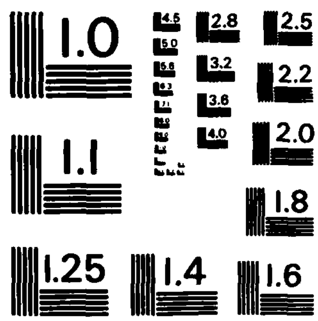
AD-A148 625 A DESCRIPTION OF THE NRL OBLIQUE-INCIDENCE-IONOGRAM DATA BASE(U) NAVAL RESEARCH LAB WASHINGTON DC J M GOODMAN 11 DEC 84 NRL-MR-5452 1/1

UNCLASSIFIED F/G 5/2 NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(2)

NRL Memorandum Report 5452

[illegible] of the NRL Oblique-Incidence-Ionogram Data Base

J. M. GOODMAN

Ionospheric Effects Branch
Space Science Division
E. O. Hulburt Center for Space Research

December 11, 1984

NAVAL RESEARCH LABORATORY
Washington, D.C.

NOTICE

[illegible] Research Laboratory does not approve, recommend, or endorse any [illegible] product, or material mentioned in this report. No reference shall [illegible] Naval Research Laboratory or to this report published by the [illegible] Laboratory in any advertising or sales promotion which would [illegible] that the Naval Research Laboratory approves, recommends, or [illegible] proprietary product or material mentioned herein.

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NRL Memorandum Report 5452	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Research Laboratory 6b. OFFICE SYMBOL (If applicable) Code 4180	7a. NAME OF MONITORING ORGANIZATION Defense Communications Agency
6c. ADDRESS (City, State, and ZIP Code) Washington, DC 20375-5000	7b. ADDRESS (City, State, and ZIP Code) Reston, VA 22090
8a. NAME OF FUNDING / SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO. DN380-432

11. TITLE (Include Security Classification)
A Description of the NRL Oblique-Incidence-Ionogram Data Base

12. PERSONAL AUTHOR(S)
Goodman, J.M.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Interim	FROM ______ TO ______	1984 December 11	28

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Oblique-incidence sounding, Frequency management, Data base, HF, Ionograms

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Since 1980 the Naval Research Laboratory has been engaged in a number of field experiments during which sequences of oblique-incidence ionograms have been obtained. Data has been accumulated in both analog-photographic and digital form with the majority of the earlier data sets being of the former category. Approximately 50,000 ionograms have been archieved for analysis purposes. This report outlines the texture of the data base indicating the mix of properties which may be employed to partition the data.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL J. M. Goodman	22b. TELEPHONE (Include Area Code) (202) 767-3729 22c. OFFICE SYMBOL Code 4180

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

CONTENTS

A DESCRIPTION OF THE NRL OBLIQUE-INCIDENCE-IONOGRAM DATA BASE

1.0 INTRODUCTION

Since the latter part of 1980, the Ionospheric Effects Branch (4180) of the Naval Research Laboratory (Space Sciences Division) has participated in field tests in support of specified HF communication and surveillance systems and concepts. The primary functions of the Branch scientists and technicians assigned to these exercizes were related to ionospheric parameter and HF channel specification. The primary instrument exploited for gathering information was the AN/TRQ-35 chirpsounder. This system was utilized because of availability rather than choice; other more sensitive scientific instruments were typically not within the DoD enventory and deemed to be inappropriate for "short-fuse" testing in a quasi-operational environment. [The reader is reminded of the notice appearing on the flyleaf of this report.]

The complete AN/TRQ-35 system typically consists of three transmitters of moderate power, a three channel receiver, and a spectrum monitor. The transmission waveform is of the chirp variety which allows for a greater capability for interference rejection and low power operation in comparison with sounders of the pulse variety. No detailed description of the AN/TRQ-35 system is provided herein since such material may be found elsewhere. An early description of the chirpsounder technique has been given by Barry and Fenwick [1965]. A comparison of various Real-Time-Channel-Evaluation (RTCE) techniques including the chirpsounder approach may be found in a paper by Darnell [1978]. Figure 1 shows the complement associated with a version of the AN/TRQ-35 known as the Tactical Frequency Management System (TFMS) currently be used by the DoD.

The purpose of this report is provide the reader with a general description of the data sets which have been archived by NRL using the AN/TRQ-35 system. It is not the purpose of this report to interpret the results. Analyses of subsets of the data base have already been published; and a comprehensive analysis of the total data base is planned in the near future.

2.0 LIST OF EXPERIMENTS

This section provides a listing of the experiments included in the data base together with the geometries involved.

2.1 Teamwork '80

Teamwork '80 was a NATO marine landing exercize conducted in the North Atlantic. During this exercize an NRL representative was positioned on the USS Mt. Whitney which was anchored off the coast of Norway. An AN/TRQ-35 receiver was located on the Mt. Whitney and transmitters were positioned at Soc Buchan

Manuscript approved August 20, 1984.

(Scotland), Kolsaas (Norway), and Orland (Norway). Figure 2 depicts the geometry. Chirpsounder ionograms were obtained during a period of time on 18-19 September, 1980. Preliminary results have been described in a reports by Uffelman [1981] and Goodman and Uffelman [1982].

2.2 Surtass-I

NRL has cooperated in two exercizes in support of the U.S. Navy Surtass system. The first was conducted in February of 1981. The experimental configuration of this initial exercise is depicted in Figure 3. During this exercise, AN/TRQ-35 transmitters were located on three (3) fixed land sites at Driver (VA), Ft. Bragg (NC), and Robins (GA). An AN/TRQ-35 receiver was placed aboard a slowly-moving ship (i.e., R/V Moana Wave) in the Atlantic Ocean off the southeastern coast of the United States. The preliminary results of this program have been discussed by Uffelman and Harnish [1981].

2.3 Polar Sea

This particular experiment arose as an opportunity to gather high latitude ionospheric data. Originally it was planned to locate an AN/TRQ-35 system aboard a temporarily "icelocked" Coast Guard vessel positioned off the north Alaskan coast. The logistics proved too perilous, however, and as a result the transmitter system was deployed to Fairbanks (Alaska) instead. Receivers were located at Anchorage (Alaska), Sacramento (CA) and the Naval Research Laboratory. The relevant geometry is provided in Figure 4. As of this writing, no analysis has been reported.

2.4 Solid Shield

The Solid Shield exercise took place between 3 and 20 May 1981. During this period chirpsounder transmitters and receivers were located at stations along the east coast of the the US, and several ships operating in the Atlantic Ocean were equipped with receivers and spectrum monitors. As far as NRL was concerned, the relevant transmitters were located at Hurlbert Field (FL), Shaw AFB (SC), Bogue Field (NC), McDill AFB (FL), and Driver (VA). Receivers were located at Ft.Bragg (NC) and Norfolk (VA). Data sets were also obtained at Norfolk using AN/TRQ-35 tramsmissions from distant Nea Makri (Greece). Figure 5 gives the geometry. Initial results from the Solid Shield exercise have been reported by Uffelman and Harnish [1982].

2.5 Indian Ocean

The Indian Ocean exercise took place during July-August of 1981. AN/TRQ-35 receivers were located aboard two ships (the USS Kitty Hawk and the USS America) which were maneuvering in the Indian Ocean region. Transmitters utilized were located at San Miguel (Phillipines), H.E.Holt Station (Australia), Diego Garcia, and Nea Makri (Greece). Much of the data has been analyzed but as yet it remains unreported. Figure 6 gives the geometry.

2.6 Surtass-II

This was the second in the series of experiments designed to support the Surtass program office. During this experiment, which was conducted in November of 1981, AN/TRQ-35 transmitters were located on the R/V Moana Wave and at Robins (GA) and Isabela (PR). The receiver at Norfolk (VA) was exploited to extract ionogram information over the three possible paths. Preliminary analyses of this data may be found in several publications including Uffelman and Hoover [1984], and Uffelman et al ,1984]. For the relevant geometry refer to Figure 7.

2.7 Classic Green Toad

This experiment was sponsored by the US Navy as a test of HF Time-Difference-Of-Arrival (TDOA) and kindred techniques for HF emitter location. The experimental phase of the program was conducted during March of 1982, and it involved a number of DoD organizations and supporting contractors. NRL was involved in a number of data gathering efforts in support of this effort and the data sets included Thomson scatter profiles using the Arecibo facility [Goodman et al,1984a] and total electron content using several sites in the Caribbean basin [Goodman et al, 1984b,1984c]. NRL also obtained oblique-incidence ionograms using the AN/TRQ-35. Receivers were located at Homestead (FLA), Isabela (PR), and Bermuda ; a lone transmitter was located aboard the USNS Bartlett. Results from the AN/TRQ-35 component of the test have not yet been released for publication. Figure 8 depicts the geometry for the experiment.

2.8 Army SFBCS

This program was designed to test system concepts in conjunction with the U.S. Army Special Forces Burst Communication System. The test was conducted between June 28 and August 9, 1982. NRL was responsible for the deployment of AN/TRQ-35 assets and was fully involved in the data collection efforts. An AN/TRQ-35 receiver was located at Ft. Bragg (NC) and transmitters were located at Ft. Knox (TN), Leavenworth (KS), Ft. Lewis (WA), Isabela (PR), Driver (VA), and Patrick AFB (FL). Figure 9 gives the geometry. Results have been reported by Harnish et al [1983].

2.9 NRL SSL-BCT

During the latter part of 1982 NRL (4180) supported the US Army as the architect and director of a test designed to assess the merits of two competing HF Single-Site-Location (SSL) technologies. This test was the most comprehensive one of its type and a considerable amount of ionospheric diagnostic information was obtained. It included: oblique-incidence ionograms over 5 paths, vertical-incidence ionograms at three specified midpath stations, topside ionogram data, total electron content data from three sites, and a number of supporting data sets. A brief open-source description has been prepared [Goodman and Uffelman, 1983]. Figure 10 gives the geometry involved.

3.0 DATA BASE DESCRIPTION

3.1 General Layout

Table 1 provides certain basic information about the NRL Oblique-incidence ionogram data base for specified experiments using the AN/TRQ-35. Approximately 50,000 ionograms have been obtained in photographic form and approximately 42% of these have been scaled for "routine" parameters such as the MOF, LOF, and the so-called FOT band. These parameters have been recorded on magnetic tape cartridges for convenience in preliminary analysis and for plotting purposes. In addition, since the beginning of 1982, all raw analog ionogram traces have been recorded on magnetic tape as well. This has assisted in automatic digitization and detailed analysis approaches.

Table 2 gives a listing of ionograms partitioned as follows:

(A) Geographical Area (High, Middle, & Low Latitude)

(B) Season (Summer, Winter, & Equinox)

(C) Time of Day (Day, Night, & Transition)

(D) Sunspot Activity (High, Medium, & Low)

(E) Magnetic Activity (Disturbed, Moderate, & Quiet)

(F) Path Distance (Very Long, Long, Medium, Short, Very Short, & Ultra Short)

For partitioning the data the following bin definitions were selected:

(A) Geographical Area

We ignore longitudinal differences (even though they are certain to exist) and only consider latitudinal dependencies which are more pronounced. The following selections were made on the basis of the locations of the midpoints of the paths in question:

"High" - $|\text{Latitude}| \geq 60^{\circ}$

"Middle" - $20^{\circ} \leq |\text{Latitude}| < 60^{\circ}$

"Low" - $|\text{Latitude}| < 20^{\circ}$

where the vertical bars refer to absolute values.

Typically the assignment is simplified by the fact that both the transmitter and receiver in question reside in a common zone. In this case the midpoint of interest usually lies in the common zone as well. The exception occurs for very long paths between terminals which lie slightly equatorward of the boundary separating the common zone from an adjacent poleward zone. This situation turns out to be rare in practice. For situations in which the terminals are not located in a common zone, it is mandatory to determine the location of the midpoint of the great circle path linking the two.

(B) Season

"Winter" : December 22 - March 21

"Equinox" : March 22 - June 21 & September 22 - December 21

"Summer" : June 22 - September 21

Naturally, for the Southern Hemisphere the definitions of summer and winter are reversed.

(C) Time of Day

"Day" : 0800 - 1600

"Transition" : 1600 - 2000 & 0400 - 0800

"Night" : 2000 - 0400

Local time at the "control point" is used. Note that there are eight hours for each epoch.

(C) Sunspot Activity

"High" : $R \geq 100$

"Medium" : $50 \leq R < 100$

"Low" : $0 \leq R < 50$

Here R is the daily sunspot number.

(D) Magnetic Activity

"Disturbed" : $K \geq 6$

"Moderate" : $3 \leq K \leq 5$

"Quiet" : $0 \leq K \leq 2$

Here K is the planetary magnetic activity index.

(E) Path Distance (Kilometers)

"Very Long"	:	d $\geq$ 4000
"Long"	:	3000 $\leq$ d < 4000
"Medium"	:	2000 $\leq$ d < 3000
"Short"	:	1000 $\leq$ d < 2000
"Very Short"	:	500 $\leq$ d < 1000
"Ultra Short"	:	0 $\leq$ d < 500

3.2 Commentary

It is seen that the distibutions for the various categories used in segmenting the data are non-uniform. Ultimately this will lead to some difficulty in developing models to represent the data in a "global" sense. Figure 11 exhibits the situation quite well.

Clearly midlatitude data dominates the data base. One would hope for a even breakdown approximating 33%/33%/33% so the 24% component obtained at low latitudes is not that inappropriate. However, the paucity of high latitude data sets is a definite problem area.

We find that the summer and equinox data sets dominate the breakdown by season. Again it would be prudent to balance the picture by acquiring more wintertime data, especially for high and low latitudes.

There is clearly a good distribution of data as pertains to time of day. This is because NRL always attempted to obtain data either "around the clock" or to otherwise maintain a schedule which would ultimately produce an even diurnal distribution. This was the easiest parameter to control.

Since most of the NRL data was obtained during the peak of the solar cycle (1980-1982), there is a strong bias toward high solar activity conditions. Thus any model deduced from the NRL data sets would clearly be a "Solar Maximum" model.

Magnetic activity indices were also imbalanced but this is not necessarily a problem area. This is the mix one would likely expect to occur. In any case, this parameter -- like solar activity -- could not be controlled.

The path length distribution is probably adequate for our purposes but there are probably too many "very long" paths in the distribution and too few "medium" length paths. Paths of the "very long" category create problems in data interpretation since multiple hops are typically involved. "Medium length" paths, on the other hand, are quite important in HF communication applications. Obviously more "medium length" data is essential.

Care must also be taken so as not to "even the distribution" in an artificial way. For example, one cannot simply take more medium path, high latitude data at solar minimum to resolve the problem. In general, we need to have uniform distributions of all relevant parameters simultaneously. To acomplish this task, one must be prepared to set up a global network of sounders and extract ionograms almost continuously for a full solar cycle (11 years). Such a vast undertaking would not only be costly but it would be formidable from a data analsis point of view as well.

One common-sense way to "fill the gaps" is to exploit information which has been previously obtained using the global network of vertical incidence ionosondes which have been operating for a number of decades. Many of the relationships between vertical incidence and oblique incidence soundings are well established and these should be exploited. The converse is also true. That is to say, one could exploit current oblique incidence data to "fill the gaps" in the decidedly more comprehensive vertical incidence data base. The author suspects that this [illegible]d be the most appropriate course of action. [It is clearly [illegible]ter to tranform a smaller data set and apply it to a larger da[illegible]base than the other way around. Futhermore the oceanic data set which are readily retrievable from oblique incidence measurements [illegible]ld fill a serious void in the climatological models obtained from the existing global vertical incidence network.]

4.0 FUTURE PLANS

It is our intention to analyze most of the ionograms within the NRL data base for the routine parameters LOF, MOF, and FOT band. It is felt that these data would be useful in the construction of a midlatitude model of these parameters for solar maximum conditions. No plans are being made to pursue this course at this time. Perhaps a more valuable short term goal would be utilization of the data base to improve simple models such as MINIMUF-3.5 developed by NOSC and as exploited in the PROPHET architecture. Most certainly, it would be possible to transform the oblique incidence ionograms into equivalent vertical incidence profiles so that parameters such as foF2, hF2, and M(3000)F2 could be obtained. This data could then be used to improve the CCIR maps of ionospheric characteristics.

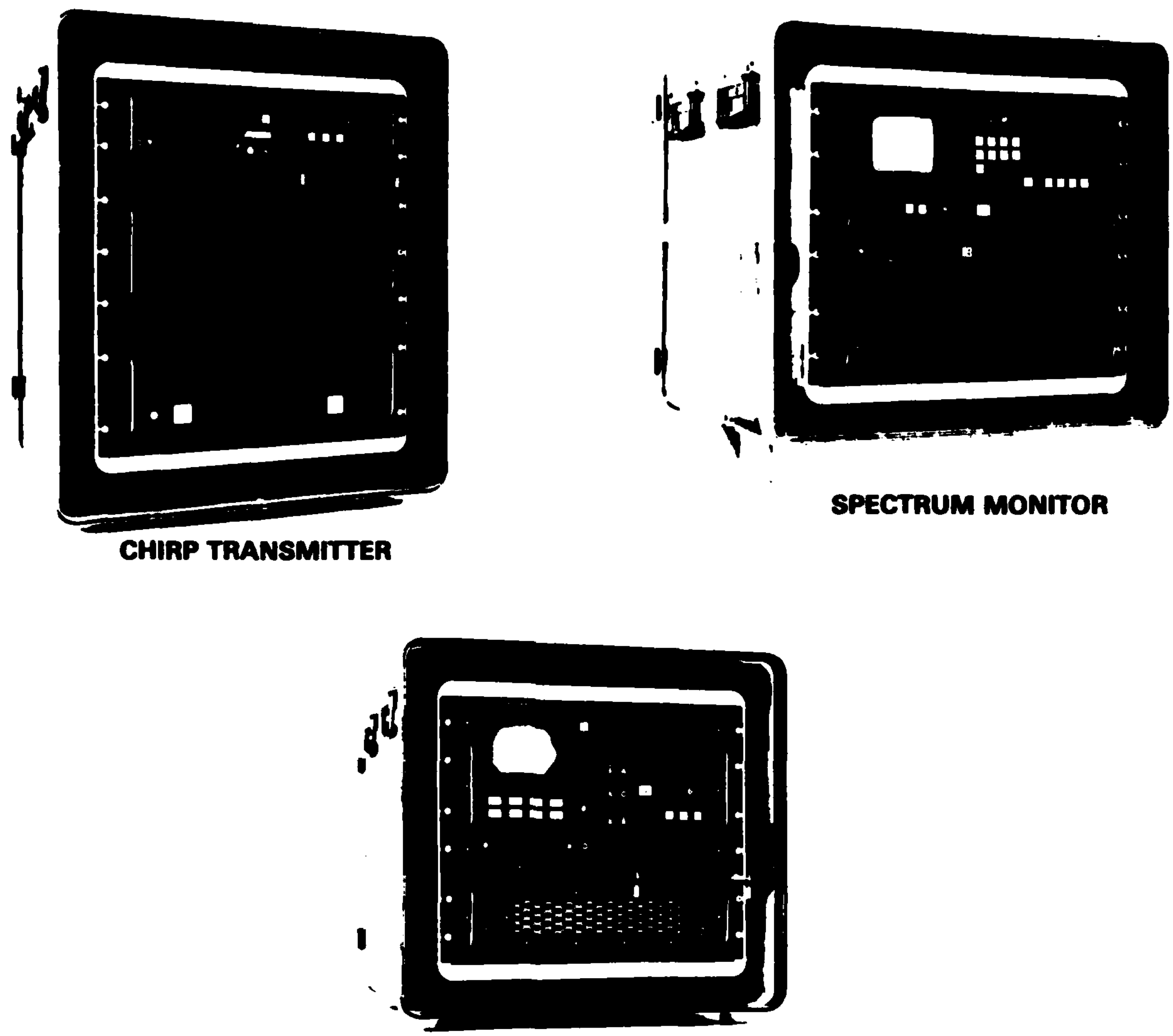
Our main thrust in the next few years is to refine the data base and engage it in the solution of certain special purpose problems. One question facing the DoD is whether oblique incidence chirpsounders will provide sufficient information for HF resource management if the transmitter constellation is is either deliberately "thinned" by US/Allied decision or otherwise reduced in scope by enemy action. This requires information about the nature of the temporal and spatial correlation of the ionosphere (as sampled over an oblique path). NRL is now investigating this problem [Goodman et al, 1983b]. The general issue of sounder deployment, networking, and data utilization is also being addressed [Goodman and Martin, 1984; Goodman, 1984a; and Goodman, 1984b]. Futher work is being carried out in this area under the sponsorship of DCA and a series of additional reports will be issued during calendar 1984.

Table 1 : List of NRL Experiments During Which Ionograms were Obtained.

TOTAL PATHS	OPERATION	RCVR(S)	XMTR(S)	DATES	MEDIA	
					RAW	PROCESSED
4	TEAMWORK '80	USS MT.WHITNEY	Robins, GA Kolsaas, Norway Orland, Norway Soc Buchan, Scotland	9/ 3-23/80	PHOTOS	CART. TAPE 88%
3	SURTASS I	R/V MOANA WAVE (SHIP)	DRIVER, VA FT.BRAGG, NC ROBINS, GA	2/15-23/81	PHOTOS	CART. TAPE 89%
3	POLAR SEA	FAIRBANKS, AK	CHESAPEAKE BAY DIV.,MD ELMONDORF, AK SACRAMENTO, CA	4/ 2-15/81	PHOTOS	CART. TAPE 28%
10	SOLID SHIELD	FT.BRAGG, NC	DRIVER, VA HURLBERT FIELD, FL SHAW AFB, SC MacDILL, FL	5/ 5-19/81	PHOTOS	CART. TAPE
		NORFOLK, VA	DRIVER, VA HURLBERT FIELD, FL SHAW AFB, SC MacDILL, FL CAMP LEJEUNE, NC (BOGUE FIELD) NEA MAKRI, GREECE	5/ 3-19/81		100%
8	INDIAN OCEAN	USS AMERICA (SHIP)	H.E.HOLT, AUSTRALIA NEA MAKRI, GREECE DIEGO GARCIA SAN MIGUEL, PHILIPPINES	7/25/81 to 8/24/81	PHOTOS	CART. TAPE
		USS KITTY HAWK (SHIP)	H.E.HOLT, AUSTRALIA NEA MAKRI, GREECE DIEGO GARCIA SAN MIGUEL, PHILIPPINES	7/25/81 to 8/21/81		16%
3	SURTASS II	NORFOLK, VA	ROBINS, GA ISABELA, PUERTO RICO R/V MOANA WAVE (SHIP)	11/10-22/81	PHOTOS	CART. TAPE 100%
3	CLASSIC GREEN TOAD	USNS BARTLETT	HOMESTEAD, FL ISABELA, PUERTO RICO BERMUDA	3/19-29/82	PHOTOS & MAG. TAPE	CART. TAPE 82%
6	SFBCS	FT.BRAGG, NC	FT.KNOX, TN LEAVENWORTH, KS FT.LEWIS, WA ISABELA, PUERTO RICO DRIVER, VA PATRICK AFB, FL	6/28/82 to 8/ 9/82	PHOTOS & MAG. TAPE	
6	SSL-BCT	FT. ORD, CA	CHINA LAKE NWC, CA NELLIS AFB, NV LUKE AFB, AZ ERIE, CO SAN DIEGO, CA FT.LEWIS, WA	11/29/82 to 12/18/82	PHOTOS & MAG. TAPE	

Table 2 : Breakdown of the NRL Data Base in Terms of Geography, Season, Diurnal Cycle, Solar Activity, Magnetic Activity, and Path Length.

OPERATION	TOTAL	A	B	C	D	E	F
TEAMWORK '80	851	H 100% M L	W E S 100%	D 33% T 36% N 31%	H 82% M 18% L	D M 9% Q 91%	VL 2% L M S VS 35% US 63%
SURTASS I	2,088	H M 100% L	W 100% E S	D 33% T 34% N 33%	H 91% M 9% L	D M Q 100%	VL L M S 100% VS US
POLAR SEA	3,700	H 31% M 69% L	W E 100% S	D 34% T 33% N 33%	H 100% M L	D 15% M 22% Q 63%	VL 38% L 30% M S VS US 32%
SOLID SHIELD	8,465	H M 100% L	W E 100% S	D 34% T 33% N 33%	H 100% M L	D M 58% Q 42%	VL .5% L M S 23.6% VS 27.3% US 48.6%
INDIAN OCEAN	15,798	H M 23% L 77%	W E S 100%	D 33% T 33% N 34%	H 100% M L	D 5% M 47% Q 48%	VL 67% L 16% M S 17% VS US
SURTASS II	2,973	H M 100% L	W E 100% S	D 33% T 33% N 34%	H 65% M 35% L	D M 85% Q 15%	VL L M 42% S 16% VS 42% US
CLASSIC GREEN TOAD	5,448	H M 100% L	W 23% E 77% S	D 33% T 33% N 34%	H 100% M L	D M 43% Q 57%	VL L M S 66% VS 34% US
SFBCS	5,962	H M 100% L	W E S 100%	D 33% T 34% N 33%	H 40% M 32% L 28%	D 6% M 72% Q 22%	VL L 23% M 11% S 21% VS 34% US 11%
SSL-BCT	4,347	H M 100% L	W E 100% S	D 25% T 34% N 41%	H 95% M 5% L	D 7% M 74% Q 19%	VL L M S 31% VS 52% US 17%
TOTALS	49,632	H 4% M 72% L 24%	W 7% E 48% S 45%	D 32% T 34% N 34%	H 89% M 7% L 4%	D 4% M 52% Q 44%	VL 24% L 10% M 4% S 27% VS 20% US 15%



CHIRP TRANSMITTER

SPECTRUM MONITOR

CHIRP RECEIVER

Figure 1 : The AN/TRQ-35 Chirpsounder System, consisting of transmitter, receiver and spectrum monitor.

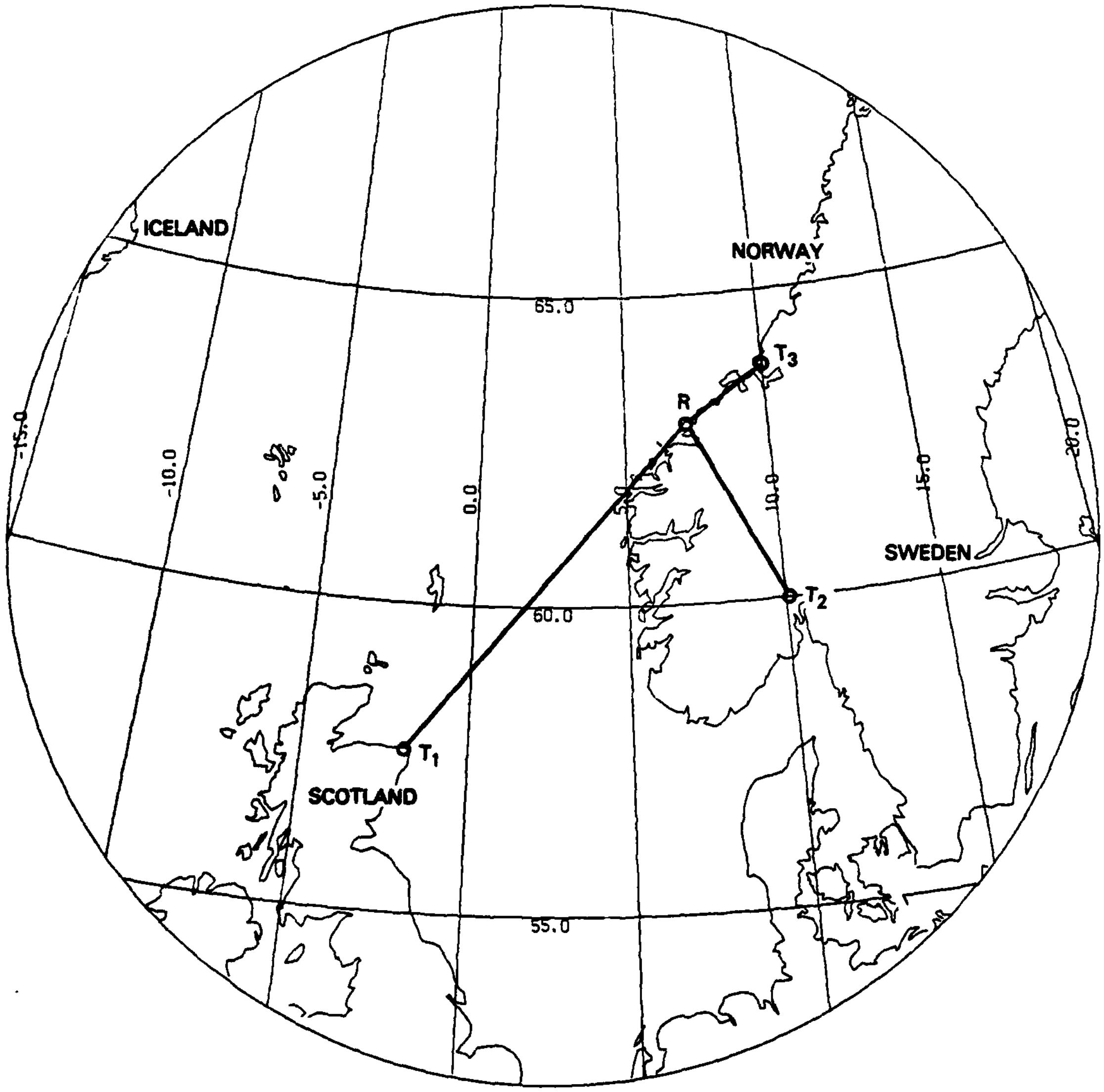


Figure 2 : Geometry associated with Teamwork 80.

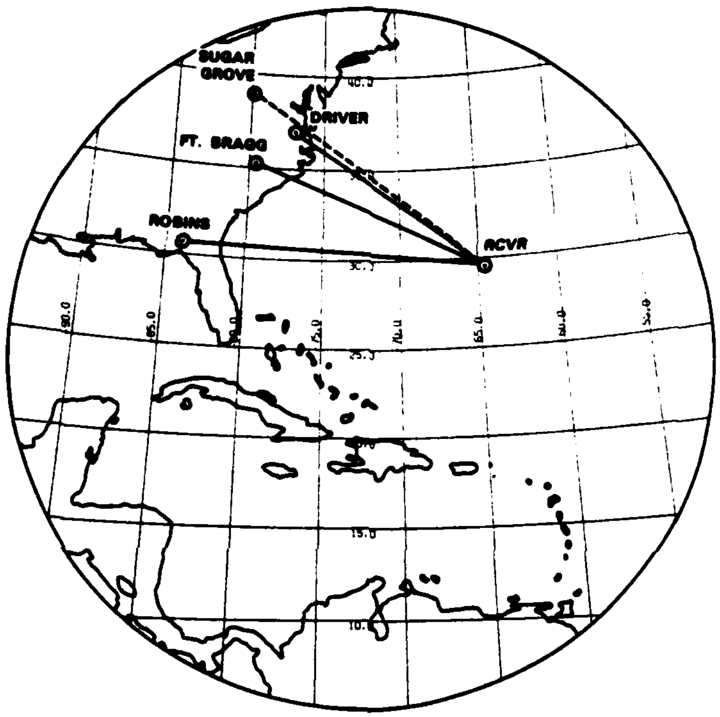


Figure 3 : Geometry associated with the SURTASS I experiment conducted during February 1981.

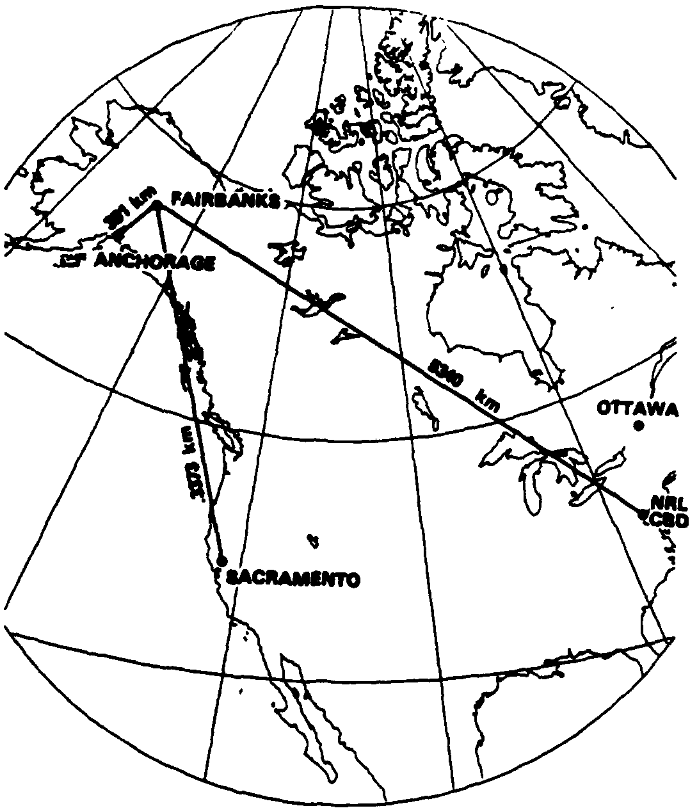


Figure 4 : Geometry associated with the Polar Sea experiment.

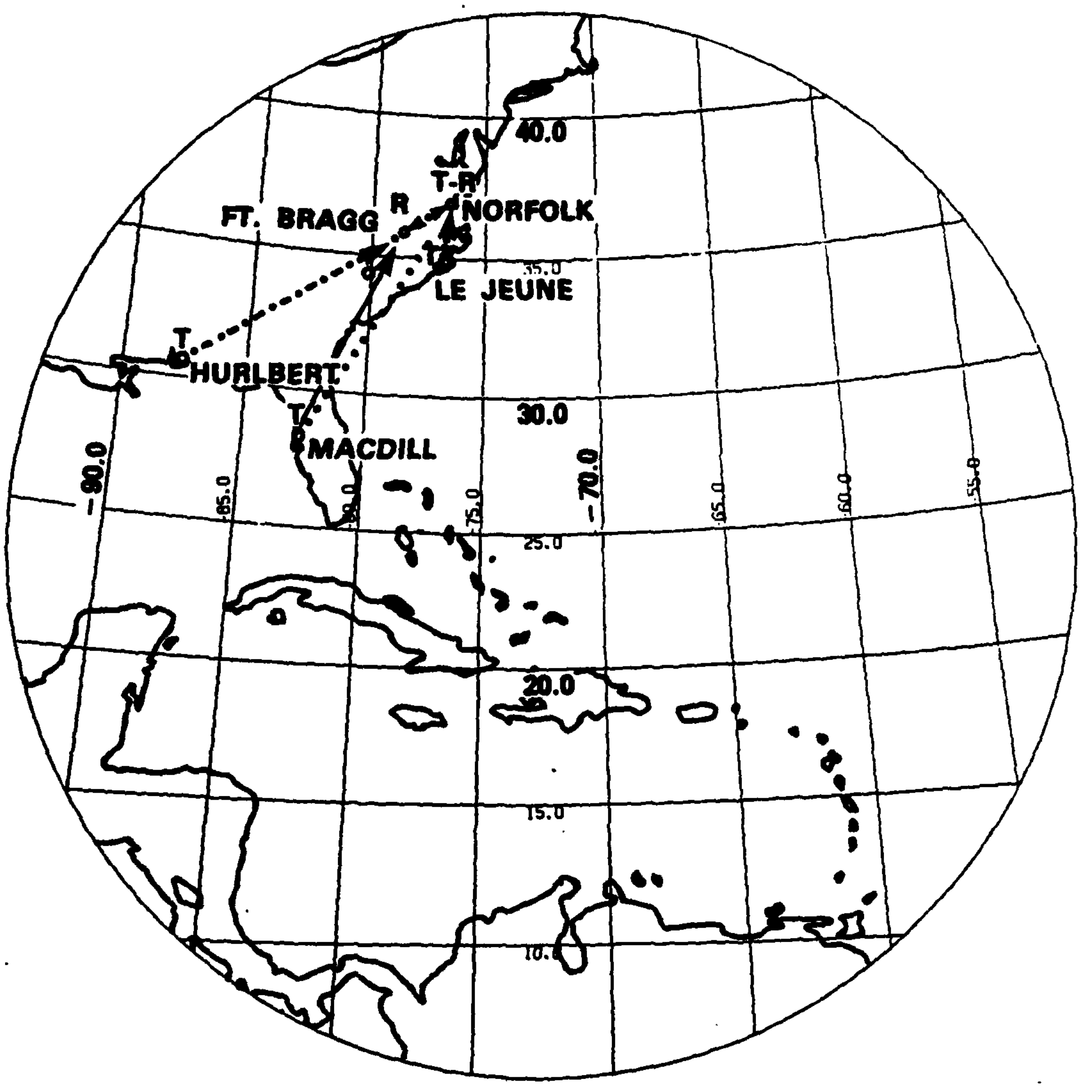


Figure 5 : Geometry associated with the Solid Shield experiment.

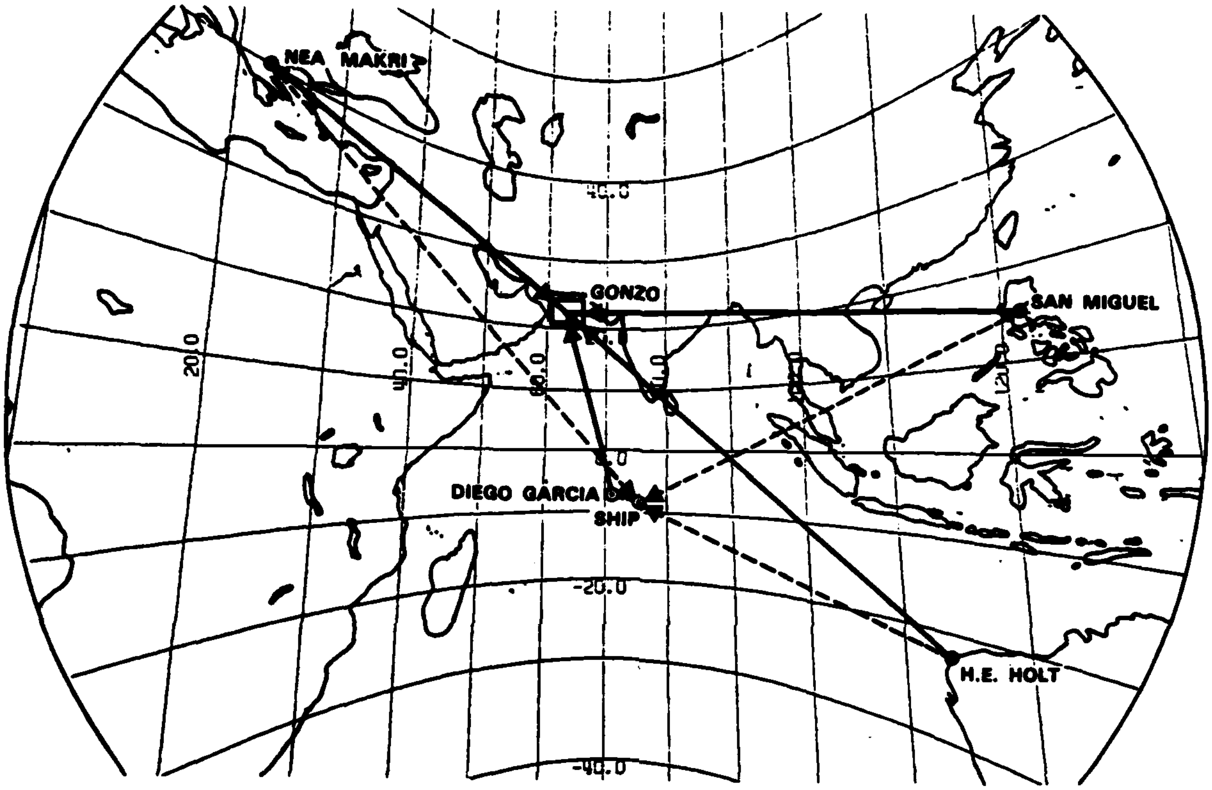


Figure 6 : Geometry associated with the Indian Ocean experiment.

Figure 7 : Geometry associated with the SURTASS II experiment conducted in November 1981.

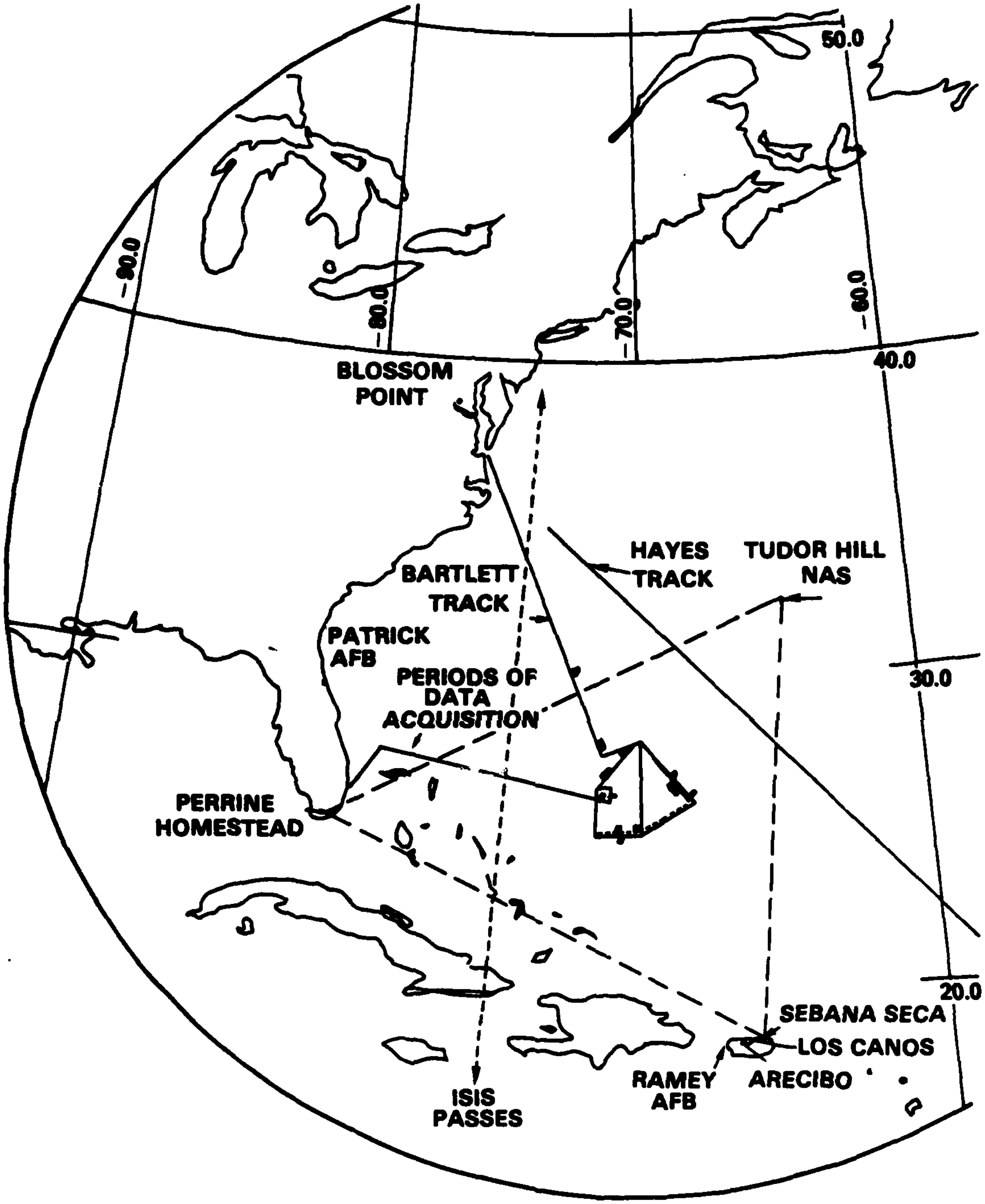


Figure 8 : Geometry associated with the Classic Green Toad experiment.

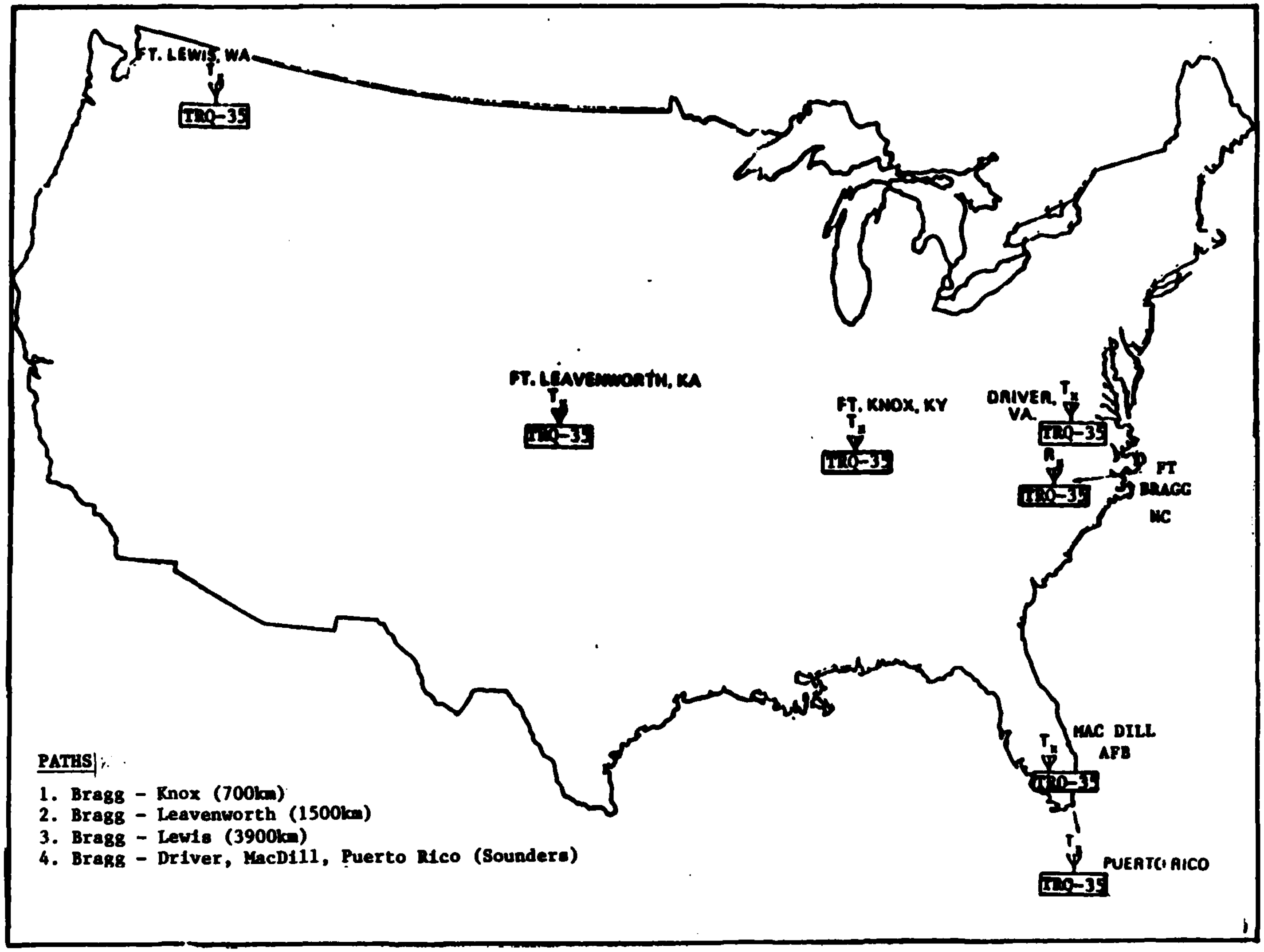


Figure 9 : Geometry associated with the U.S. Army Special Forces Communication System Test (USA-SFBCS).

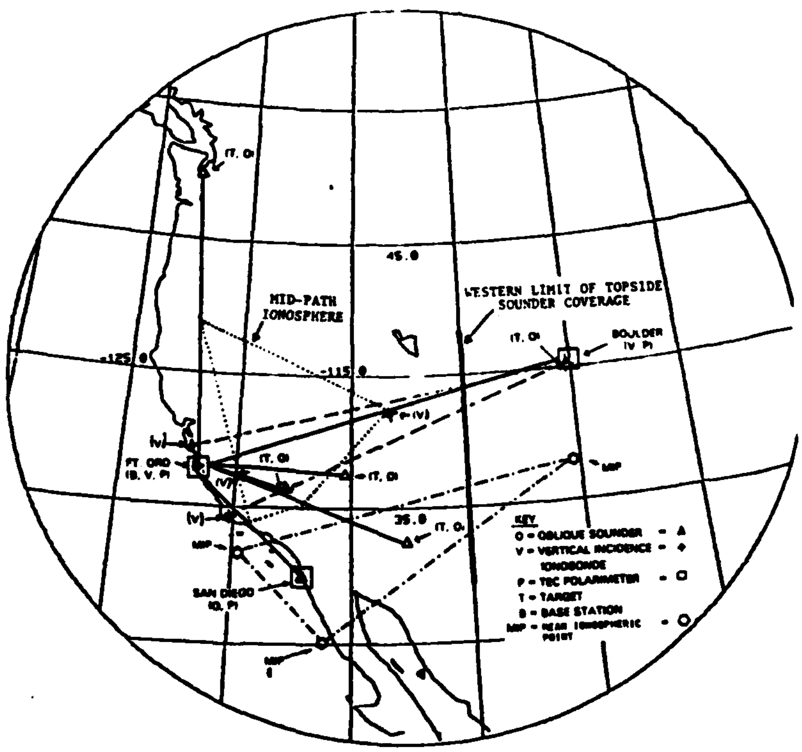


Figure 10 : Geometry associated with the NRL Single-Site-Location Baseline Certification Test (SSL-BCT).

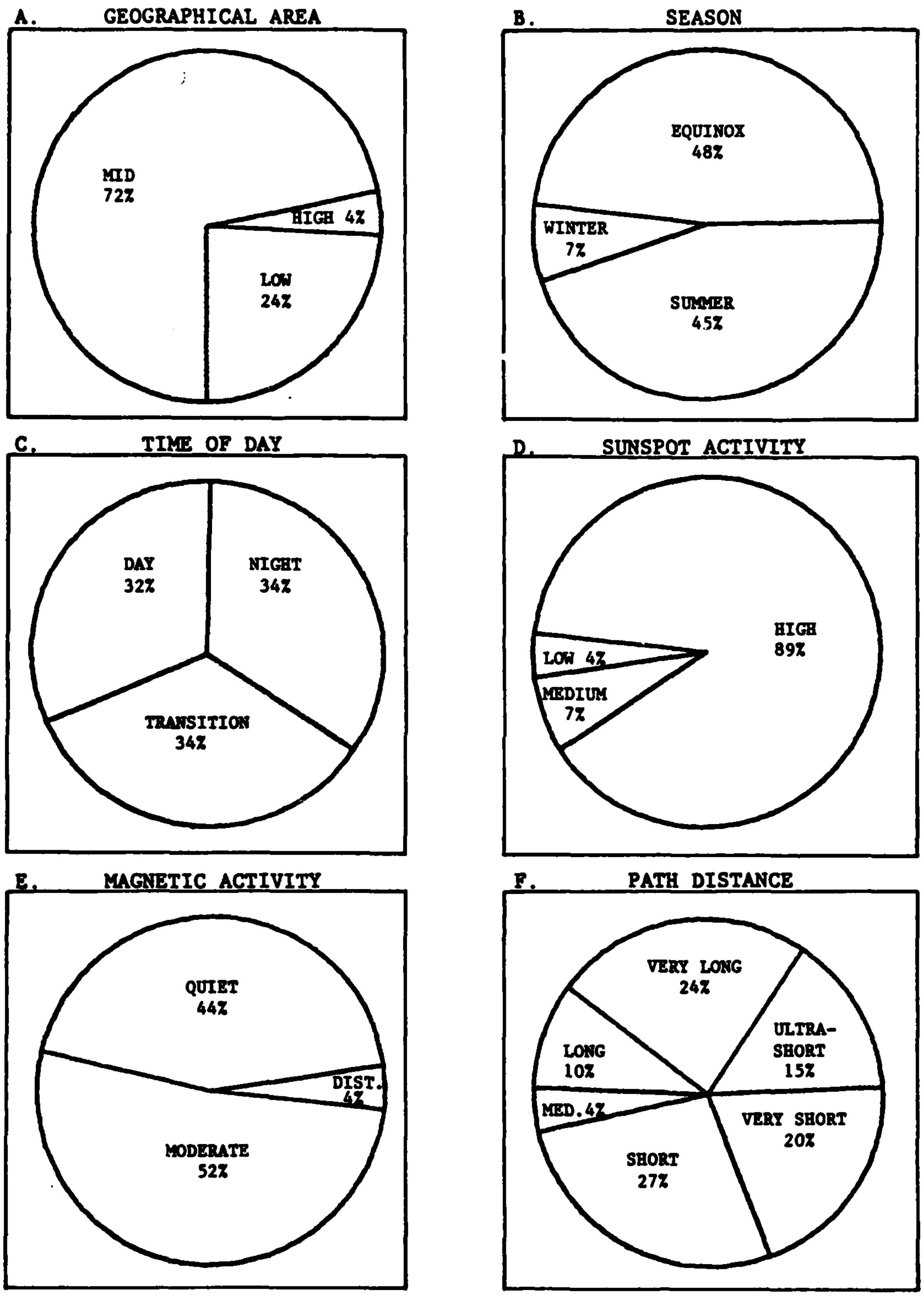


Figure 11 : Pie-Chart distributions of ionogram data.

REFERENCES

Barry G.H. and R.G. Fenwick, 1965, "Extra-Terrestrial and Ionospheric Sounding with Synthesized Frequency Sweeps", in Hewlett-Packard Journal, 16(11) pp 8-12.

Darnell, 1978, "Channel Evaluation Techniques for Dispersive Communication Paths", in Communications Systems and Random Process Theory, edited by J.K. Skwirzynski, published by Sijthoff and Noordhoff, The Netherlands, pp 425-460.

Goodman J.M. and D.R. Uffelman, 1982, "The Role of the Propagation Environment in HF Electronic Warfare", NRL Memorandum Report 4953, (23 Nov 1982). ADA121658

Goodman J.M. and D.R. Uffelman, 1983a, "On the Utilization of Ionospheric Diagnostics in the Single-Site-Location of HF Emitters", in Propagation Factors Affecting Remote Sensing by Radiowaves (NATO-AGARD-CP-345), Tech. Edit. & Reprod. Ltd., London. AD137559

Goodman J.M., M. Daehler, M.H. Reilly, and A.J. Martin, 1983b, "Global Considerations for Utilization of Real-Time Channel Evaluation Systems in HF Spectrum Management", in Proceedings of MILCOM'83, IEEE Press. paper 18.4, pg. 350

Goodman J.M., A.J. Martin, R. Tsunoda, and R. Showan, 1984a (in press), "A Thomson Scatter Investigation of the Ionosphere During the Classic Green Toad Experiment", NRL Memorandum Report 5128.

Goodman J.M., L.O. Harnish, A.J. Martin, M.H.Reilly, and T. Priddy, 1984b (in press), "Total Electron Content Studies Conducted During Classic Green Toad", NRL Memorandum Report 5126.

Goodman J.M., A.J. Martin, L.O. Harnish, M.H. Reilly, and T. Priddy, 1984c (in press), "A Catalogue of Total Electron Content Data Obtained in Conjunction with Classic Green Toad", NRL Memorandum Report (number to be assigned).

Goodman J.M. and A.J. Martin, 1984 (in press), "Global Management of the HF Channel (A Note on the Possible Utilization of Oblique-Incidence Sounders)", NRL Memorandum Report 5468.

Goodman J.M., 1984a (in press), "A Commentary on the Utilization of Real-Time Channel Evaluation Systems in HF Spectrum Management", NRL Memorandum Report 5454.

Goodman J.M., 1984b (in press), "A Note on the Applicability of Ionospheric Sounding in HF Resource Management", NRL Memorandum Report (number to be assigned).

Harnish L.O., G.H. Hagn, and W.T. Alvarez, 1983, "Comparison of IONCAP Predictions with AN/TRQ-35(V) Oblique-Incidence Sounder Measurements for a One-Month CONUS Test During July and August 1982", in Proceedings of MILCOM'83, IEEE Press.

Uffelman D.R., 1981, "HF Propagation Assessment Studies Over Paths in the Atlantic", NRL Memorandum Report 4599, (October 26, 1981). **ADA 107599**

Uffelman D.R. and L.O. Harnish, 1981, "HF Systems Test for the SURTASS Operation of February 1981", NRL Memorandum Report 4600. **ADA106 747**

Uffelman D.R. and L.O Harnish, 1982, "Initial Results From HF Propagation Studies During Solid Shield", NRL Memorandum Report 4849, (July 30, 1982). **ADA118 492**

Uffelman D.R., L.O. Harnish, and J. M. Goodman, 1984, "HF Frequency Management by Frequency Sharing by Models Updated in Real Time", NRL Memorandum Report, (also appearing in revised form in NATO-AGARD-CP-345, 1983).

Uffelman D.R. and P.A. Hoover, 1984, "Real-Time Update of Two HF Channel Evaluation Models by Oblique Sounding", NRL Memorandum Report 5246, (January 13, 1984), (also appearing in revised form in Proceedings of MILCOM'83, 1983). **ADA137556**

END

FILMED

1-85

DTIC