibitive.

2.4.1 Oscillator Performance Evaluation

Frequency versus temperature characteristics of the crystal oscillator were measured and appear in Figure 2-4. These temperature runs the oscillator was turned on at an assumed sea water temperature of 1.7°C. The unit was allowed to stabilize at that temperature and the ambient was then raised to 12.8°C. Stabilization was again permitted and the ambient was returned to 1.7°C. As the figure illustrates, the maximum deflection was 36 parts in $10^8$ for an 11.1°C change in ambient. This results in 1.8 parts per degree Fahrenheit, or a 7 1/2 Hz change per degree F. The data shown in Figure 2-5 is a reproduction of the recording chart showing frequency versus time for the varying temperature ambient. It also shows the oscillator drift for constant temperature. In this latter case, the drift was less than 10 Hz or 2 1/2 parts in $10^8$ over a 20 minute time span.

A more effective approach, from both the electrical performance and physical size viewpoints, is shown in Figure 2-6.
Figure 2-3. 416 MHz Crystal Controlled Source
Figure 2-4. Transmitter Frequency Drift vs. Temperature
Figure 2-5. Transmitter Oscillator Frequency vs. Time with Periodic Ambient Changes.
In this scheme, the 200.6 MHz crystal oscillator necessitates a 9th or 11th overtone crystal. These crystals are inherently more stable than lower overtone units by roughly the ratio of the square of the overtone \((\frac{m_1}{m_2})^2 > 3\).

The doubler is a full-wave bridge-type which gives rise to even harmonics and inherently rejects the odd harmonics. This minimizes the filtering requirement. Thus with the proper crystal used as stated, the circuitry is simpler and the stability performance substantially improved.

2.5 MULTIPLIER AND FILTER

The multiplier and filter are shown schematically in Figure 2-3. The buffer amplifier receives its input from the 52 MHz crystal oscillator. It provides about +15 dBm of power at 52 MHz. The X8 multiplier is a step-recovery diode type (utilizing a Hewlett Packard type 0180 diode). It is followed by a three-section bandpass filter and a 416 MHz amplifier. The step-recovery diode multiplies the input frequency to 416 MHz with a conversion loss of approximately 19 dB. The bandpass filter selects the eighth harmonic at 416 MHz. Its bandwidth is adjusted to be as narrow as possible while achieving appropriate power output of 0 dBm at the 416 MHz buffer amplifier. This results in adjacent spurs around the desired harmonic being rejected by 35 dB. Hence the carrier source is a 416 MHz source with spurious output down at least 35 dB, 52 MHz away from the desired carrier. The power required by the 416 MHz source line at 50 milliamperes is 500 mw.
The process of buffer amplifying, multiplying by a large order (that is, eight), bandpass filtering and further buffer amplifying consumes 0.5 W of power and requires considerable space. In the final hybrid model transmitter a 200.6 MHz crystal will be used in the oscillator. A high-efficiency, balanced type frequency doubler will be used with inherent rejection of the fundamental, third, fifth and other odd harmonics while delivering to the output, the even harmonics including the required 401.6 MHz signal. The filtering requirements will, of course, be greatly reduced resulting in considerably lower spur levels which are further removed from the carrier. As a result, the space requirement will be reduced by 50% and the power requirement by 33%.

2.6 MODULATOR

The data modulator is shown schematically in Figure 2-7. It is essentially a double-balanced mixer used to provide phase-shift keying of the CW signal. The unit employed here is an MCL-SRA-1. It introduces about a 5 dB insertion loss to the CW signal. In the final hybrid model, the insertion loss may be further reduced by applying a higher-performance mixer which may be more costly, but which will be physically smaller.

The driver directs 10 ma. of current in two different directions through the double-balanced mixer to provide phase-shift keying. The entire modulator consumes 200 mW of power (20ma. @ 10V.). The speed of the modulator is on the order of a few microseconds, considerably in excess of the data rate. Phase Shift accuracy is within 10° of ±60°.

2.7 POWER AMPLIFIER

This element is depicted schematically in Figure 2-8. Its input is received from the data modulator at a level between 0 and -2 dBm. The first stage is an HP type 26E transistor which brings the level to +12 dBm. The next two stages consist of type 2N3866 transistors bringing the level to +20 to +21 dBm. They are operated in Class-C mode. Their output at 100 mW, is fed to a CTC C2-8Z transistor which outputs between 0.5 and 1.0 watt. This then drives a 2N5646 producing the desired 2 watt final
Figure 2-7. Data Modulator (+60° PSK)
Figure 2-8. 416 MHz 2-Watt Power Amplifier
output. A total of 6160 mW is fed to the power amplifier. Its efficiency is 33%. The output stage itself runs at an efficiency of 60%.

It is anticipated that when the optimized crystal oscillator (200.6 MHz) is incorporated into the final, hybrid model transmitter that the drive to power amplifier will be increased and less amplification in that module will be required. This is expected to reduce the power amplifier power requirement by at least 15%.

2.8 CONTROL AND DATA LOGIC

The data transmission circuit consists of an oscillator, a 40-bit shift register, control logic and PSK code generation. The circuit was designed exclusively with CMOS devices to minimize power consumption and to provide high reliability.

The circuit transmits data for one second of each 60 seconds. During the transmission period a "window" signal is provided to turn on the r.f. transmitter. At the completion of the one-second transmission the transmitter is turned off. The transmitter circuit is self-starting.

The data transmitted consists of the bit sync., the frame sync., the unit identity; data words are programmable externally by placing proper voltage on the inputs. These data are all converted to PSK code prior to modulation. This type of transmission code was selected because it produces minimum bit errors. The circuit was implemented with 14 CMOS IC's. Analysis indicates that when we move on to hybrid circuits, we will reduce the number of IC's to two.

The schematic of the control and data logic is shown in Figure 2-9. The schematic for the B+ switch is shown in Figure 2-10. This switch drives everything in the regional path except the 52 MHz oscillator. This is done to eliminate warm-up frequency shifts in the oscillator while conserving as much battery power as possible.

2.9 SIZE, WEIGHT, POWER AND FREQUENCY CONSIDERATIONS

As mentioned above, the use of a 52 MHz crystal introduced severe penalties in weight, power and volume requirements. Use of the proper
Figure 2-9. Control and Data Logic
Figure 2-10. B+ Switch

(B+ (11.2 V from battery))

FROM DATA WINDOW

15K

ZNZ290TA

1.5K

2NZ3222

MJE205

TO B+ OF CONTROLLED NETWORKS

10K
crystal will cut the current drain of the crystal-controlled source by 1/3 and its volume by 1/2. The frequency stability of the oscillator will be improved.

The present power amplifier weights 3 ounces (85 f) and requires 5.9 cubic inches (97 cc). This unit is difficult to miniaturize because of series conductors used as matching elements. Nonetheless, size and weight reduction appears achievable.

The data modulator can be reduced in size with chip transistors. This will cut the volume by about 90%. The mixer is susceptible to a 33% reduction in volume. No degradation of electrical performance is anticipated. The B+ switch can also be reduced in volume by using complementary transistors in a chip configuration.

The control and data logic circuitry, currently using C-MOS IC's is susceptible to a 90 - 95% reduction in volume by shifting to two or three hybrid IC's.

The total weight of the circuitry is presently 10 ounces (284 g). We estimate that this can be reduced to 4 ounces or less (<114 g). The breadboard occupies 25.3 cubic inches (415 cc); the hybrid model has an anticipated volume less than 5.8 cubic inches (95 cc).

2.10 POWER SUPPLY CONSIDERATIONS

The breadboard transmitter operated on 11.2 V derived from four 2.8 V cells in series at a current drain of 626 ma. This current is supplied to the transmitter for one second each minute. During the remaining 59 seconds only the oscillator is operating at 10 ma. The average constant current drain is 15 ma.

Power supplied by type "AA" (size 5cm x 1.4cm) lithium flouride cell (Power Conversion, Inc.) can support the breadboard transmitter for about 80 hours. This will be further improved in the hybrid model development.
3. RECOMMENDATIONS FOR FOLLOW-UP EFFORT

It is the intent of the overall effort to involve an operational and non-harmful system for application to the great whale species. This will permit the establishment of critical migration route paths. It is such path data which will then permit the evolution of systematic and successful censusing techniques resulting in "hard" population data.

The operational system involves the availability of a suitable satellite* (Nimbus -F, or any other polar orbiting satellite with Doppler location capability), an instrument package for sensing and recording data at the subject animal throughout the migration run, a pod of releasable, expendable location transmitters for operation from the animal through the migration run and an expandable - contractable - releasable means (harness) for mounting and holding these gear on the subject animal.

The overall operation of this system is described elsewhere and need not be considered in further detail here. However, it is important to recognize that specific problem areas should be attacked in a step-wise fashion if we are to optimize results with economy and within a reasonable time frame.

The harness design represents a problem which is a complex of behavioral, biologic growth, organic attack, subject tolerance and tear and abrasion parameters. This harness must grow with the animal, yet it must not loosen when the animal dives and its body contracts. The harness must carry both the instrument and releasable transmitter pods, and the entire arrangement must be tolerated by the animal and introduce no behavioral aberrations. Upon automatic release, the harness and its

* Other systems than RAMS are potentially applicable and are described in this context in FIRL report F-C3482, "Animal Tracing Satellite System Study."

3-1
The instrument package must contain all sensors, conditioning circuits and power sources necessary to accumulate path and related behavioral data. The sensed data are to be accumulated in a recoverable recorder. In addition, this package must contain a fixed, location and homing transmitter to permit its recovery on release from the subject animal. Initial development has envolved the basic electronics for the package, pressure and temperature sensors and their conditioning circuits and a first engineering prototype miniature, micropower, high-data-density digital recorder. This preliminary system was built and tested on a juvenile gray whale in its natural habitat. It remains for the path sensors - suitable for our purposes - to be developed along with appropriate conditioning and pre-computing circuitry. Indicated improvements in recorder design must be incorporated and tested. All circuits are to be reduced to hybrid form.

An expendable transmitter has been breadboarded. Early data makes us optimistic with regard to desirable characteristics for a final package. This first design is appropriate electrically for use with the Nimbus -F satellite. It remains for the specific satellite system to be selected, transmitter electrical design optimized to that system, circuits to be reduced to hybrid form, mechanical, thermal and hydrostatic stability designs to be undertaken, release mechanism to be designed and tested and antenna release system to be built and proven.

The problems presented by the foregoing are, in our opinion, not only soluble, but will upon solution provide the "building blocks" for a variety of almost immediately applicable systems to the area of wildlife monitoring and assessment.

The sections which follow are categorized by Federal Fiscal Year on the assumption that the described effort will proceed in the systematic
way beginning with FY'76. The specific efforts to be undertaken in each period are described tersely. The goal is an operational system. It is contemplated that when operational, system application and support will be the responsibility of the User Agency.

3.1 FISCAL 1976

Effort by biology team

- Carry on expansible harness development and fabricate two harness for field test
- Continue animal behavioral studies (cine and still photography) re aberrations introduced by gear
- Study harnesses for organism attack upon their recovery from field study
- Plan and lead the field expedition, Baja, Mexic.
- Take part in analysis of recovered data.

Effort by technology team

- Complete improvements to tape recorder
- Design and fabricate electronic release mechanisms for use in field
- Design and fabricate Xenon Flasher for use in field
- Fabricate two instrument pods (P,T) for use in field study; must tolerate depths to at least 200 meters.
- Process recovered data and take part in analysis
- Participate in field study

This effort will permit work on the expansible harness to go forward, first designs of the electronic release mechanism for the harness, and allow evaluation of water pressure (depth)/temperature data at sea.

The expedition will make possible the acquisition of field performance data on the new harness design, new depth-of-dive data at sea and the subsequent evaluation of the effects of marine organisms on the harness materials as well as wear-and-tear on the harness because of the subject's behavior in the field. The data analysis will provide new insights to time at the surface and other matters of later importance to census taking strategy evolution.
3.2 FISCAL 1977

- Continue expandible harness development and fabricate two latest design units for field study
- Continue studies (cine and still photography)
- Upon harness recovery from field, study marine organism effects
- Plan and lead the field expedition; one month track at sea
- Take part in analysis of recovered data

Effort by technology team

- Initiate development of the following sensors: pitch-angel, axial velocity, magnetic heading and light level
- Develop related interfacing circuitry for above
- Identify satellite system to be used operationally
- Initiate expendable transmitter development
- Start development of expendable transmitter pod and transmitter release mechanisms
- Improve harness release mechanism designs based on previous field experience
- Fabricate Xenon flashers for field study
- Fabricate two instrument pods for 30 day track at sea
- Process recovered data and take part in analysis
- Participate in field study

This effort is preliminary to the prototype expandible harness; first designs of: key tracking sensors, expendable transmitter packages, the expendable transmitter pod and the expendable transmitter controlled-release mechanism.

This field work will add to our knowledge of subject behavior, give us performance data on the release mechanism prior to prototyping, further insights to marine organism effects and wear-and-tear. Data analysis will provide replicative behavioral data and equipment performance data prior to prototyping.
3.3 FISCAL 1978

Effort by biology team

- Pre-prototype expansible harness
- Integrate harness for two instrument pods
- Continue behavioral studies (cine and still photography)
- Upon harness recovery from field, study marine organism organism effects
- Plan and lead the field expedition; two month track
- Take part in analysis of recovered data

Effort by technology team

- Prototype: pitch angle sensor
  velocity sensor
  magnetic heading sensor
  light level sensor
  interfacing circuity
- Prototype expendible transmitter and test in coastal waters
- Prototype expendible transmitter release mechanism
- Prototype expendible transmitter pod
- Prototype expendible harness-release mechanism
- Fabricate Xenon flashers for field study
- Fabricate three instrument pods (pressure, temperature, light level, time)
- Process recovered data and take part in analysis
- Participate in field study

Indicated subsystems are prototyped in this effort and partially tested at sea during the field study. The somewhat extended track at sea permits additional necessary evaluation of the expansible harness and accumulation of further dive and other behavioral data.

3.4 FISCAL 1979

Effort by the biology team

- Prototype the 2-pod, expansible harnesses and fabricate three for sea study
• Continue behavioral studies (cine and still photogra­phy)
• Upon harness recovery from field, assess marine organism effects
• Plan and lead the field expedition (instrument three animals for satellite, 6-months track at sea.
• Take part in the analysis of recovered data.

Effort of technology team

• Fabricate three complete prototype instrumented, sensing and recording pods for 6-month track
• Fabricate three complete prototype expendible transmitter pods
• Fabricate twenty prototype expendible transmitters
• Fabricate three prototype homing transmitters
• Fabricate three prototype harness release mechanisms
• Fabricate three Xenon flashers
• Fabricate three prototype expendible transmitter release systems
• Process data recovered from field study and take part in analysis
• Participate in field study

A successful sea test in this effort means the entire system can be con­sidered operational. All aspects of the total system are tested in this effort including up-links to the satellite.

3.5 FISCAL 1980-1981 1/2 (19 mos.)

Biology team effort

• Fabricate twelve expendible, 2-pod harnesses carry out behavioral studies local to animal capture area
• Plan and lead field expedition to capture and instrument up to ten animals
• Analyze status of harnesses on recovery
• Take part in data analysis
Technology team effort

- Fabricate ten complete 2-pod data and tracking systems
- Participate in field work
- Process recovered data and take part in analysis
- Analyze recovered instrumentation for reuse on/or modification

This first operational experiment will provide path and related behavioral data from up to ten animals over a full migration (one year).
APPENDIX A: COMPUTER PROGRAMS WRITTEN FOR WHALE MIGRATION STUDIES

1. INTRODUCTION

This Appendix documents 8 of the assembly language programs written under this Project. The programs are written for FIRL's PACER-100 computer.

The programs utilize the PACER's digital input lines, direct memory access channel, moving head disk, real time clock, and digital-to-analog converters. The purposes of the programs are to read data from the miniature recorder, to store the data on a magnetic disk, to correct the data for skewing, to separate the pressure, temperature and time information, and to plot this information on a strip-chart recorder.

This Appendix includes brief descriptions of each program, provides instructions on the operation of the programs, and presents object listings of the programs.
2. DESCRIPTION AND OPERATION OF COMPUTER PROGRAMS

2.1 WLC2 - DESCRIPTION

This program samples the 8 channels of the miniature recorder at a high rate, condenses groups of these samples into data words and prints out the data words (in binary) on the teletype. The program can store up to approximately 10,000 samples and will print out all of the samples on the teletype. The teletype print-out displays the binary bit pattern as read by the computer. Channel one is left-most, channel eight right-most.

2.2 WLC2 - OPERATION

After data (or a pattern) have been written on the miniature tape, the tape must be rewound and placed in the playback interface to the computer.

1. Load WLC2 via monitor (#L, WLC2, 21)
2. Load Oedipus via monitor (#L, OED, 21)
3. Execute Oedipus (#G, 72000)
4. Set number of words to be read, in octal, in NMAX (1062:20000 20000)*
5. Turn on tape
6. Execute WLC2 via Oedipus (1000G)

2.3 PTWL2 - DESCRIPTION

This program reads a data file from the disk and types the data on the teletype in binary. This is normally used in conjunction with WLD2 and presents the data as they were read by the computer.

* NOTE: Underlined portion typed by computer is not necessarily 20000. User can type any number up to ≈ 70000, but normally 20000 is sufficient.
2.4 PTWL2 - OPERATION

1. Load PTWL2 via monitor (#L, PTWL2, 21)
2. Position the data file to be read - xxxxx represents the name of the file (#P, xxxxx, 21)
3. Execute the program (#G, 1000)

2.5 SKEW 2 - DESCRIPTION

This program is similar to PTWL2 except that SKEW 2 allows a constant correction for skewing of the miniature tape.

2.6 SKEW 2 - OPERATION

Same as PTWL 2.

2.7 WLD2 - DESCRIPTION

This program samples the 8 channels of the miniature recorder at a high rate, condenses groups of these samples into data words and writes a file on the disk. This is essentially the same program as WLC2 except WLD2 writes the condensed data not on the teletype but onto the disk.

2.8 WLD2 - OPERATION

1. Load WLD2 via monitor (#L, WLD2, 21)
2. Load Oedipus via monitor (#L, OED, 21)
3. Execute Oedipus (#G, 72000)
4. Set number of words to be read, in Octal, in NMAX (1043:1020 1020)*
5. Get back into monitor (177777G)
6. Name a file (#N, xxxxx, 21, 3, 1020)**

* Underlined portion is typed by the computer and is not necessarily 1020. User can type any number up to 70000, but normally 1020 is sufficient.

** The xxxxx can be any name not already on disk.
7. Position the file (#P, xxxxx, 21)
8. Assign the file (#A, xxxxx, 1020, 372)***
9. Execute Oedipus (#G, 72000)
10. Turn on tape
11. Execute WLD2 (1000G)
12. When the computer pause light lights, turn the recorder off.

2.9 WLSKP2 - DESCRIPTION

This program reads in data from the disk in pages of 528 words; condenses further the sampled words into single 8 bit words as originally recorded on the miniature tape; and prints the binary data words in three columns on the teletype.

2.10 WLSKP2 - OPERATION

1. Load WLSKP2 via monitor (#L, WLSKP2)
2. Position data file to be read - xxxxx represents the name of the file (#P, xxxxx, 21)
3. Execute the program (#G, 1000)
4. The computer will pause 2 (pause lamp lights)
5. If a single page is to be printed go to 5a, otherwise go to 6.
   5a. push sense switch H up
   5b. push run down
   5c. push down SGL
   5d. push run up; go to 4.
6. If it is desired to skip to the next page go to 6a; otherwise go to 7.
   6a. make sure all sense switches are down
   6b. push run down
   6c. push down sgl
   6d. push run up
   5e. go to 4.
7. To print out all pages continuously, put sense switches C and H up.

***The xxxxx must be the same as in step 7.
8. Push run down, push down sgl, push run up.

2.11 CSKW2 - DESCRIPTION

This program reads in data from the disk in pages of 528 words; condenses further the sampled words into single 8 bit words as originally recorded on the miniature tape; corrects for skewing of the tape and prints the binary data words in three columns on the teletype.

2.12 SCKW2 - OPERATION

1a. Load SCKW2 via monitor

1b. If standard skew correction desired, go to 2; otherwise go to 6.

2. Position data file to be read - xxxxx represents the name of the file (#F, xxxxx, 21)

3. Put sense switches C & H up.

4. Execute the program (#G, 1076)

5. Release run, depress single, push run up. Stop.

6. In order to program for non-standard skew Oedipus must be loaded and executed #L, OED, 21 #G, 72000

7. Skew correctors are in cells 1425 through 1934. The choice of skew correction is made based on results of running WLD2. The position of 1's in the cells 1425 to 1434 will be OR'ed in parallel, the 0's will be ignored.

8. Return to 2.

2.13 WLTD2 - DESCRIPTION

This program samples the 8 channels of the miniature recorder at a high rate, condenses groups of these samples into data words and writes 4 files on the disk using almost the full disk. This is essentially an expanded WLD2 program.

2.14 WLTD2 - OPERATION

1. Load WLTD2 via monitor (#L, WLTD2, 21)

2. Load Oedipus (#L, OED, 21)
3. Let \( y = 1 \)
4. Name a data file \((\#N, \text{xxxxy}, 2y, 3, 1020)\)*
5. Assign the file \((\#A, \text{xxxxy}, 1020, 372)\)**
6. Let \( y = y + 1 \), Do \( y = 5 \)? if no go to step 4, if yes continue to 7.
7. Execute Oedipus \((\#G, \text{72000})\)
8. Assign number of pages to be read in. The number of negative, octal and assigning to PMAS. \((2113:1774006 176766)***\)
9. Turn on tape
10. Execute WLTD2 \((2022G)\)
11. When computer pause lamp lights, turn recorder off.

2.15 ARF2 - DESCRIPTION

ARF2 is a program to read a data file from the disk and plot the temperature and pressure on a strip chart recorder.

The computer reads in a page (528 samples) at a time, corrects for skew, condenses the data so it will appear in the form, originally recorded by the miniature recorder, separates temperature, pressure and time data, converts the data to analog form and presents these analog signals on channels 4, 5 and 6 of the PACER's digital to analog converts output panel. The computer presents the data at a frequency compatible with the strip chart recorder. The computer also sends out a page turning signal to the recorder on channel 3. This signal is usually connected to the recorder's event marker input.

2.16 ARF2 - OPERATION

1. Load ARF2 via monitor \((\#L, \text{ARF2}, 21)\)
2. If standard skew correction is desired, got to 6, otherwise go to 3.
3. In order to program for non-standard skew Oedipus must be loaded and executed \#L, OED, 21
   \#G, 72000
4. Skew correctors are in cells 1541 through 1550. The choice of skew correction is made based on the results of running WLTD2.
5. Return to monitor \((77777 G)\).
6. Position the data file to be read — xxxxx represents the name of the file (#P,xxxxx, 21)

7. Put sense switches C & G up

8. Turn on strip chart recorder

9. Execute the program (#G, 1111)

10. When pause lamp lights up, turn off strip chart recorder

NOTE: Temperature is displayed on digital-to-analog (D/A) channel 4. Pressure is displayed on D/A channel 5. Time is displayed on D/A channel 6.

The strip chart recorder used on this project was a Gould Brush 220. The speed of 25mm/sec proved adequate for most runs. The temperature channel was normally set at 200 MV/DIV, and the pressure channel was set at 50 mv/div.
3. LISTING OF COMPUTER PROGRAMS
**WLC2**

* E DOUGHERTY PRGMR  4/4/74

* WHALE JOB

* SAMPLE AT 9.8 MICRO S' AND

* CONDENSE CNDS AT A TIME

* PRINT OUT DATA

```
0006: 00000 00000 REL 0
0007: 00006 53062 00062 LX NMAX
0028: 00031 141357 20060  CL  LA  CNDS  COND. #
0009: 00022 161257 00061 STA  CX
22010: 00003 26740  CLR
22011: 00034 167666 00722  STA,IX ADE
0012: 00005 20007 00007  RD  DI  7  RD BIT PAC
0013: 00086 167654 00722  OR,IX ADE  OR GROUP
0014: 00027 167663 00722  STA,IX ADE  STORE"
22015: 00018 71051 30261  AOM  CX  DONE COND?
0016: 00011 41774 30035  J  RD  NO, RD
22017: 00012 22777 00771  DCX 1

YES, NEXT, DONE ALL?

0018: 00013 41766 00001  J  CL  NO, CLR
0019: 00014 41681 00115  J  DONE  YES, PRINT
0023: 32015 53345 00662  DONE  LX  NMAX  YES, PRINT
0021: 00016 141046 00864  LA  TYPON  RDY TYPER
0022: 00017 53021 30271  CF 1
0023: 00222 61032 00952  TYPWD  L  TSTAT
22024: 00021 147651 30722  LA,IX ADE
0025: 00022 26540  EQ
0026: 00023 26362 20002  LLI 2
0027: 00224 151041 20065  A  ASCII
0028: 22025 03261 30601  LO 1
0029: 00226 141640 20066  LA  NS
0030: 00027 161342 00667  STA  CS
0031: 00032 71037 20267  KOT  AOM  CS
0032: 00033 41222 00633  J  TOL
0033: 00034 41327 20441  J  TRO  DONE TYPG WD X
0034: 00035 61027 03632  TOH  L  TSTAT
0035: 00036 26743  CLF
22035: 00025 26361 32221  LLI 1
0037: 00026 151027 20065  A  ASCII
33609: 2207 2617 28201  DO 1
0039: 00042 41777 20333  J  KOT
22042: 00241 61211 20252  TRC  L  TSTAT
22041: 00042 141026 22.70  LA  CF  CARE, FTN
32442: 00243 23231 20001  DO 1
22042: 00043 61236 .252  L  TSTAT  LINE FD
22043: 00245 23321 20821  LA  LF
22045: 00246 23321 20821  DQ 1
00346: 22047 22777 20621  DCX 1
22047: 00047 41752 22924  J  TYPWD 1
00348: 00048 25301 .201  P 1
22049: 00052 20266 20800  TSTAT  ADR 0
0025: 00053 24261 20201  SI 1
00251: 00054 24160  SAE
00052: 00055 41022 20857  J  **2
00053: 00056 41775 00083  J  **3
00054: 32057 45773 20822  J,1 TSTAT
22055: 00060 177762  CNDS  DEC  -14
00056: 00061 22001  CX  ESS 1
20057: 23062 23000  NMAX  OCT 26000

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**SKEW**

00001:  * SKEW1,2  
00002:  * DOC 6/21/74 3:30  
00003:  * READS 528 WRDS FROM DSK 21  
00004:  * CORRECTS FOR SKEW  
00005:  * PRINTS CORRECTED ON TTY  
00006:  

00006: 0000 0000 0000 REL  
00007: 0000 141660 0062 LA  STWD  SET STUS  
00008: 26706 ES  FOR TRAPS  
00009: 24540 SMI  SET MSTR INTRPT  
00010: 141656 0061 LA  PARAM  OUTPUT 21 DSK  
00011: 165056 0062 STA.1 SP  

00012:  

00012: 0005 27821 0021 INDEX T 17  MSIN  
00013: 0006 XXXX 00273 ADR  BNK  STRT ADR  
00014: 0007 XXXX 01312 ADR  DUM-I  END ADR  
00015: 41647 0057 J  EPROR  
00016: 0011 23421 SSV  H  UP PRNT  
00017: 41773 0055 J  INDEX  READ NXT  

00018:  

00018: 0013 5360 0063 LX  ANAX  
00019: 0014 141057 0064 LA  TYPON  RDY TYPER  
00020: 0015 05021 0021 DF 1  
00021: 61333 0051 TYPWD  L  TSTAT  
00022: 0016 61152 00171 L  NXTS  
00023: 614252 00272 LA  TENV3  
00024: 26540 EQ  
00025: 26322 00302 LLD 2  
00026: 151842 00865 A  ASCII  
00027: 03210 0021 DO 1  
00028: 141341 00966 LA  MS  
00029: 161841 23367 STA  C5  
00030: 71042 33677 KOT  AGN  C5  
00031: 41022 2332 J  TKR  
00032: 41267 0324 J  TR0  DONE TYPG WD X  
00033: 61617 0051 TOK  L  TSTAT  
00034: 2233 2764W CLR  
00035: 26301 0001 LLD 1  
00036: 151830 00865 A  ASCII  
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00039: 61611 0051 TRO  L  TSTAT  
00040: 141027 0072 LA  CR  CARR. RTN  
00041: 03631 0021 DO 1  
00042: 61426 0051 L  TSTAT  LINE FEED  
00043: 141325 0071 LA  LF  
00044: 0321 0061 DO 1  
00045: 22777 0091 DCX 1  
00046: 41747 03416 J  TYPWD  
00047: 41735 0325 J  INDEX  

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00048: 0051 24302 00200 TSTAT ADR 0  
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E. DOUGHERTY 5/21/74  1:30

SAMPLE AT 9.8 MICRO S AND
CONDENSE CNDS AT A TIME

WRITE ON DISK

REL  0
LA  STWD
ES
LA  PMAS
STA  SAMP
A
LA  CNDS
STA  CX
CLR  NEW
STA,IX  ADEP
RD  DI  7
RD BIT PAC
OR,IX  ADEP
OR GROUP
STAI,IX  ADEP
STORE"
A0H  CX  DONE COND?
J  RD  NO, PD
DCX  1

YES, NXT, DNE ALL?

J  CL  NO, CLR
J  DONE  YES, PRINT

DONE SMI
LA  PARA;
STA,1  SP
T  16

ADF  ENK
ADR  DUN-1
J  ERROR
AOH  SAMP
J  A
P  7

ERROR  P  1
SP  ADR  *77666
PARAL  OCT  4821
STID  OCT  132C0E
P/MAS  DEC  -522
SAMP  ESS  1
C.NLS  DEC  -14
GX  ESS  1
MiAX  OCT  1322
ADEP  ADR  ENK
B/A  ESS  528
DUri  ADR  8
END  8
ADER  00044  REL
A     00024  REL
ENR   00045  REL
-.CL.  20005  REL
CNDS  00041  REL
CX    00042  REL
DONE  00221  REL
DUM   01065  REL
ERROR 00033  REL
NMAX  00043  REL
PARAM 00035  REL
PHAS  00237  REL
RD    00011  REL
SAMP  00244  REL
SP    00234  REL
i.  STUD 00236  REL
* WHALE READ
* READ IN DATA FROM DSK21
* IN PACKS OF 528
* AT P-2, A SINGLE WILL:
* PRINT, IF SSW UP
* SKIP TO NEXT PAGE, IF SSW DOWN
* TO SKIP SEVERAL PAGES
* PUT SSW A UP; USING OED
* LOAD NEG # IN X REG
* PUT SSW C UP; ALONG WITH K WILL ALLOW
* CONTINUOUS PRINT OUT

`03315: 00330 00000` REL 0
`03316: 00020 141203 00223` LA M1
`03317: 00061 161221 00222` STA NZP
`03318: 00022 141227 00211` LA MTHRE
`03319: 00023 161227 00212` STA WPL
`03320: 00024 161207 00213` STA SCT
`03321: 00025 141216 00223` LA STVD SET STUS
`03322: 00026 26700` ES FOR TRAPS
`03323: 00023 24540` SMI SET MSTR INT RPT
`03324: 00024 141214 00224` LA PARAM OUTPUT 21 DSK
`03325: 00011 165214 00225` STA I SP

* READ 528 YRDS FROM DSK 21

`03327: 00012 27021 00221` INDEX T 17 * MSIN
`03328: 00023 00226` ADR ENK STRT. ADR
`03329: 00014 00355` ADR DUR-1 END ADR
`03330: 00015 41165 00222` C EFTR
`03331: 00016 23620` SSV A MULTI SKIP UP
`03332: 00017 41025 00224` J PAUSE
`03333: 00020 23250` SSV C
`03334: 00021 45157 00213` J I OED PUT & IN X
`03335: 00022 22221 00821` IXY 1 & PUT E UP
`03336: 00023 41767 00812` J INDEX EG -E=177778
`03337: 00024 23440` PAUSE SSV C
`03338: 00025 25022 00322` P 2
`03339: 00026 23431` SSV K UP PRNT
`03340: 00027 41763 00222` J INDEX READ NEXT

* PRINT OUT 528 BUFFER

`03341: 00037 53176 00226` LX UNLY
`03342: 00031 141176 00227` LA TYPON REY TYPER
`03343: 00032 00221 00321` CF 1
`03344: 00033 00747` CLF
`03345: 00034 161115 00221` STA ZCNT
`03346: 00035 00174 00174` TYPVD L TSTAT
`03347: 00036 00740` CLF
`03348: 00037 16115 00747` STA TEMP INTL DATA 0
`03349: 00038 141144 00274` WRITE LA NONE
`03350: 00039 161144 00755` STA SKIP
`03351: 00040 16173 00335` LA, IX nDEF
`03352: 00041 11115 00215` C ZEP
`03353: 00042 00044 27410` SE
`03354: 00043 00045 76043` J DATA NO
`03355: 00044 141133 00222` LA ZCNT YES
`03356: 00045 22227 71152 00221` A0N ZCNT
`03357: 00046 121145 00215` C ZEPD 1ST 87
* TYPEN STATUS SUBROUTINE

TSTAT ADC 3
SI 1

SAP ESS 1,3
PKS ESS 1,3
TEL ESS 1,3

DEC -3

MTHRE DEC

PLS OCT -1

SCT ESS 1

SPIE OCT 24

ZERC DEC -3

EGET DEC 5

FGET DEC 14

MTUO DLC -2

ZCNT ESS 1,4

ZCP ESS 1,3

STD OCT 13220

PARA OCT 4821

SP ALE 7766

MAX OCT 122

TYPOK OCT 5

ASC1 OCT 262

MS OCT -13

CS ADR 6

CF OCT 215
PAGE 005

00175: 00234 00212 LF OCT 212
00176: 00235 XXXXX 00236 ADR ADR BNK
00177: 30236 01020 BNK ESS 528
00178: 01256 00000 00000 DUN ADR 0
00179: 03000 END 0
ADER 2235 REL
ASCII 2233 REL
CNK 2236 REL
CR 2233 REL
D0 2232 REL
DATE 2262 REL
DATE? 2209 REL
DEZ 2205 REL
DUM 2206 REL
DZ 2274 REL
EIGHT 4216 REL
ERROR 5202 REL
FOUFT 5217 REL
GO 2014 REL
INDEX 2012 REL
KOT 2014 REL
LF 2234 REL
NONE 4204 REL
NTHPE 5211 REL
NTYO 5223 REL
.:1 2223 REL
$: 2231 REL
N:AL: 5226 REL
N2P 4222 REL
OLD 5212 REL
PAAN 4224 REL
PAUSE 4224 REL
PA:5 4225 REL
PFMT 5213 REL
SCT 5213 REL
SKIP 2217 REL
SKP 5215 REL
SPACE 5155 REL
SPCE 5214 REL
ST 5225 REL
STUD 4223 REL
TEMP 5227 REL
TO.. 2023 REL
TP0 2151 REL
TSTAT 2172 REL
TYPON 4227 REL
TYPE: 6235 REL
UPDT 6255 REL
UPL 6212 REL
UPDATE 6240 REL
ZCUT 6221 REL
ZERO 6215 REL
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Reproducibility of the original page is poor.
* L DOUGHERTY 8-27-74

* WLD

* SAMPLE AT 9.8 MICRO S AND

* CONDENSE CMDS AT A TIME

* WRITE ON ALL FOUR TRACKS OF DISK

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CX  01116  REL
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DDUN  31620  REL
DONE  01062  REL
DUN  22142  REL
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PHAS  61113  REL
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REL  21022  REL
SAMP  01114  REL
SP  01110  REL
STUD  01112  REL
ST  01024  REL
TFKCT  01126  REL
ARF2

* THIS PROGRAM FOR BAD D/A
* * 12/13/74 *
* * START AT 1111 *
* * PROGRAM TO *
* * PROGRAM TO WRITE WHALE DATA ON A STRIP *
* * CHART RECORDER VIA D/A CONVERSES *
* * CORRECTS FOR SKEW 1504 TO 1513 *
* * EIGHT IS # OF Z'S REQ'D FOR A 0 WRD *
* * FOUR " " " " DOUBLE 0 WRD *
* * TWENT " " " " TRIP 0 WRD *
* * TO RERUN SET 1111 TO 176766 *

00019: 00000 0042 REL 2
00022: 0208 22074 BUFL ESS 60
00021: 23274 23082 0003 0UF1A ESS 1,0
00022: 23275 XXXX 23080 ABUF1 ADR 2UF1
00023: 23275 77566 77566 SP ADR '77666
00024: 04077 04221 PARAND OCT 4221
00025: 00104 102392 STUD OCT 100302
00026: 22121 174616 74616 IEC ESS 1, 1656
00027: 22132 25262 00022 CVEP P 3
00028: 22133 2527 00007 ERPROF P 7
00029: 22134 177724 N68 DEC -68
00030: 22145 00020 22022 CTP ESS 1, 0
00031: 22156 177775 119 DEC -19
00032: 22167 177776 T'0 DEC 2
00033: 03112 0322 LA ACNE
00034: 22111 141262 00573 STA NIP
00035: 22112 161263 00372 LA STVD
00036: 22113 141765 02173 ES
00037: 22114 26730 SHI
00038: 22115 24544
00039: 22116 141751 22077 LA PARAIN
00040: 22117 165757 22276 STA J SP
00041: * REAL 526 WRDS FROM DISK *
00042: 22122 71761 00121 INDEX ACN AIC
00043: 22121 41062 22123 J T T
00044: 22122 41760 23122 J GULF
00045: 22123 27621 00021 TT T 17
00046: 22124 XXXX 00573 ADR BNK
00047: 22125 XXXX 01612 ALR DUB-1
00048: 22126 41755 22183 J ERPROF
00049: * SELECT CONTINUOUS OR PAUSE *
00050: 22167 23440 SSYC SSY C
00051: 22130 25602 00802 P 2
00052: 22131 23481 ESS 'SSY
00053: 22132 41766 20124 INDEX
00054: 22133 141751 02124 LA N68
00055: 22134 161751 20105 STA CTP
00056: 22135 141746 20075 LA ABUF1
00057: 22136 161736 00374 STA CUF1A
00058: 22137 26746 CLF
PAGE 205

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03177: 02323 41765 02310 J DAC
02178: 02324 41764 02312 J DAC
04179: 02325 141234 02061 LA DAN
02180: 02326 121227 20555 C FOUR
00181: 02327 27416 SE
02182: 02331 41317 02347 J PRES
04183: 02331 141223 02554 LA TEMPE
02184: 02332 121755 0237/ C ZERO
00185: 02333 27426 SNE
02186: 02334 41263 02337 J +/3
02187: 02335 141233 02547 STA TEMP4
04188: 02 333 41224 0.342 J OUT
02189: 02337 141231 02542 LA TLP4
01192: 02346 131214 02554 STA TLPE
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02193: 02348 141216 0.354 OUT LA TEMPE
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02197: 02347 11177 00245 PLS C FIUL
02198: 02350 27412 SE
02199: 02351 41055 02356 J OUT
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02202: 02354 16122 0.354 STA TEMPE
02203: 02355 141231 02356 J OUT
02204: 02356 141176 0.3554 OUT LA TEMPE
02205: 02357 32276 02876 DO '76
02206: 02362 71261 02561 MON DAN
02207: 02351 41174 0.3265 J PLOT
02208: * WAIT FOR CRAFT RECORDER
02209: 02362 141261 02563 RTC LA WIND
02210: 00363 25948 02342 DF '40
02211: 02364 32446 02342 CLOCK LI '42
02212: 02365 20266 OCA
02213: 02366 121176 02564 C TIM
02214: 02367 27414 SLE
02215: 02372 41774 02364 J CLOCK
02216: * GET NEXT W0RD
02217: 02371 41074 02265 J PLOT
02218: 02372 28266 02282 NRL BSS 1 8
02219: 02373 177777 MON E OCT -1
02220: * CONDENSE DATA SUBROUTINE
02221: *
02222: *
02223: 02374 22222 02262 CNSE ALR 3
02224: 02375 141776 02373 LA NONE
02225: 02376 161774 02372 STA HCP
02226: 02377 26742 CLP
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