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# COSPAS-SARSAT

# EXERCISE OF 1990

# EWG REPORT TO CSC-7

VOLUME 1

EXERCISE SUMMARY
WITH ANNEX

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COSPAS-SARSAT EXERCISE OF 1990

EWG REPORT TO CSC-7

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## PREFACE

The Exercise of 1990 is documented in five volumes which focus on the various facets of the Exercise in varying degrees of detail.

Volume 1 -Exercise Summary with Annex
This document contains an overview of the Exercise from design and implementation through summary and conclusions.

Volume 2 - Data Analysis
This document contains detailed data that supports the analysis.

Volume 3 - Support Data with Script
This document contains additional details of the structure of the Exercise, operational information and the Exercise script.

Volume 4 - Database
This document contains the Exercise database description, printouts of the beacon and satellite databases and a copy of the composite database for the Exercise on four 5 1/4" double sided/high density data discs.

Volume 5 - Data Analysis Software
This document contains a description of the software used to perform the data analysis with operating instructions and a copy of this software on one 5 1/4" double sided/high density data disc.

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VOLUME 1 - EXERCISE SUMMARY WITH ANNEX

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ABSTRACT

The operational characteristics of the COSPAS-SARSAT System in detecting and processing transmissions from 406 MHz beacons were demonstrated in a global System Exercise conducted in October 1990.

Operationally coded beacons of production quality were activated randomly in a variety of simulated distress environments. Data from these beacons were collected and processed by the COSPAS-SARSAT System, and the results were compared to predicted values. The more significant results of this analysis are documented herein.

The results of this demonstration were also compared to the results of a similar System Exercise conducted in November 1986. The differences and trends observed in this comparison are also documented herein.

The COSPAS-SARSAT Exercise of 1990 is documented in 5 volumes:

Volume 1 - Exercise Summary with Annex
Volume 2 - Data Analysis
Volume 3 - Support Data with Script
Volume 4 - Database
Volume 5 - Data Analysis Software

## EXERCISE SUMMARY

An operational demonstration of the COSPAS-SARSAT System's ability to detect, locate, process, and distribute alert messages from 406 MHz beacons was conducted on 22-26 October 1990.

The objectives of this demonstration, designated the Exercise of 1990, were:

1. To demonstrate the operational characteristics (fidelity, timing, accuracy etc.) of the COSPAS-SARSAT System when receiving distress messages from operationally coded 406 MHz beacons located on land and at sea.

2. To demonstrate the performance of the System when receiving data from a significant number (i.e., more than 15) of concurrently active globally located 406 MHz beacons.

3. To demonstrate the effectiveness of the "COSPAS-SARSAT Data Distribution Plan" (C/S A.001).

4. To design a global System Exercise of the COSPAS-SARSAT System that can, with minor modifications, satisfy future System demonstration requirements.

Objectives number one (operational characteristics) and three (Data Distribution Plan) were patterned after similar objectives in the Exercise of 1986; objectives number two (concurrently active beacons) and four (Exercise reuse) were unique to the Exercise of 1990.

To satisfy these objectives, the Exercise made use of the operational Space Segment, the operational Ground Segment, and 36 operationally-coded, production-quality 406 MHz beacons. The beacons were deployed globally, and were located in simulated distress situations on land and at sea (free-floating, in life rafts, in lifeboats, and on moving vessels). More than 12,500 Exercise related alert messages were generated and processed by the Ground Segment.

The Exercise of 1990 was functionally equivalent to the Exercise of 1986, but it was more realistic in that it more faithfully simulated real world distress scenarios. The Exercise of 1990 confirmed that the current COSPAS-SARSAT System is operational, is in general compliance with its design goals, and is performing at a significantly more effective level today than at the time of the Exercise of 1986.

More specifically:

1. All of the 59 beacon activations over a five day period were detected and located.

2. 98% of the available beacon data were acquired by the System, an increase from 95% in 1986.

3. 95% of the messages received by the Ground Segment for transmission to the SAR network were successfully transmitted. Message routing inconsistencies and national procedures account for the majority of the messages not transmitted.

4. 84% of the calculated locations were within 5 km of the actual locations, an increase from 72% in 1986. Problems associated with LUT and MCC enhancements, and procedural misunderstandings were identified and resolved.

   Assuming the correction of the problems identified, it is estimated that 87% of the calculated locations are now within 5 km of the actual locations.

5. 95% of the location ambiguities were resolved correctly, the same as in 1986.

6. The accuracy of calculated locations of drifting or slowly moving beacons (less than 1 knot) was equivalent to the accuracy of stationary beacons. The calculated locations of beacons installed on the ship CUMULUS traveling at approximately 10 knots on various headings were accurate to within 5 km only 50% of the time, however.

7. The average System Waiting Time (i.e., the time from beacon activation until the TCA of the first spacecraft pass) was 44 minutes, a 17% reduction from 53 minutes in 1986.

8. The average System Processing Time (i.e., the time from TCA until the associated alert message is transmitted to the SAR network) was 58 minutes, a 31% reduction from 84 minutes in 1986.

9. The average System Processing Time was partitioned into (a) 35 minutes in Space Storage (i.e., the time from the TCA until the Time of LUT processing complete) and (b) 23 minutes in Ground Processing (i.e., the time from LUT processing complete until the associated message is transmitted to the SAR network).

10. There was a gradual degradation in System performance with the receipt of data from 25 beacons concurrently active over a 12 hour period. It is projected that the observed increase in Ground Segment message transmission times resulted from elements of the communications network within the Ground Segment operating over capacity. There was no indication of a capacity constraint within the Space Segment.

11. Only 23% of the calculated Error Ellipses contained the location of the associated beacon, thus the Error Ellipses as currently calculated do not meet their design objectives.

12. The Confidence Factors, as currently calculated, do not consistently give reliable results. Some were quite good, but others were less reliable. This parameter has potential, but the need for additional work on the associated algorithms is indicated.

13. Of the 36 selected and pre-tested 406 MHz Exercise beacons, 2 failed at the beginning of the Exercise, 2 failed during the Exercise and 1 gave marginal results. Thus only 31 of the 36 original beacons (86%) operated effectively.

These results are considered more fully in the body of this document.

# CONCLUSIONS

It is concluded that:

C-1 The COSPAS-SARSAT System effectively detects and locates operational 406 MHz beacons, and transmits the associated alert messages to the RCC network.

C-2 Numerous operational anomalies were detected as a direct result of the Exercise and the subsequent data analysis. All National Exercise Coordinators (NECs) indicate that the anomalies associated with their ground facilities have been resolved.

C-3 The configuration of the Ground Segment is well fitted to the current operational data volume (i.e., a maximum of 6 beacons simultaneously active). However, the Ground Segment transmission requirements of the System under moderate stress (i.e., 25 beacons concurrently active for 12 hours) exceed the capabilities of some of its elements. The Space Segment capacity was adequate under all Exercise conditions.

C-4 Beacon performance was below expectation.

C-5 A generic System Exercise with associated data collection and analysis software has been developed and validated. The elements of this package can be tailored to meet the unique needs of activities ranging from regional tests through global System Exercises, thus providing an economical and schedule effective product.

## RECOMMENDATIONS

It is recommended that:

R-1 The OWG and TWG review the quality control system that exists within the Ground Segment, and propose enhancements as required to ensure the use of proper operational parameters (TCal, orbit vectors, orbitography beacons etc.). It is further recommended that the resultant procedures be considered for inclusion in the more generic System Monitoring activities.

R-2 The OWG periodically update the message traffic volume forecast to facilitate the timely evolution of the Ground Segment configuration to meet changing needs.

R-3 The TWG review the algorithms associated with locating beacons in an attempt to further enhance location accuracy.

R-4 The OWG review the conditions under which NOCR messages are to be transmitted, ensure that these conditions are clearly documented, and provide MCC level operational training as required to facilitate the proper and timely transmission of these messages.

R-5 The OWG address the issue of redundancy in an effort to reduce data transmission volume without degrading System performance.

R-6 Each NEC conduct appropriate reviews of their portion of the Ground Segment to demonstrate that the operational anomalies identified in the Exercise have been effectively resolved.

R-7 The Joint Committee determine whether or not there is a requirement for locating beacons moving at moderate speeds (i.e., 10 knots or greater as in the UK vessel CUMULUS).

R-8 The Joint Committee encourage the use of the structure of the Exercise of 1990 with its data collection and data analysis software as a model for future tests (national, regional or special purpose), commissioning (LUT or MCC), demonstrations (limited or system) of the System and its elements, etc.

## 1.0 Introduction

On 22-26 October 1990, the Exercise Working Group (EWG) successfully conducted an Exercise to demonstrate the 406 MHz capabilities of the COSPAS-SARSAT system. The Exercise was global in scope, utilizing 36 operationally-coded 406 MHz beacons (25 primary and 11 back-up) activated at 25 sites. Beacons were located on land and at sea (i.e., on ships, lifeboats, life rafts, and free-floating) to simulate a variety of distress situations. The beacons were of production quality and were produced by a variety of manufacturers.

For the Exercise of 1990, the Space Segment consisted of four spacecraft and the Ground Segment consisted of 10 Mission Control Centers (MCCs) and 20 Local User Terminals (LUTs).

This was the second global System Exercise, the first having been performed in November 1986.

## 2.0 The Exercise

To effectively meet the objectives given in the Executive Summary, the Exercise of 1990 was partitioned into three mutually exclusive Phases, designated Phase 1, Phase 2, and Phase 3. A total of 32 nations, overseas territories and states participated to some extent in the Exercise, as documented in the table of Figure 1: all Figures are included in Section 1 of the Annex.

### 2.1 Exercise Structure

The structure of each Phase of the Exercise is described in the following sections.

#### 2.1.1 Phase 1

Phase 1 was designed to demonstrate the readiness of the Exercise participants, beacons, procedures and software. This Phase was further partitioned into Phase 1A, Phase 1B and Phase 1C, which were conducted on 02 November 1989, 04 April 1990, and 20 June 1990, respectively. In each Phase, one or two 406 MHz control beacons were activated for 8 hours: all available data was collected and sent to the International Exercise Coordinator (IEC) for validation. Anomalies were identified by the IEC, and identified to the appropriate National Exercise Coordinator (NEC) for correction.

Phase 1 was successful in that (a) the definition and selection of parameters to be recorded, (b) the structure of the automated database and associated data discs, and (c) the design and development of processing algorithms were successfully tested by analyzing the data discs provided with the analysis software.

#### 2.1.2 Phase 2

Phase 2 was designed to demonstrate the operational characteristics of the System under normal operational conditions (thus satisfying objectives one and three), and was patterned after the Exercise of 1986. Operational beacons were placed at 25 sites, on land and at sea as shown in the Beacon Location Map of Figure 2. A more detailed presentation is given in the Beacon Distribution Table of Figure 3, which includes each beacons site number, environment, location, protocol, country code and provider, and the MCC service area in which it is located.

Two beacons were deployed, tested and available at each of the 25 Exercise sites. At the 12 "on land" and the 2 "on ship" sites only one beacon (designated the primary beacon) was to be activated and the second beacon (designated the back-up beacon) was to be available as a replacement if the primary beacon failed. At the 3 "free-floating", 4 "lifeboat" and 4 life raft sites both the primary and the back-up beacons were to be activated concurrently, thus a total of 36 beacons, 25 primary and 11 back-up were to have been activated in Phase 2. A collection of pictures of the beacons deployed in their Exercise environments is given in Section 2 of the Annex.

Phase 2 was conducted on 22-24 October 1990. Beacons were activated and deactivated in accordance with the Exercise Script (included in Volume 3). The associated times were derived from a table of pseudo random numbers and modified as required by national constraints. An average of 3.9, and never more than 6 beacons were active concurrently, as shown in the beacon Activity Profile of Figure 4. The average beacon on time was 8 hours and 22 minutes.

### 2.1.3 Phase 3

Phase 3 was designed to demonstrate the operational characteristics of the System under moderate stress (thus satisfying objective two), and is unique to the Exercise of 1990. The 25 primary beacons of Phase 2 were reactivated without relocation for use in Phase 3. This Phase was intended to simulate the anticipated message volume demands on the System through the 1995 time frame.

Phase 3 was conducted on 25-26 October 1990. Beacons were activated sequentially, one each 30 minutes in accordance with the Exercise Script, until all 25 beacons were activated. All beacons remained active for 12 hours, and were then deactivated concurrently, as shown in the beacon Active Profile of Figure 5. Thus a maximum of 25 and an average of 18.75 beacons was active concurrently in this Phase. The average beacon on time was 18 hours.

## 2.2 The Space Segment

The Space Segment utilized in the Exercise of 1990 consisted of the COSPAS-4, COSPAS-5, SARSAT-2 and SARSAT-4 satellites, as shown in Figure 6. The COSPAS-4 spacecraft was fully operational in the northern hemisphere and partially operational in the southern hemisphere, COSPAS-5 was fully operational, SARSAT-2 was operated in local mode only, and SARSAT-4 was fully operational, as shown in the Space Segment status table of Figure 7.

The operational limitation of the COSPAS-4 spacecraft in the southern hemisphere reduced its data acquisition capability for beacons located south of the equator. There were no such operational limitations in the northern hemisphere.

The "local mode only" constraint of the SARSAT-2 spacecraft limited its data acquisition opportunities to beacon events (the term "beacon event" is used to describe the passage of a spacecraft over an active Exercise beacon) in which the spacecraft had mutual visibility of a beacon and a LUT. If the pass was not acquired by that LUT, there was no future opportunity for acquiring the data. This was not true of spacecraft with global mode capabilities where data was stored and acquisition opportunities were subsequently available to all LUTS.

With the failure of the SAR Processor in 1988, the 406 MHz capability of the SARSAT 3 spacecraft was limited to the SAR Repeater (i.e., the bent pipe) mode. The data from this mode, processed operationally at the French and Indian MCCs only, resulted in a total of only five calculated locations, hence the SARSAT-3 spacecraft and its limited database were deleted from all Exercise considerations except the LUT Tracking Analysis of Section 3.7.

There appears to have been additional variations in the ability of the spacecraft to acquire and/or downlink alert data. These variations were not a primary focus of the Exercise, thus the data collected and analysis software available did not support the detailed analysis required to resolve this issue. It appears, however, that the observed variations are a function of the spacecraft, spacecraft elevation angle and/or the ground segment.

## 2.3 The Ground Segment

At the time of the Exercise of 1990, the Ground Segment consisted of 10 MCCs and 20 LUTs, as tabulated in Figure 8, and shown geographically in Figure 9. The Norwegian, Soviet and US MCCs used relatively new software systems; the Australian and Hong Kong MCCs were recent additions to the operational Ground Segment; the MCCs of Canada, Chile, France, India and the United Kingdom also participated in the Exercise.

Operational messages were distributed within the Ground Segment and to participating RCCs in accordance with the "COSPAS-SARSAT Data Distribution Plan" (C/S A.001), with minor variations introduced to accommodate Exercise-unique considerations and to ensure that there were no interruptions in the on-going operational SAR activities.

The resultant data distribution matrix is given in "Volume 3 - Support Data with Script." The MCC service areas used for the Exercise are given in Figure 10.

## 2.4 Exercise Beacons

Thirty-six (36) production quality 406 MHz beacons were selected for use in the Exercise of 1990. The beacons were produced by and procured from a variety of manufacturers, and were operationally coded to simulate all approved operational protocols given in "Specification for COSPAS-SARSAT 406 MHz Distress Beacons" (C/S T.001) and a variety of country codes. All 36 beacons were activated and tested prior to deployment.

During Phase 2, five beacon failures were observed: the primary beacon at Oahu and the back-up beacon at the Black Sea (both 2-beacon sites) failed, reducing the number of Exercise beacons from 36 to 34; the primary beacons at Novosibirsk and Molodezhnaya (both 1-beacon sites) failed and were replaced by their back-up beacons with no change in the number of active Exercise beacons; and the primary beacon at Trenton (a 1-beacon site) failed but was not replaced because of the intermittent nature of the failure.

Thus, data was collected from 34 beacons during the Exercise, though only 31 of the original 36 beacons (86%) operated effectively during Phases 2 and 3.

2.5 Data Collection

The data to be collected at LUTs, MCCs and RCCs in support of the Exercise was documented in "The Exercise Database Description - Final" (EWG-4, London, September 1990). This data was compiled and validated by the collecting agency, recorded on computer compatible discs in the pre-determined format, and sent to the IEC for System-level validation, compilation into an international System-level database, and analysis.

In most cases, automated techniques were used to extract the desired data from MCC databases, to format and validate this data, and to record the resultant data on computer compatible discs. Data collection forms were provided by the IEC to facilitate the initial steps of this process where manual data collection was required. Manual data collection by some MCCs was effective, but in others it resulted in delays, omissions and errors whose identification and correction was time consuming. The missing data (small in volume as related to the volume of available data) did not significantly affect the results presented in this report. The use of automated data collection techniques was effective in the reduction of clerical errors, and in providing the resultant data in timely fashion.

3.0 Analysis Results

The multiple activation of selected beacons during the Exercise (i.e., Phase 2 and Phase 3) resulted in a total of 59 beacon activations, each of which was accurately located in timely fashion. The associated analysis focused on eighteen System-level parameters that were related to the Exercise objectives: Location Acquisition Probability (LAP), Message Filtering Factor (MFF), MCC Reliability Probability (MRP), Ground System Fidelity (GSF), Location Accuracy, Initial Locations Accuracy, A-Selection Reliability Probability (ARP), Error Ellipse Reliability, Error Ellipse Heading, Small Error Circle, Large Error Circle, System Waiting Time, System Processing Time, Notification Message Analysis, Confidence Factor Analysis, LUT Tracking Analysis, Image Notification Analysis, and Low Elevation Angle Analysis.

A summary of the statistical analysis is given in the following sections. A more detailed presentation of the results is given in "Volume 2 - Data Analysis," and the raw data is given in "Volume 4 - Database."

3.1 System Fidelity Analysis

The various aspects of System fidelity are measured by four statistics; (1) Location Acquisition Probability (LAP), (2) Message Filtering Factor (MFF), (3) MCC Reliability Probability (MRP), and (4) Ground System Fidelity (GSF).

3.1.1 Location Acquisition Probability (LAP)

The Location Acquisition Probability (LAP) was defined as the number of COSPAS-SARSAT satellite passes acquired (i.e., for which a beacon location was calculated) divided by the number of passes predicted (i.e., for which a beacon location was anticipated), expressed as a percent. Thus the LAP can be used to evaluate the data collection and location capability of a LUT, an MCC or the total System.

In calculating the LAP, only spacecraft passes with a beacon-to-spacecraft elevation angle of greater than or equal to 8° were included, thus ensuring that the time duration of each predicted pass would be long enough to permit the acquisition of at least four beacon data bursts, hence for the LUTs to calculate accurate locations from the data collected. The LAP for low elevation angle passes (i.e., less than 8°) is considered in the Low Elevation Angle Analysis of Section 3.9 of this document.

During the Exercise, 574 beacon locations were calculated by at least one MCC from 585 opportunities, resulting in a calculated System-level LAP of 98 percent.

The eleven unlocated opportunities appear to be associated with (1) the SARSAT-2 satellites local-mode only capability, (2) the COSPAS-4 satellites reduced southern hemisphere coverage capability, or (3) the activation of beacons in areas of known interference.

### 3.1.2 Message Filtering Factor (MFF)

An MCC may receive information concerning a specified beacon event from multiple sources, including its directly connected LUTs and/or other MCCs, in accordance with the "COSPAS-SARSAT Data Distribution Plan" (C/S A.001). This multi-path communications network was designed to ensure that distress data are transmitted to the appropriate MCC in minimum time, independent of the LUT that originally acquires the data. The network accomplishes its intended objective but results in the receipt of redundant messages (i.e., messages from the same beacon event acquired by multiple LUTs) at all MCCs. The first message from a "beacon event" to be received by the MCC servicing the area in which the beacon is located is classified as the "unique message" for that beacon event: subsequent messages received by the MCC associated with that beacon event are classified as "redundant messages." In accordance with the Data Distribution Plan, all unique alert data are to be transmitted to the RCC network, but redundant messages (i.e., copies) are to be filtered out of the system by the MCCs at which they are detected.

To measure MCC filtering effectiveness, the Message Filtering Factor (MFF) was defined for the System as the total number of alert messages received by all MCCs divided into the number of unique alert messages transmitted from all MCCs, expressed as a percentage.

In calculating the MFF, all alert messages were included regardless of beacon to spacecraft elevation angle (i.e., greater than or equal to 0°). No subsequent Low Elevation Angle Analysis was performed.

Collective analysis indicates that 12,527 alert messages were received by all MCCs, and that 3624 alert messages were transmitted from these MCCs, resulting in a System MFF of 29%, with no significant variation between Phase 2 (28%) and Phase 3 (29%). Thus, 29% of the messages received at MCCs were unique and were transmitted to the SAR network or other MCCs, and 71% were found to be redundant and therefore were not transmitted.

The MFF will vary from MCC to MCC as a function of a MCCs position in the Communications Network (nodal MCC, unique interfaces, etc.), and the number of directly connected LUTs it supports. Nevertheless, a significant number of redundant messages were transmitted by the Canadian and Indian MCCs: a need for the clarification of filtering requirements is indicated.

In accordance with the Data Distribution Plan, messages transmitted to locations outside of defined COSPAS-SARSAT MCC service areas (i.e., Other Areas) are partially filtered by the three nodal MCCs (French, Soviet and US) and are transmitted by each directly to the appropriate national RCC.

### 3.1.3 MCC Reliability Probability (MRP)

The MCC Reliability Probability (MRP) was designed to measure the fidelity of individual MCCs in processing filtered messages. The MRP was defined as the number of unique alert messages received by an MCC divided into the number of unique alert messages transmitted from that MCC, expressed as a percent.

Collectively, 3,959 unique alert messages were received by the MCCs of the System. MCC-level MRPs were calculated and the majority equaled or exceeded 0.99 for Exercise Phase 2 and Phase 3. The exceptions include the Australian MCC (Phase 2 and Phase 3), the Chilean MCC (Phase 2), the Soviet MCC (Phase 2 and Phase 3) and the US MCC (Phase 2). The Australian MCC's problem was associated with a national procedure that resulted in improperly merging unique solutions, and has been corrected; the Chilean MCC's problem appears to be associated with database errors; the Soviet MCC's problem was associated with software anomalies, and has been corrected; the US MCC's problem was associated with a timing anomaly in a TELEX interface, and has been corrected. Accordingly, only 3,624 unique alert messages were transmitted by the MCCs of the System.

With the implementation of the corrections noted, national tests now suggest that the MRP for each MCC is equal to or exceeds 0.99.

The receipt and transmission of partially filtered messages to and from other MCCs result in the number of messages considered herein (3,624) that significantly exceed the number of messages ultimately transmitted to RCCs (557).

### 3.1.4 Ground Segment Fidelity (GSF)

The reliability of individual MCCs is calculated in section 3.1.3. A more accurate measure of total ground system reliability is given by the Ground Segment Fidelity (GSF), which was defined as the total number of unique alert messages received at all LUTs divided into the total number of unique alert messages transmitted to RCCs, expressed as percent. This concept is illustrated in Figure 10A.

It was determined that 662 unique alert messages were received at LUTs, and that 628 unique alert messages were transmitted to RCCs, resulting in a GSF of 0.95. There was no variation between Phase 2 (with a GSF of 0.95) and Phase 3 (with a GSF of 0.95).

A more detailed analysis of the 34 "missing" unique alert messages indicated that 18 were associated with MCC operational issues (routing errors, procedures, etc.), and 16 are for unknown reasons. The responsible National Exercise Coordinators (NECs) indicated that the associated MCC procedures have been modified to resolve the 18 operational anomalies. The remaining 16 messages, missing for "unknown" reasons, are associated with beacon-events involving the local mode only capabilities of the SARSAT-2 spacecraft, hence each was available in local-mode to one LUT only. The need for additional analysis is indicated.

### 3.2 System Accuracy Analysis

A qualitative overview of System Accuracy in locating beacons is given in the Star Burst display of Figure 11. All locations calculated in Phase 2 and Phase 3 are included in this display: calculated locations greater than or equal to 50 km from their true locations are moved toward the center (i.e., origin) of this display and placed on a circle of 50 km radius.

The associated quantitative analysis was partitioned into two components, Location Accuracy, and A-Selection Reliability Probability.

In both the Location Accuracy and the A-Reliability Probability, only data from spacecraft passes (i.e., from beacon events) with a beacon-to-spacecraft elevation angle of greater than or equal to 8° were used. The Location Accuracy and A-Reliability Probability associated with low elevation angle passes are considered in the Low Elevation Angle Analysis of Sections 3.9.2 and 3.9.3, respectively.

#### 3.2.1 Location Accuracy

Location Accuracy is a measure of the distance (in kilometers) from a beacon's calculated location to its actual location. The actual location of each beacon is documented in its Beacon Installation Plan (BIP), provided by the responsible NEC and included in "Volume 3 - Support Data with Script."

Nine thousand one-hundred fifty-two (9,152) beacon locations were calculated: 3,508 in Phase 2 and 5,644 in Phase 3. The accuracy of these calculated locations is shown collectively for Phases 2 and 3 in the histogram of Figure 12. A total of 7,647 calculated locations (84%) were within 5 km of the actual beacon location, and a total of 8,258 calculated locations (90%) were within 10 km of the actual beacon location: 563 calculated locations (6%) were greater than 20 km from the actual beacon location, and were evaluated in greater detail.

The 563 calculated locations that were found to be greater than 20 km from the reported beacon locations were partitioned into eleven mutually exclusive categories, as shown in the table of Figure 13, and considered in the following sections.

(a) Partial Doppler Curve

Partial Doppler curve locations are those solutions derived from data sets taken from a portion of the total Doppler curve (Figure 14). These data sets come from one of the tails of the curve, thus do not include data near the spacecraft time of closest approach (TCA) to a beacon (i.e., the point of inflection on the curve). Data sets from partial Doppler curves are often associated with beacon activity (activation or deactivation) during a spacecraft pass, or unique local-mode geometry.

Partial Doppler curves accounted for 26 (4%) of the 563 calculated locations with inaccuracies in excess of 20 km, and 16 (8%) of the 206 calculated locations with inaccuracies greater than 50 km.

(b) Residual Curve

Residual curve locations include those solutions derived from incomplete data sets. These solutions result from two consecutive acquisitions of a spacecraft by a LUT, in which the first acquisition produces a solution based on local and global mode data, and the second acquisition produces a solution based on global mode data only, therefore producing a solution from an incomplete data set.

Residual curves accounted for 9 (2%) of the 563 calculated locations with inaccuracies in excess of 20 km and 5 (3%) of the 206 calculated locations with inaccuracies greater than 50 km.

(c) Pass Geometry

Pass geometry locations are those solutions derived from data sets taken from overhead passes in which the beacon-to-spacecraft elevation angle at TCA was greater than 85 degrees (Figure 14).

Pass geometry accounted for 43 (8%) of the 563 calculated locations with inaccuracies in excess of 20 km, and 2 (1%) of the 206 calculated locations with inaccuracies greater 50 km.

(d) 3-Point Solutions

Three-point solutions are determined from only three points on a Doppler curve (Figure 14), and are characteristically less accurate than solutions based on additional data points. In the absence of additional data, however, solutions based on three points are calculated by some LUTs.

The location accuracy associated with three-point solutions is shown qualitatively in the Star Burst diagram of Figure 15, and quantitatively in the histogram of Figure 16.

Three-point solutions accounted for 34 (6%) of 563 calculated locations with inaccuracies in excess of 20 km, and 19 (9%) of the 206 calculated locations with inaccuracies greater than 50 km.

(e) 4-Point Solutions

Four-point solutions are determined from only four points on a Doppler curve (Figure 14), and are somewhat less accurate than solutions based on additional data points. In the absence of additional data, however, solutions based on four points are calculated by all LUTs.

The location accuracy associated with four-point solutions is shown qualitatively in the Star Burst diagram of Figure 17, and quantitatively in the histogram of Figure 18.

Four-point solutions accounted for 17 (3%) of 563 calculated locations with inaccuracies in excess of 20 km, and 13 (6%) of the 206 calculated locations with inaccuracies greater than 50 km.

(f) Orbit Vectors

The orbital positions of the COSPAS and SARSAT satellites are determined from orbit vectors provided by the Soviet and US MCCs, respectively. These orbit vectors are updated periodically and are provided to all MCCs through normal operational channels.

Because of inadequacies in operational procedures at the local level, obsolete orbit vectors for SARSAT-4 were used by the San Francisco LUT during Phase 2 and Phase 3 of the Exercise (Figure 19). This accounts for 159 (28%) of the 563 calculated locations with inaccuracies in excess of 20 km, and 6 (3%) of the 206 calculated locations with inaccuracies greater than 50 km.

(g) Time Calibration

An additional parameter, time calibration (TCal), is required to determine the position of beacons acquired by the SARSAT satellites. These parameters are updated periodically, and are provided to all MCCs by the US MCC through normal operational channels.

Because of inadequacies in operational procedures at the local level, obsolete TCal values were used by the Nakhodka and Novosibirsk LUT during Phase 2 and Phase 3 of the Exercise. This accounts for 78 (14%) of the 563 calculated locations with inaccuracies in excess of 20 km, and 2 (1%) of the 206 calculated locations with inaccuracies greater than 50 km.

(h) LUT Software

Various nations installed replacement or significantly enhanced computer software in their LUTs a short time before the Exercise began, thus the pre-Exercise operational time on the new software systems was limited.

During the Exercise, problems with this new software accounted for 112 (20%) of the 563 calculated locations with inaccuracies in excess of 20 km, and 108 (53%) of the 206 calculated locations with inaccuracies greater than 50 km.

(i) LUT Hardware

Various nations installed replacement or significantly enhanced computer hardware in their LUTs a short time before the Exercise began, thus the pre-Exercise operational time on the new hardware systems was limited.

During the Exercise, problems with this new hardware accounted for 17 (3%) of the 563 calculated locations with inaccuracies in excess of 20 km, and 17 (8%) of the 206 calculated locations with inaccuracies greater than 50 km.

(j) Beacons

Post-Exercise analysis indicated that the batteries in a beacon located at Trenton perfomed inadequately.

This beacon accounted for 9 (2%) of the 563 calculated locations with inaccuracies in excess of 20 km, and 9 (4%) of the 206 calculated locations with inaccuracies greater than 50 km.

(k) Moving Beacon

One beacon was located on the ship CUMULUS moving at 10-12 knots on a variety of headings. The beacon was mounted on the upper deck amidships and forward of the stack.

This beacon accounted for 18 (3%) of the 563 calculated locations with inaccuracies in excess of 20 km, and none of the 206 calculated locations with inaccuracies greater than 50 km.

(l) Unknown

A total of 41 (7%) of the 563 calculated locations with inaccuracies in excess of 20 km and 9 (4%) of the 206 calculated locations with inaccuracies greater than 50 km cannot be associated with any definitive anomaly.

The responsible NEC's indicate that:

- Procedures have been modified to ensure that only proper orbit vectors and/or TCal values will be used in LUTs and MCCs, and

- Hardware and software problems associated with enhanced LUTs and MCCs have been resolved.

With these corrections, it is projected that 7,647 calculated locations (87%) would have been within 5 km, and 8,258 calculated locations (94%) would have been within 10 km of the reported beacon locations; 197 calculated locations (2%) would have been greater than 20 km from the actual beacon locations (Figure 20). The associated distribution of projected location accuracies is given in the histogram of Figure 21.

Continued analysis of the location algorithms associated with Partial Doppler Curves, Pass Geometry, and 3-Point and 4-Point Solutions is recommended.

3.2.2 Initial Locations Accuracy

The accuracy of the initial (i.e., first three) locations provided to a RCC from each Exercise beacon was investigated in greater detail. A total of 158 locations were considered, which was less than the theoretical maximum of 177 (59 beacon activations multiplied by 3) because RCC data was not provided for some locations.

The distribution of initial location accuracies is given qualitatively in the Star Burst diagram of Figure 22, and quantitatively in the histogram of Figure 23.

A total of 119 of the initial locations (75%) were within 5 km of the actual beacon location, and 135 of the initial locations (85%) were within 10 km of the actual beacon location: 13 of the initial locations (8%) were greater than 20 km from the actual location.

As viewed from the perspective of the RCC, all of the first three locations received for a beacon were within 5 km of the actual location 40% of the time, and at least two of the first three locations received were within 5 km of the actual location 83% of the time.

In all but one of the remaining cases, one location was within 5 km and the remaining two locations were within 30 km of the actual beacon location.

The one case remaining includes one location within 5 km and two less accurate locations based on three and four data points.

A summary of these results is given in the table of Figure 24.

3.2.3 A-Selection Reliability Probability (ARP)

The beacon location algorithm generates a pair of potential beacon locations. This ambiguity is resolved, and the statistically most probable location is identified as the A-solution; the statistically less probable location is identified as the B-solution as shown in Figure 25.

In order to evaluate the System's ability to resolve location ambiguities, each selected A-solution was compared with the actual location of the associated beacon, and the number of correct A-selections was expressed as a percent of the total number of selections.

In evaluating the System's A-selection capability, only spacecraft passes (i.e., beacon events) with a beacon-to-spacecraft elevation angle of greater than or equal to 8° above the beacon's local horizon were used. The System's A-Selection capability with data acquired from low elevation angle passes (i.e., less than 8°) was considered in the Low Angle Elevation Analysis of Section 3.9.3.

Based on the 9,152 locations calculated, the correct location was chosen as the A-solution over 95% of the time, with no significant variation between Phase 2 (96%) and Phase 3 (95%) as shown in Figure 26.

3.3 Error Ellipse Analysis

An Error Ellipse can be calculated with each beacon location (Figure 27). This calculation is intended to define an ellipse that, with 50% reliability, will contain the associated beacon location (see "COSPAS-SARSAT Mission Control Centre Standard Interface Description" (SID), C/S A.002). The calculated Ellipses were evaluated by determining the percent that contain the actual location of the associated beacon, and the effect of rotating (i.e., changing the heading of) each ellipse in an attempt to include more beacon locations within its circumference.

Additionally, Small Error Circles and Large Error Circles were defined and evaluated as possible alternatives to the Error Ellipse.

The results of the following analysis indicate that the Error Ellipses, as currently calculated, do not meet their required specifications documented in the SID. Additionally, neither the Small nor the Large Error Circles, as currently defined, are viable replacements for the Error Ellipse.

In considering the Error Ellipse, the Small Error Circle and the Large Error Circle, only data from spacecraft passes with a beacon-to-spacecraft elevation angle of greater than 8° were used. In all cases, the evaluation associated with low elevation angle passes are considered in the Low Elevation Angle Analysis in Section 3.9.4.

3.3.1 Error Ellipse Reliability

A total of 8,473 Error Ellipses were calculated, each associated with a calculated beacon location. It is noted that not all MCCs calculate Error Ellipses, and that the Exercise databases provided by some MCCs were incomplete, thus the number of Error Ellipses calculated (8,473) is less than the number of beacon locations calculated (9,152).

In total, only 23% (Figure 28) of the calculated ellipses contained the location of the associated beacon, with minor variation between Phase 2 (27%) and Phase 3 (20%). There were, however, significant differences between MCCs. The Australian MCC with Error Ellipses enlarged by a factor of 6 (and subsequently reduced to original size) meet the 50% reliability level with a composite (i.e., Phase 1 and Phase 2) reliability of 53%: the Hong Kong, UK, and US MCCs produced Error Ellipses with composite reliabilities of 8%, 8% and 4%, respectively.

This MCC-to-MCC variation, ranging from 53% to 4%, appears to be a function of the individual algorithms used for determining Error Ellipses, which vary significantly in design and in implementation technique among the MCCs of the Ground Segment.

3.3.2 Error Ellipse Heading

Each calculated Error Ellipse includes an Error Ellipse Heading, which defines the orientation (or the direction of the major axis) of the ellipse. In evaluating these headings, each calculated ellipse was rotated both clockwise and counterclockwise to determine its "correct" heading, or the heading that would "point" it in the direction of the actual location of the associated beacon. The variations between calculated and correct headings were calculated, compiled and displayed.

This analysis considered 8,473 ellipse headings, and indicated that the rotation angles (±90°) required for optimum orientation was relatively equal (Figure 29), with a slight bias for small rotation angles (i.e., ±10°). This suggests that improving the orientation of the Error Ellipse would not significantly improve its reliability. This conclusion was for all MCCs, and for both Phase 2 and Phase 3.

3.3.3 Small Error Circle

With each Error Ellipse, a Small Error Circle was determined whose radius was the semi-minor axis of the Error Ellipse (Figure 30). The reliability of this family of Small Error Circles was evaluated by determining whether or not the individual circles contained the actual locations of the associated beacons.

This analysis considered 8,473 Small Error Circles, each associated with a beacons location. In total, only 15% of these Small Error Circles contained the location of the associated beacons, hence the Small Error Circle, as currently defined, is not a viable replacement for the Error Ellipse.

3.3.4 Large Error Circle

With each Error Ellipse, a Large Error Circle was determined whose radius was the semi-major axis of the Error Ellipse (Figure 30). The reliability of this family of Large Error Circles was evaluated by determining whether or not the individual circles contain the actual locations of the associated beacons.

This analysis considered 8,473 Large Error Circles, each associated with a beacon location. In total, 36% of these Large Error Circles contained the location of the associated beacon, the Large Error Circle, as currently defined, is not a viable replacement for the Error Ellipse.

3.4 System Timing Analysis

The System Timing was evaluated by analyzing (1) the time from beacon activation until the first satellite Time of Closest Approach (TCA), defined herein as System Waiting Time; and (2) the time from TCA until a MCC has received and processed the associated alert data and has transmitted the resultant message to a RCC, defined herein as the System Processing Time (Figure 31). It follows that System Processing Time includes spacecraft processing and storage time, LUT processing time, MCC processing time, and intra-system communications times.

3.4.1 System Waiting Time

By definition, System Waiting Time applies to only the first satellite pass over an active beacon, hence there are a maximum of 25 samples each from Phase 2 and Phase 3, or a total of 50 samples for the Exercise (in order not to bias the results only one beacon from each site was used in this analysis).

The distribution of System Waiting Times is given in the histogram of Figure 32. The average System Waiting Time was 44 minutes, with no significant difference between the average Waiting Time of Phase 2 (43 minutes) and Phase 3 (44 minutes).

Forty-seven of the 50 samples occurred within 90 minutes of beacon activation; the three remaining samples were from beacons located at Oahu/Phase 2 (163 minutes), Libreville/Phase 3 (143 minutes), and Ascension/Phase 3 (186 minutes). All three locations experienced earlier passages of the SARSAT-2 spacecraft: (1) Oahu at 90 minutes, but the local-mode data was not acquired by the available LUT (one of the missing events in Section 3.1.1), and (2) Libreville at 51 minutes and Ascension at 91 minutes, but no LUT was within the real-time field of view of these south bound passes, and only the local mode data (i.e., not global mode data) from the SARSAT-2 spacecraft is acquired and processed operationally.

The processing of global data from the SARSAT-2 spacecraft, a capability that was activated operationally after the completion of the Exercise, now provides data that was not previously available, thus reducing the average system waiting time.

3.4.2 System Processing Time

The Processing Times were divided into two distinct categories: the Processing Times associated with the first message from each beacon to be available at a MCC for transmission to an RCC (i.e., First Message Processing Times) and the Processing Times associated with non-redundant (i.e., unique) messages from all beacons to be available at a MCC for transmission to an RCC (i.e., Non-Redundant Message Processing Times).

It should be noted that the satellite pass associated with the Waiting Time may not be the satellite pass associated with the First Message Processing Time. In selected cases, a beacon may be acquired by a satellite which experiences a long delay before being tracked by a LUT: another satellite may acquire the beacon, and be tracked by a LUT before the first satellite is tracked, thus the data provided by the second satellite may generate the first message through the System.

3.4.2.1 First Message Processing Time

A total of 59 beacon-activations occurred in Phase 2 and Phase 3 of the Exercise. All 59 were located, but only 49 (29 in Phase 2 and 20 in Phase 3) resulted in First Message Timing data. The missing data associated with the beacons with no First Time Processing times result from the fact that (1) some messages were not transmitted to RCCs during the Exercise because of National Procedures, and that (2) databases were not provided by all MCCs (i.e., the Hong Kong and UK MCCs). The times associated with the 49 confirmed First Time messages were analyzed in this Section.

The distribution of First Message Processing Times is given in the histogram of Figure 33. The average First Message Processing Time was 43 minutes, with minor difference between the First Message Processing Times of Phase 2 (45 minutes) and Phase 3 (40 minutes). Twenty-two (22) of the 49 messages (45%) were processed in less than 30 minutes and 46 of the 49 messages (94%) were processed in less than 90 minutes. The three First Message Processing Times that exceed 90 minutes were associated with beacons located at Cachoeira Paulista, Brazil (Phase 2) and Libreville, Gabon (Phase 2 and Phase 3).

The longer delays associated with the Cachoeira Paulista and Libreville beacon were a function of the current Ground Segment configuration, data transmission delays associated with the Libreville site and extended Space Storage Times.

Subsequent analysis indicated that 63% of all First Message Processing Times (i.e., an average of over 27 minutes) was spent prior to MCC receipt, or, in space storage and LUT processing (Figure 34) Because messages normally transmit the LUTs in minimum time, the more significant portion of this 63% was spent in Space Storage.

3.4.2.2 Non-Redundant Message Processing Time

A total of 508 Non-Redundant Messages were processed and transmitted to RCCs, (190 in Phase 2 and 318 in Phase 3). This includes messages from every beacon, and the various combinations of spacecraft, TCAs and MCCs.

The distribution of Non-Redundant Message Processing Times is given in the histogram of Figure 35. The average Non-Redundant Message Processing Time was 58 minutes with no significant difference between the average Non-Redundant Message Processing Times of

Phase 2 (58 minutes) and Phase 3 (59 minutes). Three hundred and forty six (346) of the 508 alert messages (68%) were processed in less than 60 minutes, and 490 of the 508 alert messages (96%) were processed in less than 180 minutes.

Four of the 18 remaining Non-Redundant Message Processing Times were from Phase 2, and, 14 were from Phase 3, thus the majority of the larger Non-Redundant Message Processing Times were from Phase 3.

In Phase 2, three of the four excessive timing values (Figure 35) include large space storage times resulting from an incomplete Exercise database or a LUTs failure to track available spacecraft. The fourth excessive timing value was associated with a MCC procedural problem.

In Phase 3, the 14 excessive timing values are all associated with LUTs and MCCs having new or significantly enhanced hardware and/or software systems. Nine of the 14 values are associated with excessive TELEX delays, and 5 are associated with MCC procedure and software problems.

A summary of the large Processing Times from Non-Redundant Messages of Phase 2 and Phase 3 is shown in Figure 35. National Exercise Coordinators (NECs) indicate that the noted LUT/MCC software and procedural anomalies have been resolved. Nevertheless, the data indicates that ground data transmission constraints continue to contribute to excessive ground processing delays, especially under the moderate stress of Phase 3.

### 3.5 Notification Message Analysis

The protocol of each beacon includes a country code indicating the country of beacon registration. The MCC in whose service area the beacon is located is responsible for transmitting a Notification of Country of Beacon Registration (NOCR) message to the Support MCC or to the SAR Point of Contact (SPOC) associated with the beacon's country code (Data Distribution Plan, Annex E).

The System's performance in transmitting the appropriate NOCRs was evaluated for Phase 2 only. It was determined that 31 (91%) of the anticipated 34 NOCR messages were transmitted, and that an additional 12 unanticipated redundant NOCR messages were also transmitted.

There appears to be some misunderstandings among the MCCs concerning the conditions under which NOCRs are to be transmitted, indicating the need to clarify the associated sections of the Data Distribution Plan, and/or provide MCC-level operational training.

### 3.6 Confidence Factor Analysis

With each beacon location calculated, an associated Confidence Factor is determined. The Confidence Factor provides a measure of the reliability of the associated calculated location. Confidence factors 4, 3 and 2 indicate that the actual beacon location may be within 5, 20 or 50 nautical miles, respectively, of the calculated beacon location (see C/S A.002, Annex B).

The reliability of the assigned Confidence Factors was evaluated by determining whether or not the confidence-level circles contained the associated beacon location.

It was determined that some MCCs under-classify (i.e., incorrectly assign low Confidence Factors to) good solutions, while other MCCs over-classify (i.e., incorrectly assign high classification factors to) less-accurate solutions (Figure 36).

More specifically, some MCC's confidence factors optimized the estimation of good solutions (Type I accuracy, Figure 37). Other MCC's confidence factors optimized the estimation of less accurate solutions (Type II accuracy). Type I accuracy was produced by France, India and the Soviet Union. Type II accuracy was produced by Canada and the United States.

The results were:

| | Type I | Type II |
|---|---|---|
| Good Solutions Correctly Predicted | 94% | 55% |
| Bad Solutions Correctly Predicted | 54% | 85% |

A good solution is one when the actual error was less than 5 nm, the results are presented in more detail in Figure 38.

If Confidence Factor calculations were optimized for both Type I and II accuracy, LUTs would all be operating in the "ideal" area shown in Figure 37. However, problems with TCal and ephemeris data were noted during the Exercise analysis. When this data were removed from the data sets, Confidence Factors improved significantly at three LUTs. This is reflected in improved Type II accuracy results as shown in Figure 39.

For less accurate locations (errors > 20 nm), six LUTs performed in the "ideal" region. Results also improved in three other LUTs when TCal and ephemeris problems were removed as shown in Figure 40.

Confidence Factors would produce more reliable results if:

(a) better monitoring and/or control of orbitography is established in the COSPAS-SARSAT Ground Segment, and/or

(b) orbitography data are added to the Confidence Factor algorithm.

### 3.7 LUT Tracking Analysis

The large number of operational satellites, five at the time of the Exercise, results in LUT tracking conflicts: a LUT has to choose between multiple concurrently visible satellites. This selection is made at a national level, without international coordination.

It follows that individual LUT tracking schedules are not optimal when viewed as part of a global network. This may result in increased data processing times as current alert data is not acquired, but remains in "space storage" until the spacecraft is subsequently tracked by another LUT.

To better understand this situation, the number of spacecraft passes visible, and the number of passes actually tracked were determined by spacecraft and analyzed.

The tracking analysis was conducted for Phases 2 and 3 of the Exercise during which 317 orbits were observed (an average of 63.4 orbits for each satellite). The average number of trackings per orbit is given by satellite in Figure 41, and the observed time interval between consecutive trackings is given in the histogram of Figure 42.

The primary results are:

(a) each satellite has an average of 8.5 opportunities to be tracked on each orbit (an opportunity is defined to be a satellite pass relative to a LUT with a maximum elevation angle of greater than 5°).

(b) the average number of LUT/satellite passes actually tracked per orbit was 5.5 for COSPAS-4, COSPAS-5 and SARSAT-4 (which were operated in global mode), was 4 for SARSAT-2 (operated in the local mode only), and was 1.8 for SARSAT-3. These values are satisfactory.

(c) from orbit to orbit the actual number of tracking opportunities varied from 6 to 12 (with rare exceptions at 5 and 13 opportunities), and the number of passes actually tracked varied from 0 to 11. The need to reduce this variation is indicated.

(d) the result of this dispersion is that the time interval between consecutive trackings is normally short (less than 30 minutes 80% of the time), but there are occasionally large gaps which result in large space storage time gaps: intervals of 90 minutes or more occurred 11 times for COSPAS-4, 14 times for COSPAS-5, and 7 times for SARSAT-4.

The current situation at the systems level does not take advantage of all the potentialities of the COSPAS-SARSAT System. A degree of coordination at the international level could avoid long gaps between consecutive trackings, but may be difficult to implement.

The Canadian and Soviet MCCs are directly connected to three and four high latitude LUTs, respectively, that provide the opportunity to track each satellite at least one time for each orbit. The Indian and US MCCs also have opportunities to track a large number of satellite passes with their two and three operational LUTs respectively.

In summary, as a result of this analysis, it was determined that (1) the SARSAT-2 spacecraft (operated in the local mode only during the Exercise) is scheduled and tracked less frequently than SARSAT-4, COSPAS-4 and COSPAS-5 spacecraft (with global capability); (2) approximately 60% of the available SARSAT-4, COSPAS-4 and COSPAS-5 passes are tracked and yield results; and (3) the time interval between consecutive trackings of the same satellite is less than 30 minutes 83% of the time, but is greater than 90 minutes 7% of the time. Every reasonable effort should be made to eliminate these large gaps in satellite tracking (i.e., in data acquisition). It is noted that the operation of additional LUTs in the coming years will facilitate an effective solution to the problem.

### 3.8 Image Notification Analysis

When a MCC receives its first location of a beacon, the location ambiguity has generally not been resolved, and alert messages are sent to MCCs and SAR agencies supporting the actual and the image solutions.

With the subsequent resolution of the ambiguity, alert messages are sent to the MCC supporting the actual solution only. The MCC supporting the image solution is not informed that it has not been selected, until it determines from its directly connected LUTs that the first solution received was an image. The image notification procedure between MCCs attempts to save time by making the responsible MCC, and consequently the associated SAR agency, aware of the image solution.

Analysis of the Image Notification data indicated that:

(a) The Image Notification procedure is of minimum value when actual and image solutions of the first location sent to an MCC are both in the same MCC service area. This happened 14 times, out of the 25 Exercise beacon sites.

(b) The Image Notification procedure has limited value for MCCs with multiple LUTs (Canada, USSR, US), for high latitude beacons (4 Exercise beacon sites).

In fact, beacon #18 (Kodiak) may have caused problem to the Soviet MCC which got the first image in its service area. The Soviet MCC resolved ambiguity from its LUTs 44 minutes after the US MCC. Here, Image Notification would have been advantageous.

(c) When the first calculated location (either A or B) is in an "Other Area", the three regional MCCs (France, Soviet Union and US) are to exchange alert messages until the location ambiguity is resolved. During the Exercise, this involved a calculated Molodezhnaya "A" location and a calculated Nakhodka "B" location, and alert messages were transmitted by the three regional MCCs. This is consistent with the current procedure, and should be more clearly stated in the Data Distribution Plan.

(d) For six Exercise beacons the MCCs responsible for the first image resolved the ambiguity from their own LUTs significantly later that it was resolved by another MCC, as tabulated herein.

| Location | Service Area Image | Additional Delay (Hrs) | First MCC |
|---|---|---|---|
| Libreville | US | 3.0 | France |
| Ascension | US | 5.5 | UK |
| Johannesburg | US | 1.3 | UK |
| Ishigaki | India | 2.0 | US |
| Santiago | US | 2.0 | Chile |
| Nadi (Back-up) | Australia | 4.5 | US |

(e) Ambiguity can be resolved from wrong locations, even for location errors that are greater than 100 km. This range of location error is normal for local mode locations associated with remote beacons (i.e., Libreville beacon located in local mode by the Toulouse LUT) or when a beacon is activated during a satellite pass.

A threshold of 120 or 150 km between the closest solutions of two different locations should be included in the software at MCCs.

The Exercise demonstrated the value of an Image Notification procedure in 8 cases out of a total 26 situations examined. In actual operations using 406 MHz beacons the situation differs in the way that ambiguities may be resolved, taking advantage of the knowledge of the mobile identification, which is derived from the beacon identification.

New procedures for exchanging alert data are being explored by the OWG. One objective of the enhanced procedures is expected to be a method for reducing the time for MCCs to resolve ambiguities.

3.9 Low Elevation Angle Analysis

Only data from beacon events with beacon-to-spacecraft angles of greater than or equal to 8° were included in the analysis of the LAP, Location Accuracy, ARP, Error Ellipse and Confidence Factor, in Sections 3.1.1, 3.2.1, 3.2.3, 3.3 and 3.6 respectively.

The data from low elevation angle passes (i.e., passes in which the beacon-to-spacecraft elevation angle at TCA is less than 8°) was collected and analyzed independently from these statistics. The results of this analysis are presented in the following sections.

3.9.1 Low Elevation Angle Location Acquisition Probability (L-LAP)

During the Exercise of 1990, a total of 81 beacon locations were calculated from low elevation angle passes by at least one MCC from 146 opportunities, resulting in a calculated System L-LAP of 55%.

The 65 unlocated opportunities are composed of 18 "detect only" passes and 47 missing passes, as shown in Figure 43.

It follows that the LAP calculated from low angle passes (55%) is significantly less than the LAP calculated from the passes of greater than or equal to 8° (98%).

3.9.2 Low Elevation Angle Location Accuracy

During the Exercise of 1990, a total of 1,498 beacon locations were calculated from low elevation angle passes as shown in Figure 44. Within this total, it was determined that 956 calculated locations (64%) were within 5 km of the actual beacon location, and that 1,231 calculated locations (82%) were within 10 km of the actual locations: 20 calculated locations (13%) were greater than 20 km from the actual location.

It follows that the locations calculated from low elevation angle passes were significantly less accurate than locations calculated from passes of greater than or equal to 8°, as tabulated herein.

| Elevation Angle | % <=5km | % <=10km | % >20km |
|---|---|---|---|
| < 8° | 64 | 82 | 13 |
| >= 8° | 84 | 90 | 6 |

3.9.3 Low Elevation Angle A-Reliability Probability (L-ARP)
Based on the 1,498 location calculations from low elevation angle passes, the correct location was chosen as the A-solution 86% of the time as shown in Figure 45.

It follows that the ambiguity resolution from low elevation angle passes (86%) was significantly less reliable than the ambiguity resolutions calculated from passes of greater than or equal to 8° (95%).

3.9.4 Low Elevation Angle Error Ellipse
Of the 1,390 Error Ellipses calculated from low elevation angle passes, 412 (30%) contain the location of the associated beacon as shown in Figure 46.

It follows that the reliability of error ellipses calculated from low elevation angle passes (30%) was greater than the reliability of the error ellipses calculated from passes of greater than or equal to 8° (23%).

Additionally, the Error Ellipse Headings calculated from low elevation angle passes demonstrated a significantly greater tendency for small heading errors than the headings calculated from passes with elevation angles of greater than or equal to 8°, as shown in Figure 47.

3.9.5 Low Elevation Angle Confidence Factors
For low elevation angle passes the North American LUTs did very well in identifying inaccurately located beacons, but they did not do well in identifying accurately located beacons. The opposite is true of all other beacons as shown in Figure 48.

It follows that the Confidence Factors calculated from low elevation angle passes is equivalent to the Confidence Factors calculated from passes of greater than or equal to 8°.

3.10 Comparison with the Exercise of 1986
The COSPAS-SARSAT System performance for the Exercise of 1990 showed an overall positive change when compared with the Exercise of 1986. The comparison of COSPAS-SARSAT Exercise results shown in Figure 49, addresses the System measurement percentages of LAP, MRP, Location Accuracy, Waiting Time and Processing Time:

- The Systems LAP is 98%, an improvement over the 95% of 1986.

- The MRP was not evaluated at the System level in 1990, hence a direct comparison to the results of 1986 is not possible. It is noted, however, that with the resolution of the software, procedural and database anomalies detected, each individual MCC is now believed to be operating with a MRP in excess of 99%.

- The calculated locations are within 5 km of the actual locations 84% of the time, an improvement over the 72% of 1986.

- The waiting times are within 30 minutes of beacon activation times 44% of the time, an improvement over the 40% of 1986.

- The processing times are within 30 minutes of spacecraft data acquisition times 45% of the time, an improvement over the 35% of 1986.

In summary, all facets of the 406 MHz detection, processing and distribution capabilities of the COSPAS-SARSAT System have been improved in recent years. The improvements, demonstrated quantitatively in the Exercise of 1990, have resulted form the resolution of inadequacies observed in the Exercise of 1986, and from the normal evolution of the System.

With the planned System growth and System monitoring activities, System performance is expected to continue to increase, thus providing even more accurate, more timely, and more complete services to the search and rescue community in coming years.

VOLUME 1

EXERCISE SUMMARY

ANNEX

# Section 1: Supporting Figures

# Ground Segment Participants

| Participants | Level of Participation | | | | | | Comments |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| Alaska | | | | X | | | |
| Antarctica | | | | X | | X | "Other" Area |
| Ascension Island | | | | X | | | |
| Australia | | X | | X | X | X | |
| Bermuda | | | | | X | | |
| Brazil | | | | X | | X | |
| Bulgaria | | | | X | X | X | |
| Canada | X | X | X | X | | X | NOCR Not Required |
| Chile | | X | X | X | X | X | |
| Denmark | | | X | | X | X | |
| Fiji | | | | X | | X | |
| Finland | | | | | X | | |
| France | X | X | X | | X | X | |
| French Polynesia | | | | X | | X | |
| Gabon | | | | X | | X | |
| Greece | | | | | X | | |
| Greenland | | | | X | X | X | |
| Hawaii | | | | X | | | |
| Hong Kong | | X | | | | | |
| Iceland | | | | | X | | |
| India | | X | X | X | X | X | |
| Italy | | | | | X | | |
| Japan | | | X | X | X | X | |
| New Zealand | | | | X | X | X | |
| Norway | | X | X | X | X | X | |
| Pakistan | | | | | X | X | |
| Reunion Island | | | | X | | X | |
| South Africa | | | | X | | X | |
| Sweden | | | | | X | | |
| Switzerland | | | | | X | | |
| U.K. | | X | X | X | X | X | |
| U.S.A. | X | X | X | X | X | X | |
| U.S.S.R. | X | X | X | X | X | X | |
| Venezuela | | | | | X | | |

**Key to Participation**

1: Space Segment Provider
2: Ground Segment Provider
3: Beacon Provider
4: Beacon Activator
5: NOCR Message Recipient
6: Alert Message Recipient

Figure 1

# Beacon Locations: Phase 2/3

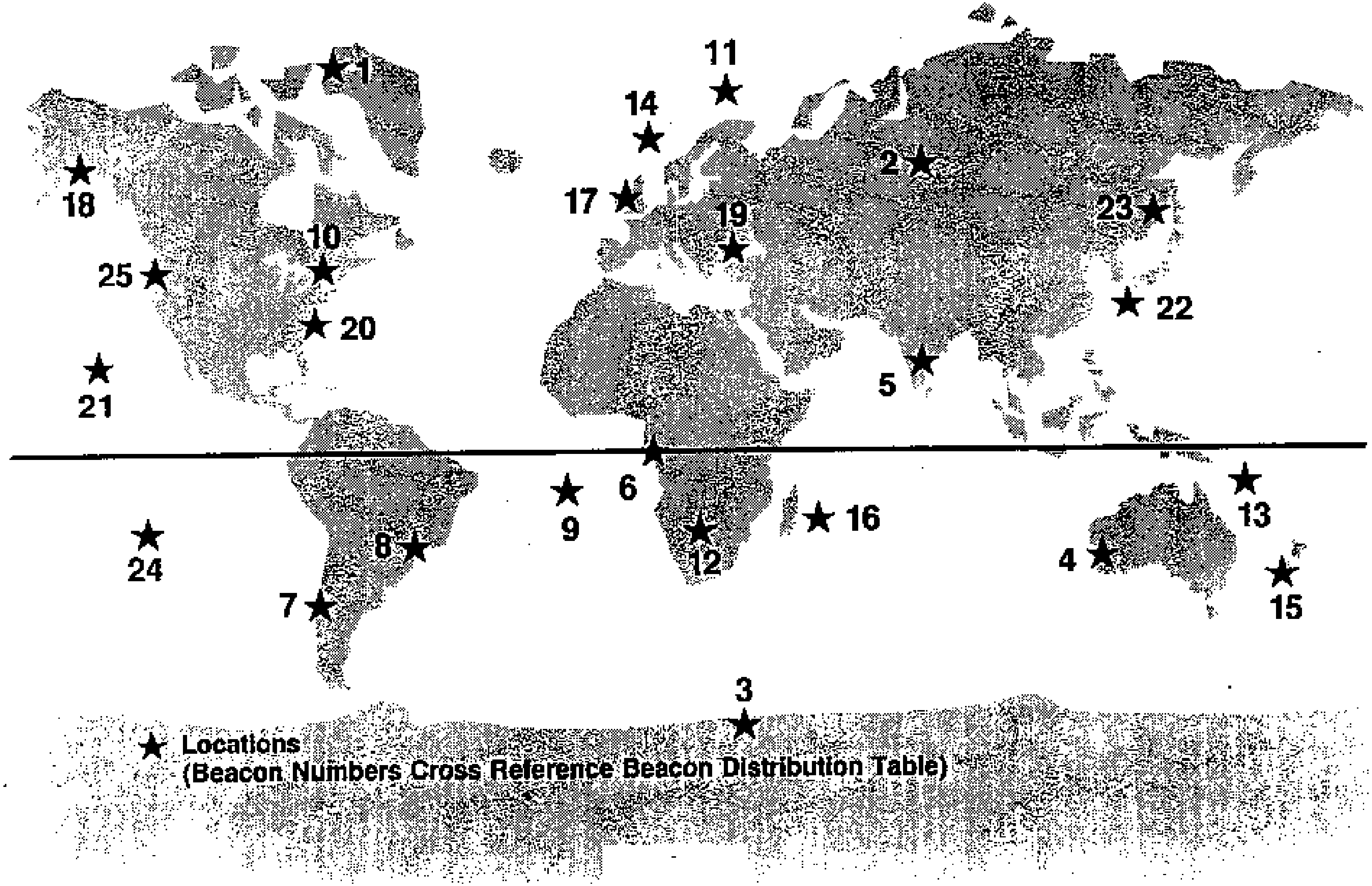



Figure 2

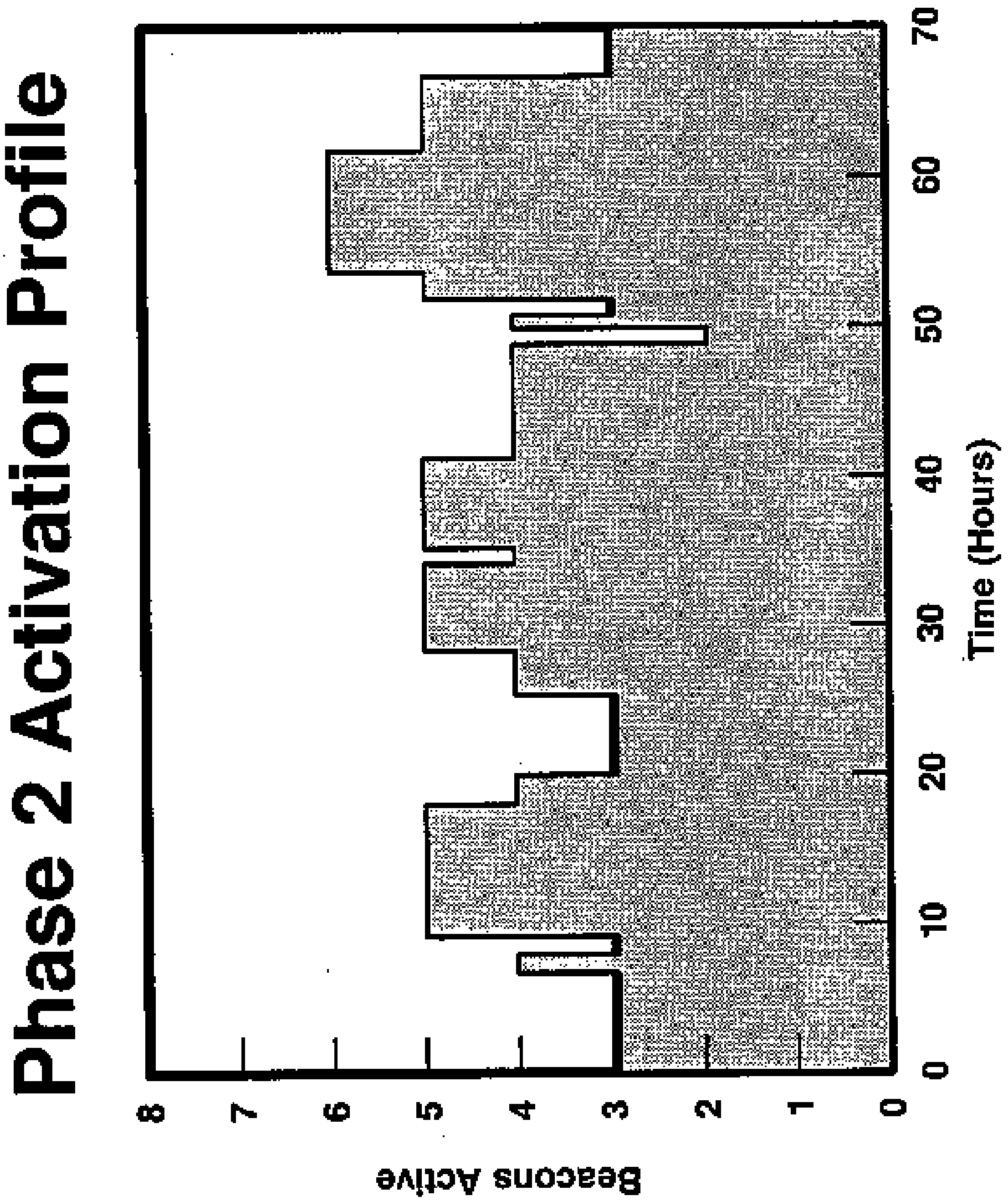
# BEACON DISTRIBUTION
## PHASES II AND III

| BEACON NUMBER | BEACON ENVIRONMENT (1) | BEACON LOCATION | BEACON USER PROTOCOL (2) | COUNTRY CODE | BEACON PROVIDER | SERVICE AREA | REMARKS |
|---|---|---|---|---|---|---|---|
| 1 | Land | Thule, Greenland | Serialized (PLB) | Denmark | Denmark | NMCC | |
| 2 | Land | Novosibirsk, USSR | Serialized (Aviation) | USSR | USSR | CMC | |
| 3 | Land | Molodezhnaya, Antarctica | Serialized (Aviation) | USSR | USSR | Other Areas | |
| 4 | Land | Perth, Australia | Aviation | Canada | UK | AUMCC | |
| 5 | Land | Bangalore, India | Aviation | India | India | INMCC | |
| 6 | Land | Libreville, Gabon | Aviation | Australia | France | FMCC | |
| 7 | Land | Santiago, Chile | Aviation | Chile | Chile | CHMCC | Note (3) |
| 8 | Land | Cachoeira Paulista, Brazil | Maritime | Switzerland | USA | USMCC | |
| 9 | Land | Ascension Island, UK | Aviation | Pakistan | UK | UKMCC | |
| 10 | Land | Trenton, Canada | Serialized (Aviation) | Sweden | Canada | CMCC | |
| 11 | Land | Spitsbergen, Norway | Aviation | Iceland | Norway | NMCC | |
| 12 | Land | Johannesburg, South Africa | Aviation | France | France | UKMCC | |
| 13 | Floating | Nadi, Fiji Islands | Maritime | Norway | Japan | USMCC | |
| 14 | Ship | Norwegian Sea | Maritime | Bermuda | Norway | NMCC | Ship - POLARFRONT |
| 15 | Floating | New Zealand | Maritime | New Zealand | France | USMCC | |
| 16 | Floating | Reunion Island, France | Radio Call-Sign | Greece | France | FMCC | |
| 17 | Ship | North Atlantic | Maritime | Greenland | UK | UKMCC | Ship - CUMULUS |
| 18 | Lifeboat | Kodiak, Alaska, USA | Maritime | Italy | USA | USMCC | |
| 19 | Lifeboat | Black Sea | Maritime | Bulgaria | USSR | CMC | |
| 20 | Lifeboat | Norfolk, Virginia, USA | Serialized (PLB) | Finland | USA | USMCC | |
| 21 | Lifeboat | Oahu, Hawaiian Islands, USA | Aviation | Brazil | USA | USMCC | |
| 22 | Liferaft | Ishigaki, Ishigaki Island, Japan | Serialized (Maritime) | Japan | Japan | USMCC | |
| 23 | Liferaft | Nakhodka, USSR | Maritime | USA | USSR | CMC | |
| 24 | Liferaft | Tahiti, French Polynesia | Maritime/Location | Venezuela | France | FMCC | |
| 25 | Liferaft | Seattle, Washington, USA | Serialized (Aviation) | UK | USA | USMCC | |

Notes:

1. Floating-tethered, Lifeboat-hard shell, Liferaft-inflated.
2. All beacons used short message format.
3. Service area proposed by the document Joint Committee 4/8/7.

Figure 3



Phase 2 Activation Profile
Beacons Active
0
1
2
3
4
5
6
7
8
Time (Hours)
0
10
20
30
40
50
60
70


Figure 4

# Phase 3 Activation Profile

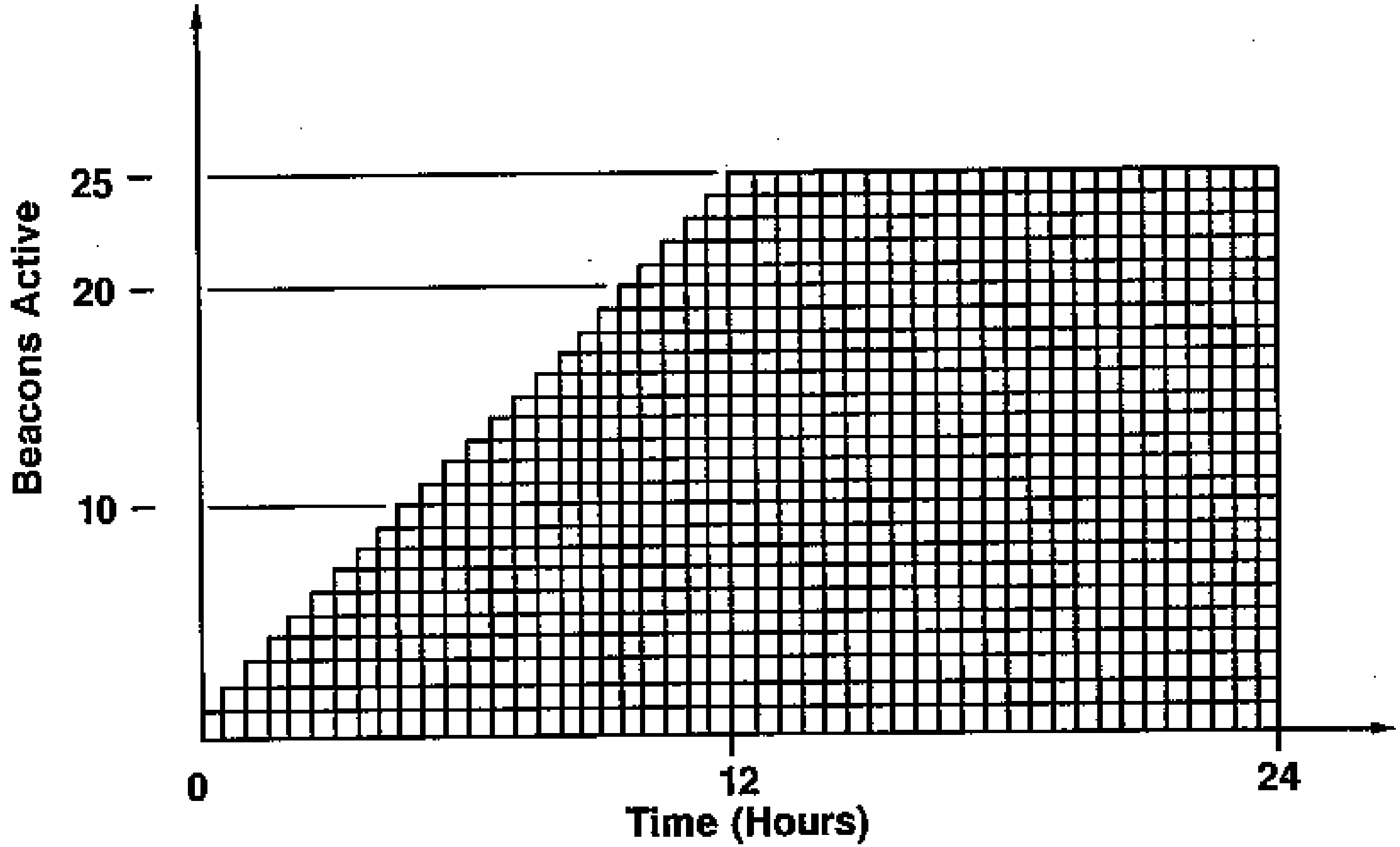



Figure 5

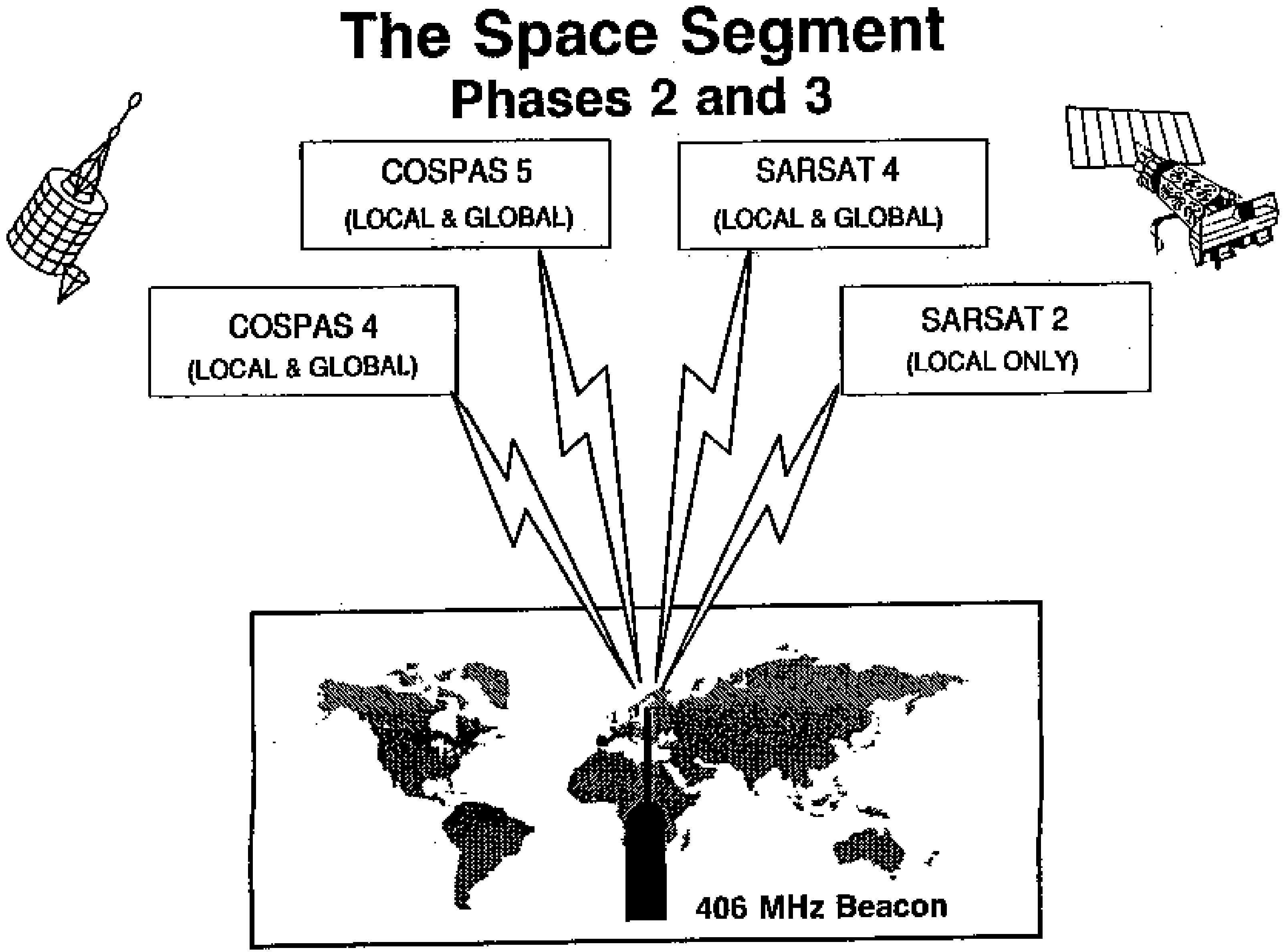

The Space Segment
Phases 2 and 3
COSPAS 5
(LOCAL & GLOBAL)
SARSAT 4
(LOCAL & GLOBAL)
COSPAS 4
(LOCAL & GLOBAL)
SARSAT 2
(LOCAL ONLY)
406 MHz Beacon

Figure 6

# THE SPACE SEGMENT STATUS

| SPACECRAFT | LOCAL MODE | GLOBAL MODE | COMMENTS |
|---|---|---|---|
| S-2 | YES | NO | OPERATIONAL:<br>GLOBAL DATA NOT ACQUIRED |
| S-4 | YES | YES | FULLY OPERATIONAL |
| C-4 | YES | YES | FULLY OPERATIONAL IN THE NORTHERN HEMISPHERE AND USED WITH RESTRICTIONS IN THE SOUTHERN HEMISPHERE |
| C-5 | YES | YES | FULLY OPERATIONAL |

Figure 7

# THE GROUND SEGMENT

| NATION | MCCs | LUTs |
|---|---|---|
| AUSTRALIA | 1 | 1 |
| CANADA | 1 | 3 |
| CHILE | 1 | 1 |
| FRANCE | 1 | 1 |
| HONG KONG | 1 | 2 |
| INDIA | 1 | 2 |
| NORWAY | 1 | 1 |
| U.K. | 1 | 1 |
| U.S.A. | 1 | 4 |
| U.S.S.R. | 1 | 4 |
| TOTALS | 10 | 20 |

Figure 8

# Exercise of 1990
## Ground System

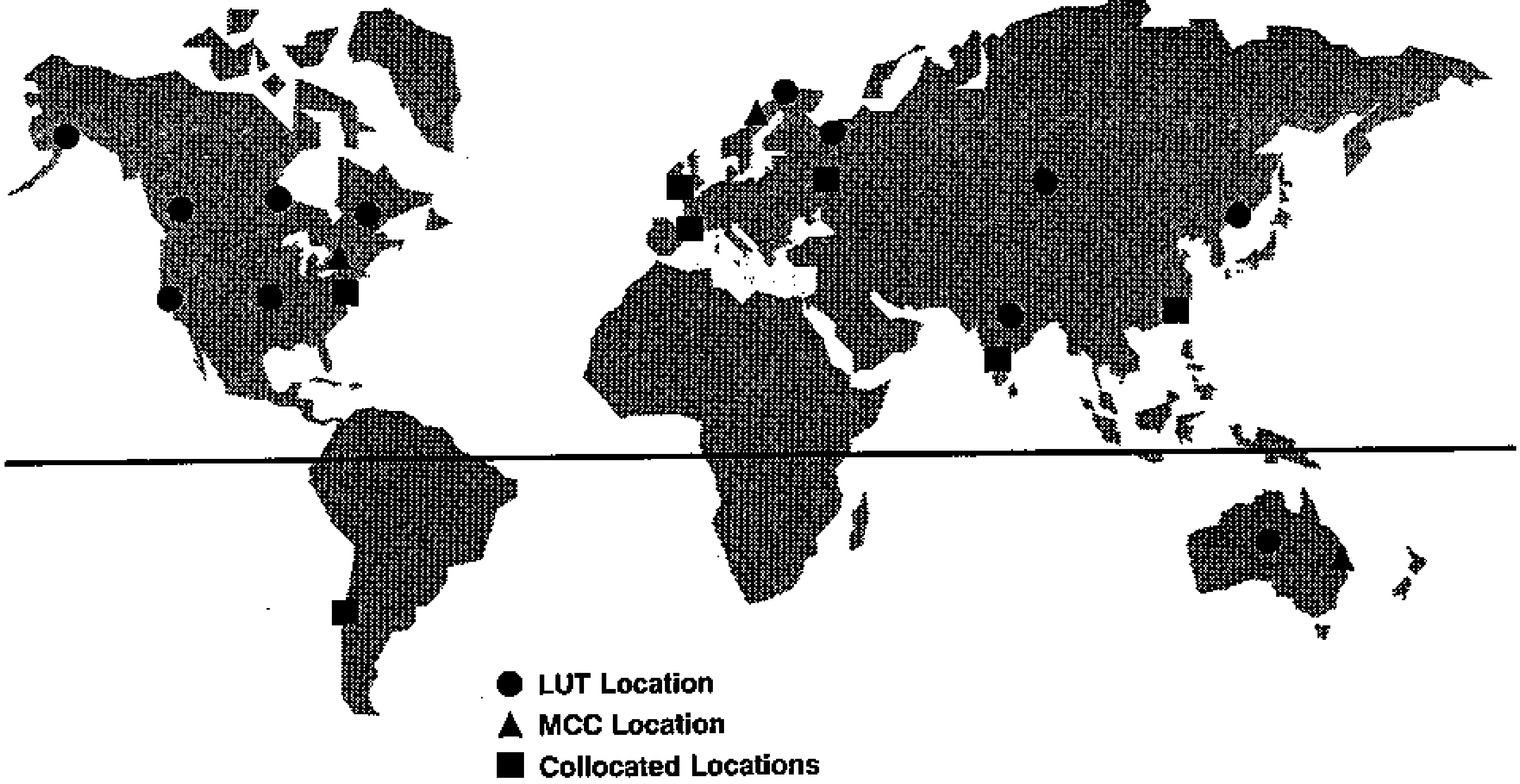



Figure 9

# MCC Service Areas
## for the Exercise 1990

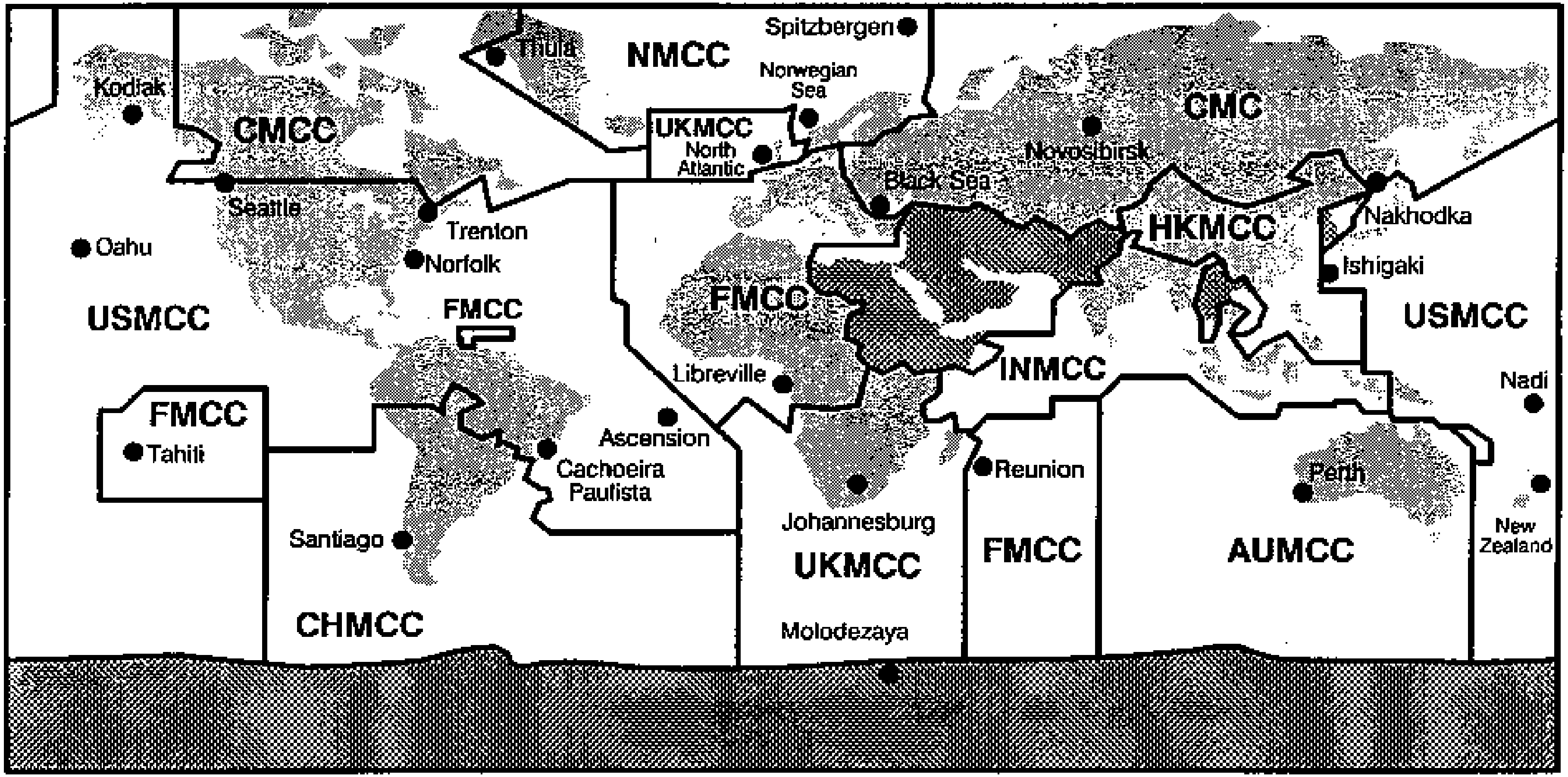



Figure 10

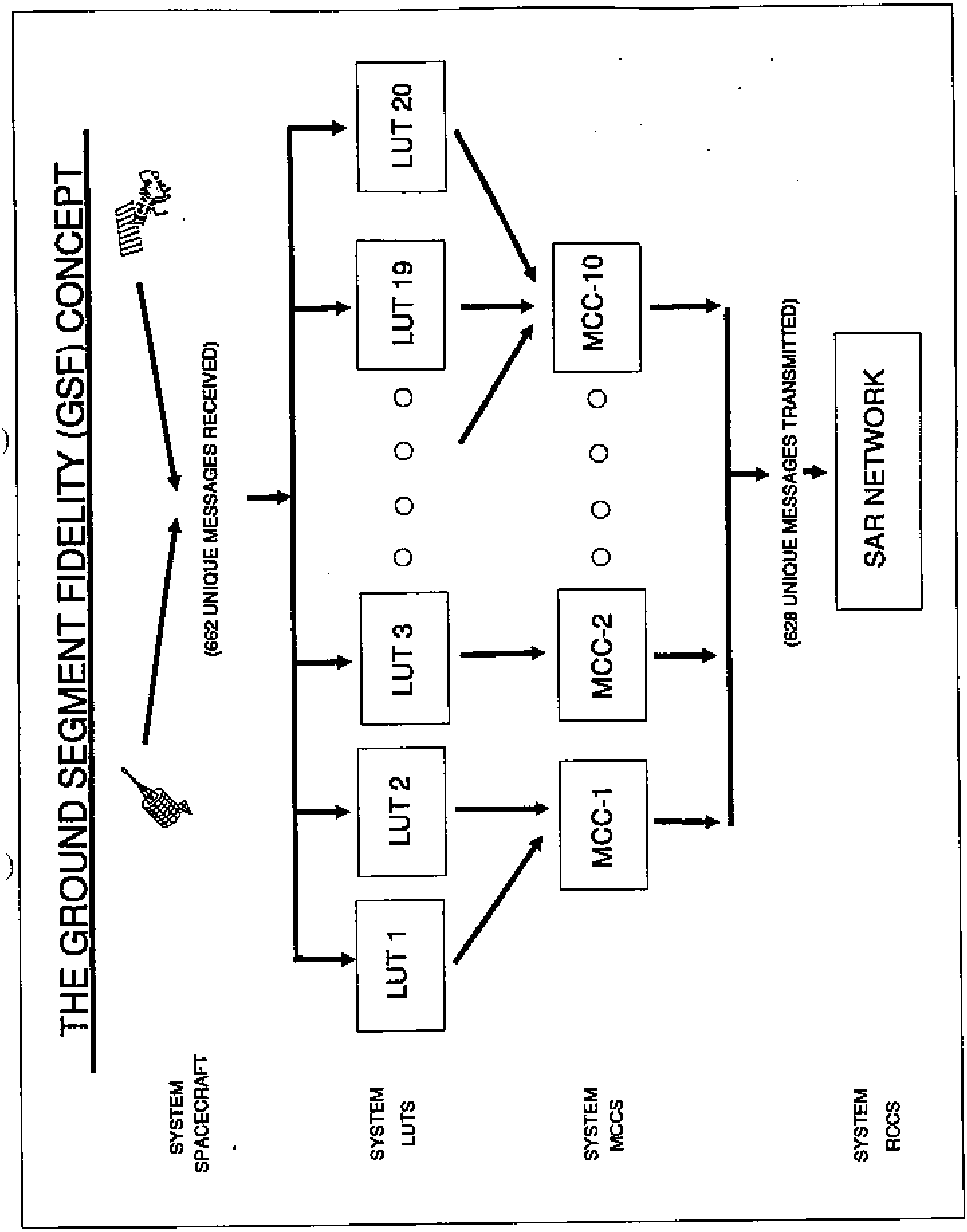

THE GROUND SEGMENT FIDELITY (GSF) CONCEPT
(662 UNIQUE MESSAGES RECEIVED)
LUT 1
LUT 2
LUT 3
LUT 19
LUT 20
MCC-1
MCC-2
MCC-10
(628 UNIQUE MESSAGES TRANSMITTED)
SAR NETWORK
SYSTEM SPACECRAFT
SYSTEM LUTS
SYSTEM MCCS
SYSTEM RCCS

Figure 10A

# DISTRIBUTION OF LOCATION ACCURACY

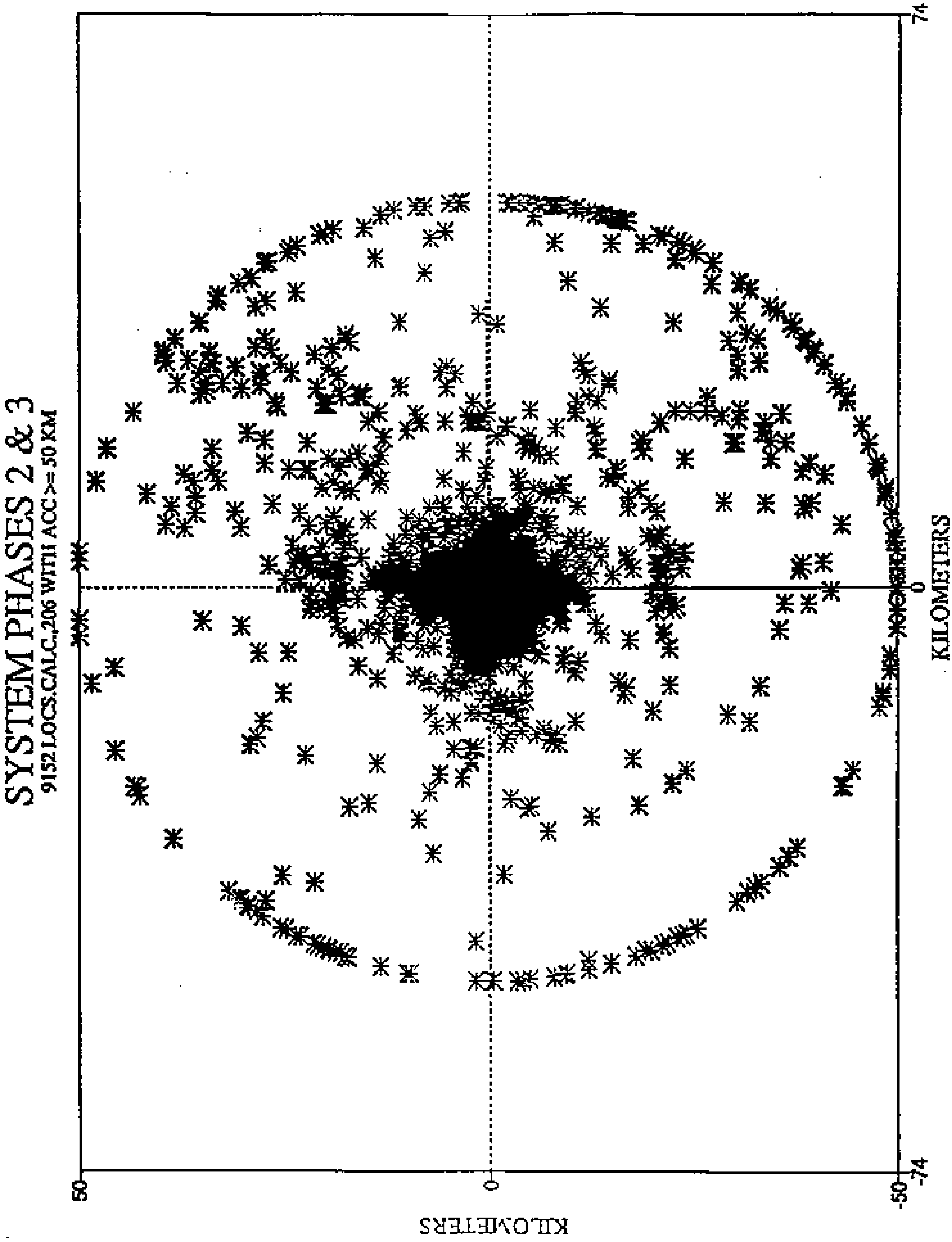
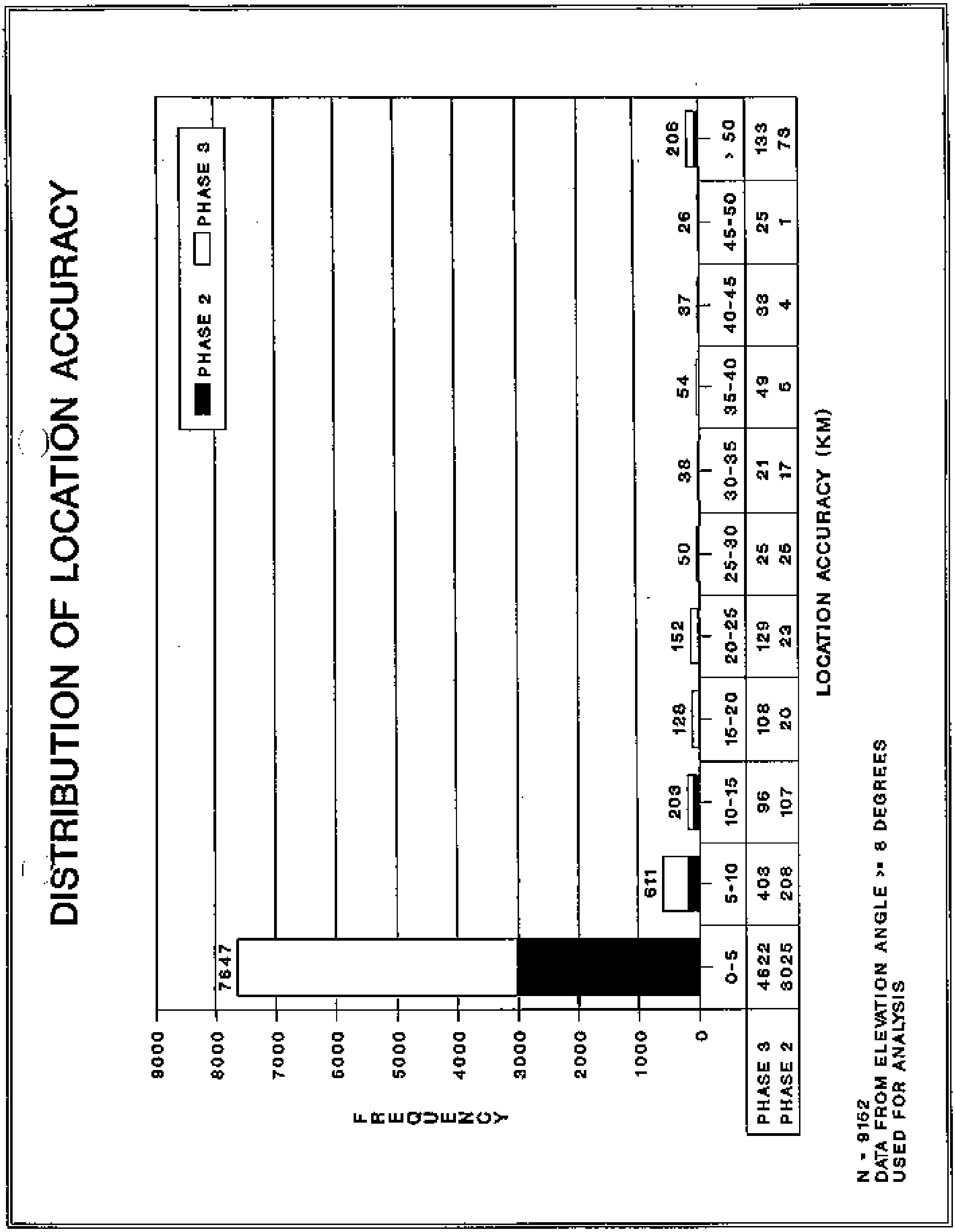



Figure 11




| | 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-50 | > 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PHASE 3 | 4622 | 403 | 96 | 108 | 129 | 25 | 21 | 49 | 33 | 25 | 133 |
| PHASE 2 | 3025 | 208 | 107 | 20 | 23 | 25 | 17 | 5 | 4 | 1 | 73 |

Figure 12

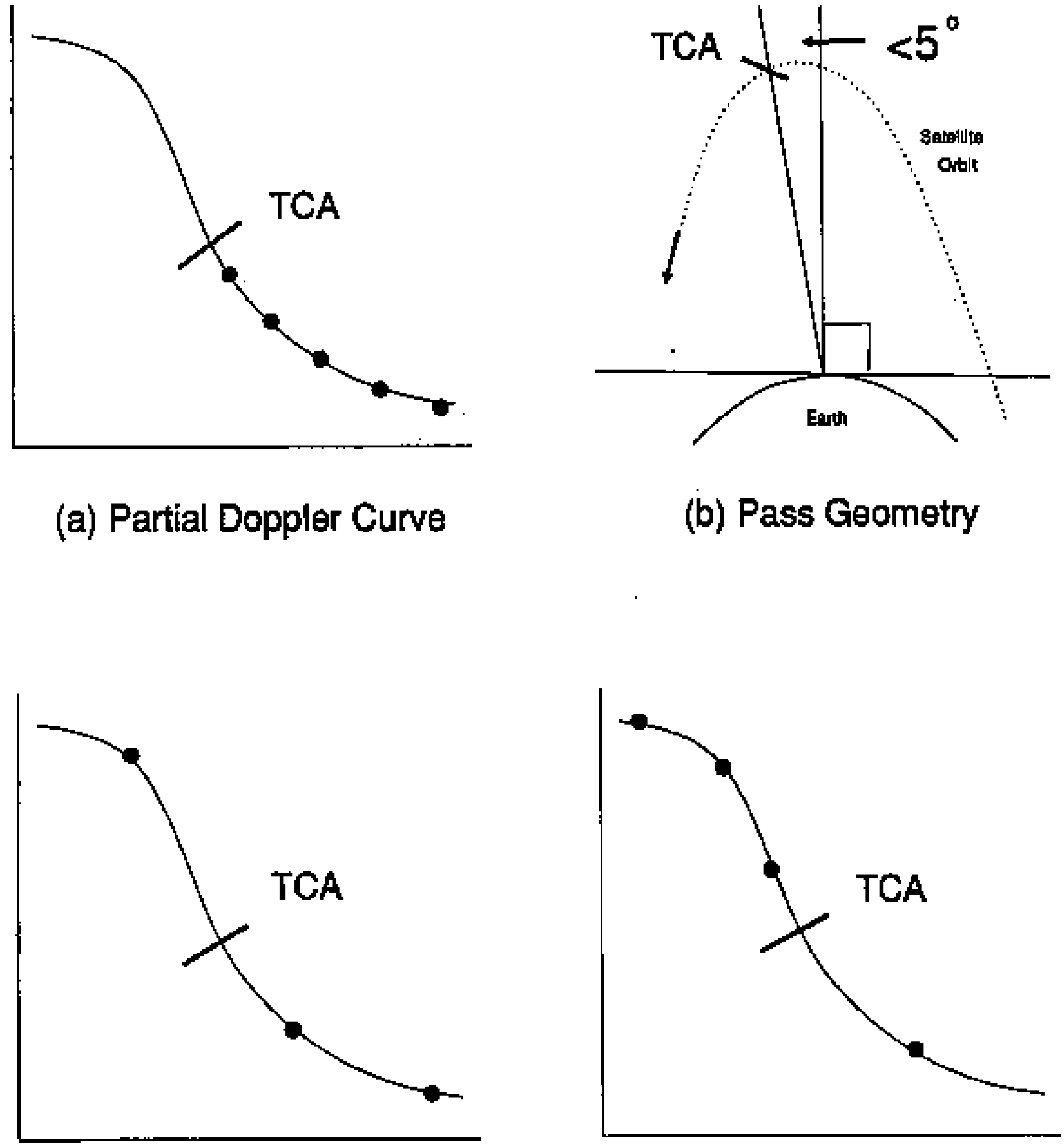
**Classification of Location Inaccuracies (>20 KM)**

| CLASSIFICATION | N | % |
|---|---|---|
| PARTIAL DOPPLER CURVE | 26 | 4.6 |
| RESIDUAL CURVE | 9 | 1.6 |
| PASS GEOMETRY | 43 | 7.7 |
| 3-POINT SOLUTIONS | 34 | 6.0 |
| 4-POINT SOLUTIONS | 17 | 3.0 |
| ORBIT VECTORS | 159 | 28.2 |
| TIME CALIBRATION | 78 | 13.9 |
| LUT SOFTWARE | 112 | 19.9 |
| LUT HARDWARE | 17 | 3.0 |
| BEACON | 9 | 1.6 |
| MOVING BEACON (>10 KTS) | 18 | 3.2 |
| WARMUP | 0 | 0.0 |
| UNKNOWN | 41 | 7.3 |
| TOTAL | 563 | 100 |

Figure 13

## Classification of Location Inaccuracies (>20 km)

## A Pictorial Representation




(a) Partial Doppler Curve

(b) Pass Geometry

(c) 3-Point Solution

(d) 4-Point Solution

Figure 14

DISTRIBUTION OF LOCATION ACCURACY

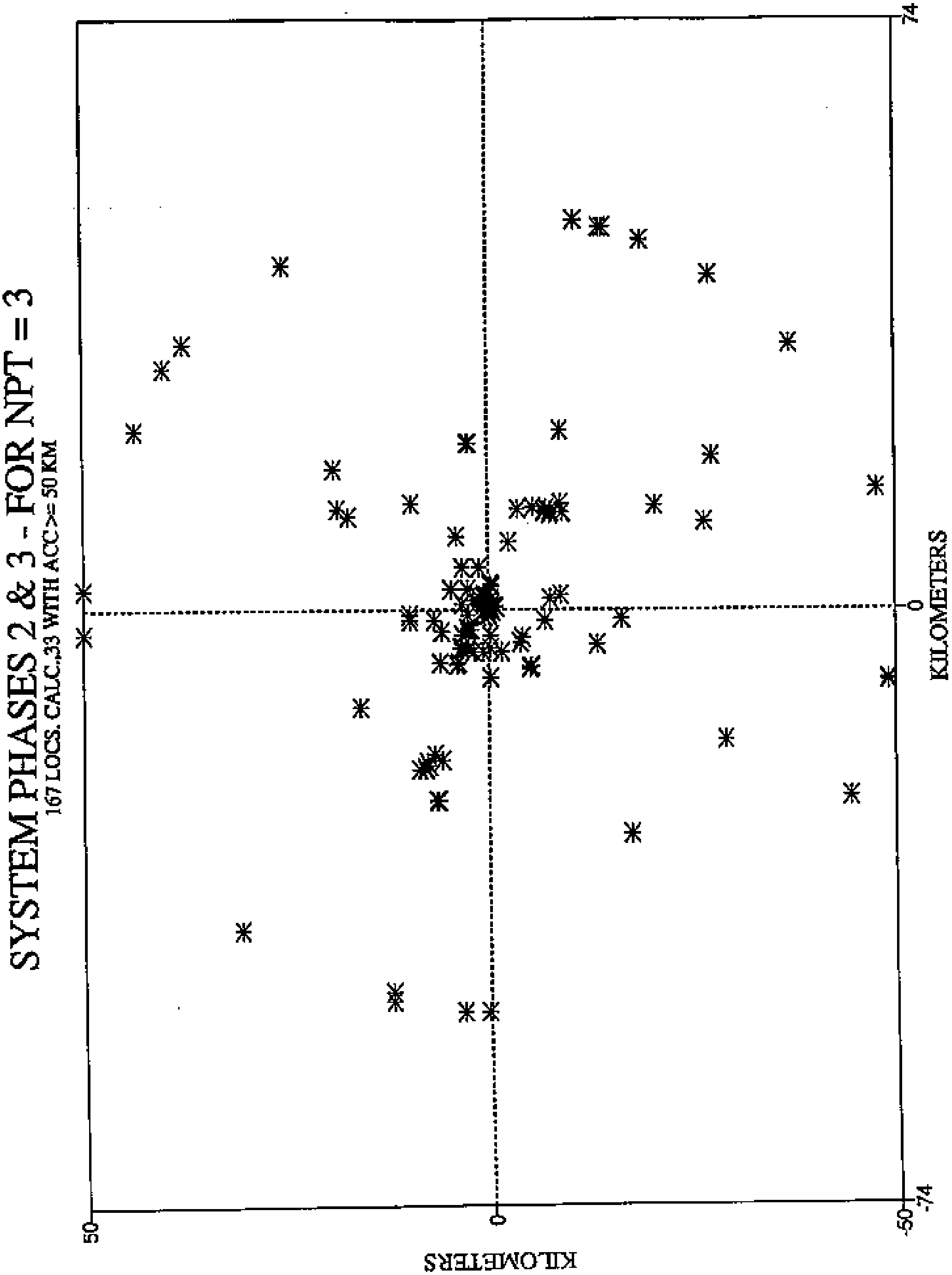
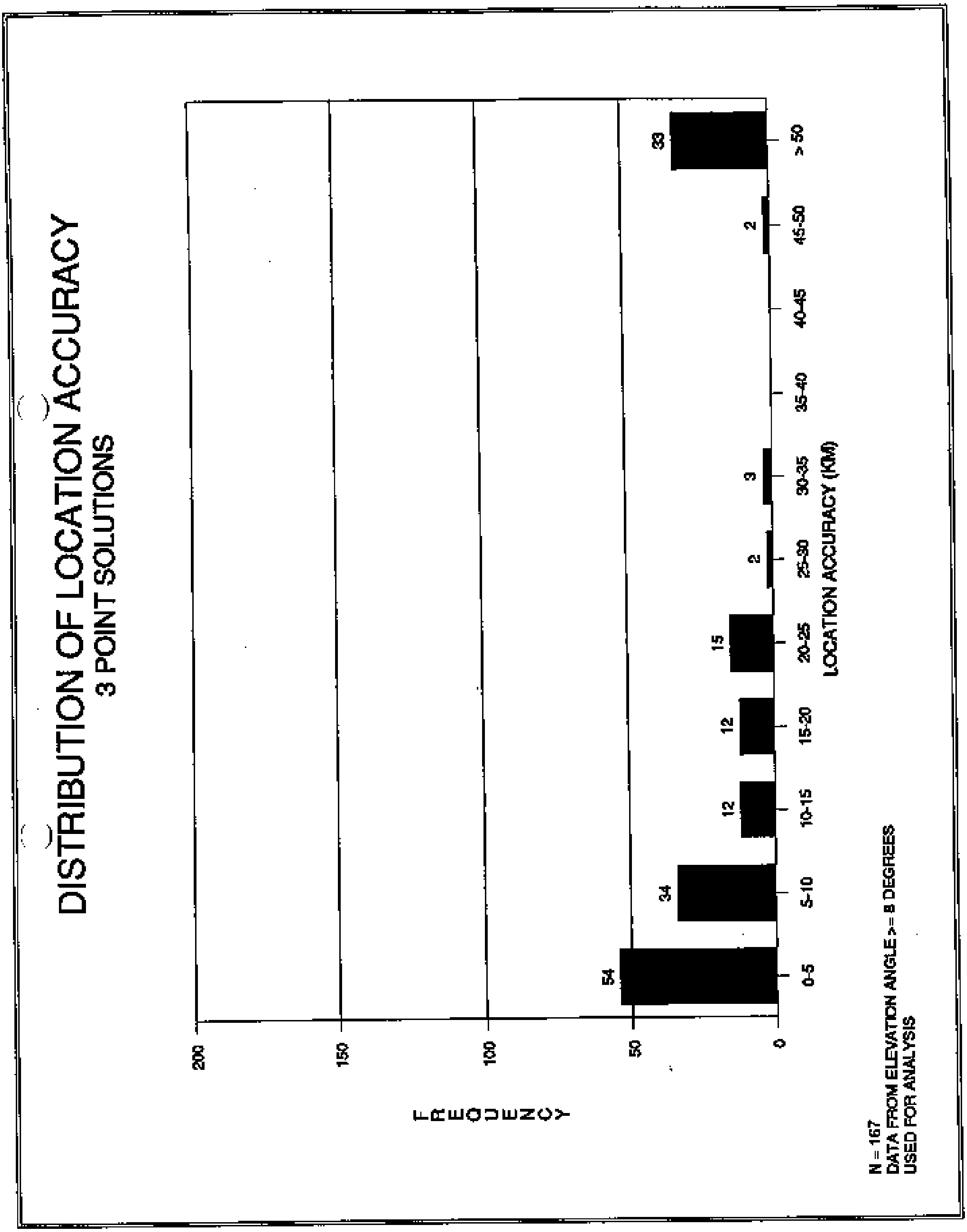



Figure 15



DISTRIBUTION OF LOCATION ACCURACY
3 POINT SOLUTIONS
FREQUENCY
200
150
100
50
0
54
34
12
12
15
2
3
2
33
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
> 50
LOCATION ACCURACY (KM)
N = 167
DATA FROM ELEVATION ANGLE >= 8 DEGREES
USED FOR ANALYSIS


Figure 16

# DISTRIBUTION OF LOCATION ACCURACY

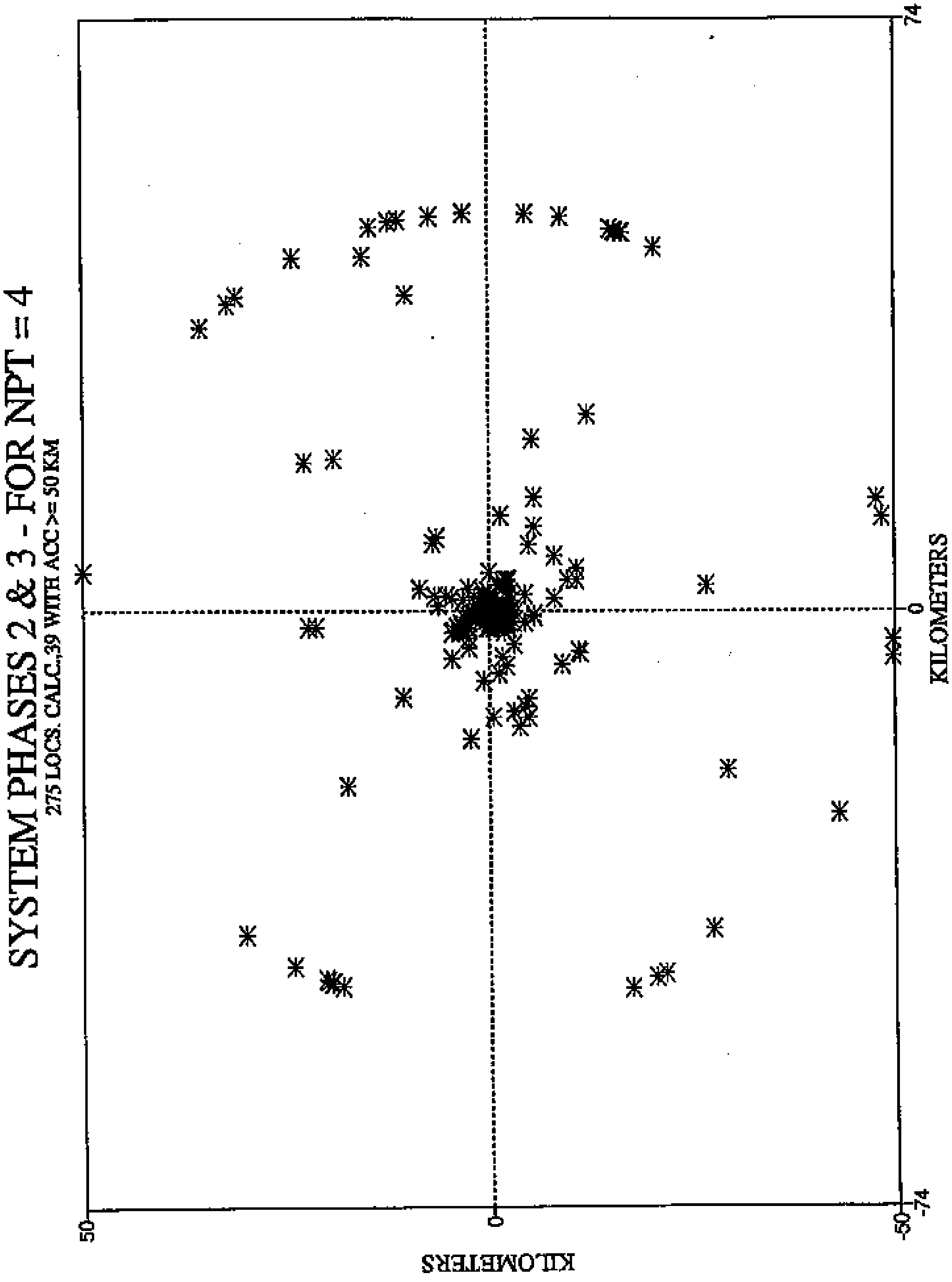
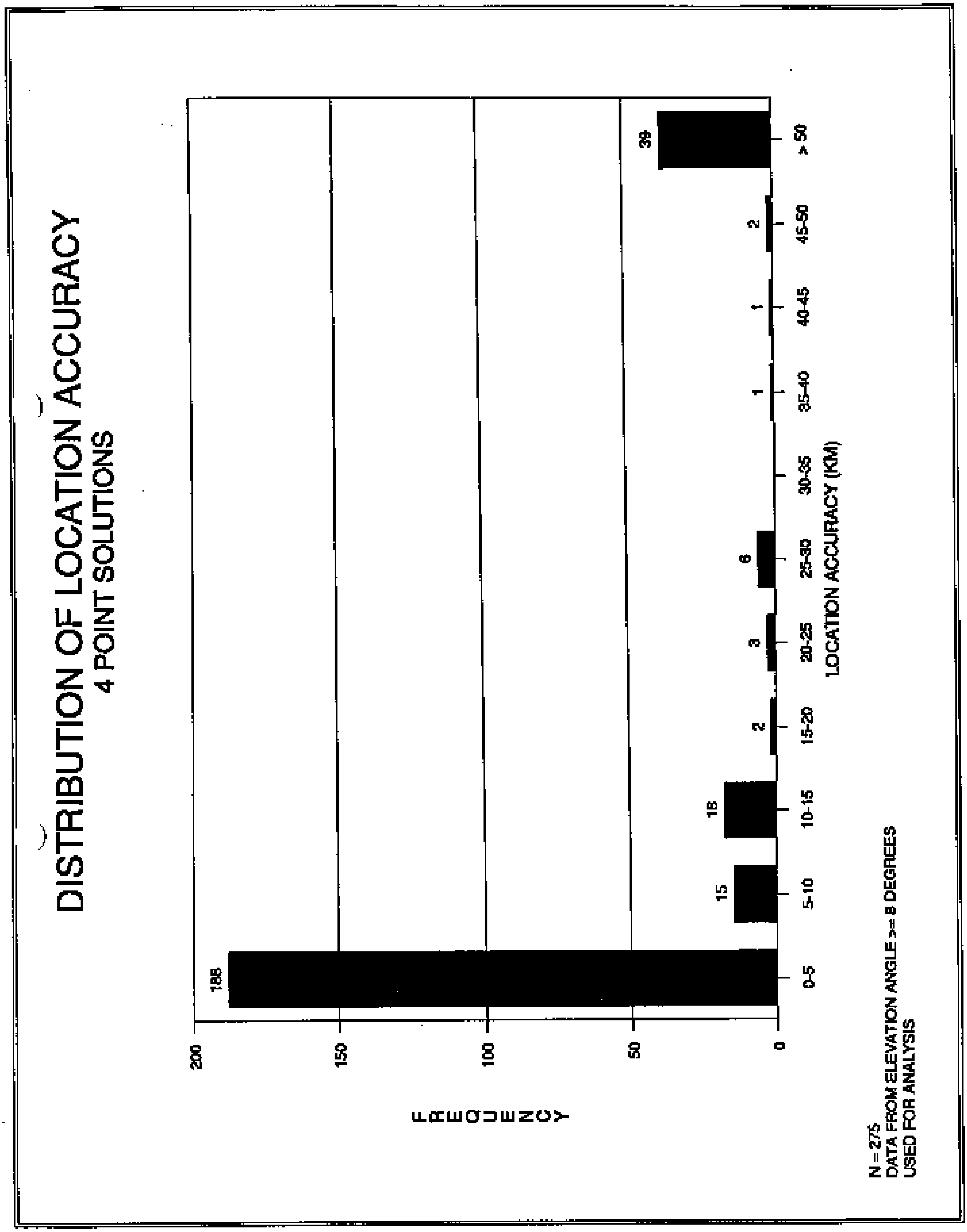



Figure 17



DISTRIBUTION OF LOCATION ACCURACY
4 POINT SOLUTIONS
FREQUENCY
200
150
100
50
0
188
15
18
2
3
6
1
1
2
39
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
> 50
LOCATION ACCURACY (KM)
N = 275
DATA FROM ELEVATION ANGLE >= 8 DEGREES
USED FOR ANALYSIS


Figure 18

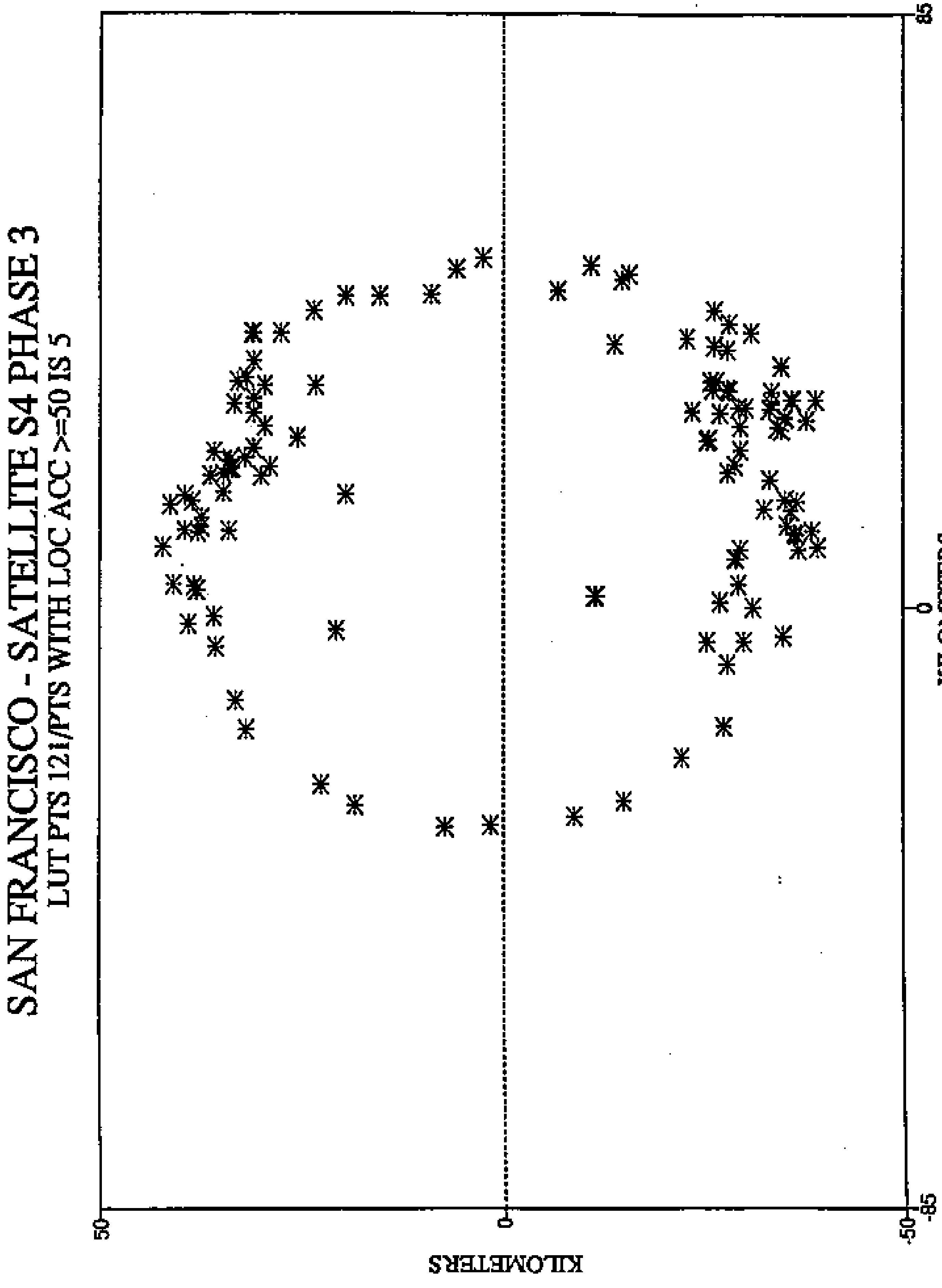

SAN FRANCISCO - SATELLITE S4 PHASE 3
LUT PTS 121/PTS WITH LOC ACC >=50 IS 5
KILOMETERS
KILOMETERS
50
0
-50
-85
0
85

Figure 19

## Projected

## Classification of Location Inaccuracies (>20 KM)

| CLASSIFICATION | N | % |
|---|---|---|
| PARTIAL DOPPLER CURVE | 26 | 13.1 |
| RESIDUAL CURVE | 9 | 4.6 |
| PASS GEOMETRY | 43 | 21.8 |
| 3-POINT SOLUTIONS | 34 | 17.3 |
| 4-POINT SOLUTIONS | 17 | 8.7 |
| BEACON | 9 | 4.6 |
| MOVING BEACON (>10 KTS) | 18 | 9.1 |
| WARMUP | 0 | 0.0 |
| UNKNOWN | 41 | 20.8 |
| TOTAL | 197 | 100 |

Figure 20

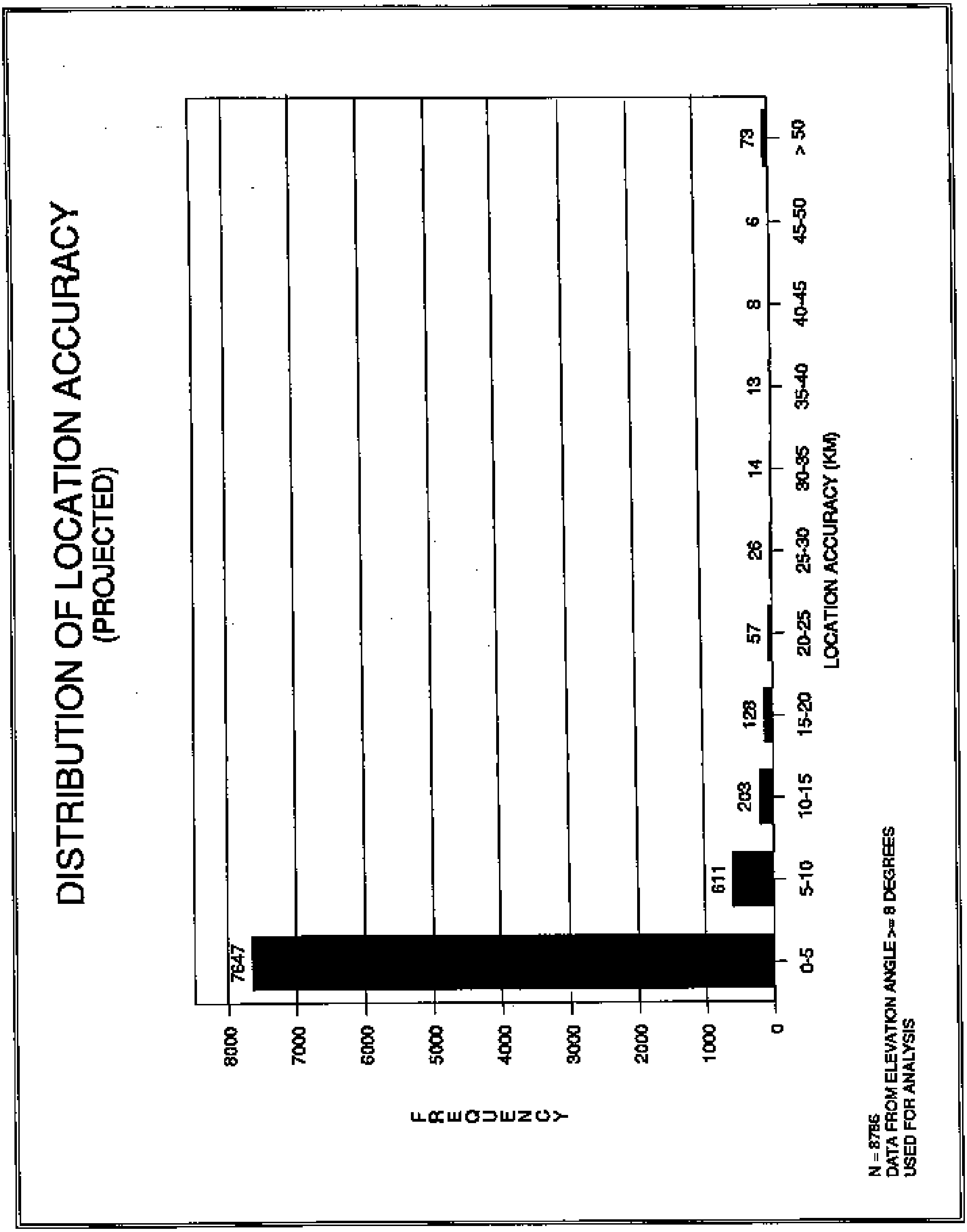

DISTRIBUTION OF LOCATION ACCURACY
(PROJECTED)
FREQUENCY
0
1000
2000
3000
4000
5000
6000
7000
8000
7647
611
203
128
57
26
14
13
8
6
73
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
> 50
LOCATION ACCURACY (KM)
N = 8786
DATA FROM ELEVATION ANGLE >= 8 DEGREES
USED FOR ANALYSIS

Figure 21

# DISTRIBUTION OF LOCATION ACCURACY

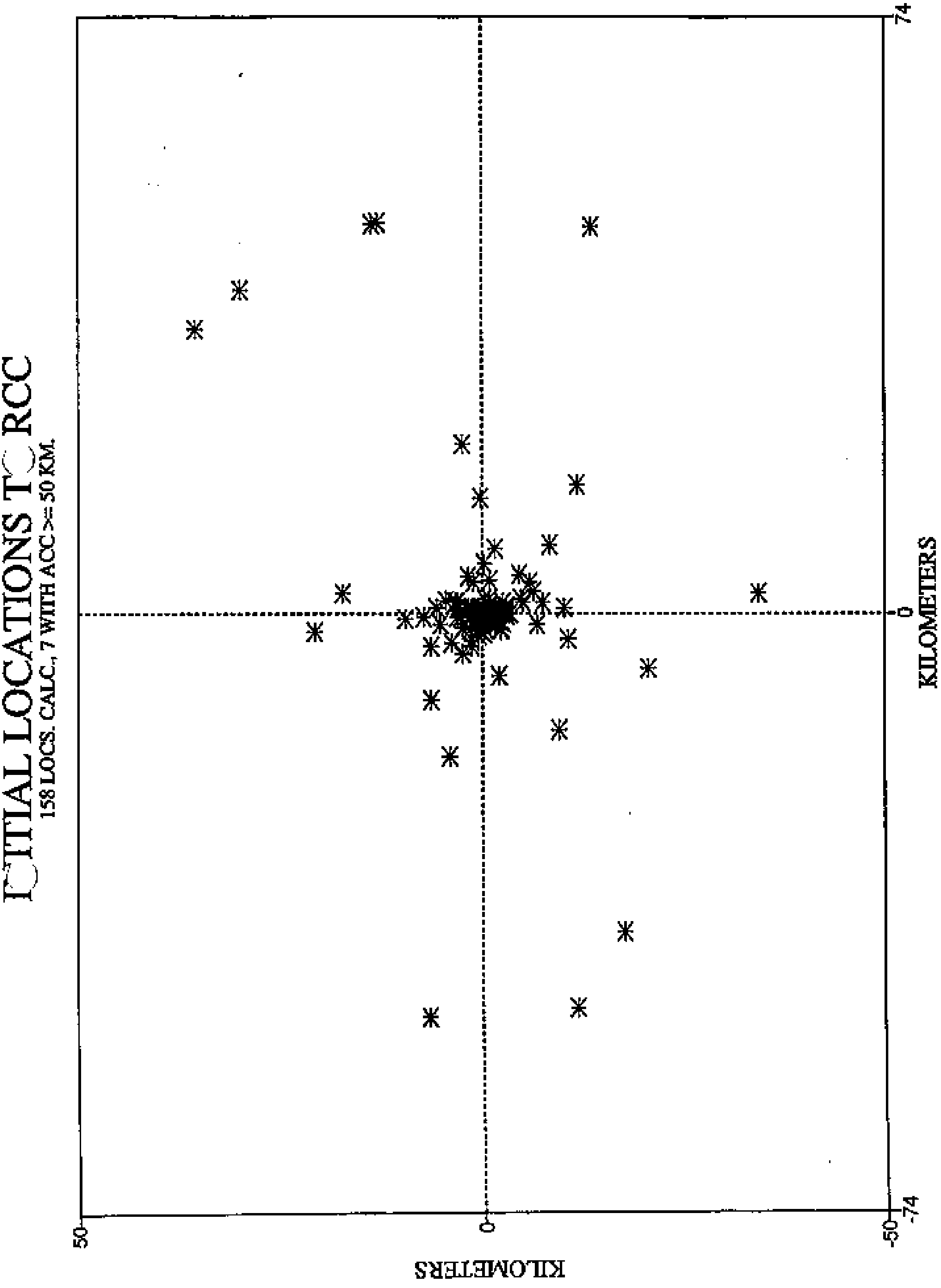



Figure 22

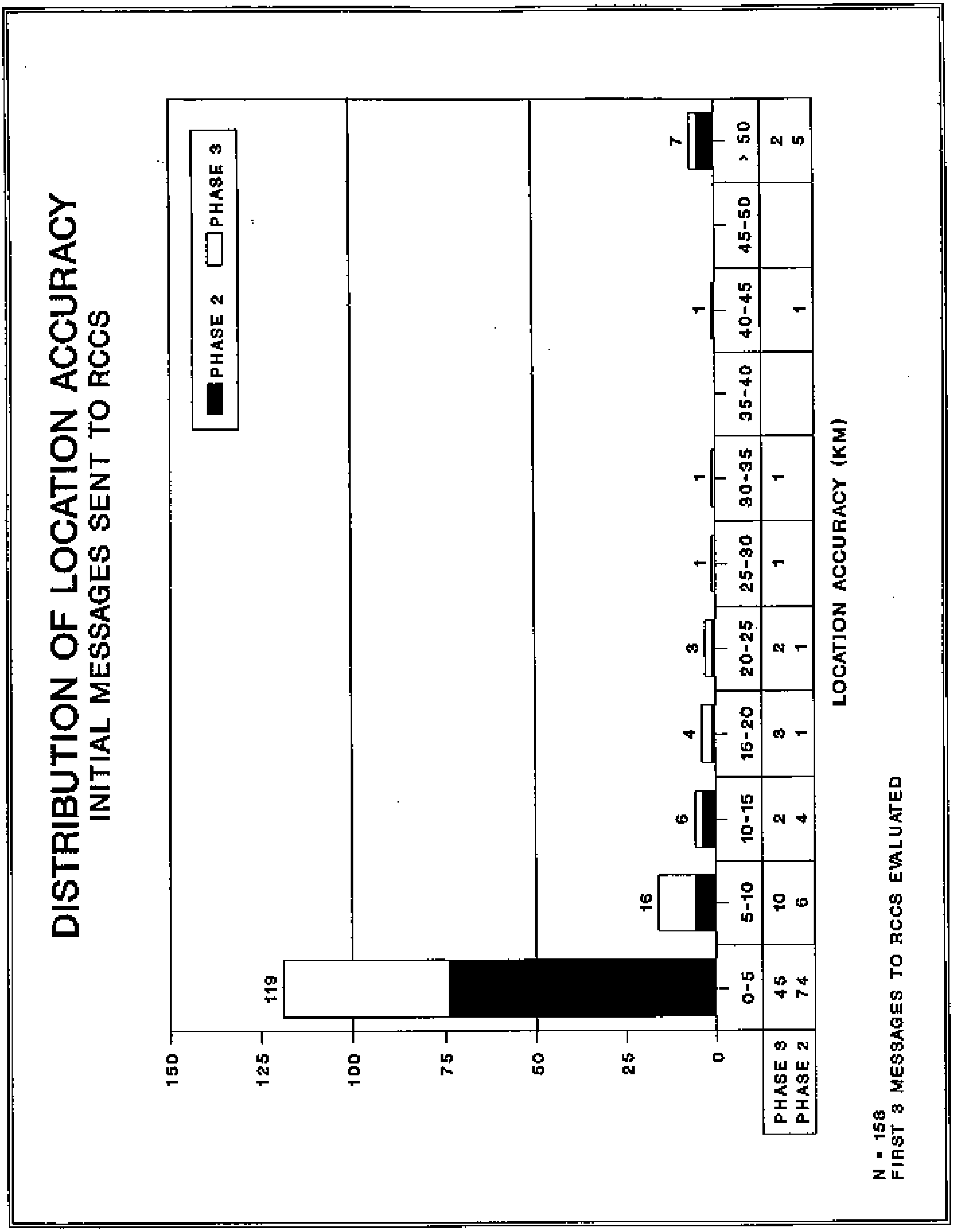

DISTRIBUTION OF LOCATION ACCURACY
INITIAL MESSAGES SENT TO RCCS
PHASE 2
PHASE 3
150
125
100
75
50
25
0
119
16
6
4
3
1
1
1
7
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
> 50
PHASE 3 45 10 2 3 2 1 1 2
PHASE 2 74 6 4 1 1 1 5
LOCATION ACCURACY (KM)
N = 158
FIRST 3 MESSAGES TO RCCS EVALUATED

Figure 23

## ACCURACY OF INITIAL LOCATIONS RECEIVED AT RCCS

### (FIRST THREE MESSAGES)

| CLASSIFICATION | NUMBER OF CASES | |
|---|---|---|
| | PHASE 2 | PHASE 3 |
| Three locations within 5 km | 13 | 8 |
| Two locations within 5 km | 16 | 7 |
| One location within 5 km and one location between 5 to 10 km | 1 | 4 |
| One location within 5 km and one location between 10 to 20 km | 1 | 2 |
| One location within 5 km and one location between 20 to 30 km | 0 | 1 |
| All locations beyond 5 km | 0 | 0 |
| Total | 31 | 22 |

Figure 24

# A/B Resolution

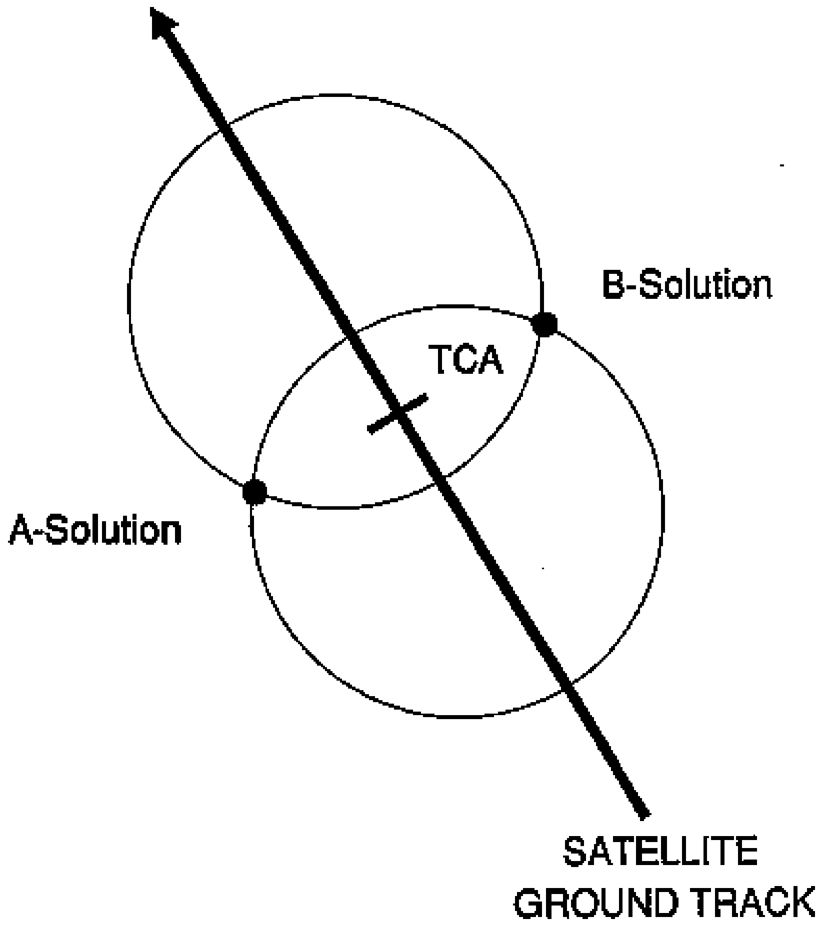



Figure 25

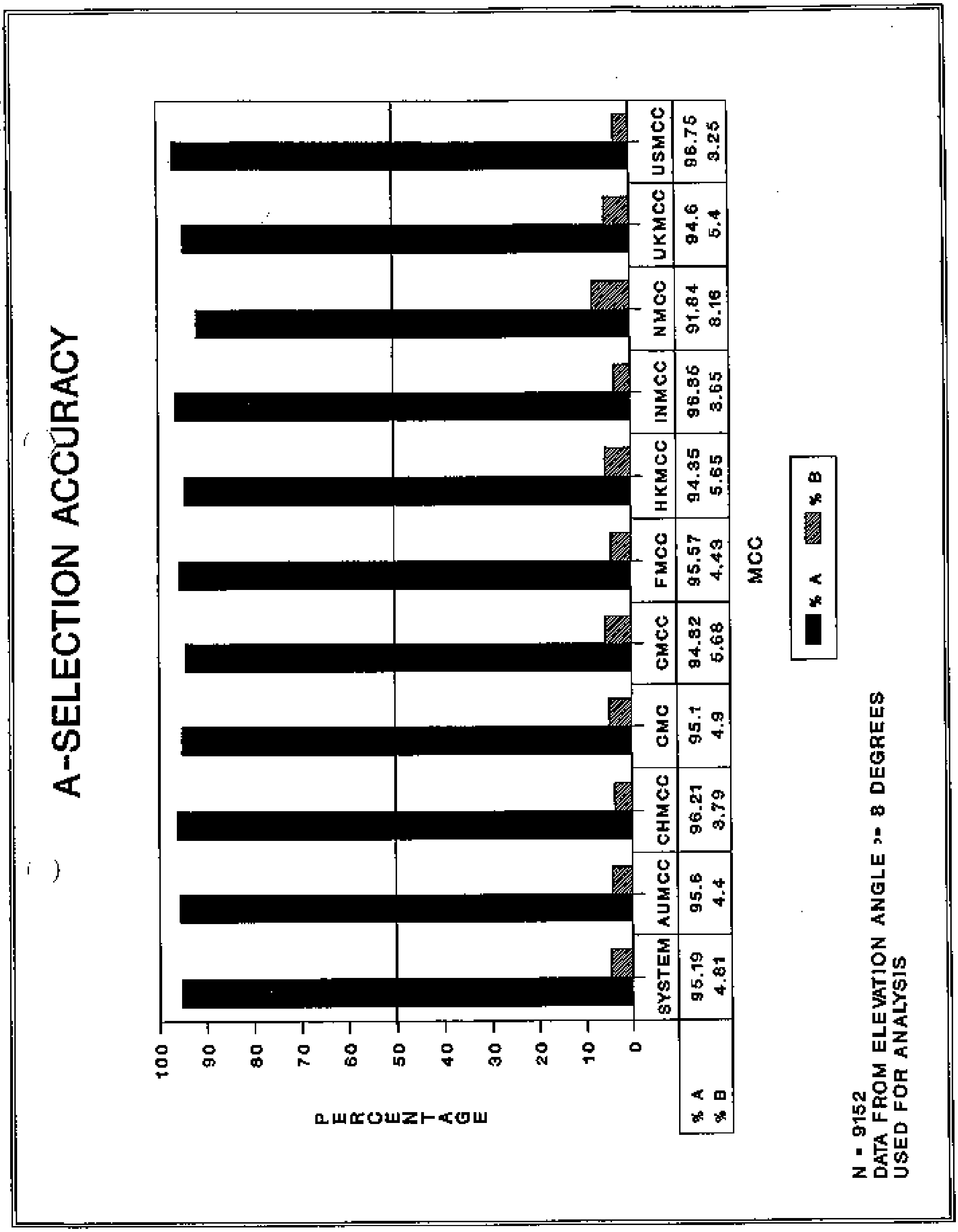

A-SELECTION ACCURACY
PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
SYSTEM AUMCC CHMCC CMC CMCC FMCC HKMCC INMCC NMCC UKMCC USMCC
% A 95.19 95.6 96.21 95.1 94.32 95.57 94.35 96.35 91.84 94.6 96.75
% B 4.81 4.4 3.79 4.9 5.68 4.43 5.65 3.65 8.16 5.4 3.25
MCC
% A
% B
N = 9152
DATA FROM ELEVATION ANGLE >= 8 DEGREES
USED FOR ANALYSIS

Figure 26

# ERROR ELLIPSE CONCEPT

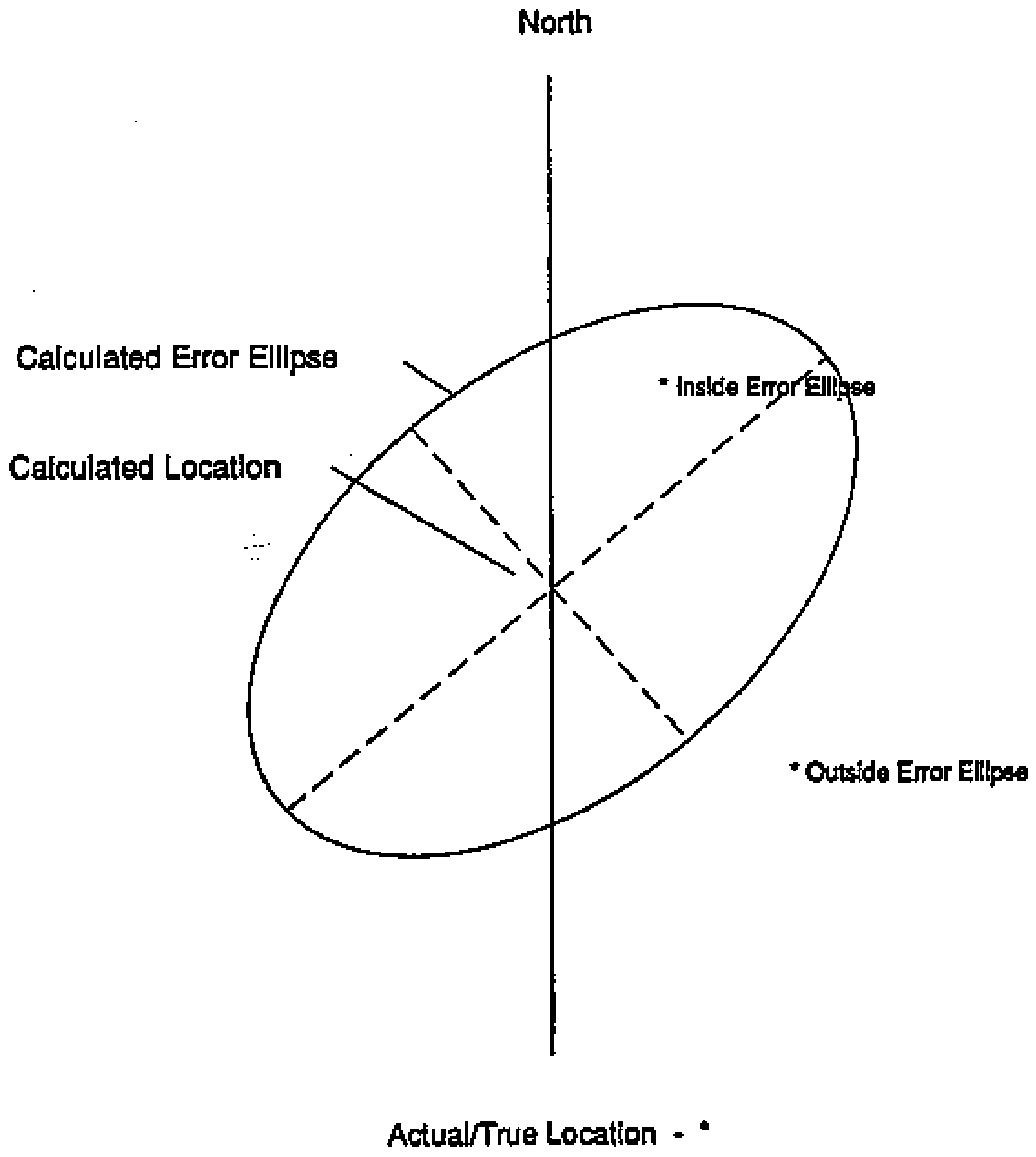
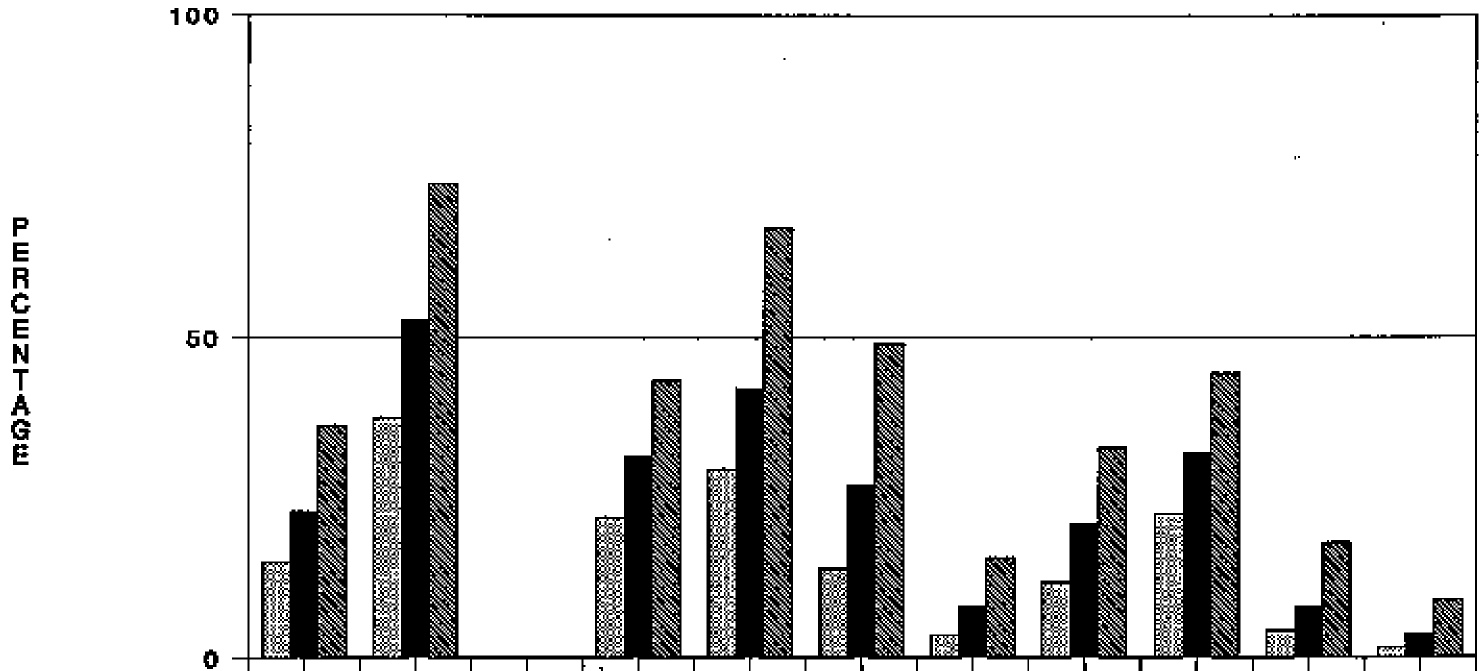



Figure 27

# ERROR ELLIPSE ANALYSIS

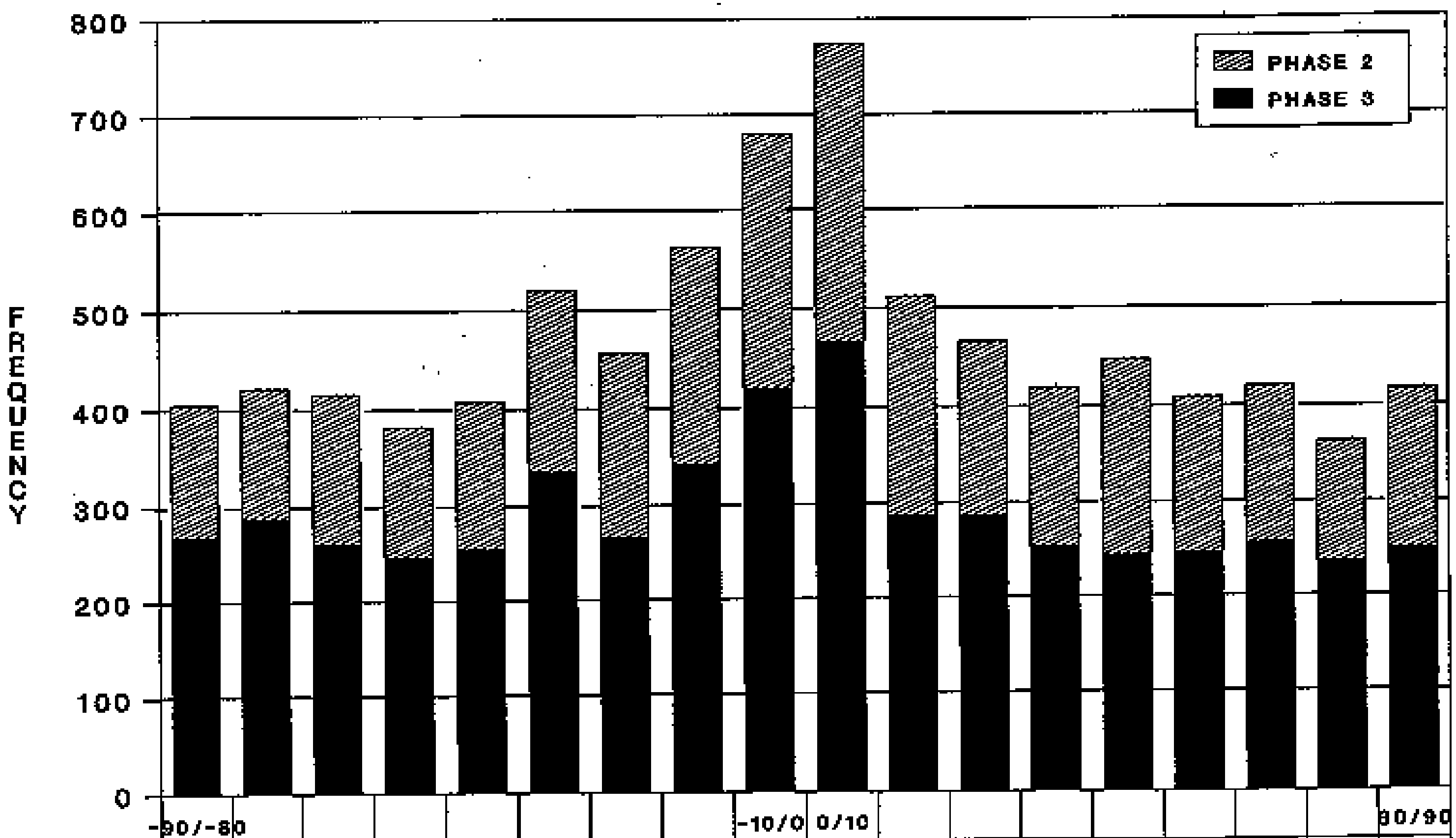



| | SYSTEM | AUMCC | CHMCC | CMC | CMCC | FMCC | HKMCC | INMCC | NMCC | UKMCC | USMCC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL | 8473 | 365 | | 1245 | 1564 | 536 | 921 | 856 | 636 | 505 | 1845 |
| SMALL CIRCLE | 15 | 37.5 | | 22 | 29.5 | 14 | 3.5 | 11.8 | 22.5 | 4.2 | 1.5 |
| ERROR ELLIPSE | 23.1 | 52.6 | | 31.6 | 42.2 | 27.2 | 8.1 | 21 | 32.2 | 7.9 | 3.6 |
| LARGE CIRCLE | 36.4 | 73.7 | | 43.4 | 66.9 | 49.1 | 15.7 | 32.9 | 44.5 | 18 | 8.9 |

DATA FROM ELEVATION ANGLE >= 8 DEGREES
USED FOR ANALYSIS

Figure 28

# ERROR ELLIPSE HEADING ANALYSIS




| | -90/-80 | | | | | | | | -10/0 | 0/10 | | | | | | | | 80/90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PHASE 2 | 137 | 133 | 154 | 136 | 162 | 185 | 190 | 221 | 261 | 307 | 225 | 179 | 163 | 201 | 160 | 160 | 124 | 164 |
| PHASE 3 | 268 | 288 | 261 | 246 | 255 | 336 | 266 | 343 | 420 | 467 | 288 | 288 | 255 | 246 | 248 | 259 | 238 | 251 |

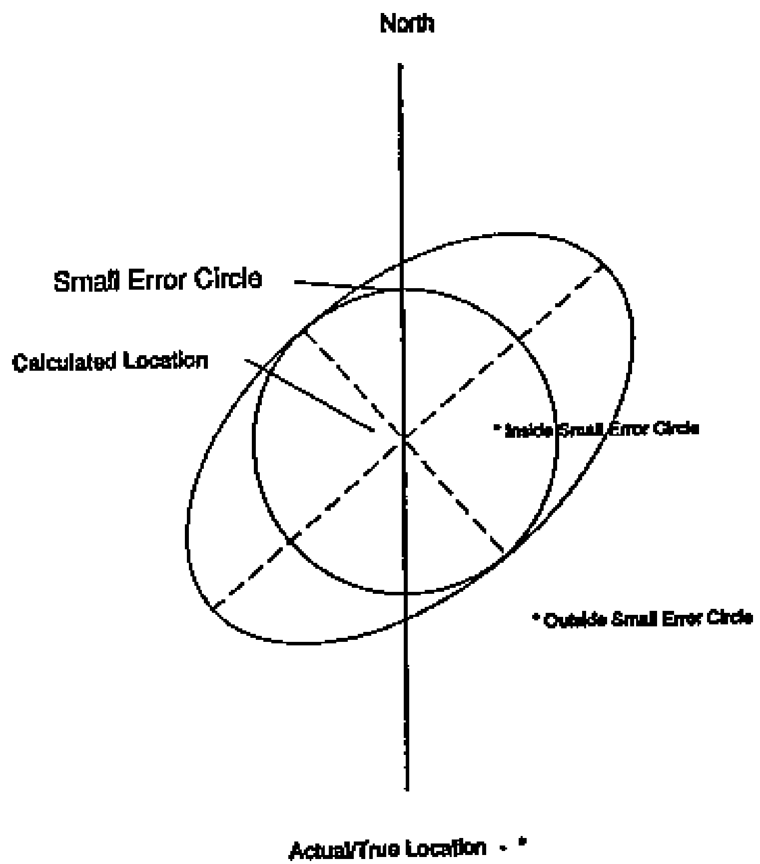
ROTATION NEEDED TO CORRECT HEADING (DEG)

N = 8473
DATA FROM ELEVATION ANGLE >= 8 DEGREES
USED FOR ANALYSIS

Figure 29

# Error Circles

## SMALL ERROR CIRCLE CONCEPT




## LARGE ERROR CIRCLE CONCEPT

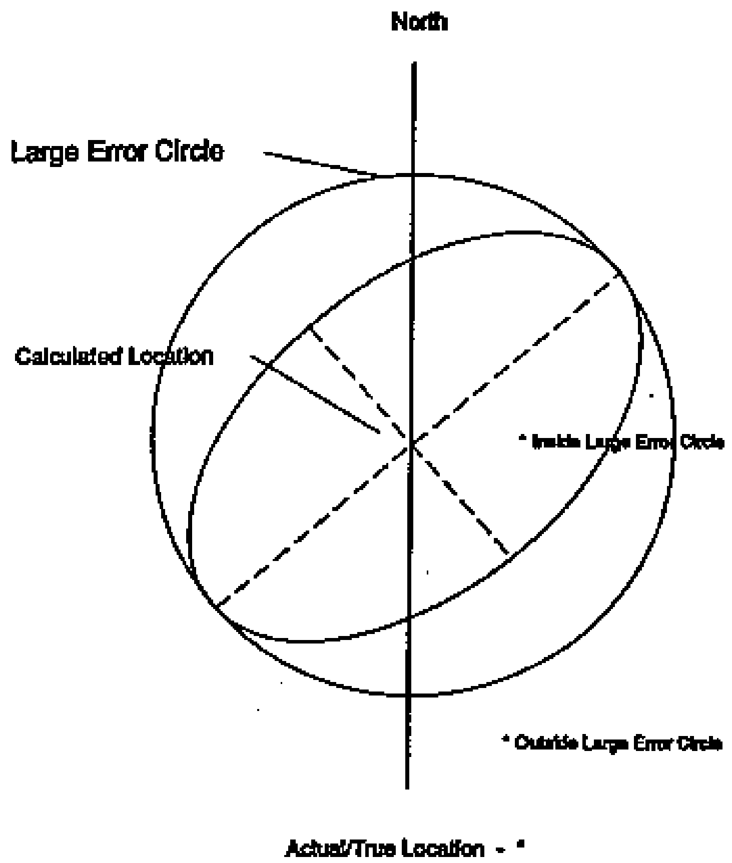



Figure 30

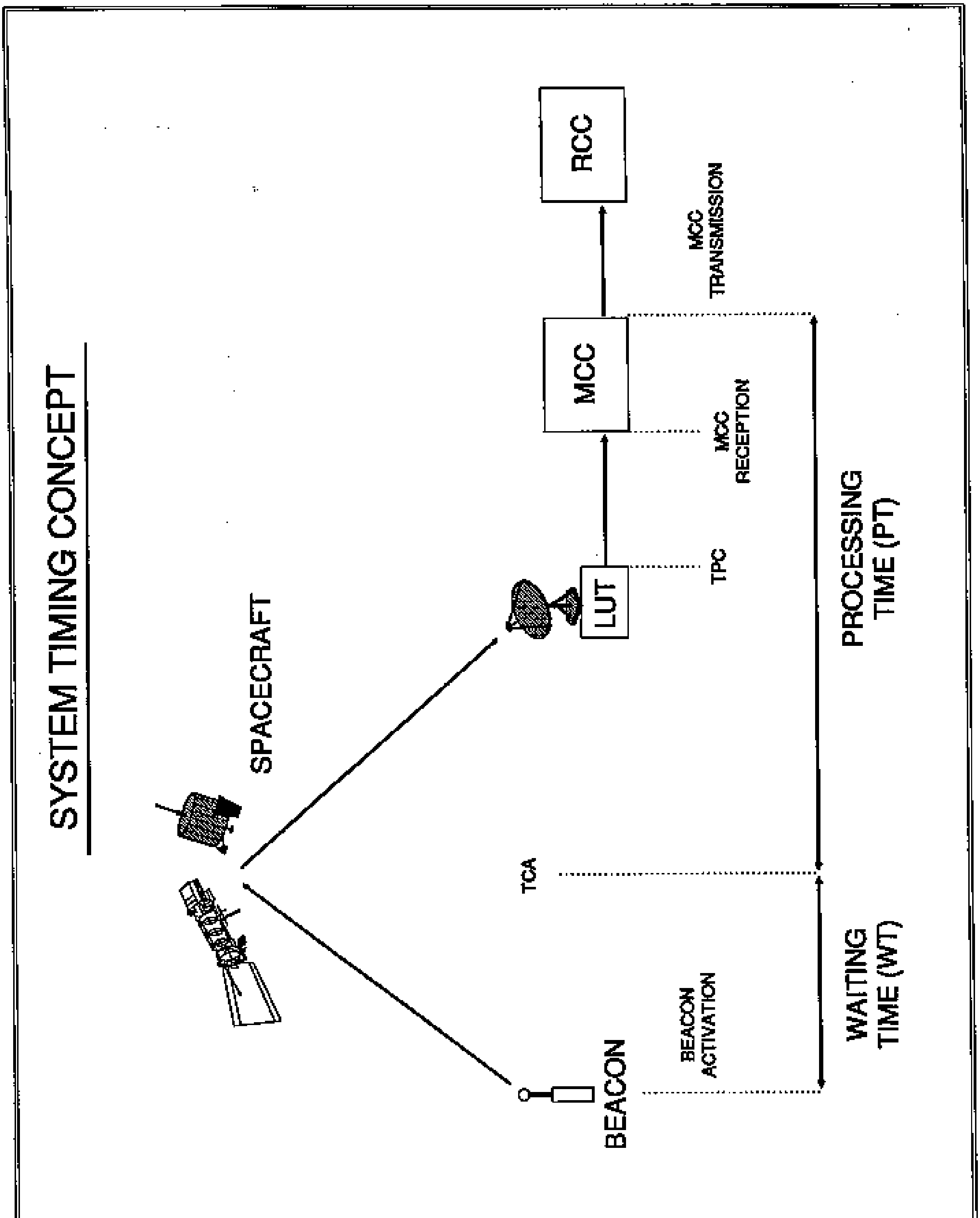

SYSTEM TIMING CONCEPT
SPACECRAFT
RCC
MCC
MCC TRANSMISSION
MCC RECEPTION
LUT
TPC
TCA
BEACON
BEACON ACTIVATION
PROCESSING TIME (PT)
WAITING TIME (WT)

Figure 31

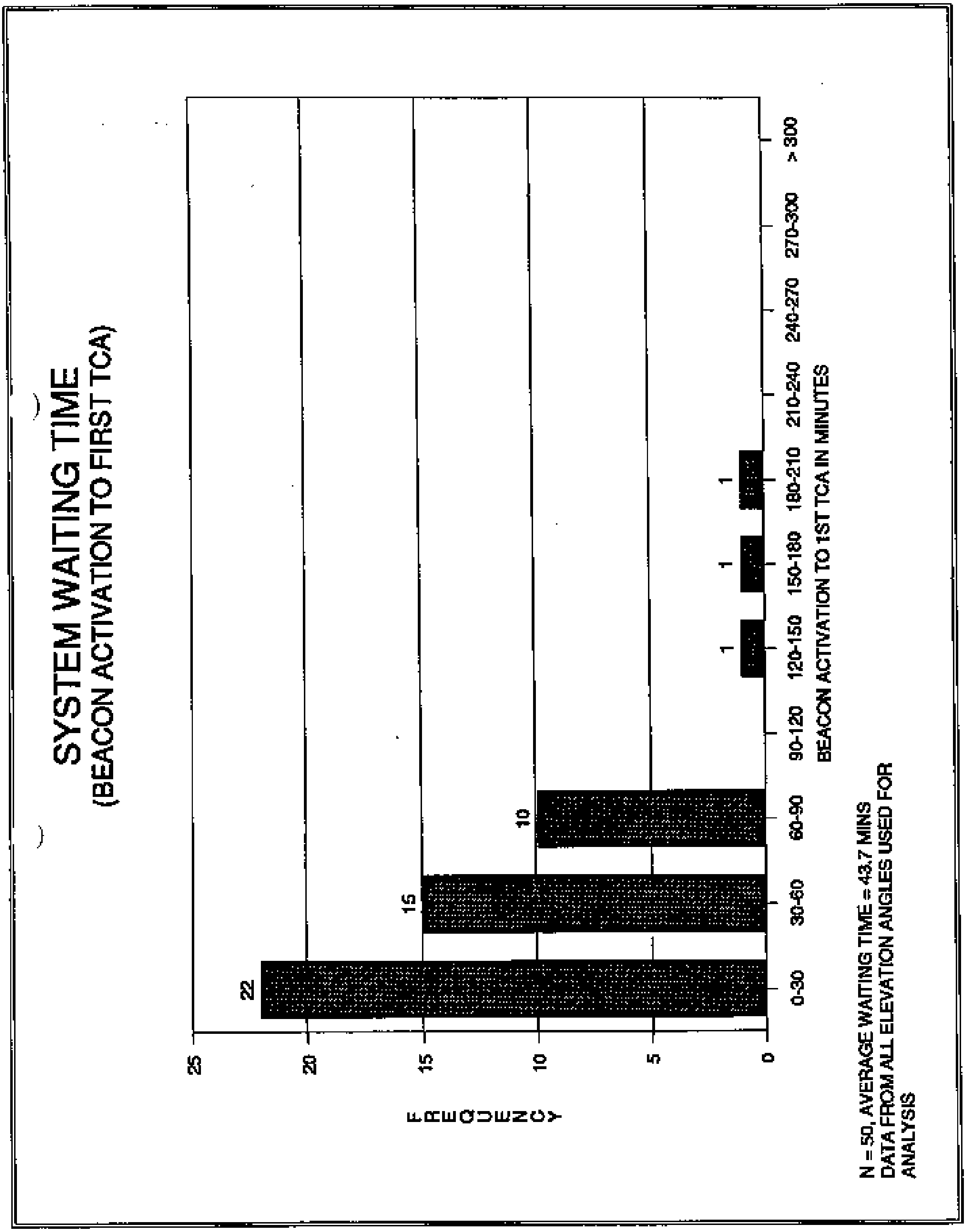

SYSTEM WAITING TIME
(BEACON ACTIVATION TO FIRST TCA)
FREQUENCY
25
20
15
10
5
0
22
15
10
1
1
1
0-30
30-60
60-90
90-120
120-150
150-180
180-210
210-240
240-270
270-300
> 300
BEACON ACTIVATION TO 1ST TCA IN MINUTES
N = 50, AVERAGE WAITING TIME = 43.7 MINS
DATA FROM ALL ELEVATION ANGLES USED FOR
ANALYSIS

Figure 32

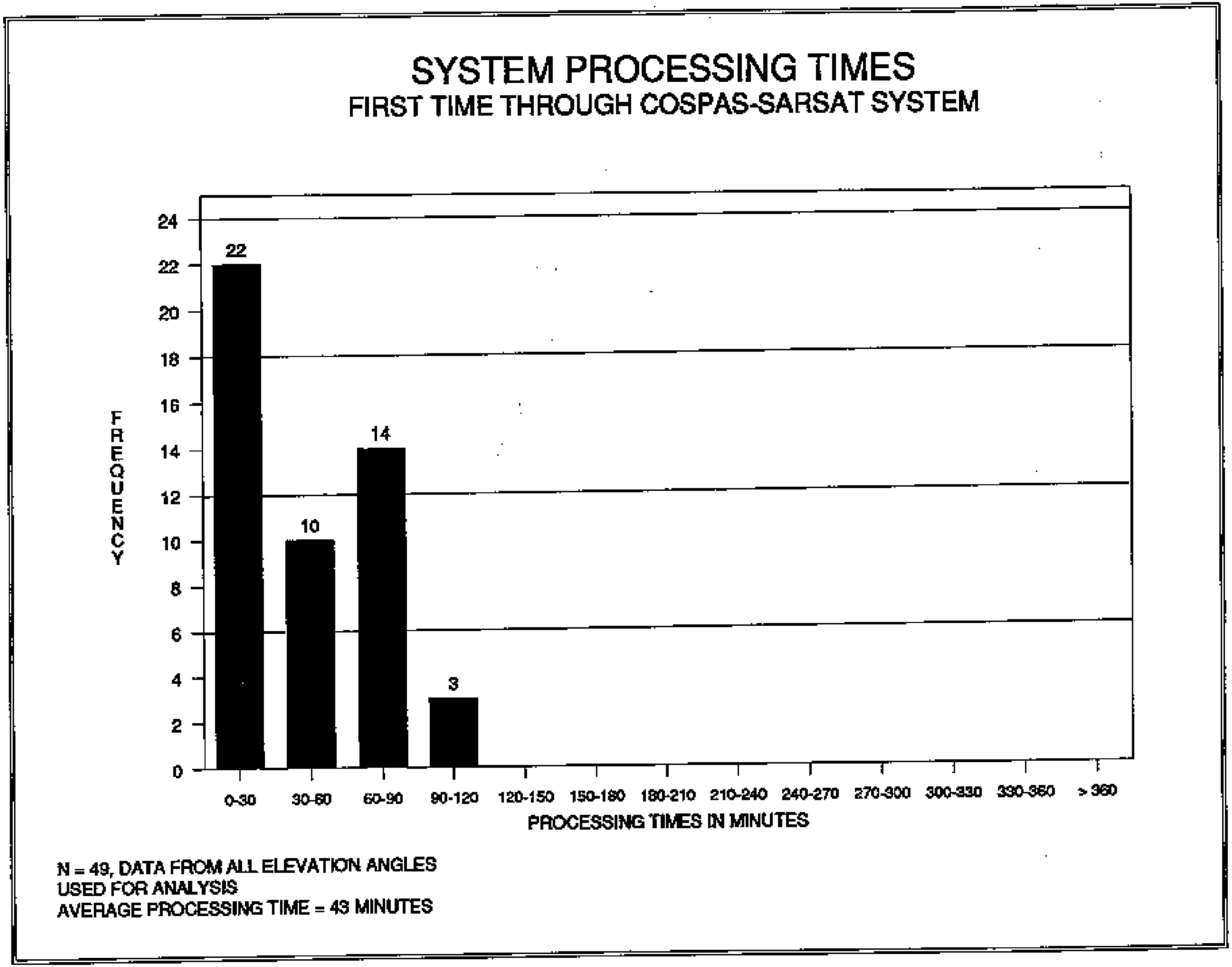
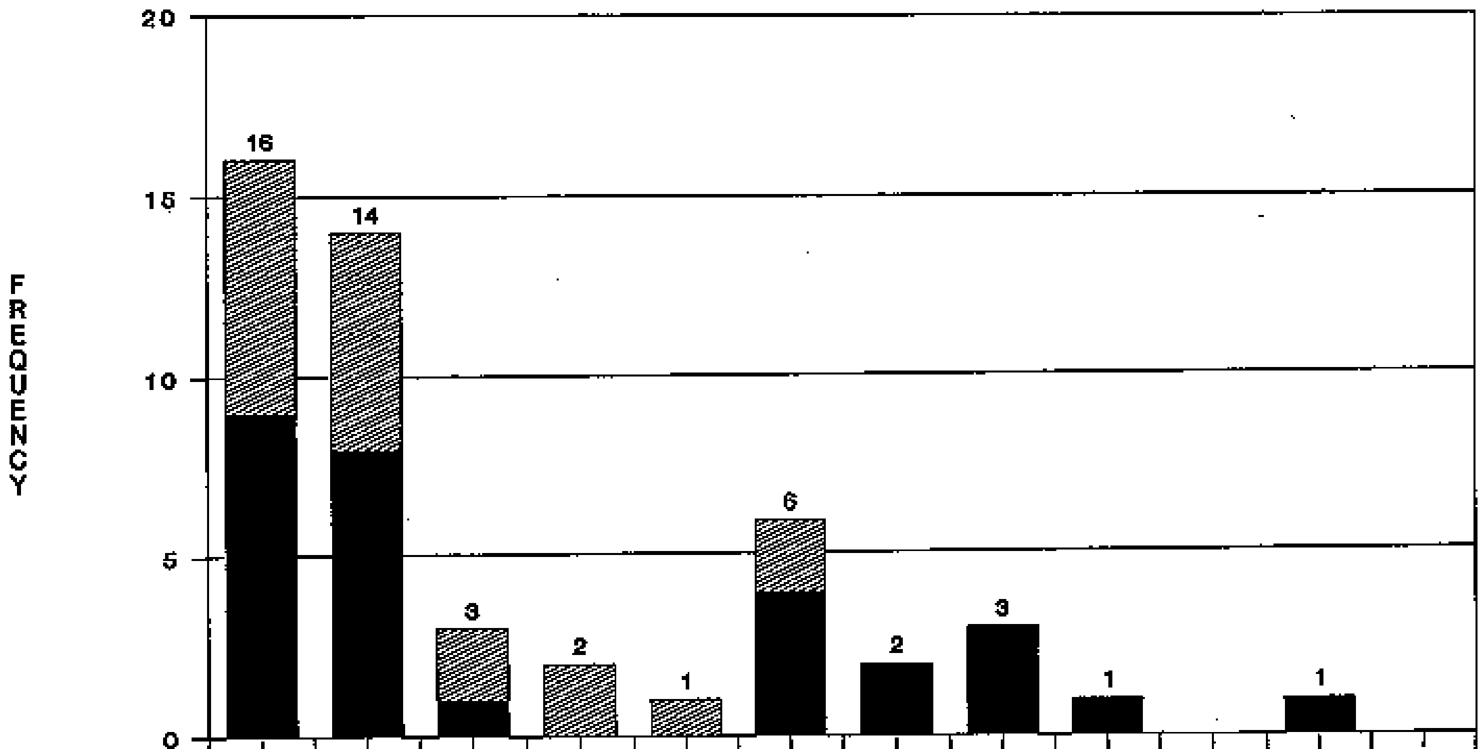

SYSTEM PROCESSING TIMES
FIRST TIME THROUGH COSPAS-SARSAT SYSTEM
FREQUENCY
24
22
20
18
16
14
12
10
8
6
4
2
0
22
10
14
3
0-30
30-60
60-90
90-120
120-150
150-180
180-210
210-240
240-270
270-300
300-330
330-360
> 360
PROCESSING TIMES IN MINUTES
N = 49, DATA FROM ALL ELEVATION ANGLES
USED FOR ANALYSIS
AVERAGE PROCESSING TIME = 43 MINUTES

Figure 33

# FIRST MESSAGE THROUGH THE SYSTEM

## SPACE STORAGE

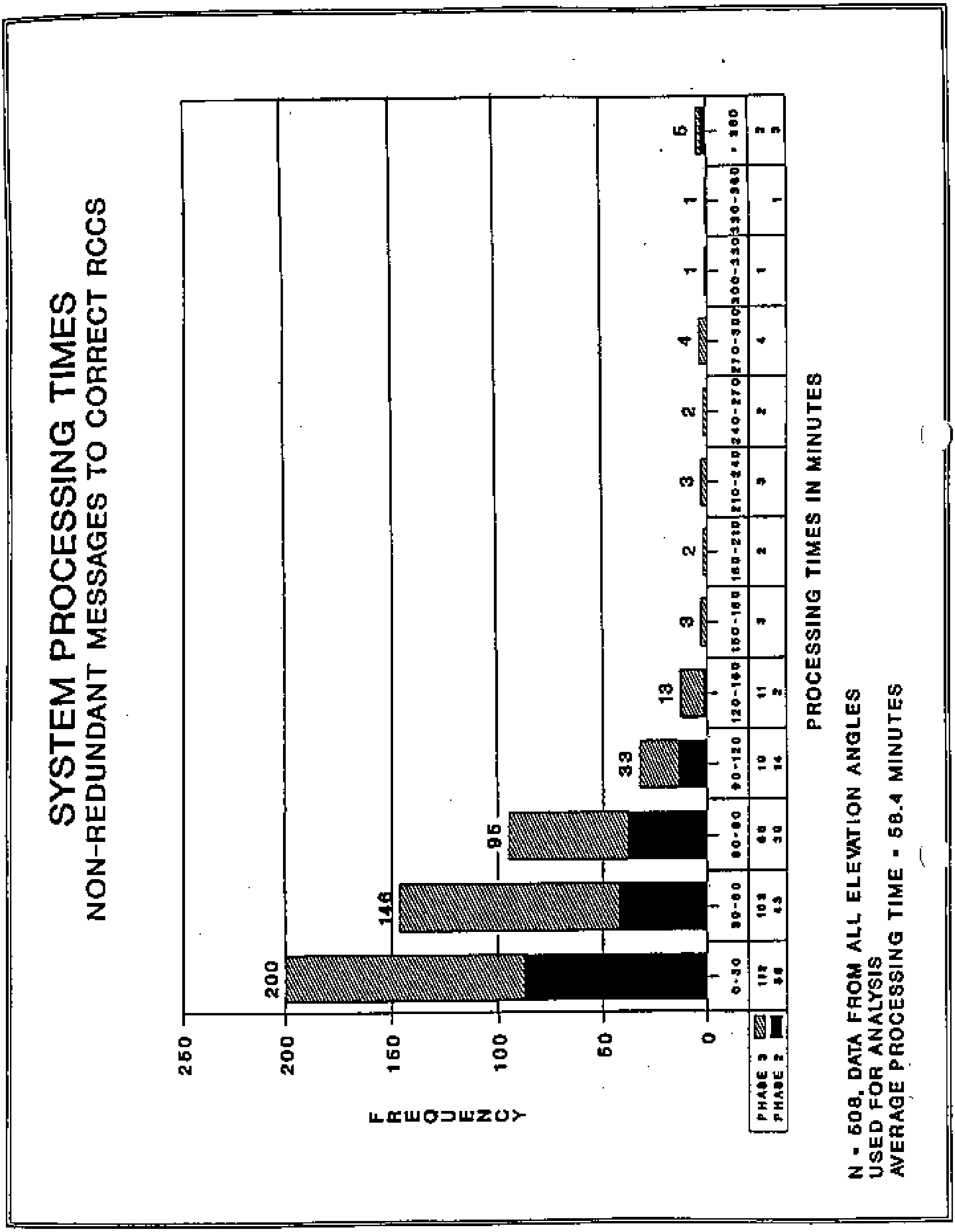



| | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | 80-90 | 90-100 | 100-110 | 110-120 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PHASE 3 | 7 | 6 | 2 | 2 | 1 | 2 | | | | | | 0 |
| PHASE 2 | 9 | 8 | 1 | | | 4 | 2 | 3 | 1 | | 1 | |

SPACE STORAGE TIME IN MINUTES

N = 49, DATA FROM ALL ELEVATION ANGLES
USED FOR ANALYSIS
AVERAGE SPACE STORAGE TIME = 27.2 MINS

Figure 34



SYSTEM PROCESSING TIMES
NON-REDUNDANT MESSAGES TO CORRECT RCCS
FREQUENCY
250
200
150
100
50
0
200
146
95
33
13
3
2
3
2
4
1
1
5
0-30
30-60
60-90
90-120
120-150
150-180
180-210
210-240
240-270
270-300
300-330
330-360
> 360
PHASE 3
PHASE 2
PROCESSING TIMES IN MINUTES
N = 508, DATA FROM ALL ELEVATION ANGLES
USED FOR ANALYSIS
AVERAGE PROCESSING TIME = 56.4 MINUTES


Figure 35

# CONFIDENCE FACTOR RESULTS

| MCC | ACTUAL DISTANCE ERRORS FROM S-2, C-4, AND C-5 | | | | | |
|---|---|---|---|---|---|---|
| | WITHIN 5 NM | | | GREATER THAN 5 NM | | |
| | PERCENT OF TOTAL | PREDICTED WITHIN 5 NM (CF=4) | LESS CONFIDENT (CF=3, 2 OR 1) | PERCENT OF TOTAL | INCORRECTLY PREDICTED WITHIN 5 NM (CF=4) | JUSTIFIABLY LESS CONFIDENT (CF=3, 2 OR 1) |
| FRANCE | 93.4 | 97.2 | 2.8 | 6.6 | 43.5[3] | 56.5 |
| U.S.S.R. | 90.1 | 90.7 | 9.3 | 9.9 | 40.9[3] | 59.1 |
| CANADA | 94.0 | 56.9[1] | 43.1 | 6.0 | 13.3 | 86.7[2] |
| U.S.A. | 97.9 | 53.4[1] | 46.6 | 2.1 | 16.7 | 83.3[2] |
| INDIA | 93.2 | 94.9 | 5.1 | 6.8 | 58.3[3] | 41.7 |

1-CANADA AND U.S.A APPEAR TO IDENTIFY GOOD SOLUTIONS LESS OFTEN.

2-CANADA AND U.S.A. APPEAR TO IDENTIFY POOR SOLUTIONS MORE OFTEN.

3-FRANCE, U.S.S.R. AND INDIA APPEAR TO MISCLASSIFY A LARGE PROPORTION OF THE POOR SOLUTIONS.

Figure 36

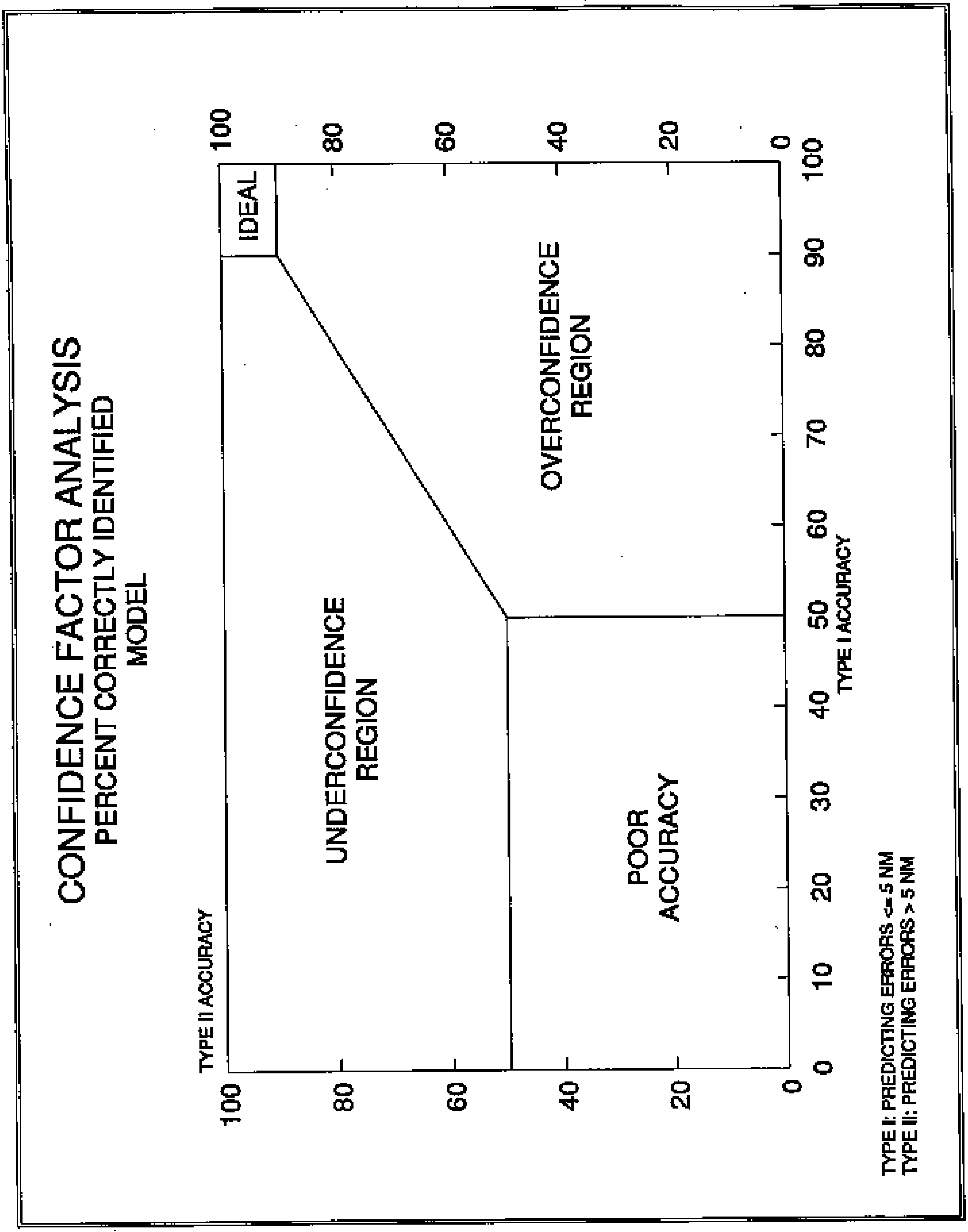

CONFIDENCE FACTOR ANALYSIS
PERCENT CORRECTLY IDENTIFIED
MODEL
TYPE II ACCURACY
100
80
60
40
20
0
IDEAL
UNDERCONFIDENCE
REGION
OVERCONFIDENCE
REGION
POOR
ACCURACY
0
10
20
30
40
50
60
70
80
90
100
TYPE I ACCURACY
TYPE I: PREDICTING ERRORS <= 5 NM
TYPE II: PREDICTING ERRORS > 5 NM

Figure 37

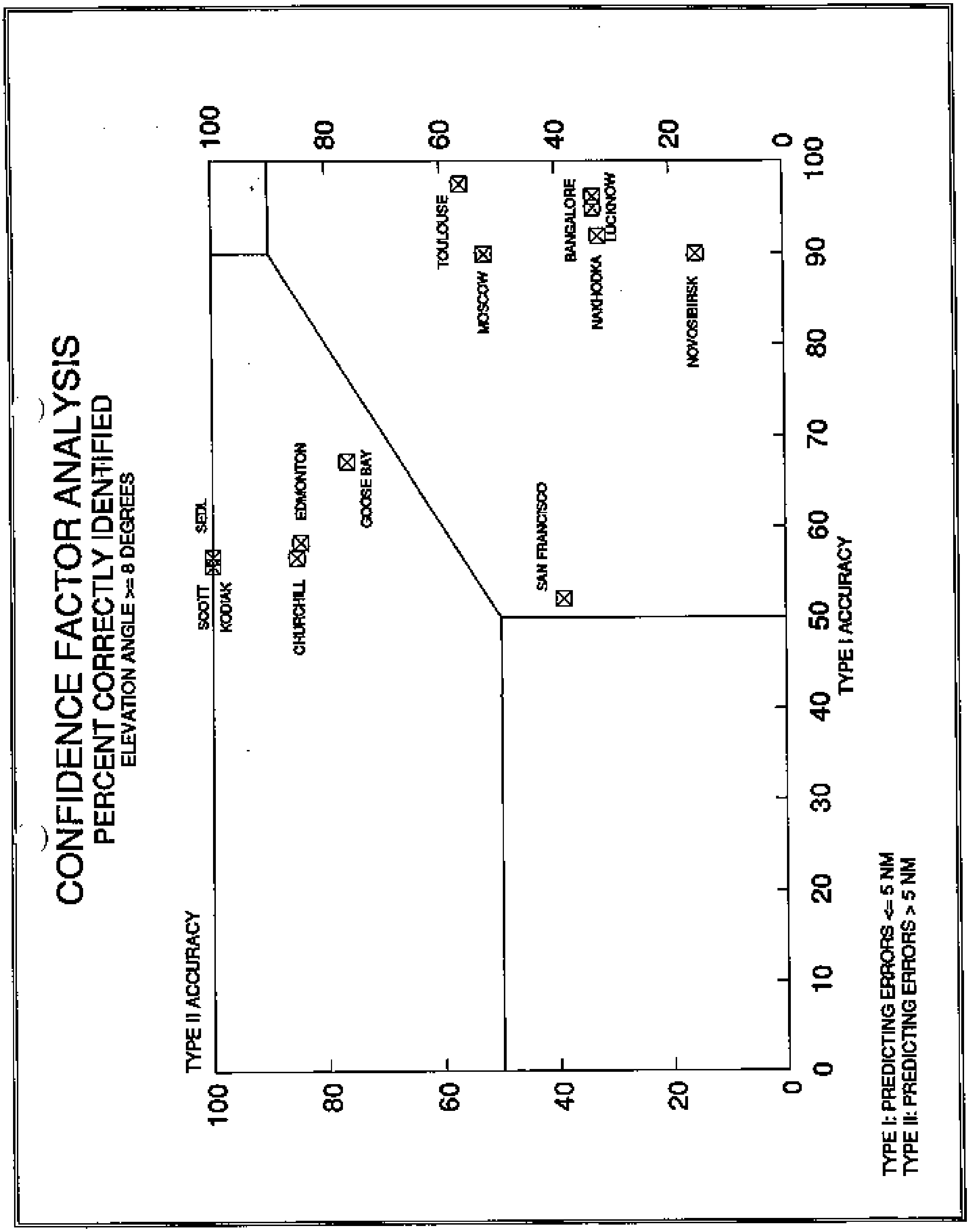

CONFIDENCE FACTOR ANALYSIS
PERCENT CORRECTLY IDENTIFIED
ELEVATION ANGLE >= 8 DEGREES
TYPE II ACCURACY
TYPE I ACCURACY
SCOTT
SEIL
KODIAK
CHURCHILL
EDMONTON
GOOSE BAY
SAN FRANCISCO
TOULOUSE
MOSCOW
BANGALORE
NAKHODKA
LUCKNOW
NOVOSIBIRSK
0
10
20
30
40
50
60
70
80
90
100
TYPE I: PREDICTING ERRORS <= 5 NM
TYPE II: PREDICTING ERRORS > 5 NM

Figure 38

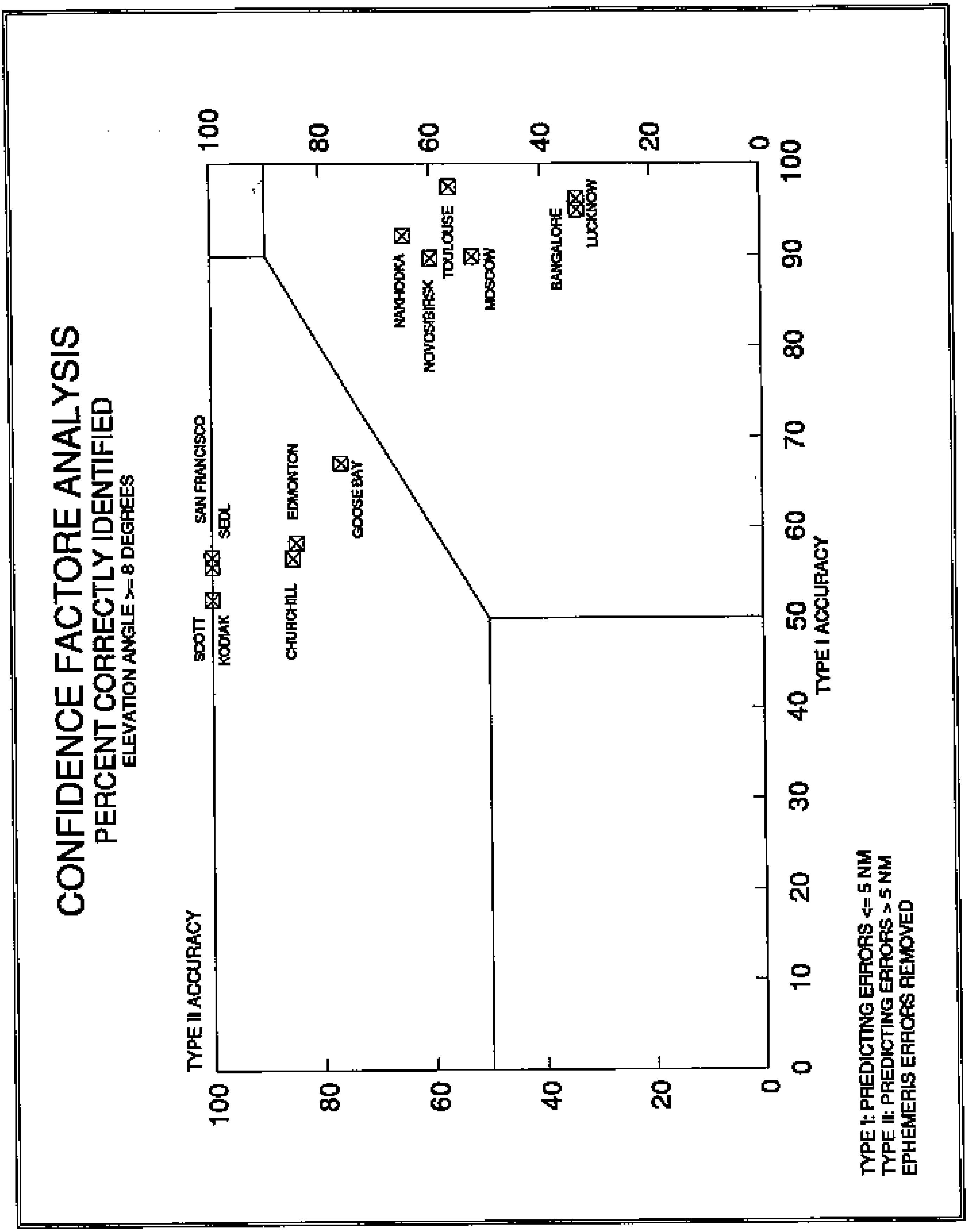

CONFIDENCE FACTORE ANALYSIS
PERCENT CORRECTLY IDENTIFIED
ELEVATION ANGLE >= 8 DEGREES
TYPE II ACCURACY
TYPE I ACCURACY
SCOTT
KODIAK
SAN FRANCISCO
SEDL
CHURCHILL
EDMONTON
GOOSE BAY
NAKHODKA
NOVOSIBIRSK
TOULOUSE
MOSCOW
BANGALORE
LUCKNOW
TYPE I: PREDICTING ERRORS <= 5 NM
TYPE II: PREDICTING ERRORS > 5 NM
EPHEMERIS ERRORS REMOVED

Figure 39

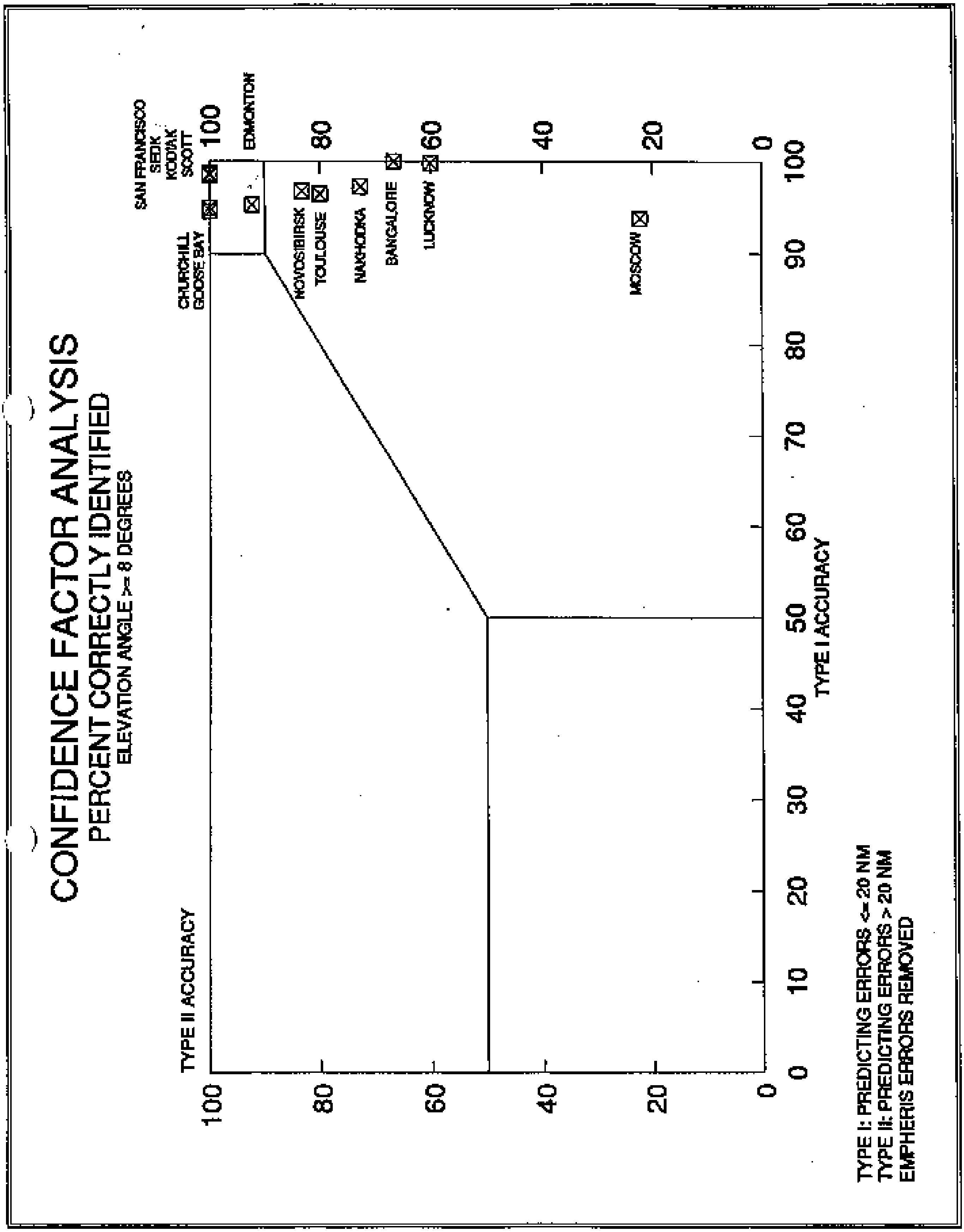

CONFIDENCE FACTOR ANALYSIS
PERCENT CORRECTLY IDENTIFIED
ELEVATION ANGLE >= 8 DEGREES
TYPE II ACCURACY
TYPE I ACCURACY
SAN FRANCISCO
SEDK
KODIAK
SCOTT
CHURCHILL
GOOSE BAY
EDMONTON
NOVOSIBIRSK
TOULOUSE
NAKHODKA
BANGALORE
LUCKNOW
MOSCOW
TYPE I: PREDICTING ERRORS <= 20 NM
TYPE II: PREDICTING ERRORS > 20 NM
EMPHERIS ERRORS REMOVED

Figure 40

# OCCURRENCE OF TRACKING PER ORBIT

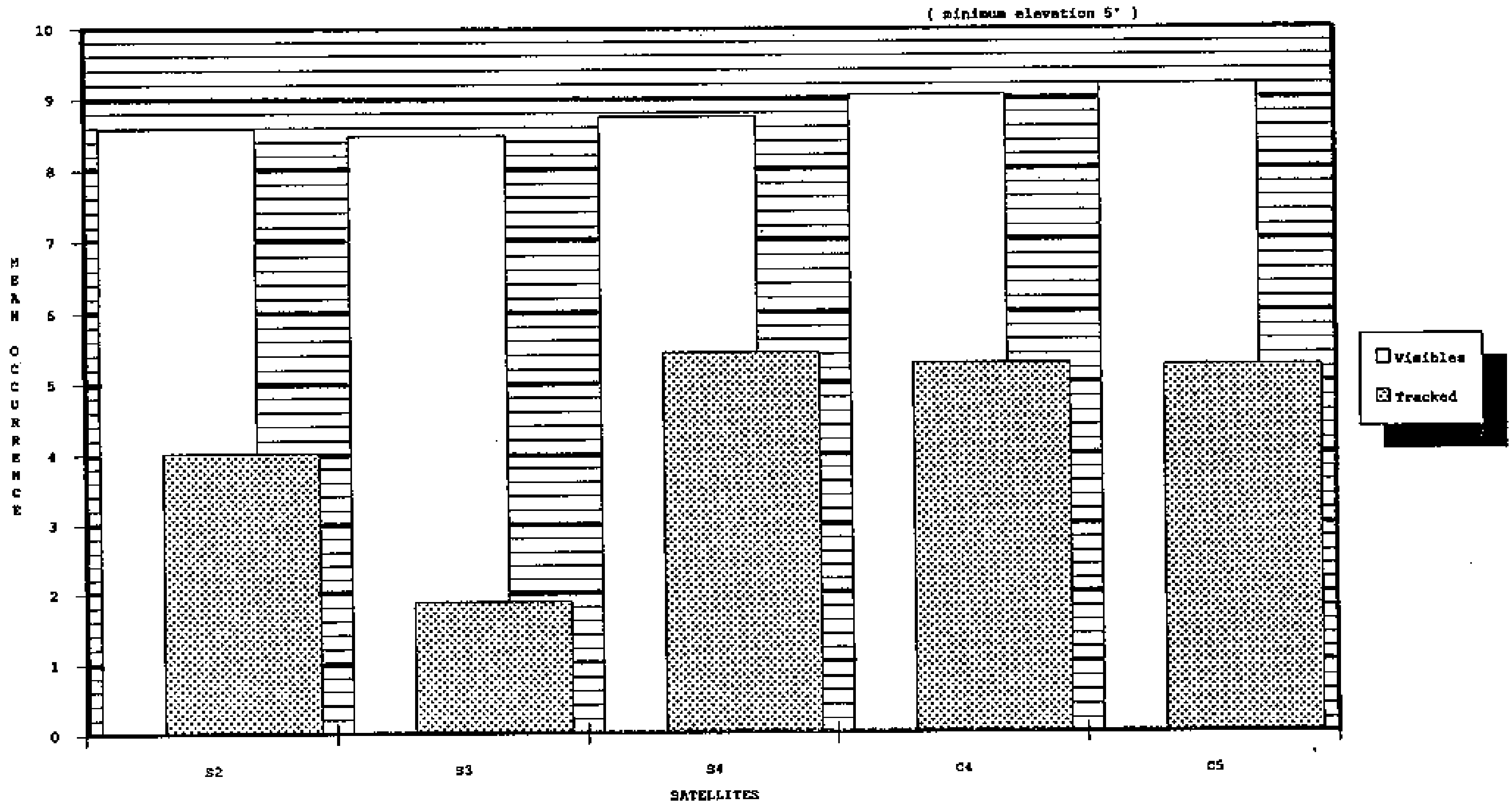



Figure 41

## TIME INTERVALS BETWEEN CONSECUTIVE TRACKINGS FOR COSPAS-5

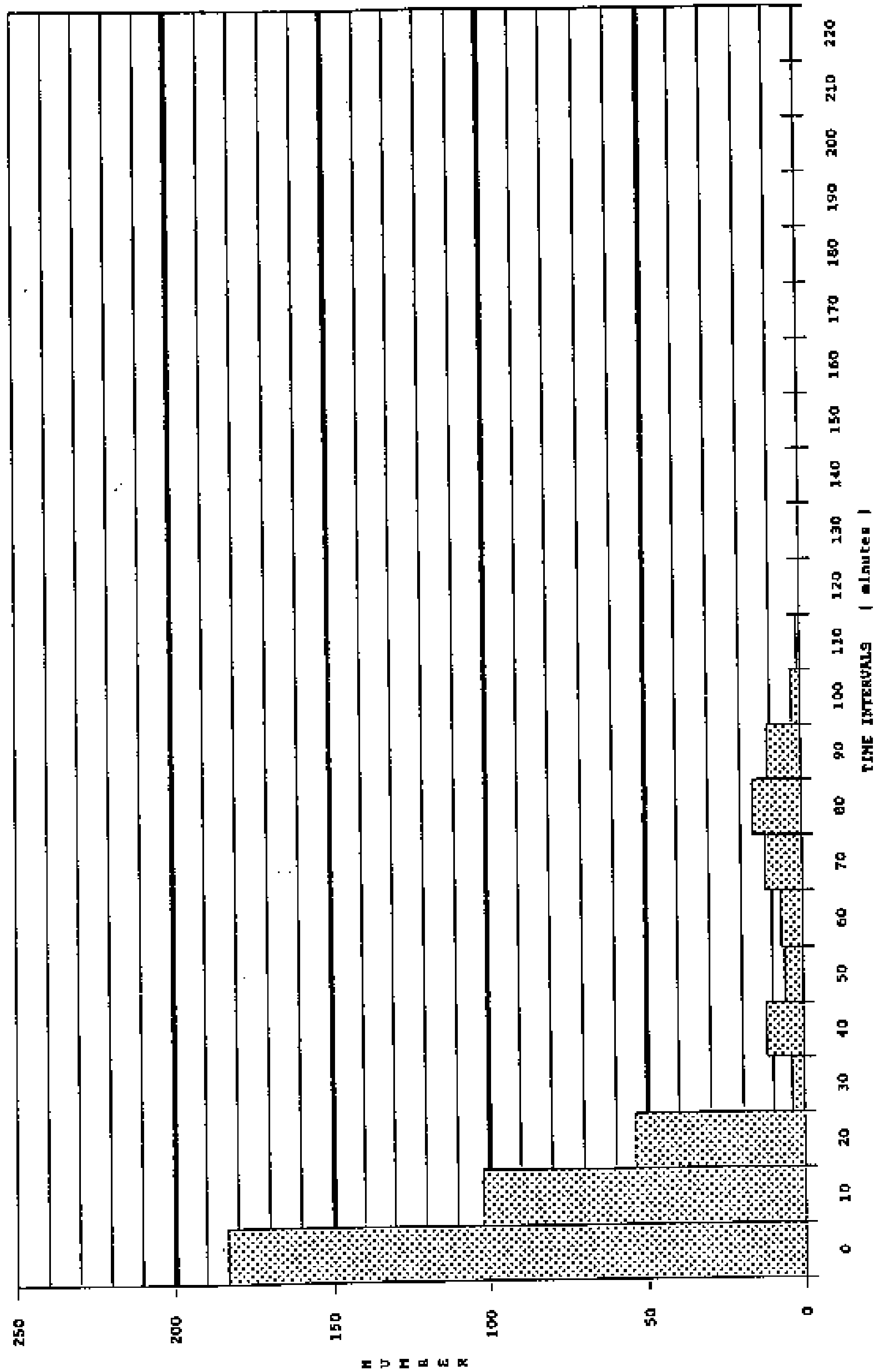



Figure 42

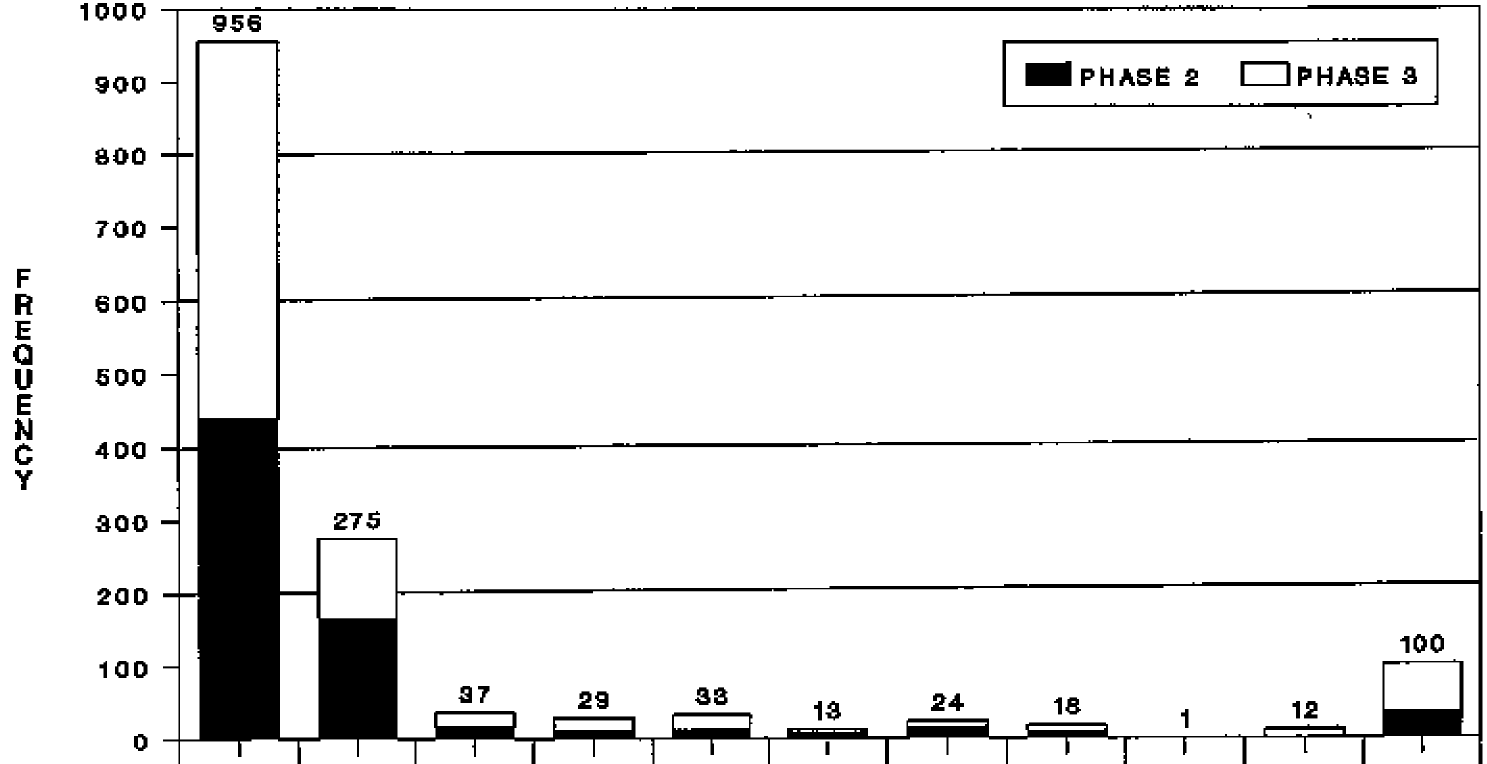
**LOCATION ACQUISITION PROBABILITY (LAP)**
**COSPAS-SARSAT SYSTEM BY MCC**
**ELEVATION ANGLE < 8 DEGREES**

TO BE PROVIDED

Figure 43

# DISTRIBUTION OF LOCATION ACCURACY

## LOW ELEVATION ANGLE ANALYSIS



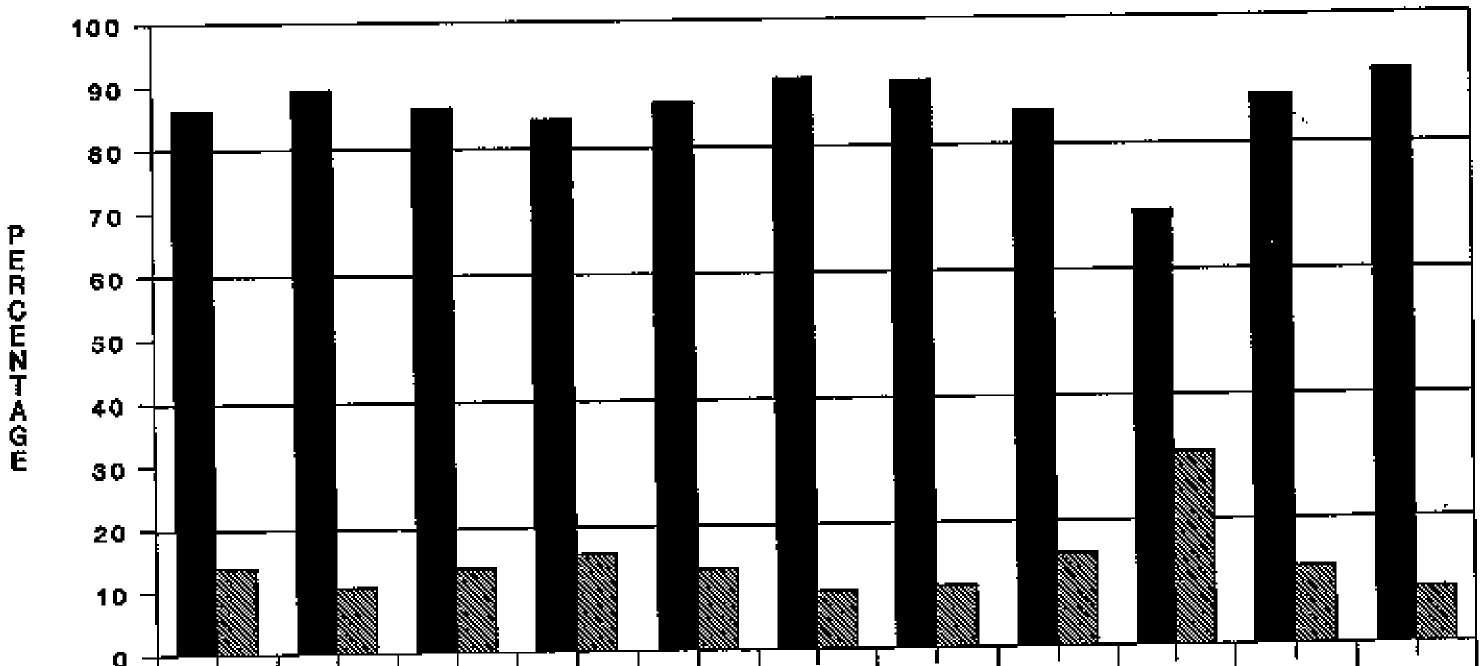

| | 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-50 | > 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PHASE 3 | 516 | 110 | 18 | 16 | 20 | 4 | 8 | 8 | 1 | 12 | 65 |
| PHASE 2 | 440 | 165 | 19 | 13 | 13 | 9 | 16 | 10 | | | 35 |

LOCATION ACCURACY (KM)

N = 1498
DATA FROM ELEVATION ANGLE < 8 DEGREES
USED FOR ANALYSIS

Figure 44

# A-SELECTION ACCURACY
## LOW ELEVATION ANGLE ANALYSIS




| | SYSTEM | AUMCC | CHMCC | CMC | CMCC | FMCC | HKMCC | INMCC | NMCC | UKMCC | USMCC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % A | 86.24 | 89.55 | 86.53 | 84.46 | 87.1 | 90.8 | 90.24 | 85.16 | 69.12 | 87.65 | 91.3 |
| % B | 13.76 | 10.45 | 13.47 | 15.54 | 12.9 | 9.2 | 9.76 | 14.84 | 30.88 | 12.35 | 8.7 |

MCC

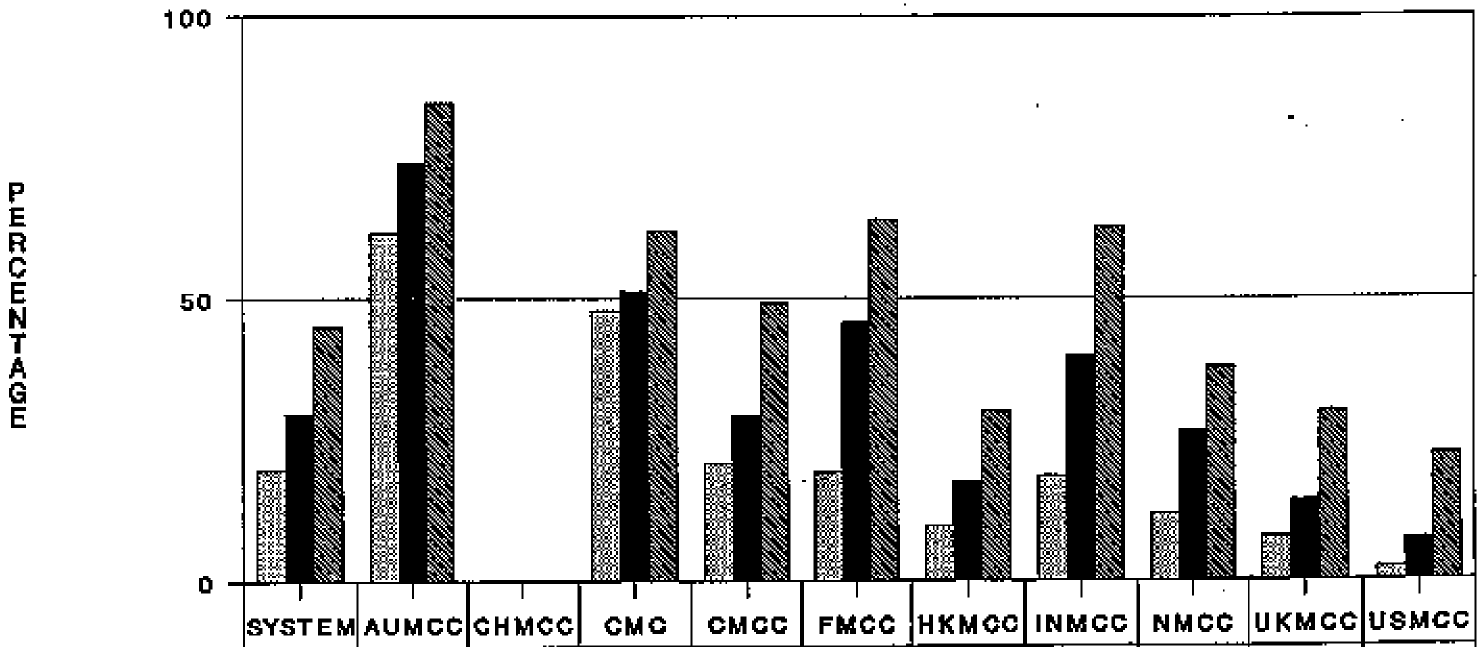
% A   % B

N - 1498
DATA FROM ELEVATION ANGLE < 8 DEGREES
USED FOR ANALYSIS

Figure 45

# ERROR ELLIPSE ANALYSIS

## LOW ELEVATION ANGLE ANALYSIS



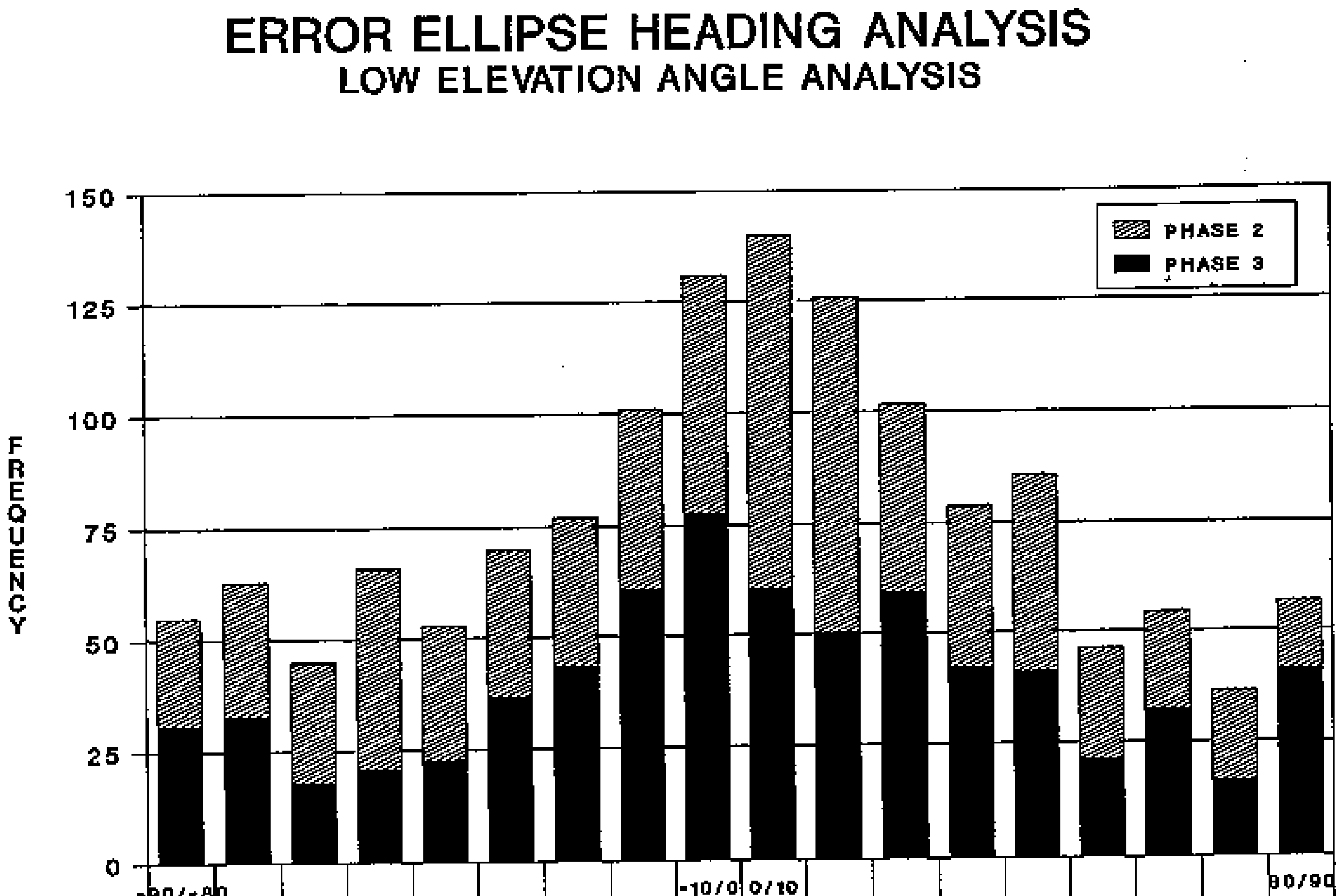

| | SYSTEM | AUMCC | CHMCC | CMC | CMCC | FMCC | HKMCC | INMCC | NMCC | UKMCC | USMCC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL | 1390 | 65 | | 205 | 256 | 83 | 113 | 136 | 143 | 77 | 313 |
| SMALL CIRCLE | 19.64 | 61.53 | | 47.8 | 20.7 | 19.27 | 9.73 | 18.38 | 11.88 | 7.79 | 2.23 |
| ERROR ELLIPSE | 29.64 | 73.84 | | 51.21 | 29.29 | 45.78 | 17.69 | 39.7 | 26.57 | 14.28 | 7.34 |
| LARGE CIRCLE | 45.1 | 84.61 | | 61.95 | 49.21 | 63.85 | 30.08 | 62.5 | 37.76 | 29.87 | 22.36 |

MCC

SMALL CIRCLE · ERROR ELLIPSE · LARGE CIRCLE

DATA FROM ELEVATION ANGLE < 8 DEGREES
USED FOR ANALYSIS
N = 1390

Figure 46




| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PHASE 2 | 24 | 30 | 27 | 46 | 30 | 33 | 33 | 40 | 53 | 79 | 76 | 42 | 36 | 44 | 25 | 22 | 20 | 15 |
| PHASE 3 | 31 | 33 | 16 | 21 | 23 | 37 | 44 | 61 | 78 | 61 | 51 | 60 | 43 | 42 | 22 | 33 | 17 | 42 |

ROTATION NEEDED TO CORRECT HEADING (DEG)

N = 1390
DATA FROM ELEVATION ANGLE >= 8 DEGREES
USED FOR ANALYSIS

Figure 47

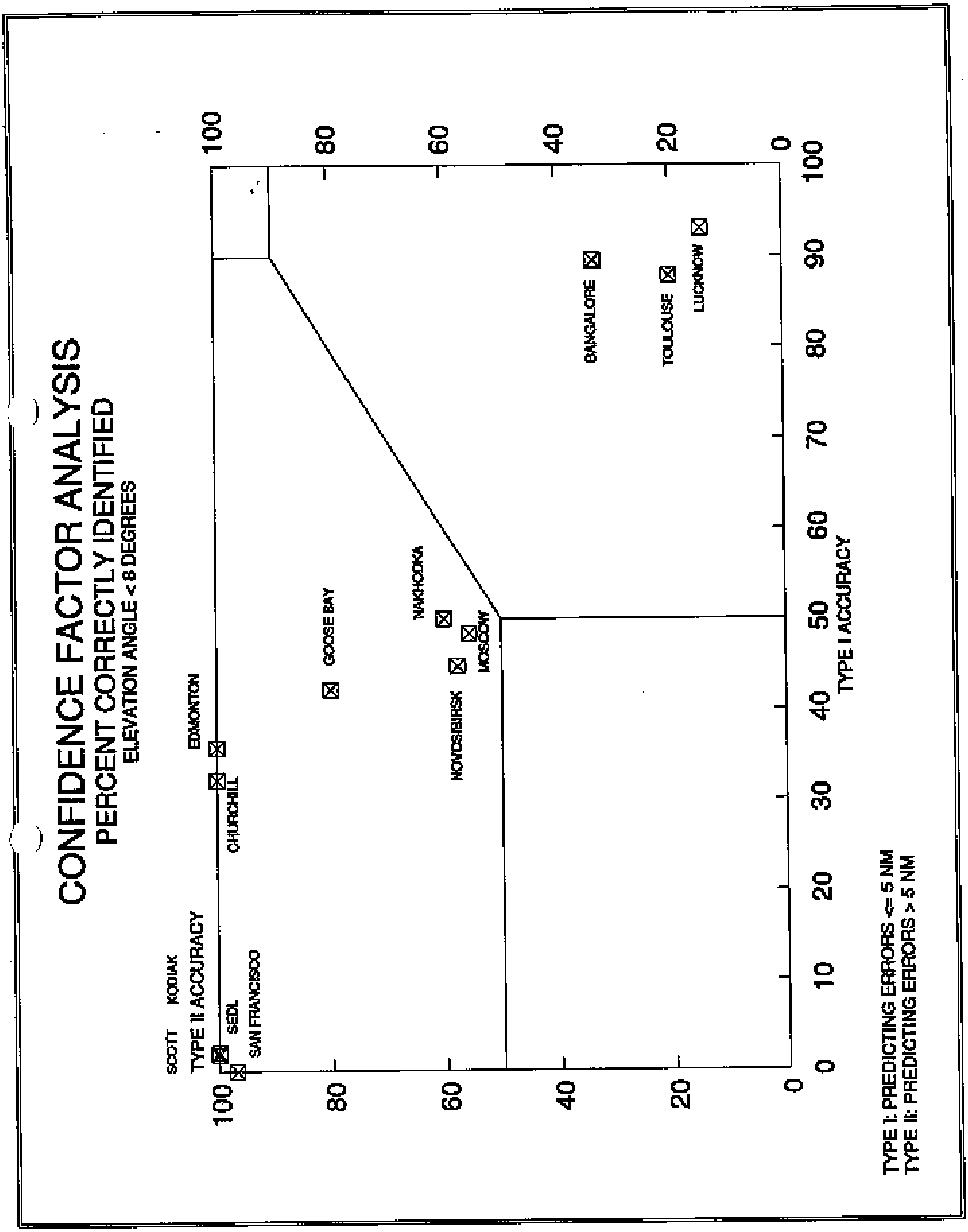

CONFIDENCE FACTOR ANALYSIS
PERCENT CORRECTLY IDENTIFIED
ELEVATION ANGLE < 8 DEGREES
TYPE II ACCURACY
TYPE I ACCURACY
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80
90
100
SCOTT
KODIAK
SEDL
SAN FRANCISCO
CHURCHILL
EDMONTON
GOOSE BAY
NAKHODKA
NOVOSIBIRSK
MOSCOW
BANGALORE
TOULOUSE
LUCKNOW
TYPE I: PREDICTING ERRORS <= 5 NM
TYPE II: PREDICTING ERRORS > 5 NM

Figure 48

## A COMPARISON OF COSPAS-SARSAT EXERCISES RESULTS

## THE SYSTEM OF 1990 VERSUS THE SYSTEM OF 1986

| MEASUREMENT | EXERCISE OF 1990 (%) | EXERCISE OF 1986 (%) | CHANGE (%) |
|---|---|---|---|
| LAP | 98 | 95 | + 3 |
| MRP | * | 99 | --- |
| Locations < 5 km | 84 | 72 | +12 |
| Waiting Time < 30 min. | 44 | 40 | + 4 |
| Processing Time < 30 min. | 45 | 35 | +10 |

* The MRP, considered at the MCC and System-level in 1986, was considered at the MCC-level only in the data analysis of 1990.

Figure 49

# Section 2: Beacon Pictures

| Picture Number | Description |
|---|---|
| Picture 1: | |
| Picture 2: | |
| Picture 3: | |
| Picture 4: | |
| Picture 5: | |
| Picture 6: | |
| Picture 7: | |
| Picture 8: | |
| Picture 9: | |
| Picture 10: | |
| Picture 11: | |
| Picture 12: | |
| Picture 13: | |
| Picture 14: | |
| Picture 15: | |
| Picture 16: | |
| Picture 17: | |
| Picture 18: | |
| Picture 19: | |
| Picture 20: | |

**To be provided.**