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AFTAC Project No. VELA T/8705
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FINAL REPORT
1968 ALEUTIAN ISLANDS EXPERIMENT
OCEAN-BOTTOM SEISMOGRAPHIC EXPERIMENTS

Prepared by

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TEXAS INSTRUMENTS INCORPORATED
Science Services Division
P.O. Box 5621
Dallas, Texas 75222

Effective Date of Contract: 1 March 1968
Contract Expiration Date: 19 June 1968
Amount of Contract: $112,000

ACKNOWLEDGMENT

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Contract No. F33657-68-C-0875

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SECTION I

INTRODUCTION AND SUMMARY

The 1968 Aleutian Islands Experiment's objective was to obtain and analyze data for the determination of thicknesses and seismic velocities of crustal structures in the Amchitka Island vicinity. Deployment of three linear arrays of Ocean-Bottom Seismographs and detonation of a series of chemical explosions were proposed to accomplish the data acquisition portion of the program. The preliminary crustal model obtained during the analysis portion of the 1967 Aleutian Islands Experiment under Contract F33657-67-C-1341 would be supplemented by the data analysis.

For the successful completion of the 1968 effort, four tasks were defined:

- Task a - Planning
- Task b - Instrument Preparation
- Task c - Field Operations
- Task d - Analysis

Experience gained through similar field operations in the Amchitka Island area has shown the value of the earliest possible start date for field operations; therefore, all planning and preparation portions of the contract were begun immediately after contract receipt. Experiment preparation accomplishments (Section II) included the following:

- Completing modifications and routine maintenance on Ocean-Bottom Seismographs and auxiliary equipment
- Submitting a completely detailed technical plan

- Selecting the ship (up to final negotiations and awarding of subcontract)
- Evaluating the present condition of each item of field equipment located outside the TI Dallas facilities
- Establishing operating and documentation procedures for the field program navigation facility
- Outlining a complete hydroacoustic program, including the development of a charge-depth recorder and the design of an improved charge-support buoy system

Included in experiment preparation were two major engineering applications. The first was a central timing system designed to provide an accurate time signal for coordinating all shipboard functions on a "real-time" basis. The second was an automatic direction-finder which provides a unit location system with a visual display designed to facilitate recovery operation. Information on both engineering applications is detailed in Section III.

Official notification of the present contract's partial termination (modification of Task b and deletion of Tasks c and d) for the convenience of the Government was received on 9 May 1968. All phases of experiment preparation were on or ahead of schedule when notification was received. An immediate response was made to the contract change notice, resulting in modified program objectives and schedules in compliance with the AFTAC directive (Section IV). All work on the modified Task b was completed on schedule, and the Ocean-Bottom Seismographs and auxiliary equipment were stored at the TI Dallas facility.

At the request of ARPA, two Mark IV units and sufficient auxiliary equipment for six launch and recovery operations were transferred to the Lamont Geophysical Observatory, Columbia University (Section V).

An Ocean-Bottom Seismograph equipment inventory, including the location of each item, is presented in the appendix.

SECTION II

EXPERIMENT PREPARATION

A. OCEAN-BOTTOM SEISMOGRAPHS AND AUXILIARY EQUIPMENT

Properly operating equipment is essential to the success of field operations; consequently, a program of maintenance and repair of all equipment was begun immediately after receipt of the present contract. Maintenance performed on the Ocean-Bottom Seismographs and auxiliary equipment in preparation for the 1968 Aleutian Islands Experiment is presented in Tables II-1 and II-2. In general, required routine equipment maintenance was minimal, attesting to improved instrument reliability and personnel experience gained during past field programs.

In addition to completing routine equipment maintenance, the instrument preparation task included the design, procurement, fabrication, and testing of additional auxiliary equipment. Among these items, which are discussed in later sections of this report, are the following:

- Charge-depth recording package (Section II.B.5)
- Charge-support buoy system (Section II.B.5)
- Central timing system (Section III.A)
- Automatic direction-finder (Section III.B)

Table II-1

MAINTENANCE PERFORMED ON THE OCEAN-BOTTOM SEISMOGRAPHS

Unit	Maintenance Performed
1	Repaired tape recorder
15	Replaced batteries B-100 and B-300
16	Replaced battery B-300 Repaired and reanodized center ring Repaired pressure transducer
18 and 19 (and all other units)	Cleaned completely Replaced all O-rings
20	Reanodized upper hemisphere
21	Replaced battery B-300
22	Repainted center ring
24	Repainted center ring Replaced battery B-300
25	Returned Bulova Accutron clock to factory for repair
General	Replaced bent turnbuckles and rings, all beacon light batteries and spares, antenna springs, plastic-coated bails and other hardware, and all batteries dated before 1966

Table II-2

MAINTENANCE PERFORMED ON THE OCEAN-BOTTOM SEISMOGRAPH AUXILIARY EQUIPMENT

Item	Maintenance Performed
Sonar transmitter	Cleaned and replaced necessary transistors and rectifiers in units 1 and 2
Sonar transducers (3 units)	Returned damaged transducer to factory for repair (1 unit only); repainted nose cone and fin assemblies; reworked cables on 2 units
Tape recorder (playback)	Modified to provide 10-channel recording capability
Visicorders (2 units)	Repaired 4 galvanometers and rack-mounted 1 unit
Fathometers (2 units)	Returned to factory for maintenance
D-X navigators (2 units)	Returned to factory representative for maintenance and calibration
Omega Navigation System	Returned chart recorder to factory for repair; cleaned unit
WWV receivers (2 units)	Returned to factory for maintenance and alignment
Intercoms (5 stations, 3 auxiliary speakers)	Performed routine maintenance and cleaned
OEC loop	Cleaned
Electrical blasters	Cleaned
Oscilloscopes (4 units)	Completed necessary maintenance and alignment
Function generators (3 units)	Cleaned and calibrated
High-frequency generator	Cleaned and calibrated
Strobotac	Calibrated
RF dummy load and wattmeter	Cleaned
Volt-ohm meters (3 units)	Returned to Repair and Maintenance for cleaning and calibration
Hammarlund receiver	Returned to factory representative for maintenance and alignment
KWM-2A	Cleaned
Secondary clocks (2 units)	Performed routine maintenance
Cadre receivers (4 units)	Repaired to improve sensitivity
Hand tools (2 complete sets)	Cleaned; replaced missing or unusable items

B. FIELD OPERATIONS

Planning on all portions of the 1968 Aleutian Islands Experiment field operations was begun on 1 March. Areas of major concentration of effort included

- Technical plan
- Ship selection
- Field equipment
- Navigation
- Hydroacoustic program

The general field operations' schedule is presented in Table II-3; detailed information and specific schedules are presented in the following sections.

1. Technical Plan

The preliminary crustal model of the Amchitka Island area resulting from analysis of data collected during the 1967 Aleutian Islands Experiment (Contract F33657-67-C-1341) and reported in the Preliminary Analysis Report under the same contract indicated that additional data are needed to better define the crustal structure in the area. Experience gained from the 1967 effort was a major contributing factor in the choice of the specific array configuration (including station locations, explosion locations, and charge size) to be employed in the 1968 field program. The configuration was designed to provide first-arrival data from each major crustal refractor. Data obtained from the 1968 effort could be interpreted separately or combined with 1967 data using the time-term method to determine the crustal model.

Table II-3

GENERAL FIELD-OPERATIONS SCHEDULE

Task	Schedule	
	Initiation (1968)	Completion (1968)
Ship rigging	15 May	31 May
Equipment installation	1 June	7 June
Phase I	1 July	23 July
Phase II	27 July	23 Aug
Phase III	26 Aug	19 Sept
Ship derigging	30 Sept	5 Oct

The proposed technical plan, submitted to AFTAC on 28 March, consisted of three linear arrays of Ocean-Bottom Seismographs and explosions (1-, 3-, and 5-ton) located approximately perpendicular to the 1967 profile and crossing at stations S1 (51°25'12"N, 178°45'00"E), S23 (51°41'00"N, 179°09'30"E), and S31 (52°46'30"N, 179°12'24"W) (Figure II-1). Specific information on the proposed arrays is presented in Tables II-4 through II-6. A detailed schedule for all three phases of the field operations is presented in Table II-7.

2. Ship Selection

An extensive search for a suitable vessel to use during the 1968 Aleutian Islands Experiment field operations was conducted by TI personnel during the first half of March. The search was concentrated on the West Coast, although the main Gulf Coast ports also were checked. Information on three vessels that were found to be generally satisfactory for field operations is presented in Table II-8.

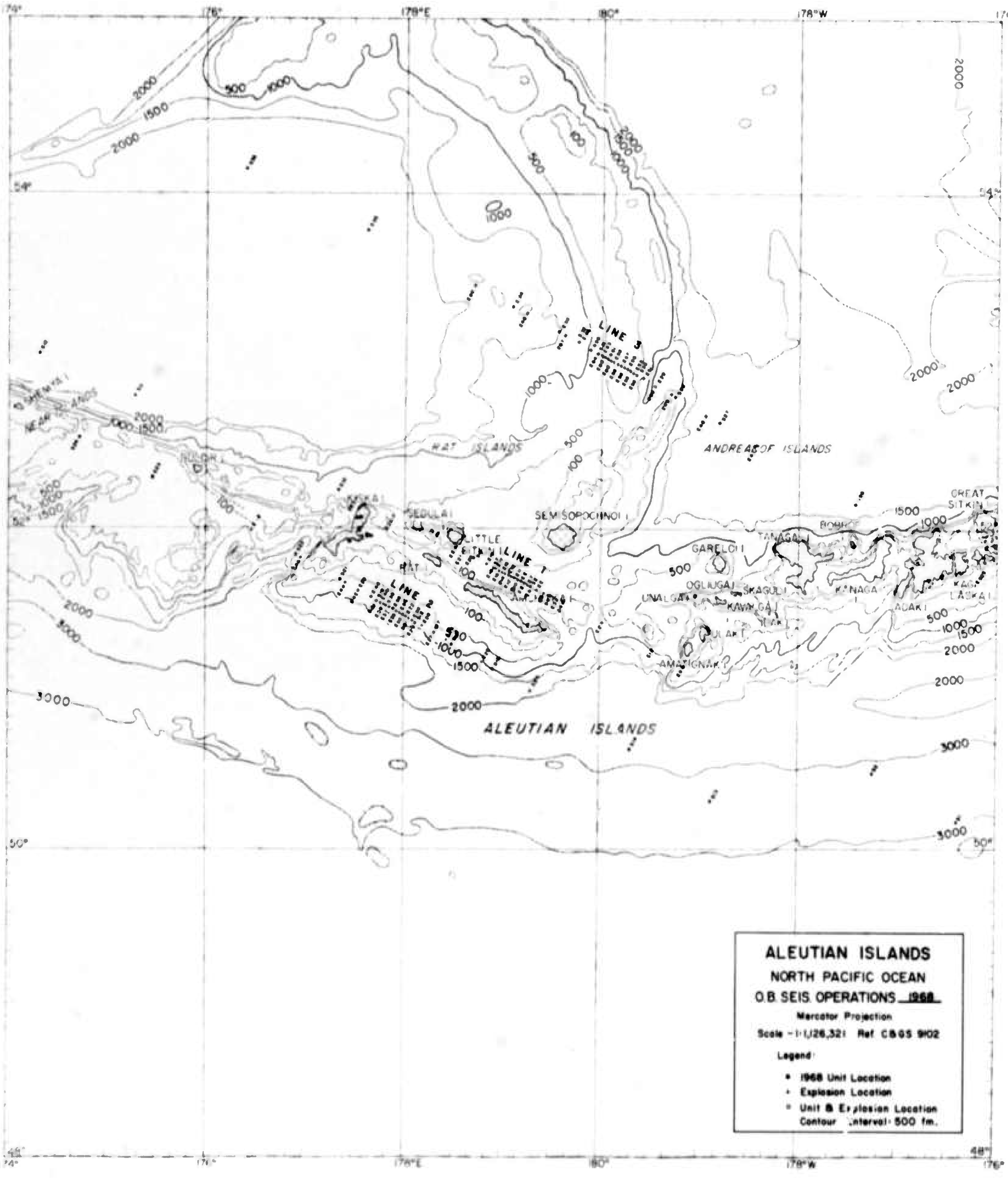

Figure II-1. Proposed Linear Arrays for 1968 Aleutian Islands Experiment

Table II-4

PROPOSED PHASE-I STATION AND CALIBRATION EXPLOSION LOCATIONS

Station (S) or Explosion (E)	Location		Water Depth (fm)	Charge Size (ton)
	Latitude	Longitude		
S1	50°09'00.1"N	176°19'58.9"W	3100	-
S2	50°27'41.9"N	177°11'11.7"W	3650	-
S3	51°07'43.9"N	179°06'58.6"W	275	-
S4	51°31'18.1"N	179°40'26.0"E	225	-
S5	51°33'44.4"N	179°32'43.3"E	280	-
S6	51°37'22.7"N	179°21'07.6"E	470	-
S7	51°44'36.1"N	178°57'50.6"E	452	-
S8	51°48'11.0"N	178°46'09.3"E	380	-
S9	51°51'44.8"N	178°34'26.2"E	280	-
S10	52°12'42.7"N	177°23'29.0"E	770	-
S11	52°47'06.8"N	175°18'42.7"E	2140	-
S12	53°01'55.3"N	174°21'18.5"E	2200	-
E1	51°14'00.4"N	179°25'57.5"W	1010	5
E2	51°23'56.4"N	179°56'30.6"W	750	5
E3	51°32'28.0"N	179°36'33.0"E	300	5
E4	51°34'56.0"N	179°28'48.0"E	300	3
E5	51°36'10.1"N	179°24'59.7"E	360	5
E6	51°37'22.7"N	179°21'07.6"E	470	1
E7	51°37'59.0"N	179°19'11.4"E	500	1
E8	51°38'35.3"N	179°17'15.2"E	525	3
E9	51°39'11.5"N	179°15'19.0"E	470	1
E10	51°39'47.7"N	179°13'22.7"E	455	1
E11	51°40'23.9"N	179°11'26.4"E	505	1
E12	51°41'00.0"N	179°09'30.0"E	500	5
E13	51°41'36.1"N	179°07'33.6"E	510	1
E14	51°42'12.2"N	179°05'37.1"E	530	1
E15	51°42'48.2"N	179°03'40.5"E	525	1
E16	51°43'24.2"N	179°01'43.9"E	490	3
E17	51°44'00.2"N	178°59'47.3"E	470	1
E18	51°44'36.1"N	178°57'50.6"E	452	1
E19	51°45'47.9"N	178°53'57.0"E	420	5
E20	51°48'11.0"N	178°46'09.3"E	380	3
E21	51°50'33.7"N	178°38'20.8"E	360	5
E22	52°03'00.0"N	177°56'27.0"E	410	5
E23	52°09'33.0"N	177°33'58.0"E	500	5

Table II-5

PROPOSED PHASE-II STATION AND CALIBRATION EXPLOSION LOCATIONS

Station (S) or Explosion (E)	Location		Water Depth (fm)	Charge Size (ton)
	Latitude	Longitude		
S13	50°17'00.0"N	178°50'56.0"W	4000	-
S14	50°36'43.5"N	179°41'20.8"W	2670	-
S15	51°06'58.4"N	178°58'01.2"E	1145	-
S16	51°16'24.0"N	178°32'00.0"E	785	-
S17	51°20'24.6"N	178°20'47.7"E	600	-
S18	51°24'24.2"N	178°09'33.4"E	882	-
S19	51°32'20.1"N	177°46'58.9"E	922	-
S20	51°36'16.4"N	177°35'38.8"E	696	-
S21	51°40'11.6"N	177°24'16.7"E	640	-
S22	51°49'16.1"N	176°57'37.5"E	450	-
S23	52°17'07.4"N	175°32'42.0"E	337	-
S24	52°31'52.9"N	174°45'38.3"E	122	-
E24	50°58'48.9"N	174°20'11.0"E	1920	5
E25	51°09'40.6"N	178°50'36.2"E	1000	5
E26	51°17'44.3"N	178°28'16.1"E	665	5
E27	51°20'24.6"N	178°20'47.6"E	600	3
E28	51°23'04.4"N	178°13'18.2"E	875	5
E29	51°24'24.1"N	178°09'33.2"E	875	1
E30	51°25'04.0"N	178°07'40.8"E	875	1
E31	51°25'43.8"N	178°05'48.2"E	865	3
E32	51°26'23.6"N	178°03'55.5"E	800	1
E33	51°27'03.3"N	178°02'02.7"E	810	1
E34	51°27'43.0"N	178°00'10.0"E	770	1
E35	51°28'22.7"N	177°58'17.1"E	710	5
E36	51°29'02.3"N	177°56'24.2"E	715	1
E37	51°29'41.9"N	177°54'31.3"E	710	1
E38	51°30'21.5"N	177°52'38.3"E	1045	1
E39	51°31'01.1"N	177°50'45.2"E	970	3
E40	51°31'40.6"N	177°48'52.1"E	915	1
E41	51°32'20.1"N	177°46'58.9"E	920	1
E42	51°33'39.0"N	177°43'12.4"E	780	5
E43	51°36'16.4"N	177°35'38.8"E	685	3
E44	51°38'53.3"N	177°28'04.2"E	615	5
E45	51°48'16.0"N	177°00'20.0"E	444	5
E46	51°58'11.0"N	176°34'43.4"E	300	5

Table II-6

PROPOSED PHASE-III STATION AND CALIBRATION EXPLOSION LOCATIONS

Station (S) or Explosion (E)	Location		Water Depth (fm)	Charge Size (ton)
	Latitude	Longitude		
S25	51°39'33.0"N	176°07'04.2"W	150	-
S26	52°07'27.6"N	177°21'33.6"W	1650	-
S27	52°37'14.2"N	178°45'20.8"W	1935	-
S28	52°46'30.0"N	179°12'24.0"W	970	-
S29	52°50'26.3"N	179°24'03.2"W	775	-
S30	52°54'21.5"N	179°35'44.4"W	500	-
S31	53°02'08.4"N	179°59'13.2"W	525	-
S32	53°06'00.1"N	179°48'59.2"E	1215	-
S33	53°09'50.6"N	179°37'09.5"E	1475	-
S34	53°18'43.9"N	179°09'25.5"E	1510	-
S35	53°45'57.3"N	177°41'00.9"E	2140	-
S36	54°07'24.4"N	176°27'16.8"E	2145	-
E47	52°29'12.8"N	178°22'18.6"W	1940	5
E48	52°39'53.6"N	178°53'03.4"W	1930	5
E49	52°47'25.0"N	179°15'00.0"W	345	5
E50	52°50'26.3"N	179°24'03.2"W	780	3
E51	52°53'03.2"N	179°31'50.4"W	940	5
E52	52°54'21.5"N	179°35'44.4"W	500	1
E53	52°55'00.6"N	179°37'41.5"W	340	1
E54	52°55'39.6"N	179°39'38.6"W	325	3
E55	52°56'18.6"N	179°41'35.8"W	315	1
E56	52°56'57.6"N	179°43'33.1"W	310	1
E57	52°57'36.6"N	179°45'30.4"W	340	1
E58	52°58'15.5"N	179°47'27.8"W	360	5
E59	52°58'54.4"N	179°49'25.2"W	390	1
E60	52°59'33.3"N	179°51'22.7"W	420	1
E61	53°00'12.1"N	179°53'20.2"W	455	1
E62	53°00'50.9"N	179°55'17.8"W	480	3
E63	53°01'29.6"N	179°57'15.5"W	500	1
E64	53°02'08.4"N	179°59'13.2"W	525	1
E65	53°03'25.7"N	179°56'51.2"W	680	5
E66	53°06'00.1"N	179°48'59.2"E	1215	3
E67	53°08'33.9"N	179°41'06.3"E	1435	5
E68	53°16'12.2"N	179°17'22.1"E	1620	5
E69	53°26'15.8"N	178°45'30.0"E	1552	5

Table II-7

PROPOSED DETAILED PHASE SCHEDULE

Task	Phase I		Phase II		Phase III	
	Date (1968)	Position	Date (1968)	Position	Date (1968)	Position
Launch	1 July	S1, S2	27 July	S13, S14	26 Aug	S25, S26
Launch	2 July	S3, S4, S5	28 July	S15, S16, S17	27 Aug	S27, S28, S29
Launch	3 July	S6, S7, S8, S9	29 July	S18, S19, S20, S21	28 Aug	S30, S31, S32, S33
Launch	4 July	S10	30 July	S22	29 Aug	S34
Weather	5 July	-	31 July	-	30 Aug	-
Launch	6 July	S11, S12	1 Aug	S23, S24	31 Aug	S35, S36
Travel	7 July	-	2 Aug	-	1 Sept	-
Fire	8 July	E23, E22	3 Aug	E46, E45	2 Sept	E69, E68
Fire	9 July	E21, E20, E19	4 Aug	E44, E43, E42	3 Sept	E67, E66, E65
Fire	10 July	E18, E17, E16	5 Aug	E41, E40, E39	4 Sept	E64, E63, E62
Weather	11 July	-	6 Aug	-	5 Sept	-
Fire	12 July	E15, E14, E13	7 Aug	E35	6 Sept	E61, E60, E59
Fire	13 July	E12, E11, E10	10 Aug*	E38, E37, E36, E34	7 Sept	E58, E57, E56
Fire	14 July	E9, E8, E7	11 Aug	E33, E32, E31, E30	8 Sept	E55, E54, E53
Weather	15 July	-	12 Aug	-	9 Sept	-
Fire	16 July	E6, E5, E4	13 Aug	E29, E28, E27	10 Sept	E52, E51, E50
Fire	17 July	E3, E2, E1	14 Aug	E26, E25, E24	11 Sept	E49, E48, E47
Weather	18 July	-	15 Aug	-	12 Sept	-
Retrieve	19 July	S12, S11	16 Aug	S24, S23	13 Sept	S36, S35
Retrieve	20 July	S10, S9, S8	17 Aug	S22, S21, S20	14 Sept	S34, S33, S32
Retrieve	21 July	S7, S6, S5	18 Aug	S19, S18, S17	15 Sept	S31, S30, S29
Retrieve	22 July	S4, S3	19 Aug	S16, S15, S14	16 Sept	S28, S27
Retrieve	23 July	S2, S1	20 Aug	S13	17 Sept	S26, S25
Standby	24 July	Adak	21 Aug	Clock release	18 Sept	Clock release
Standby	25 July	Adak	22 Aug	Clock release	19 Sept	Clock release
Port call	26 July	Adak	23 Aug	Adak	-	-
Port call	-	-	24 Aug	Adak	-	-
Port call	-	-	25 Aug	Adak	-	-

*Travel to Adak on 8 and 9 August to obtain second cargo of explosives

Table II-8

INFORMATION ON SHIPS AVAILABLE FOR 1968 ALEUTIAN ISLANDS EXPERIMENT

Item	Vessel		
	M/V RIG BUILDER	R/V SEA SCOPE	M/V PACIFIC APOLLO
Owner	Puget Sound Tug and Barge	Sea Scope Corporation	Pacific Towboat and Salvage
Home port	Seattle, Washington	Santa Barbara, California	Long Beach, California
Type	Offshore supply boat	WWII minesweeper	Offshore supply boat
Size	165 ft x 36 ft	184 ft x 34 ft	165 ft x 36 ft
Gross tonnage	199	784	251
Advantages	Excellent deck space for engineering house and explosives	Excellent quarters and equipment	Excellent deck space for engineering house and explosives
Disadvantages	Inadequate number of quarters aboard; owner will remedy this situation by adding additional quarters at own expense	Lack of deck space requires using the hold as an instrument room and storing explosives on two deck levels; gross tonnage subjects the vessel to the new Coast Guard regulations for research vessels, which could complicate rigging	Inadequate number of quarters aboard; owner not enthusiastic about short-term lease

3. Field Equipment

Upon completion of the 1967 Aleutian Islands Experiment, some field equipment was stored either at the Naval Inactive Ship Maintenance Facility in Orange, Texas, or at Burton's Shipyard in Port Arthur, Texas. During a ship selection trip to the Gulf Coast, both facilities were visited to obtain an up-to-date evaluation of each item's condition. Cost of refurbishment and shipment to the West Coast was an important factor to be considered if a Gulf Coast ship were not chosen for use during field operations. A list of equipment located at both Orange and Port Arthur is presented in the appendix.

4. Navigation

Previous field experiments demonstrate the necessity for accurate navigational fixes throughout all field-operations phases. Navigational accuracy affects not only the usefulness of data recorded during a field experiment where station and explosion locations are important but often is a deciding factor in the overall operational success of the effort. Considerable time can be saved and better use of breaks in local weather can be made by efficient and correct navigational procedures. Therefore, procedures to maintain a 24-hr operational schedule during the 1968 Aleutian Islands Experiment field operations were established. Navigational aids to be employed on a routine basis include

- Omega
- Loran C
- Loran A
- Radar
- Celestial
- Deadreckoning
- Fathometer data

Routine navigation fixes were scheduled to be taken hourly (on the hour) during day watches except during periods requiring frequent operational fixes (station drops, charge launches, etc.) and hourly (on the hour) during night watches or as required. The following operational navigation fixes were scheduled to be taken:

- Station drops — necessary prefixes, station-drop fix
- Charge launches — necessary prefixes, charge-launch fix, ship location at detonation, and ship-to-buoy radar fix at detonation
- Unit retrieval — retrieval location
- Calibration checks — celestial and radar fixes daily, if possible, or as often as practical

Since complete documentation is essential to navigation, operational planning included the design of various charts and logs and the adoption of specific procedures for documenting navigational operations. A daily review and evaluation of all navigation fixes computed during the previous 24 hr was planned for the 1968 Aleutian Islands Experiment to increase overall navigational accuracy.

5. Hydroacoustic Program

A charge-depth-determination study conducted following the 1967 Aleutian Islands Experiment field operations revealed that the hydroacoustic data recorded, while of good quality, was insufficient for conclusive results. The three methods used in the 1967 study (bubble-pulse period measurements, traveltime determinations, and rope stretch-factor calculations) could not be evaluated due to the lack of actual velocity and/or charge-depth measurements.

The two objectives of the 1968 Aleutian Islands Experiment hydroacoustic program were

- To develop a reliable, self-contained on-charge sensor and recorder package to determine actual charge depth accurately
- To design a charge-support buoy to replace the box buoys destroyed during the 1967 Aleutian Islands Experiment; prime design consideration was to be given to handling and storage problems

Specifications for the designed charge-depth recording package are presented in Table II-9. Hydrostatic-pressure measurements would be converted to depth values. The package would be rigidly attached to the charge before launch, released prior to detonation, and retrieved during support-buoy recovery. A sketch of the proposed charge-depth recording package is presented in Figure II-2.

Box buoys used for charge support during previous experiments, namely, the 1966 Kurile Islands Experiment (Contract F33657-67-C-0105) and the 1967 Aleutian Islands Experiment (Contract F33657-67-C-1341), posed many handling and storage problems. The necessity to replace the box buoys used during the 1967 Aleutian Islands Experiment field operations provided an opportunity to design an alternate charge-support buoy system. Previous experience and the 1968 Aleutian Islands Experiment operational plan indicated that the buoy system should satisfy the following requirements:

- Capacity to withstand 3-ton maximum stress
- Ease of handling
- Efficient storage
- Maximum safety
- Continuous maintenance-free service

Table II-9

DEPTH-RECORDER PACKAGE SPECIFICATIONS

Unit	Item	Description
Sphere	Material	Glass
	Outer diameter	13 in.
	Inner diameter	12.2 in.
	Buoyancy	19 lb
	Construction	Hemisphere
	Seal	Sealing compound, 2 stainless-steel hose clamps
Pressure transducer	Type	Twisted Bourdon tube
	Accuracy	±2 percent, full recording scale
Recorder	Chart	Circular paper
	Drive	Mechanical, hand-wound clock
	Speed	Variable
	Accuracy	±0.3 percent
Release timer	Clock	Mechanical, hand-wound
Release mechanism	Type	Mechanical, spring-loaded
	Activation	Corrosive link
	Release time	15 min (electrically accelerated corrosive action) 20 min (normal corrosive action)
Transmitter	Frequency	CB
	Activation	Pressure switch
	Antenna	Short whip
Power	Battery	9-v dry cell
Activation	System	Magnetic switch, externally activated
Feedthroughs	Antenna	Electrical
	Release mechanism	Electrical
	Transmitter switch	Pressure
	Pressure transducer	Pressure

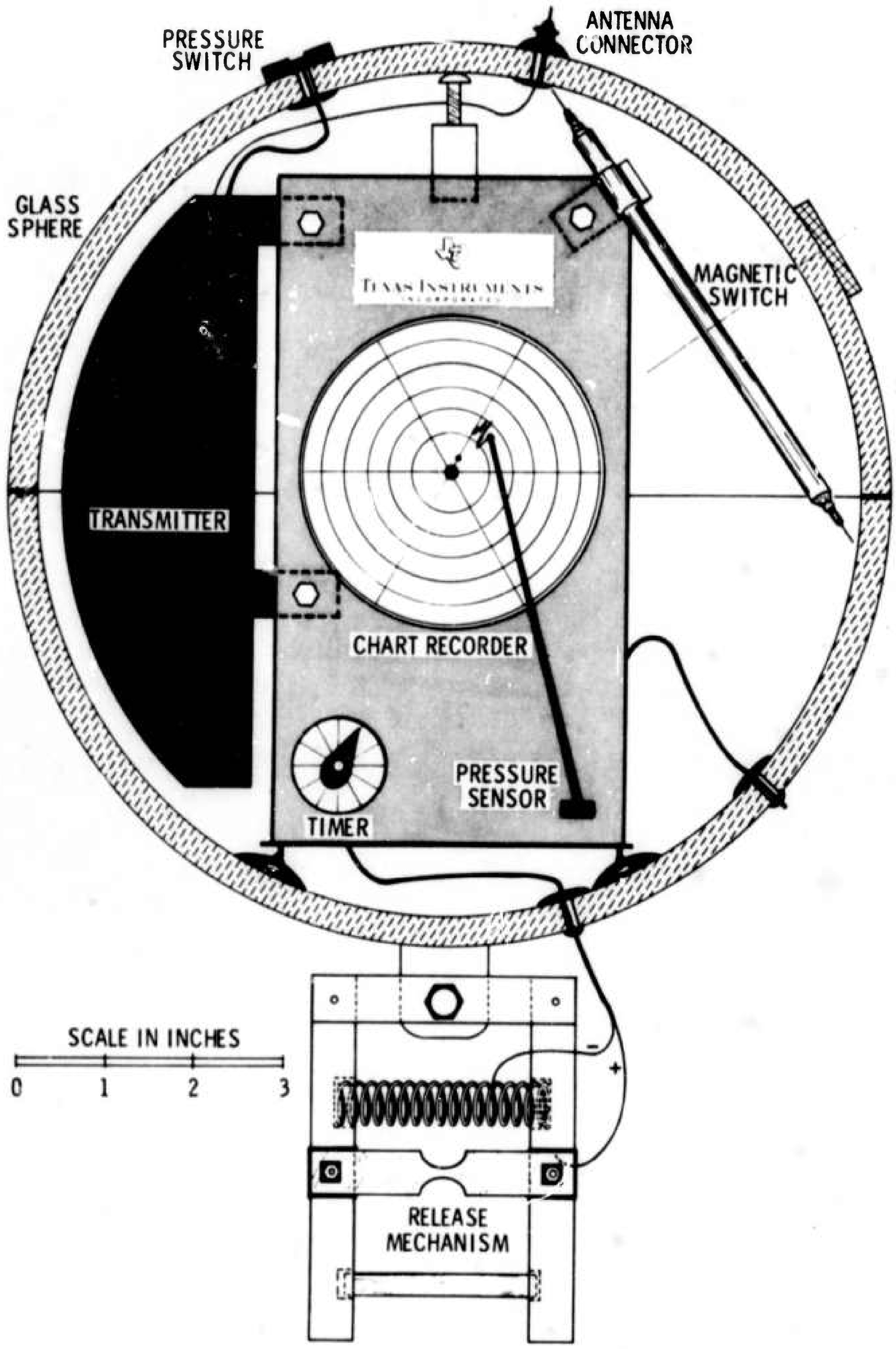

Figure II-2. Proposed Charge-Depth Recording Package

A charge-support system employing nylon-reinforced rubber dunnage bags was considered superior to the box-buoy system used during previous field operations. A comparison of the two systems' characteristics is presented in Table II-10. Two dunnage bags would be used to replace the box buoy. A major advantage of dunnage bags is the increased safety factor in normal on-deck movement, launch, and retrieval operations and also in the event of a charge misfire. In previous experiments, much effort and time were required to cut a charge loose after misfire, and the ship and crew were subjected to a certain amount of danger. If the dunnage bags were used as a charge-support system, the charge could be easily disposed of after a misfire by puncturing the dunnage bags and allowing them to sink with the charge. The relatively inexpensive bags and buoy-system hardware would make the subsequent loss negligible.

Table II-10

BUOY-SYSTEM COMPARISON

Characteristic	Box Buoy	Rubber Buoy
Size	8 ft x 4 ft x 4 ft	7 ft x 4 ft (deflated) 6 ft x 3.5 ft x 2 ft (inflated)
Construction	Plywood and styrofoam	Nylon-reinforced rubber
Weight	≈350 lb	32 lb
Storage	35 sq ft of deck space	≈20 sq ft of deck space (inflated) Off-deck storage when deflated and folded
Durability	Rugged and relatively maintenance-free	Rugged and relatively maintenance-free Easily repaired with standard repair kit
Life expectancy	≈1 yr	≈3 yr

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SECTION III

EQUIPMENT DESIGN

A. CENTRAL TIMING SYSTEM

1. General

The purpose of the central timing system is to provide an accurate time-signal source for coordinating all shipboard functions in "real time." In the past, the standard procedure has been to start or reset various functions manually while listening to WWV, WWVH, or JJY. Accuracy depended on the audibility and clarity of the received signal which varied greatly with weather conditions, time of day, and local interference from other shipboard equipment. Addition of the Omega Navigation System to the Ocean-Bottom Seismograph auxiliary equipment provided a source of accurate timing information. The rubidium frequency standard operates with a frequency stability of one part in 10^{11}. Furthermore, the system operates from a floating power supply which is immune to shipboard power losses of duration less than the silver-cadmium batteries' discharge time.

The 100-kHz output of the rubidium frequency standard is utilized to drive a countdown logic circuit which provides both a visual time display and a coded output suitable for magnetic recording. Both outputs may be paralleled as many times as desired to display or record time anywhere on the ship.

2. Operation

The central timing system consists of the Omega Navigation System rubidium standard, a time-code generator (Figure III-1), and necessary power supplies. Figure III-2 presents a block diagram of the system.

Figure III-1. Central Timing System Time-Code Generator

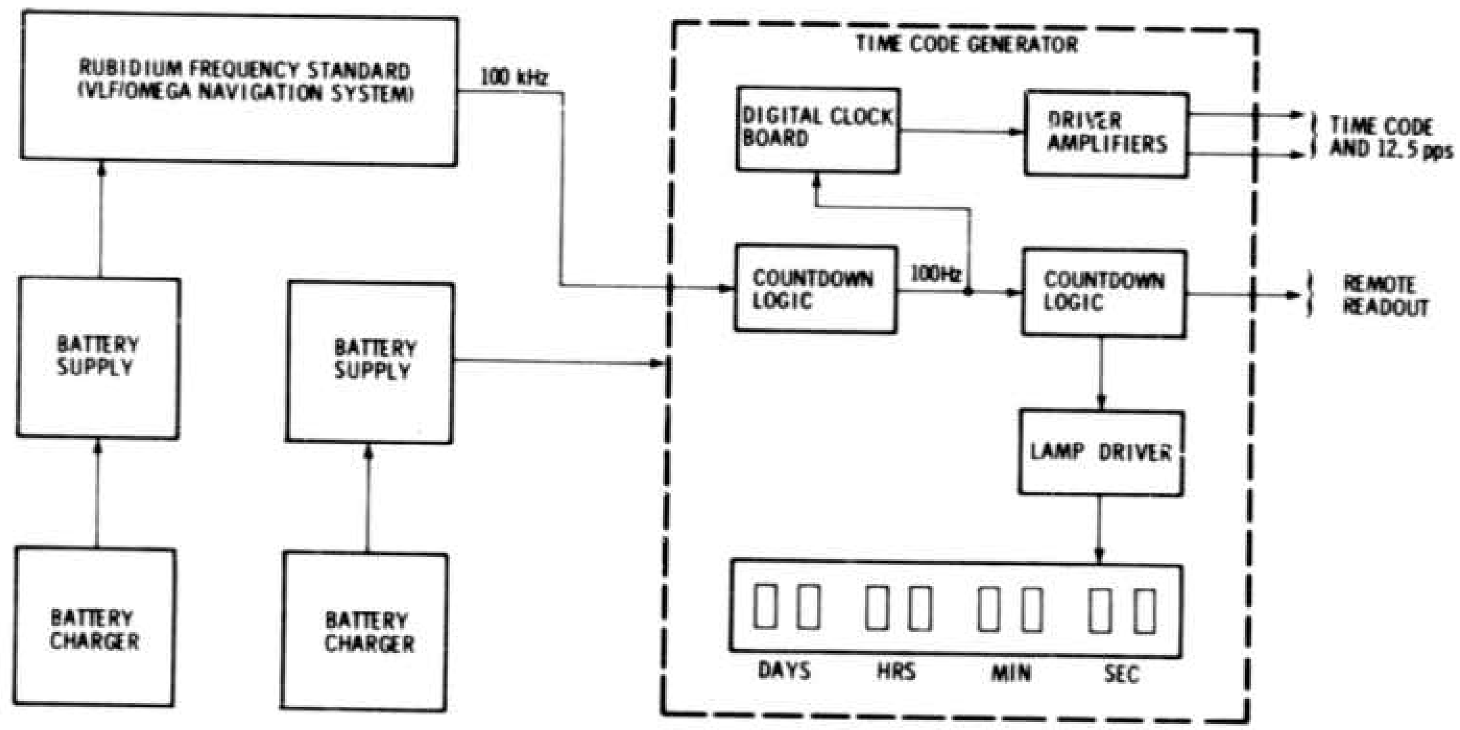

Figure III-2. Central Timing System Block Diagram

The 100-kHz signal from the rubidium standard is input to the time-code generator, where decade counters are employed to produce a 100-Hz signal. Time-code and 12.5-pps signals suitable for magnetic recording are output from a digital-clock board, and the utilization of driver amplifiers permits simultaneous recording on different recorders. Visual time display (days, hours, minutes, and seconds) is accomplished by dividing the 100-Hz signal to drive the individual readout tubes.

Six switches are provided for initial synchronization of the central timing system with UT (Universal Time). The front panel of the time-code generator must be removed to obtain access to these controls (Figure III-3). Switches are provided to perform the following functions:

- Clear the clock
- Hold a specific time
- Advance the clock at a fast (10 counts/1000) or slow (1 count/1000) rate
- Retard the clock at a fast (10 counts/1000) or slow (1 count/1000) rate

With the aid of an oscilloscope, the central timing system can be synchronized to within ±1 msec of WWV. Once set, the time-code generator should not need adjustment for several months, the duration of a typical Ocean-Bottom Seismograph field program.

The central timing system also contains several programming features which may be used with various peripheral equipment. A 4-phase, 400-Hz output is provided to drive a synchronous motor; a remote firing switch is available for detonating calibration charges on any exact minute; and switching is provided to turn other equipment such as the Ocean-Bottom Seismograph reset on or off as desired.

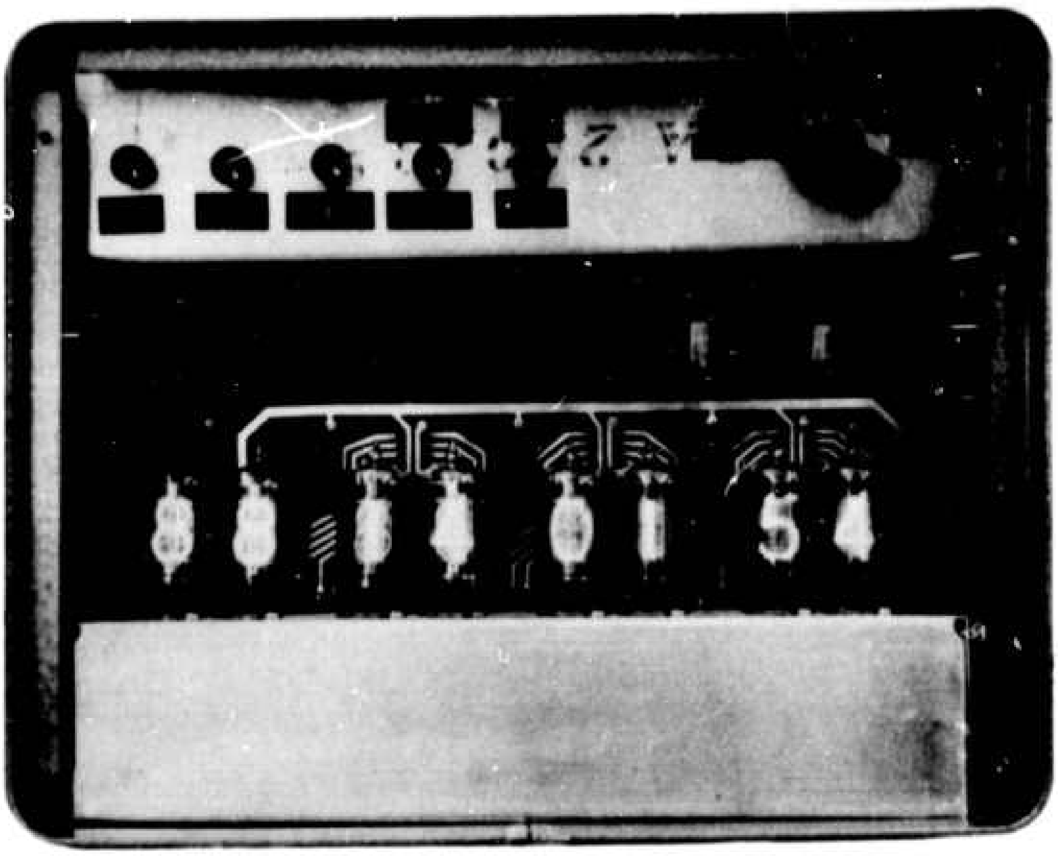

Figure III-3. Time-Code Generator Controls

B. AUTOMATIC DIRECTION-FINDER

1. General

The Ocean-Bottom Seismograph's radio beacon is its primary means of location. Signals transmitted by a surfaced unit may be detected for 50 mi from a surface ship or for several hundred miles from a high-flying aircraft. Radio direction-finding equipment is necessary for unit location since, even under ideal daytime weather conditions, a surfaced Ocean-Bottom Seismograph is visible only up to about 3000 ft from a surface vessel. During past operations, a manually operated hand-held loop has been used for radio direction-finding. This system, although dependable, has many disadvantages from the operation standpoint:

- In most cases, correct directional readings can be obtained only when the loop is held in a specific location on the ship which is dependent on the superstructure's reflective characteristics. This location varies from ship to ship but generally is located at the bow or some spot on the foredeck.

- During some location and recovery operations, operators must stand out in the weather for several hours.
- Under very strong wind conditions, the noise level inside the earphones tends to mask out the nulls and audible signals which are the criteria for correct interpretation and operation of the loop receiver.
- During extreme weather conditions, outside operation of the hand loop may be impossible.

In an effort to overcome the loop receiver's disadvantages, experiments on a dual-channel receiver were conducted during previous operations. Three vertical whip antennas were arranged so that a phase shift in the beacon signal could be measured. This system is sound in theory but, in practice, the slightest phase error between the two receivers was found to be of greater magnitude than the signal shift. In addition, crossfeed problems were observed between the two receivers, which had to operate from a common oscillator.

The need for an improved radio direction-finding system has been clearly identified from previous experience in field programs. A standard commercial automatic direction-finder (ADF) was obtained and modified for use in Ocean-Bottom Seismograph field operations.

2. Operation

Standard marine ADF units are designed to operate on beacon (200 to 600 kHz), broadcast (600 to 1700 kHz), and marine (1.7 to 4.0 MHz) bands. After considering various commercial units, the Bendix ADF Model 100 (Figure III-4) was chosen as the basic unit of the automatic direction-finder system. An ADF-100 unit was obtained, along with a dual loop and sense antenna (Figure III-5). Receiver output is both audio and visual; in operation, the visual display (CRT) always points in the direction of the transmitted signal.

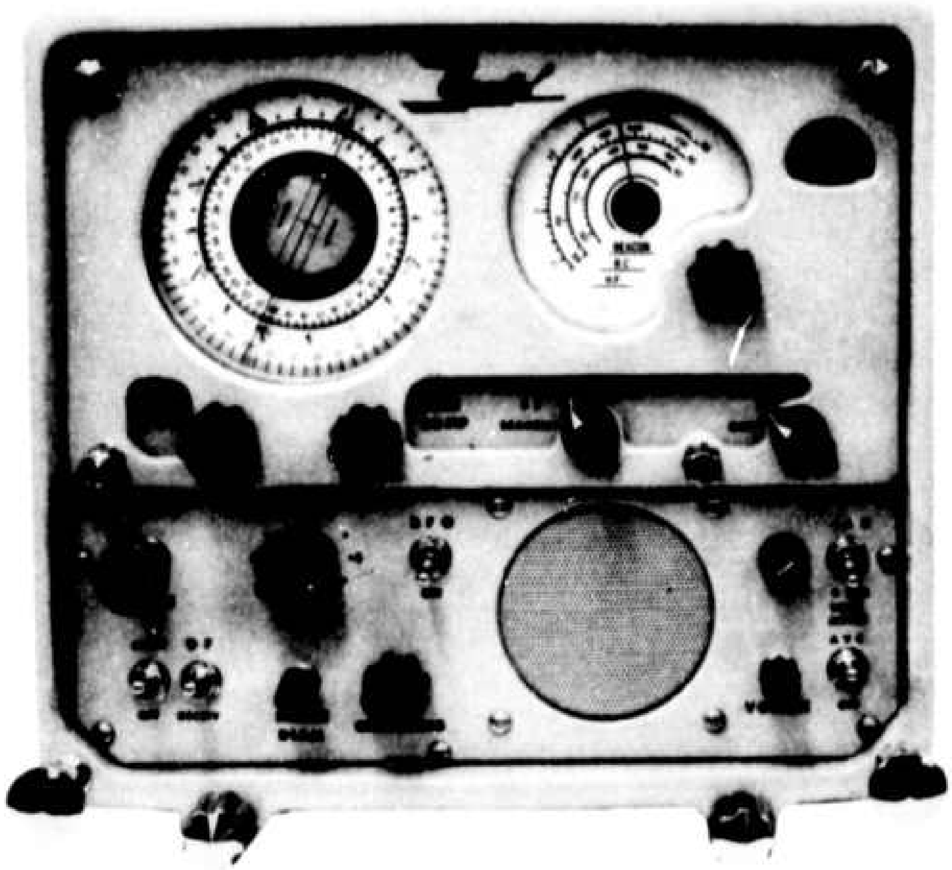

Figure III-4. Bendix Automatic Direction-Finder Model 100

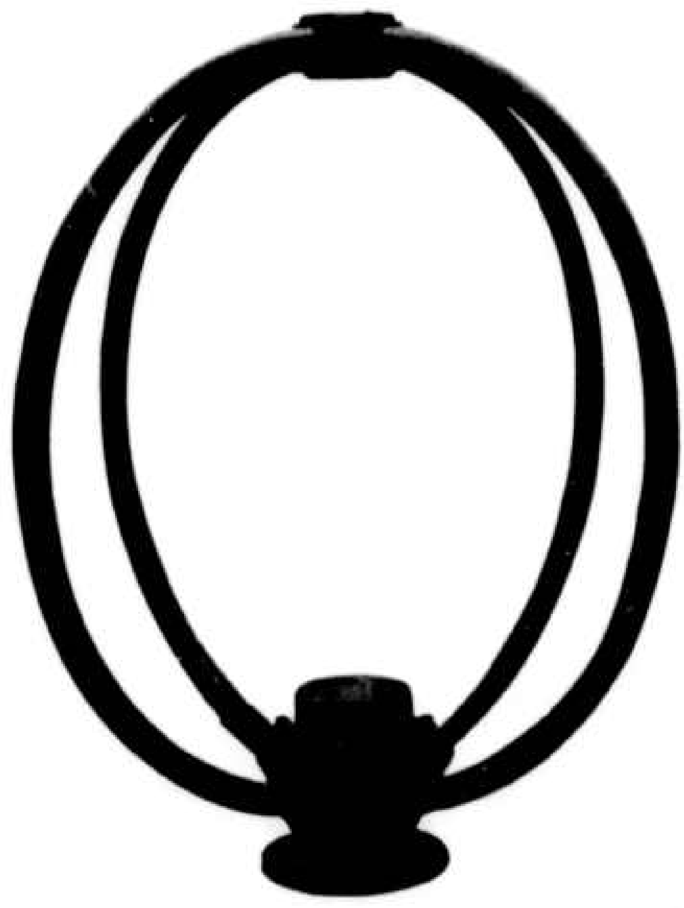

Figure III-5. Bendix ADF-100 Dual-Loop and Sense Antenna

The Ocean-Bottom Seismograph radio beacon transmits at a frequency of 26.670 MHz. Beacon frequency is converted to a lower frequency within the range of the ADF receiver by the automatic direction-finder system. The ADF-100 and antennas are used as received from the factory. The frequency converter consists of a 30-MHz oscillator and a preamplifier designed to feed three Hewlett Packard 10534A mixers, one for each loop antenna and one for the sense antenna. Thus, the 26.670-MHz signal which is phase-detected by the two loop antennas is converted to 3.330 MHz (30.000 MHz minus 26.670 MHz) which is fed to the receiver for display.

Bench tests were conducted to measure system sensitivity, to measure and balance out any phase shifts occurring during frequency conversion, to measure system noise, and to calibrate the system.

The automatic direction-finder was mounted in an 18-ft Chris Craft, and tests were conducted on a freshwater lake. Correct directional readings were achieved for a distance of approximately 4.5 mi, even though both video and audio receptions were cluttered with local noise. This noise is attributed to CB transmitters in the area; therefore, problems resulting from this type of disturbance are assumed to be nonexistent at sea. Field intensity curves in the handbook Reference Data for Radio Engineers indicate that transmission of a signal over 4.5 mi of fresh water is equivalent to transmission over approximately 32 mi of salt water. Verification can be made only by tests at sea, which will be scheduled during the next operational program.

SECTION IV
CONTRACT TERMINATION PROCEDURES

Official notice of the partial termination of the present contract for the convenience of the Government was received on 9 May 1968. The contract change notice included the modification of Task b (instrument preparation) and the deletion of Tasks c (field operations) and d (analysis).

The objectives of the modified Task b were threefold:

- Complete major modifications to make the 10 older units fully operational
- Complete improvements and modifications on the Ocean-Bottom Seismographs and auxiliary equipment approved by the AFTAC project officer
- Prepare the 16 Ocean-Bottom Seismographs and major auxiliary equipment for storage for a period not to exceed 12 months

Specific steps taken by project personnel to modify original objectives and schedules after receipt of the termination notice are as follows:

- Ship charter, crane lease, and powder trade negotiations were dropped; these negotiations were in the final stages of completion
- A detailed check of all issued purchase orders was conducted, and a "hold" was placed on all items that had not been shipped
- The status of Task b was reviewed and a list of recommended actions in the following areas was prepared and discussed with the AFTAC project officer
  - — work which should be completed
  - — work which should be stopped
  - — material which should be kept
  - — material which should be returned to the vendor; (restocking charges were obtained on all items to be returned)
  - — additional material required to accomplish the modified Task b

Instrument preparation (Section II. A) was completed, and two major engineering efforts (central shipboard timing system and automatic direction-finder) were accomplished (Section III). A secure area was obtained at the TI Dallas facility, and the Ocean-Bottom Seismographs and auxiliary equipment were placed in temporary storage. Preparation of the Ocean-Bottom Seismographs for storage consisted of disconnecting batteries and sealing the units under normal pressure.

SECTION V

EQUIPMENT TRANSFER

AFTAC notified TI on 19 July 1968 that two Mark-IV Ocean-Bottom Seismographs and necessary auxiliary equipment to support six launch and recovery operations would be transferred to the Office of Naval Research (ONR) for a field experiment to be conducted during August and September 1968 by Lamont Geophysical Observatory (LGO), Columbia University. In compliance with the AFTAC directive, accountability for the equipment was transferred from the present contract to Contract N00014-67-A-0108-0004 for a period not to exceed 6 months.

A list of the equipment transferred to ONR is presented in the appendix of this report.

APPENDIX A

OCEAN-BOTTOM SEISMOGRAPH
EQUIPMENT INVENTORY

APPENDIX A

OCEAN-BOTTOM SEISMOGRAPH EQUIPMENT INVENTORY

The equipment inventory of Ocean-Bottom Seismographs and auxiliary equipment was updated during the present contract. A complete listing is presented in Tables A-1 through A-11 and is divided into the following categories:

- Ocean-Bottom Seismographs
- Auxiliary equipment
  - — launch and recovery
  - — navigation
  - — communications
  - — explosive detonation
  - — data playback and hydroacoustic recording
  - — deck
  - — experimental
  - — test
  - — expendable
  - — miscellaneous

All including both contract and TI-owned equipment (marked with an asterisk * in the following tables) required for Ocean-Bottom Seismograph field operations has been included in the inventory. Equipment-location codes apply to the following:

- Dallas, Texas — OBS equipment located at the TI Dallas facility
- Orange, Texas — OBS equipment located at the Naval Inactive Ship Maintenance Facility in Orange, Texas
- Port Arthur, Texas — OBS equipment located at Burton's Shipyard in Port Arthur, Texas
- Columbia University — OBS equipment loaned at ARPA request to Lamont Geological Observatory (LGO), Columbia University, under Contract N00014-67-A-0108-0004. Equipment is to be returned within 6 months

Table A-1

INVENTORY AND LOCATION OF OCEAN-BOTTOM SEISMOGRAPHS

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Mark-III Units	2				
No. 1		1			
No. 25		1			
Mark-IV Units	8				
No. 15		1			
No. 16		1			
No. 18		1			
No. 19		1			
No. 20					1
No. 21		1			
No. 22		1			
No. 24					1
Mark-V Units	6				
No. 26		1			
No. 27		1			
No. 28		1			
No. 29		1			
No. 30		1			
No. 31		1			

Table A-2

INVENTORY AND LOCATION OF
LAUNCH AND RECOVERY AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Sonar equipment					
Transmitter	2	1			1
Transducer	3	1			2
Chain hoist					
Peerless-1 ton	1	1			
Wright-3/4 ton	4	3			1
WWV Receiver, Specific Products, No. WWV5	2	1			1
Seismometer turntable and sled	1		1		
Vacuum pump	2				
E. H. Sargent 63-40425		1			
E. H. Sargent 64-144060					1
Vacuum gage	2	1			1
Hydraulic pump, Shefter Corp., 184879	1				1
Radio-beacon antenna cables	18	12			6
Quick-release hook	1				1
Lifting bail assembly	2	1			1
Radio direction-finder					
ADF-100	1	1			
OEC loop antenna	1				1
CB transceiver, Cadre 510	4	4			
Lifting collar	3	2			1
Spare antenna	5	2			3
Recorder takeup reels	7				7

Table A-3

INVENTORY AND LOCATION OF NAVIGATION AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Omega Navigation System	1	1			
Loran A D-X Navigator					
AF 57061-33G	1	1			
AF 57061-33H	1	1			
Spare parts kit	1	1			
Timing system					
Central	1	1			
Secondary	2	2			
Fathometer					
Ocean Sonics precision recorder	2	2			
EDO pierced-lobe transducer	2	2			
Spare parts kit	1	1			
Receiver, Hammarlund HQ-250, 5417	1	1			

Table A-4

INVENTORY AND LOCATION OF COMMUNICATIONS AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
SSB equipment					
Transceiver, Collins KWM2A	1	1			
RF linear amplifier, Collins 30-L1	1	1			
Antenna, 30 ft vertical (with base)	1	1			
Antenna coupler, RF302	1	1			
Johnson Viking matchbox	1	1			
Carrying cases	4	4			
Receiver, general purpose					
Northern N620	1	1			
Hallicrafter S120	1	1			
Intercom					
Fanon master stations	5	5			
Master-station power supplies	5	5			
Auxiliary speakers	4	4			

Table A-5

INVENTORY AND LOCATION OF
EXPLOSIVES DETONATION AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Firing-line reel	1*		1		
Cable, telephone 18TC-WPK	5000 ft		5000 ft		
Blaster					
SIE, SCD-2000 BA, 4669-E	1*	1			
SIE, SCD-2000 BA, 0273-J	1*	1			
SIE, SCD-2000 BA, 1500-H	1*	1			
Geotron-K, 78	1*	1			
HS-1200, 219508	1*	1			
ET, BCI-A, 1013	1*	1			
Charge launch "A" frame	1			1	
Galvanometer, cap checker, 4787	1	1			

*TI-owned equipment

Table A-6

INVENTORY AND LOCATION OF DATA PLAYBACK AND HYDROACOUSTIC RECORDING AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Magnetic tape recorder					
Precision Instruments 14-channel	1				1
Ampex Model 30	1	1			
Galvanometer amplifier 6-channel	2				2
Playback channel selector	1				1
Recorder, paper					
Visicorder, 906-C, 12-channel	2(1*)	1*			1
Galvanometers, M1650	10(6*)	4*			6(2*)
Galvanometers, M3300	2	2			
Paper takeup assembly	1	1			
Rack-mount adapter	1				1
Hydrophones					
Geospace, MP-8	3	3			
GSI, 2-element	1	1			
Wire reel, DR-5	1*		1*		

*TI-owned equipment

Table A-7

INVENTORY AND LOCATION OF DECK AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Instrument house, 25 ft x 45 ft	1		1		
Crane accessories					
Base plate	1			1	
Pedestal	1			1	
Boom support	1			1	
Load reduction pully, 5 ton	1	1			
Hydraulic slack-thrower	1	1			
Welding equipment					
Acetylene	1	1			
Electric arc	1	1			
Fire extinguishers	3	3			
Bench grinder	1	1			
Winch, single-drum Nova, 10 hp	1			1	

Table A-8

INVENTORY AND LOCATION OF EXPERIMENTAL AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Light beacon, Benthos 9-1/2 in. glass	1	1			
Acoustic transponder EDO No. 450	1	1			
Radar reflector, 4 in. dia.	1	1			

Table A-9

INVENTORY AND LOCATION OF TEST AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Attenuator sets	4*				
HP-350 B, 7155		1			
HP-350 B, 003-06796					1
HP-350 D, 220-02662		1			
Boonton M-600, 601		1			
Electronic counter, HP-5243L, 219463	1*	1			
Low-frequency function generator HP-202A, 237098	3*	3			
Power supplies					
Marquette 307A, modified	2				2
Kepco ABC 15-1A	2	2			
Kepco ABC 30-0.3A	2*				2
TI 219229	1	1			
Sorenson QR 18-4	1	1			
Sorenson QRB 40-2	4				4
Sorenson QSB 28-4	1	1			
Oscilloscopes					
HP-130B	3*	3			
Tektronix 321	1*	1			
Tektronix 535A	1	1			
Tektronix 564	1*	1			
Tektronix plug-in unit 3A1	1*	1			
Tektronix plug-in unit 3B1	1*	1			
Tektronix plug-in unit D	1*	1			
Tektronix plug-in unit L	1	1			
Tektronix plug-in unit CA	1	1			
Tektronix mobile type 500/53A	1	1			
Recorder-head demagnetizer 400	1				1
Magnetic-tape eraser					
Microtran HD-11	1	1			
Lafayette ML-120	1				1

*TI-owned equipment

Table A-9 (Contd)

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Sonar test box	1				1
Strobotac 1531-A, 237266	1*				1
Voltmeters					
HP 403A	2*	2			
Triplett 630A	5*	5			
Wattmeter, RF dummy load, 43-113-51	1*	1			
Bandpass filter set 1612, 107318	1	1			
Bud filter	1	1			

*TI-owned equipment

Table A-10

INVENTORY AND LOCATION OF EXPENDABLE AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Anchors	23	8	7		8
Anchor hardware sets	64	54			10
Aircraft engine containers	7			7	
Beacon light batteries, 540 v	10				10
Magnetic tape, 1 in., 1800 ft	11	6			5
Release mechanism hardware sets	64	54			10
Desiccant, lbs	300	150			150

Table A-11

INVENTORY AND LOCATION OF MISCELLANEOUS AUXILIARY EQUIPMENT

Item	Quantity	Location			
		Dallas, Texas	Orange, Texas	Port Arthur, Texas	Columbia University
Buoys					
Polyurethane	8		8		
Rubber	2		2		
Styrofoam	2		2		
Technician cabinets	2		2		
Loading harnesses					
3-cable	1		1		
4-cable	1		1		
Houses					
Equipment, 3-section collapsible	1*			1	
Wooden, 5 ft x 5 ft x 8 ft	1			1	
Ladder, 6-ft metal	1		1		
Work vests	7	7			
Cameras					
Polaroid, automatic with case	1	1			
B & H 16-mm movie-200S, 908818	1	1			
Wide-angle lens, 410297	1	1			
Air nozzle	1	1			
Miscellaneous equipment (bolts, hook, rope, chain, turnbuckles, styrofoam, clamps, welding supplies, etc.) — lot	1		1		

*TI-owned equipment

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13. ABSTRACT
The 1968 Aleutian Islands Experiment's objective was to obtain and analyze data for the determination of thicknesses and seismic velocities of crustal structures in the Amchitka Island vicinity. Deployment of three linear arrays of Ocean-Bottom Seismographs (OBS) and detonation of a series of chemical explosions were proposed to accomplish the data acquisition portion of the program. Planning, instrument preparation, field operations, and analysis were defined for the successful completion of the 1968 effort. Since the earliest possible start date is necessary for successful field operations, all planning and preparation portions began immediately after contract receipt. The following experiment preparations were accomplished: modifications and routine maintenance of OBS and auxiliary equipment were completed; a completely detailed technical plan was submitted; the ship was selected; condition of field equipment located outside the TI Dallas facilities was evaluated; operating and documenting procedure for field navigation was established; and a complete hydroacoustic program was outlined. A central timing system was designed to provide an accurate time signal for coordinating all shipboard functions on a "real-time" basis. An automatic direction-finder which provides a unit location system with a visual display was designed to facilitate recovery operations. Official notification of the present contract's partial termination for the conveniance of the Government was received on 9 May 1968. An immediate response was made to the contract change notice, resulting in modified program objectives and schedules in compliance with the AFTAC directive.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ocean-Bottom Seismograph						
Aleutian Islands Experiment						
Field Equipment						
Field Operations						
Navigation						
Hydroacoustic Program						
Central Timing System						
Automatic Direction Finder						

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