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MEASUREMENT OF THE ATCRBS SURFACE INTERROGATION ENVIRONMENTS AT CHICAGO O'HARE AND LOS ANGELES INTERNATIONAL AIRPORTS

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16. Abstract

The Transportation Systems Center is conducting a program to develop a surface surveillance sensor that uses replies from ATCRBS transponders. The operation of this system can be affected by surface interrogations at major airports where such a system might eventually be deployed. Consequently, tests were conducted at Chicago O'Hare and Los Angeles International Airports to measure the surface interrogation environment and to determine the number of interrogators causing surface transponders to reply.

This report describes the tests that were performed, presents the analysis of collected data, and offers conclusions pertinent to future operational ASTC systems.

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PREFACE

The test series described in this report is part of a comprehensive program at the Transportation Systems Center (TSC) to investigate and evaluate factors bearing on the development of a surface surveillance system that operates with replies from ATCRBS transponders. This program is being conducted by the Airport Surface Traffic Control (ASTC) Program Office at TSC and is sponsored by the Federal Aviation Administration (FAA) through the Systems Research and Development Service. One of the factors being investigated is the ATCRBS interrogation rate for vehicles on the surface of airports. The surface surveillance system would function in the dead time of local ASR(s) in order to be compatible with ATCRBS. It is expected that this method of operation will be technically feasible unless high surface interrogation rates exist due to radiation from surrounding ATCRBS sites. Analytical studies have indicated that the surface interrogation environments at Chicago O'Hare and Los Angeles International Airports might be very severe. It was necessary, therefore, to measure exactly the surface interrogation rates at these airports since both are candidates for advanced surface surveillance systems.

The test program was carried out by the following team:

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J. D. Vinatieri, The Mitre Corporation
P. J. Woodall, Bendix Communications Division.

Our endeavors were greatly facilitated by cooperation from the Federal Aviation Administration Adminstration, the O'Hare Airport Administration Office and the Los Angeles Airport Management Office. In particular we wish to acknowledge the interest, encouragement and efforts of Mr. Jim Burns and Mr. Norm Oleson, FAA, Chicago O'Hare Airport; Mr. Jim Donovan, O'Hare Airport Administration Office; Mr. Frank Scollick, Mr. Doug LePage and Mr. Bob Curtis, FAA Los Angeles International Airport.

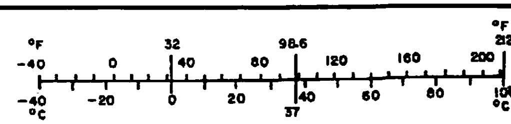
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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LIST OF ABBREVIATIONS AND SYMBOLS

ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ASR	Airport Surveillance Radar
ASTC	Airport Surface Traffic Control
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
BCN	Beacon
DAS	Data Acquisition Subsystem
IFR	Instrument Flight Rules
ISLS	Interrogate Side Lobe Suppression
I^2SLS	Improved Interrogate Side Lobe Suppression
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
NM	Nautical Mile
PRF	Pulse Repetition Frequency
RSLS	Receive Side Lobe Suppression
TRACON	Terminal Radar Control
TSC	Transportation Systems Center
SLS	Side Lobe Suppression
VFR	Visual Flight Rules

1. INTRODUCTION

1.1 PURPOSE OF THE MEASUREMENT PROGRAM

The purpose of measuring the Surface Interrogation Environment at Chicago O'Hare (ORD) and at Los Angeles Airport (LAX) was to enlarge the body of data previously collected at the NAFEC and Logan Airports. The O'Hare and Los Angeles airports were selected because they are representative of large hubs and are candidates for installation of an operational ATCRBS-based Airport Surface Traffic Control (ASTC) system. Furthermore, O'Hare Airport is being considered for advanced testing of the brassboard model ATCRBS-based Surface Trilateration Data Acquisition Subsystem presently being built by TSC for planned feasibility tests at NAFEC. O'Hare also is a candidate site for installation and checkout of the Tower Automated Ground Surveillance (TAGS) system which will be the advanced ASTC system based on ATCRBS-trilateration as the primary surveillance sensor. Hence, there was a need to measure the interference environment at O'Hare. On the other hand, it has been suggested that the severity of the surface interrogation environment at Los Angeles might preclude the operation of an ATCRBS-based ASTC system. Indeed, analytical studies indicated that as many as ten interrogators might have line-of-sight coverage of the Los Angeles airport surface. Measurements at this site were needed to validate the analytical results and to provide valuable data representative of a heavy surface interrogation environment. The tests at both airports were performed in accordance with the test plan of reference 1.

1.2 PREVIOUS TESTS

The tests performed at these airports were similar to those previously made at Logan Airport and reported in Reference 2. Measurements were made using portable equipment which could easily be transported by automobile to various locations on the airport surface. This equipment was used to gather information on interrogation and improved interrogate side lobe suppression (I^2SLS)* rates occurring for a surface transponder at designated airport locations.

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*ISLS generally refers to Interrogate Side Lobe Suppression whereby the P_2 pulse is radiated from an omni antenna. The FAA has widely implemented a system known as "improved ISLS" (I^2SLS). In this system, a portion of the P_1 signal is radiated along with P_2 through the omni antenna to suppress all transponders within the omni coverage volume not in the mainbeam. The equipment used in this test program does not differentiate between the two types, but simply records all suppression events occurring in the transponder whether from ISLS or I^2SLS. Henceforth, in this document, the transponder suppression rate will be referred to as the I^2SLS suppression rate. Reference 1, pages 2 and 3, describe both suppression systems in more detail.

1.3 TEST OBJECTIVES

The objectives for this test program were: (1) to collect data at ORD and LAX airports and (2) perform a detailed analysis of the data in order to: (a) provide a first order assessment of the extent to which a surface operated transponder is interrogated by existing ATCRBS interrogators; (b) determine the uniformity of the surface transponder interrogation rate as a function of airport surface location; and (c) determine the number of interrogators in the vicinity of each airport causing surface transponder interrogations.

The field test data were obtained from a specially constructed test unit containing an instrumented transponder and associated electronics. This equipment provided data relative to the surface interrogation rate and I^2SLS rate and, through post-test analysis, provided a measure of the number of interrogators illuminating each test point.

Specifically, the test objectives were as follows:

a. To take multiple counts of the number of interrogations and suppressions occurring during specified time intervals at several airport locations. These counts were later compared and analyzed.

b. To determine the periodicity of bursts of interrogations occurring during specified time intervals, and to compare these periodicities with known beacon interrogator scan rates. By means of this procedure the number of interrogators illuminating a given test location was determined.

2. DATA COLLECTION

2.1 METHOD OF APPROACH

As previously stated, tests were made at the Chicago O'Hare and Los Angeles airports. In general, the same three basic steps were used at each airport site. First, a preliminary meeting was held at which the test team, composed of representatives from TSC, FAA, MITRE and the Bendix Communications Division, were introduced to FAA and Airport Authority operating personnel. A briefing was given by TSC to explain the purpose of the visit, the objectives of the ASTC program at TSC and the relationship of data that would be collected at the airports to the overall program. At this meeting, the manner in which data would be gathered on the airport surface was stressed and the interface between the test team, ATC controllers and Airport Authority personnel was discussed in detail. Also at this meeting, the operating characteristics (e.g., scan rate, PRF, stagger) of the local ASR beacon(s) were reviewed and the location and identity of the ASR and ARSR beacons in the airport vicinity which might have line of sight to the airport surface were noted.

Second, the test data was collected over a period of one to one and one-half days by driving an instrumented transponder to the planned test points. The test team and test equipment were driven on the airport surface by an authorized driver in a vehicle supplied by the FAA or the Airport Authority.

Third, a departure briefing was held at the conclusion of the test data gathering. Highlights of the testing were discussed and an attempt was made to give a very preliminary assessment of the interrogator environment based on a cursory examination of the data. It was emphasized that the data analysis would take several weeks and the test results for both airports would be presented in a final report.

2.2 TEST EQUIPMENT

At both airports portable equipment (see Figure 2-1) was employed to obtain measurements at selected locations. A major component of this equipment was a transponder (see Appendix A) which had been modified to provide outputs from its decoder circuitry in order to allow counts to be made of: (1) the number of valid interrogations received and (2) the number of suppressions which occurred during a prescribed time interval. The time interval was selectable in 0.1 second increments from 0.1 seconds to 10.0 seconds and the equipment had provision for recording in sequence the counts for 61 such intervals. At the conclusion of 61 intervals, the total count was printed and the counter automatically reset in preparation for the next test sequence.

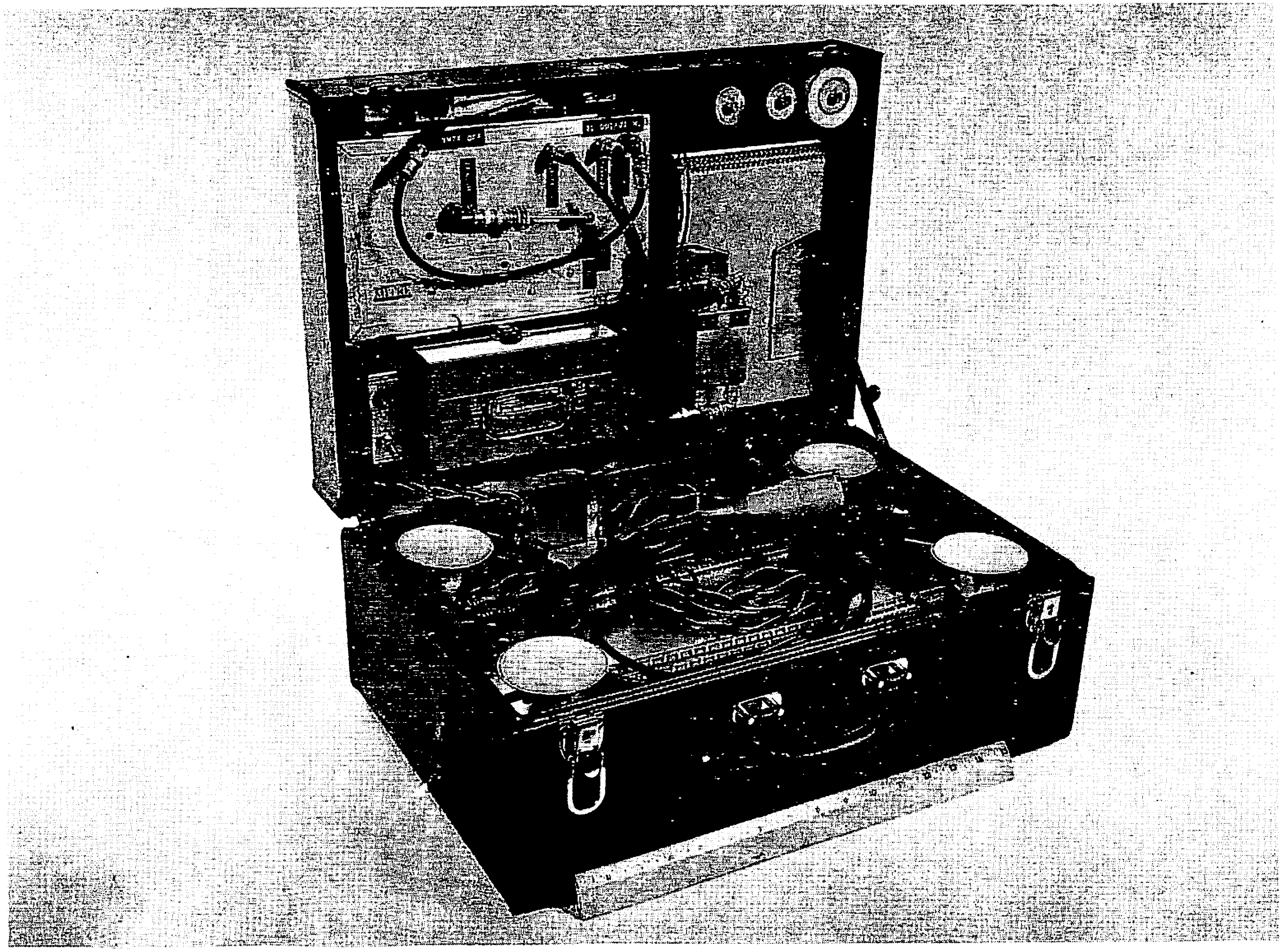

FIGURE 2-1. PACKAGING OF EQUIPMENT SHOWING STORAGE OF ANTENNA GROUND PLANE AND ALL NECESSARY CABLES

The equipment was designed so that it could be easily installed and operated in an ordinary surface vehicle such as an automobile or truck for rapid transportation to each test point. Set up time in the vehicle required only 5 to 10 minutes. A stub antenna was mounted on an aluminum ground plane which contained four suction cups. This antenna assembly was placed on the roof of the vehicle and held in place by two clamps fastened to the vehicle's rain gutter. Power for the equipment was provided by the 12 volt car battery either through battery cables and clips or by means of a plug inserted into the cigarette lighter.

Figures 2-1 and 2-2 illustrate the packaging of the equipment. Figure 2-1 shows the equipment with the necessary cables, antenna and ground plane packaged in a single case. The transponder can be seen mounted in the lid of the case and the counter electronics and strip printer are shown directly beneath the antenna ground plane. Figure 2-2 shows the equipment as it is set up at an airport site with the exception, of course, that the antenna and ground plan will be fastened to the roof of a vehicle. The counter electronics can be clearly seen and the strip printer is shown immediately to the left of the electronic assembly.

Before starting the series of measurements at O'Hare and Los Angeles, the transponder was bench tested at MITRE. This bench test showed the transponder to have a sensitivity of -72 dbm and a power output of 220 watts. These values are within the ATCRBS national standard* and thus the interrogation and I^2SLS counts obtained are representative of typical operational values. In addition, the portable equipment was checked out at Logan airport prior to the initiation of these tests. This field check provided verification that the transponder and counter electronics were properly interfaced and were accurately recording the surface interrogation rate.

2.3 SURFACE TEST PROCEDURES

Testing was accomplished using the portable test equipment to record the number of successful interrogations occurring in a specified time interval and the number of successful sidelobe suppressions received by the transponder during a specified time interval. After the equipment was installed in the test vehicle a check was made to verify its readiness. Once installed, the equipment, including the antenna fastened to the roof and the battery

*U.S. National Standard for the IFF Mark X Air Traffic Control Radar Beacon System Characteristics (ATCRBS), AC No. 00-27, Jan. 1969

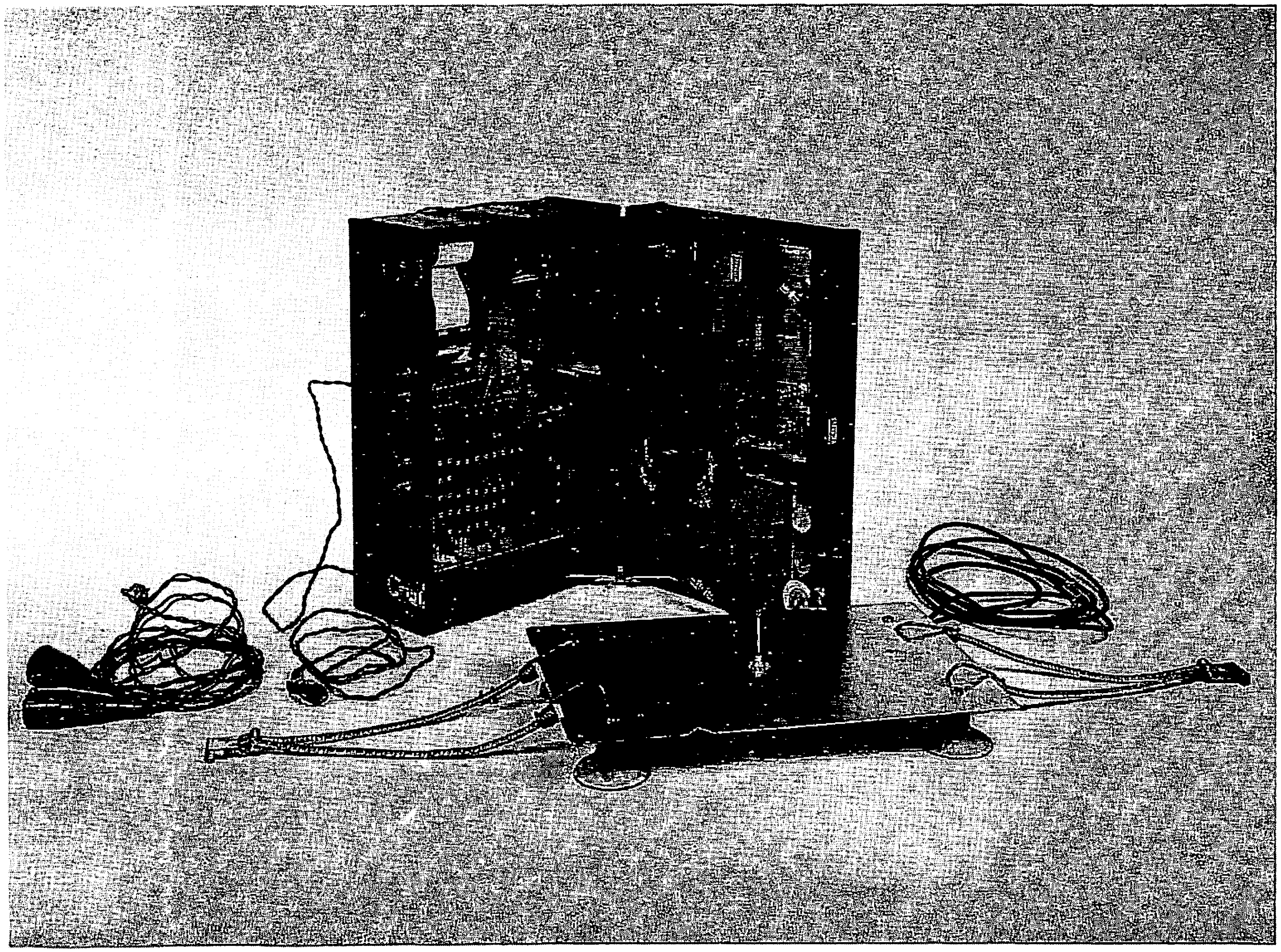

FIGURE 2-2. EQUIPMENT SHOWN WITH TRANSPONDER ANTENNA AND GROUND PLANE REMOVED

connection, remained in place while the vehicle travelled between test locations. In this way a minimum amount of time was required at each test point since the equipment was ready for data collection when the vehicle arrived at each test point. At both airports, the vehicle was driven by an experienced driver familiar with the airport runway and taxiway system. In addition the test team had VHF communications with ground controllers to request and receive clearances when needed to proceed to specific test points.

The surface interrogation and suppression rate due to each interrogator illuminating the airport surface was measured by taking interrogation counts over time intervals of 0.5 second and sidelobe suppression counts over time intervals of 1.0 seconds. Using this procedure, interrogation counts were made in a 30.5 second period based on data collected for 61 intervals. In general, Airport Surveillance Radar (ASR) interrogators have a scan rate in the order of 4 seconds and Air Route Surveillance Radar (ARSR) interrogators have a scan rate of about 12 seconds. A 30.5 second sample therefore provided for roughly 7 scans of ASR beacon data and 2-3 scans of ARSR data. During the post-test analysis, the strip printer tapes containing 0.5 second counts for each of the 61 intervals recorded were examined for periodicity of interrogation counts to determine the number of ASR and ARSR beacon interrogators illuminating the field.

The I^2SLS counts measured over time intervals of 1.0 second provided data relative to the suppression rates of surface transponders, and were correlated with interrogation counts and known PRFs for interrogators in the vicinity of the airport. This provided an additional aid in evaluating the surface interrogation environment.

Total counts of the number of interrogation and I^2SLS events during the 30.5 second data collection period also were printed on the paper tapes. In addition, another sample was collected using a 1.0 second sampling rate to measure total suppression and interrogation counts. Light emitting diodes (LED) were used to indicate total counts over the 61 second test period rather than the paper tape readout.

Although original test points were located directly on runway and taxiway surfaces and would have required the test vehicle to be parked at these locations for periods of five to ten minutes, interference with normal airport surface operations was effectively eliminated by parking the vehicle on access roads and grass areas adjacent to test points. Thus test points in Figures 3-1 and 3-4 represent only approximate locations where measurements were made. In this manner, the performance of these tests did not obstruct the normal flow of surface traffic and conversely surface traffic did not impede the collection of data.

Data Recording Requirements

In the test vehicle, a record (log) of all significant events which occurred during the test was maintained. This log included the following types of data:

- Test point number
- Date
- Time-of-day
- Run number
- Average interrogation and I^2SLS counts for each run
- Comments such as equipment malfunctions and difficulties observed.

It also was a required procedure that each paper tape produced by the test equipment was annotated with the following data:

- Test point number
- Time-of-day
- Interrogation or I^2SLS data
- Time interval used to collect data
- Run number at each location.

3. DATA ANALYSIS

3.1 GENERAL APPROACH

The equipment used to collect the data was different than that used in earlier tests (see References 2 and 3), but provided the means for collecting data with greater precision than that previously obtained. These data included not only the average surface interrogation rates similar to those obtained at Logan and Atlantic City airports but also individual bursts of interrogations as each radar scanned the airport surface. These data were useful in determining how many interrogators actually illuminated the airport surface. Individual interrogation bursts were analyzed to assess the effective interrogation beamwidth of individual interrogators. This provided a means to discriminate between interrogations from ASR beacons and ARSR beacons. Bursts also were examined for periodicities equal to scan rates of nearby interrogators. This helped to develop an approximation of the number of interrogators with line-of-sight to the airport surface. This estimate was substantiated by correlating the SLS total count with the sum of the PRF's for nearby interrogators.

Once the analysis had established the number of interrogators illuminating the surface, the test data was compared with analytical data. Analytical results on the number of interrogators illuminating each airport surface had been derived by using the known locations of interrogators in the vicinity of each airport and by examining topographical maps to determine those interrogators with probable line-of-sight coverage of the airport surface. This method was suspect because factors such as the limited information on the topographical maps, their date, and unknowns such as recent construction around the airport perimeter which could block or shield the surface from interrogations. In the analysis, peripheral interrogators were assumed to contribute to the surface transponder interrogation rate. The results from this test series established a measure of the validity of predicting surface interrogation rates for any airport based on anything other than a measurement of the surface environment.

Data which have been collected at Logan and Atlantic City Airports (NAFEC) were designed to assess the extent of the interrogation and side lobe suppression of surface vehicle transponders at various airport locations. NAFEC offered the opportunity to examine these effects under various conditions of interrogator population ranging from one to three beacon interrogators. In addition, data were collected during the NAFEC test series for various configurations of ASR and ARSR beacon interrogators. Logan Airport, on the other hand, offered the opportunity for examination of surface interrogation rates at higher surface traffic volumes.

One result of the previous tests was the generation of several interrogation maps of each airport surface showing the surface vehicle interrogation rates at various locations on the airport surface. Since the O'Hare and Los Angeles tests were designed to extend these results and thereby increase the data base, the final step in the analysis was a comparison of data obtained at O'Hare and Los Angeles with data previously obtained at Logan and NAFEC.

3.2 SURFACE INTERROGATION ANALYSIS

Data collection consisted of counting the number of interrogation and SLS events occurring in the instrumented transponder. As previously explained, the types of data collected at each test location were:

a. Interrogation counts at 0.5 seconds using paper tape

b. Total interrogations for 30.5 seconds using paper tape

c. Total I^2SLS counts for 30.5 seconds using paper tape.

d. Total interrogations for 61 seconds using LED

e. Total I^2SLS counts for 61 seconds using LED.

3.2.1 Chicago O'Hare Data

3.2.1.1 Surface Interrogation and SLS Map. Interrogations of the surface transponder occurred in bursts as the O'Hare ASR interrogator scanned the airport. These data have been broken down into the average number of replies per ASR scan and the average replies per second. An interrogation map for the 25 test points showing the replies per second and SLS counts per second is presented in Figure 3-1. Two numbers are shown at each test point. The top number is the number of successful interrogations (replies generated) per second. The bottom number is the number of SLS counts generated per second.

From Figure 3-1 it can be seen that the average surface interrogation rate at O'Hare is very low; generally ranging between 7 and 13 counts per second. This indicates that the only source of surface interrogations was the local O'Hare ASR interrogator. This can be confirmed by observing that the SLS counts which show an average of 408 per second is very close to the average O'Hare PRF of 423 per second. Moreover, the sum of the average interrogation rate (12.8) and the average SLS rate (408) is seen to be 421 per second versus the known PRF of 423 per second. This provides a better than 98% correlation. A comparison of the O'Hare data with Logan Data reveals that although O'Hare has only a single ASR interrogator, as opposed to

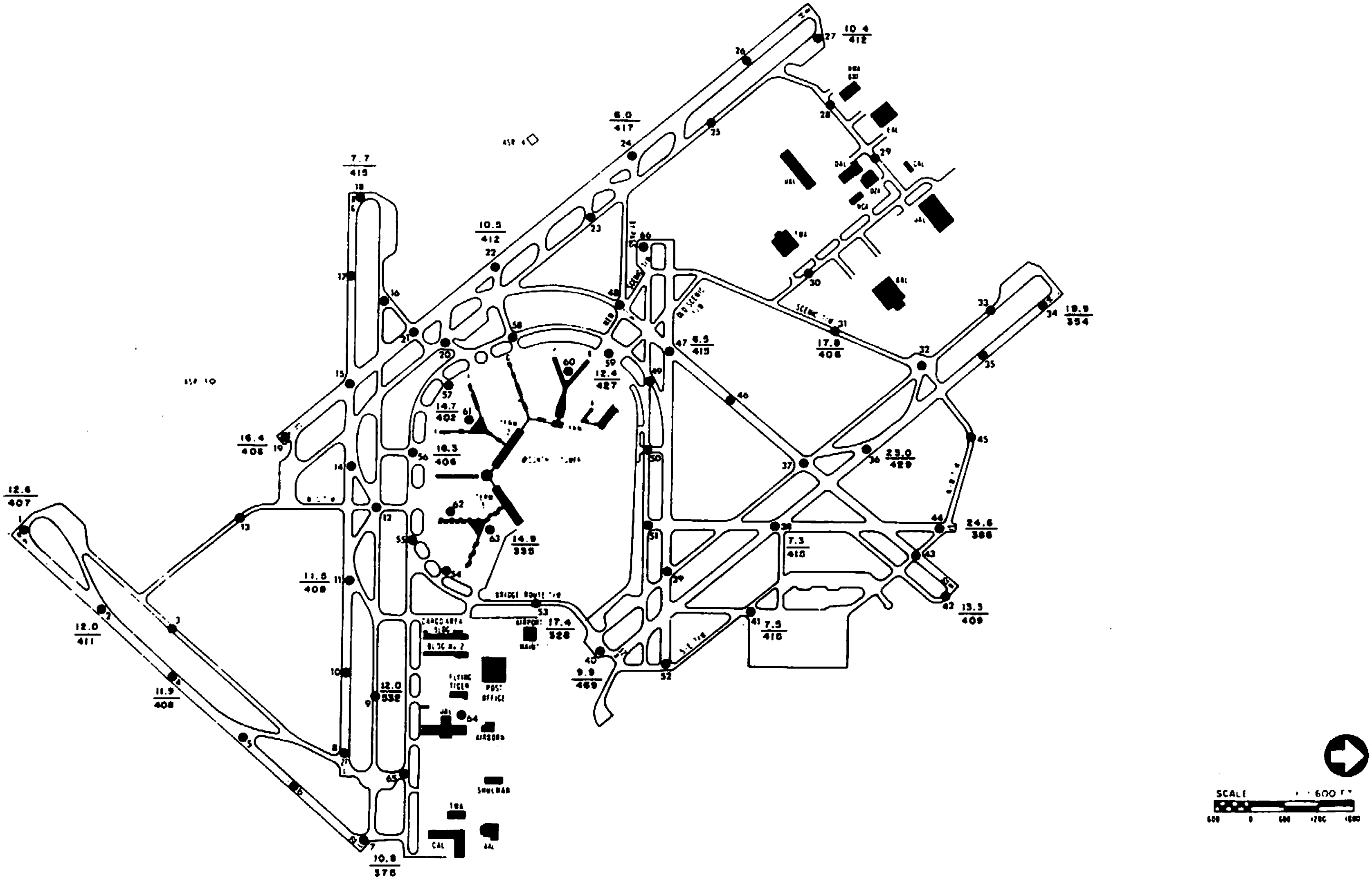

Figure 3-1 SURFACE INTERROGATION MAP FOR CHICAGO O'HARE AIRPORT

the single ASR single ARSR interrogator environment at Logan, the average reply rate for O'Hare is 13, compared to 9.5 for Logan. This can be explained by the fact that the average number of replies per scan triggered by the O'Hare ASR interrogator is somewhat higher than that triggered by the Logan ASR interrogator suggesting that the beamwidth of the O'Hare interrogator is greater than that at Logan. Nevertheless, the reply rate at O'Hare is consistently at a very low value.

3.2.1.2 Effective Interrogation Beamwidth. Figure 3-2 shows a typical example of the temporal distribution of replies triggered from the surface transponder. Replies are seen to occur in bursts of 40 to 50 at periodic intervals of approximately 4.5 seconds. This coincides very well with the O'Hare scan rate of 4.62 seconds. The average number of replies per scan is 40 which is considerably larger than the 18.5 per scan previously measured at Logan. The differences between these two values must be regarded with some reservations because the reply per scan data for Logan was inferred based upon total reply counts measured over 70 scans whereas a high sampling rate approach was employed at O'Hare. Nevertheless, the average reply rate has been shown to be slightly higher for O'Hare. Hence there is a great likelihood that the reply per scan counts are, in fact, higher for O'Hare than Logan.

3.2.1.3 Number of Interrogators. Examination of Figure 3-2 clearly shows that only one interrogator is triggering replies since only one set of interrogation bursts is present with a periodic rate of 4.5 seconds and essentially no interrogations are present between these bursts. Thus, it can be concluded that only the local O'Hare ASR interrogator is successful in triggering surface transponder replies.

In the previous analytical study which was performed to provide data on the number of interrogators within line-of-sight to the O'Hare airport surface, vertical contour maps were constructed for each interrogator in the vicinity of the airport. Those interrogators with an unobstructed view (based on available information) of the airport were then assumed to contribute to surface interrogation, provided, of course, that the interrogator was active at the time surface interrogation data were collected. The results of this study indicated that there were 12 interrogators within 25 nmi of O'Hare and that of these 12 interrogators, 8 probably had line-of-sight coverage of the O'Hare surface. This is not substantiated by the results which show that only one interrogator actively interrogates surface transponders. It is possible that some of the 8 interrogators were not operational while surface measurements were being made. However, as was indicated in Section II, test data were collected on two successive days and for several time periods. Thus, it seems reasonable to conclude that

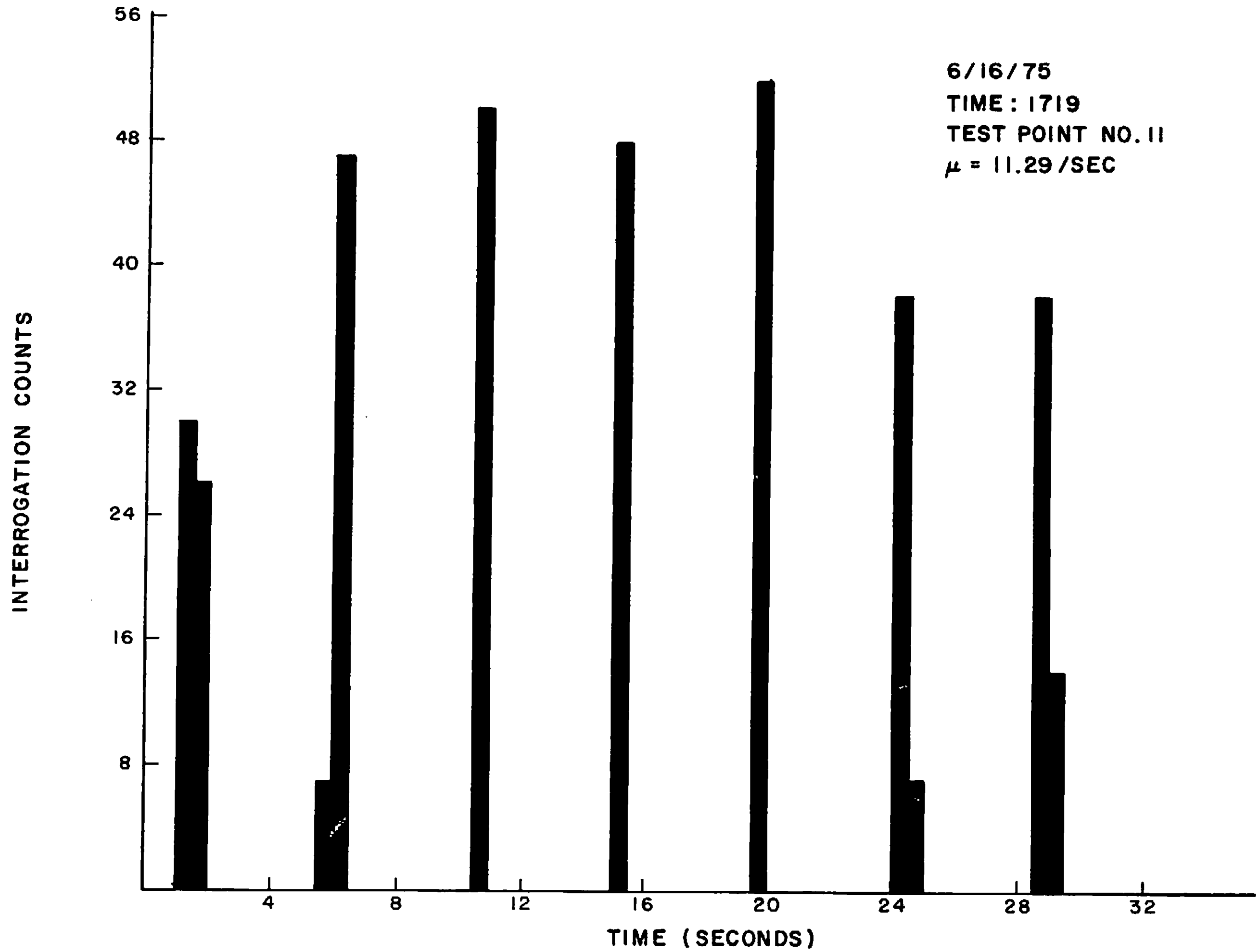

Figure 3-2 TYPICAL INTERROGATION HISTOGRAM FOR O'HARE AIRPORT

the nominal surface interrogation environment at O'Hare is composed of a single ASR interrogator. Furthermore, based on these results, the use of topographical maps and known interrogator locations as a means for estimating the surface interrogation environment at a given airport does not appear to be reliable. In fact, the examination of topographical maps indicated that the McCook ARSR located approximately 10.5 nmi southwest of the airport would have line-of-sight coverage of the airport surface and thus contribute to the surface interrogation environment. Since this interrogator was known to be operational at all times, but was not observed in the test data, it must be concluded that the interrogator does not radiate energy to the airport surface. Once again, this can be accounted for by the many additional variables such as man-made obstructions, antenna patterns, etc., that were not taken into account in the analytical studies.

Finally, on one occasion there seemed to be a second interrogator triggering surface replies. These data are shown in Figure 3-3. In the histogram, the O'Hare ASR interrogations are still present at a 4.5 second periodicity, but now additional replies are generated at a periodicity of approximately 10 seconds. These interrogations may have come from the McCook ARSR interrogator or possibly from a nearby military installation. In any event these additional interrogations were observed only on this one occasion.

3.2.2 Los Angeles International Data

3.2.2.1 Surface Interrogation and SLS Map. The same analysis technique previously described in Section 3.2.1 for the O'Hare data was also used for the Los Angeles data. An interrogation map of the replies per second and SLS gates generated per second is shown in Figure 3-4 for each of the 16 test points. Here again, the top number is the number of successful interrogations (replies generated) per second, while the bottom number is the number of SLS gates generated per second.

Figure 3-4 shows that the average interrogation rate is somewhat higher than O'Hare but, nevertheless, still relatively low. Typically, the interrogation rate was between 20 to 30 replies per second. Subsequent analysis showed that surface interrogations at Los Angeles were caused principally by two local ASR interrogators and one ARSR interrogator. Although these three interrogators can be identified in the data, the SLS rate is only 767 per second, which is roughly equivalent to the sum of the average PRF for both local ASR interrogators. Thus, the I^2SLS of the ARSR interrogator is not actively suppressing surface transponders at Los Angeles even though this interrogator is triggering surface transponder replies.

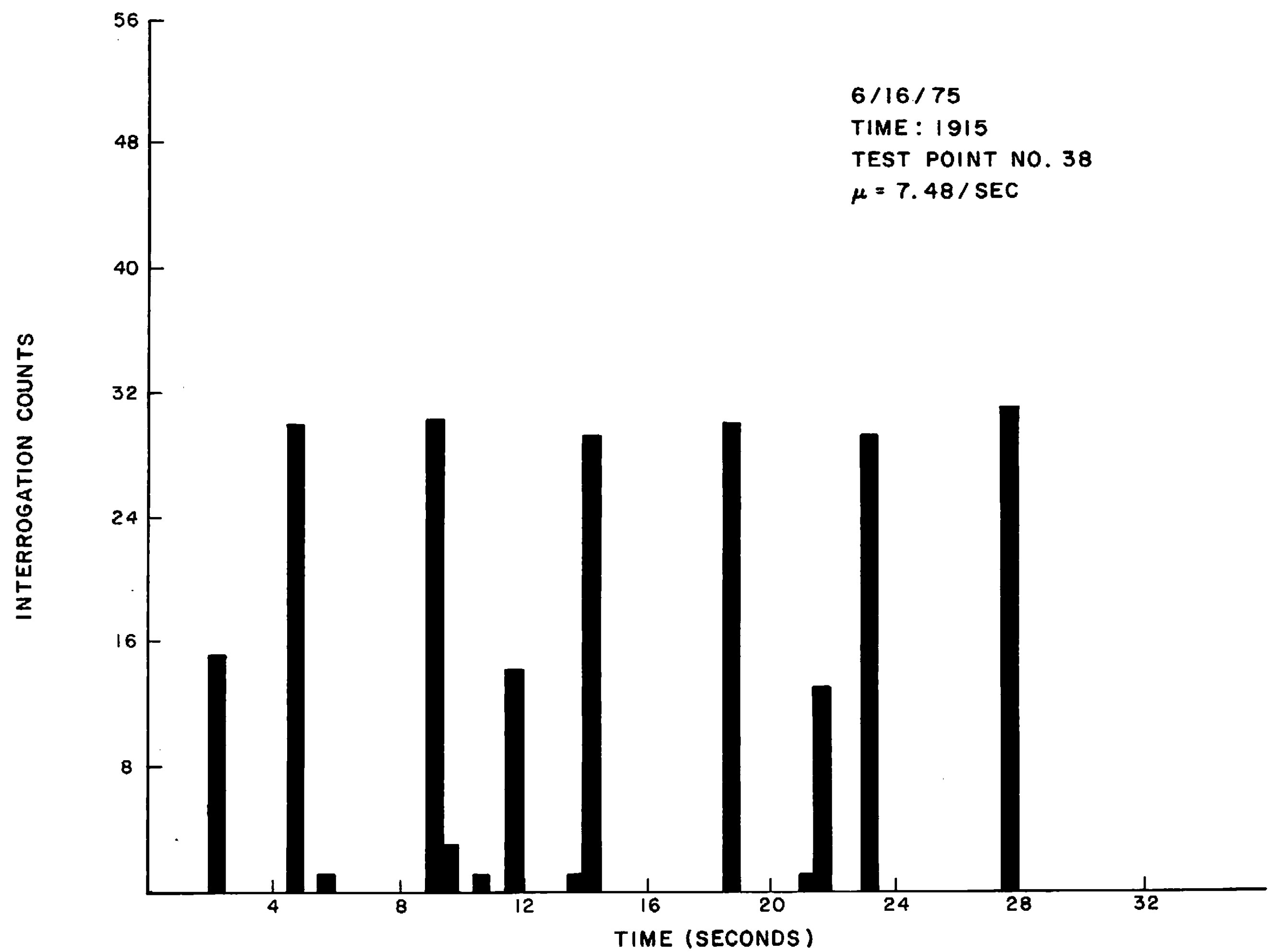

Figure 3-3 INTERROGATION HISTOGRAM FOR O'HARE AIRPORT SHOWING BURST FROM TWO INTERROGATORS

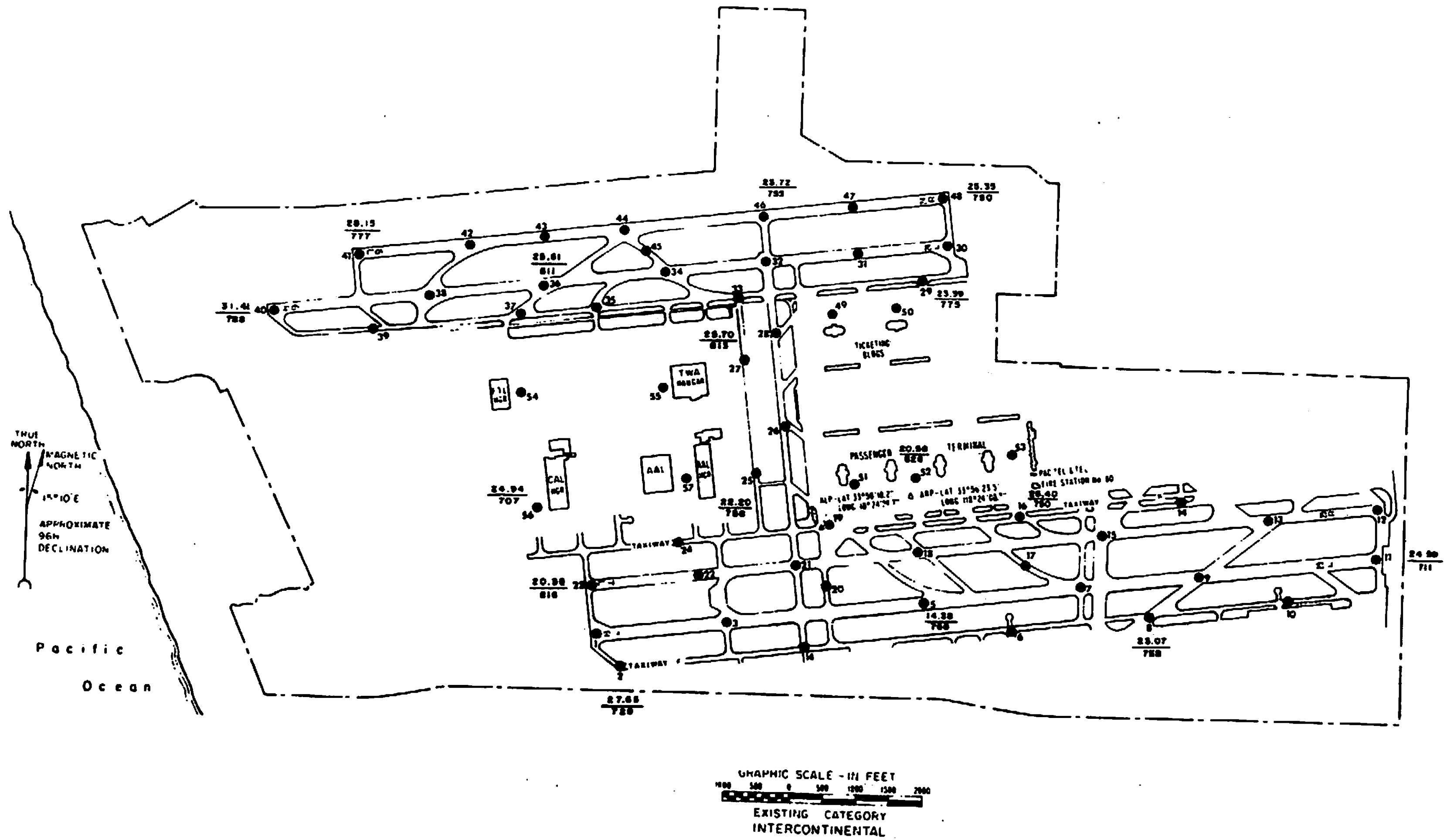

Figure 3-4 SURFACE INTERROGATION MAP FOR LOS ANGELES INTERNATIONAL AIRPORT

3.2.2.2 Effective Interrogation Beamwidth. Figure 3-5 shows a typical example of the temporal distribution of replies triggered from the surface transponder at LAX. Three sets of interrogation bursts are evident. Two sets have periodicities of roughly 4.8 seconds corresponding to the scan rates of the Los Angeles ASR-7 and ASR-4 beacon interrogators. It was not possible with this test data to determine the particular interrogator responsible for each set of interrogation bursts. The third set has a periodicity of 12 seconds and is in good agreement with the 12 second scan rate of the ARSR interrogator located approximately 5 miles southwest of the airport.

Examination of the number of interrogations in each burst reveals that for both ASR interrogators there are about 32 interrogations per scan. This is somewhat less than the O'Hare ASR interrogator which triggered around 48 replies per scan, but it is more than the 18.5 per scan generated by the Logan ASR interrogator. The ARSR interrogator caused 70 to 80 replies per scan and seems to be consistent with the beamwidth and scan rate for this radar. Between interrogation bursts the environment was relatively clean. The data presented in Figure 3-5 was collected at 0120 local time. It is interesting to observe that data collected at the same test location at 1123 the following morning show nearly identical results. Nevertheless, the distribution of data from test point to test point shows more variations than that previously experienced at either O'Hare or Logan. For example, the average reply rate was seen to vary from a high of 53 per second at test point 7 to a low of 19 at test point 14 (see Appendix C). This can be attributed to the numerous buildings on the airport surface which for various locations can cause shielding for either the ASR-7 or ASR-4 interrogators.

3.2.2.3 Number of Interrogators. The surface interrogation environment at Los Angeles as depicted in Figure 3-5 is due principally to three interrogators: 2 ASR interrogators and one ARSR interrogator. Analytical studies indicated that 19 interrogators are within 25 nmi of LAX, and of these, 10 had line-of-sight to the airport surface. This again points out the hazards in attempting to use analytical techniques to predict the surface interrogation environment at airports.

Although the nominal environment at Los Angeles was seen to be three interrogators, this was not always the case. The first test period at Los Angeles from 1600 to 2051 on June 16 provided data which indicated very high interrogation rates in the order of 80 to 90 per second and for every test point with the exception of test location number 8. A typical example of the data collected during this period is shown in Figure 3-6 for test location 25. It can be seen that interrogation bursts for the three radars are present,

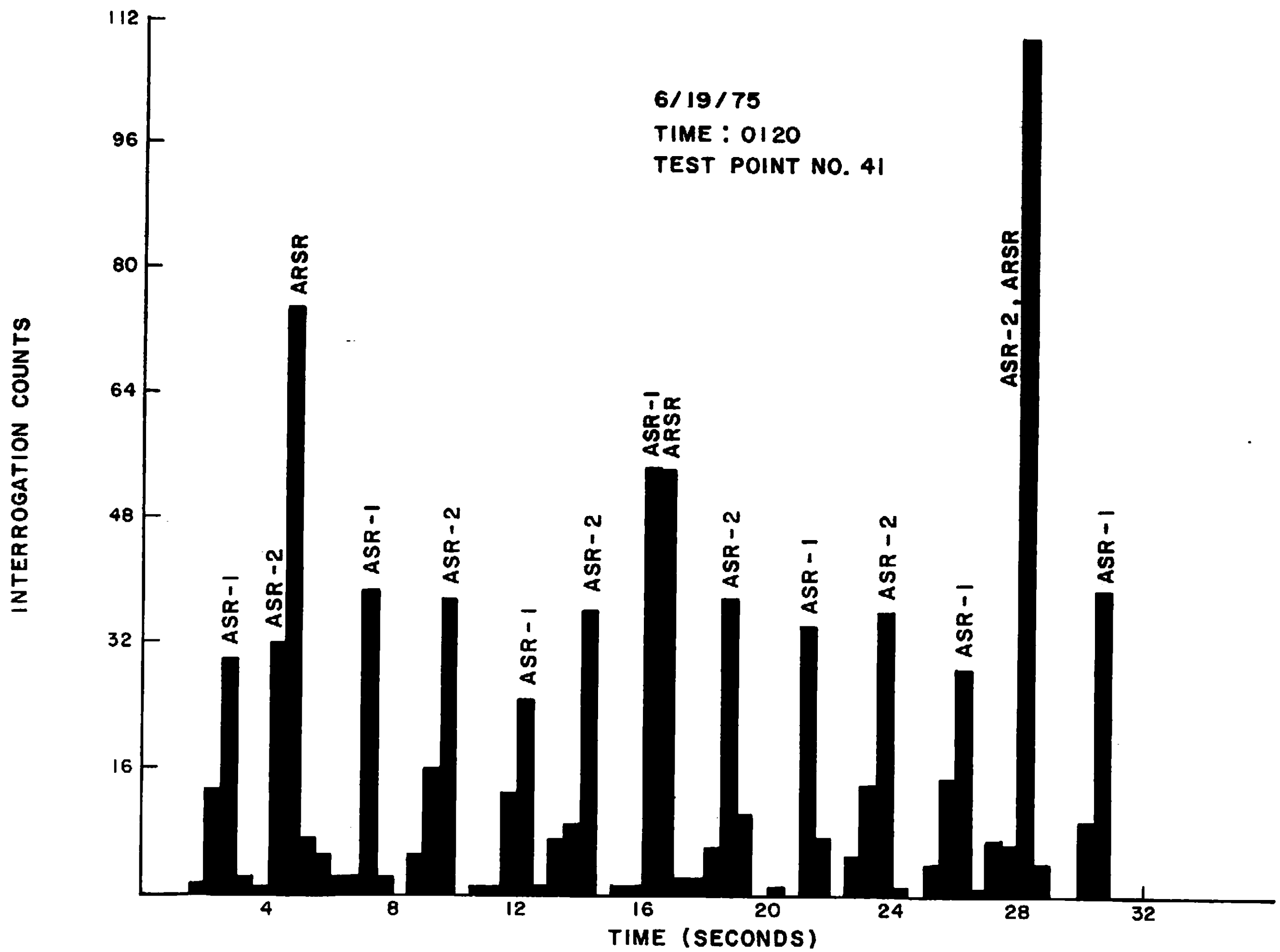

Figure 3-5 TYPICAL INTERROGATION HISTOGRAM FOR LOS ANGELES INTERNATIONAL AIRPORT

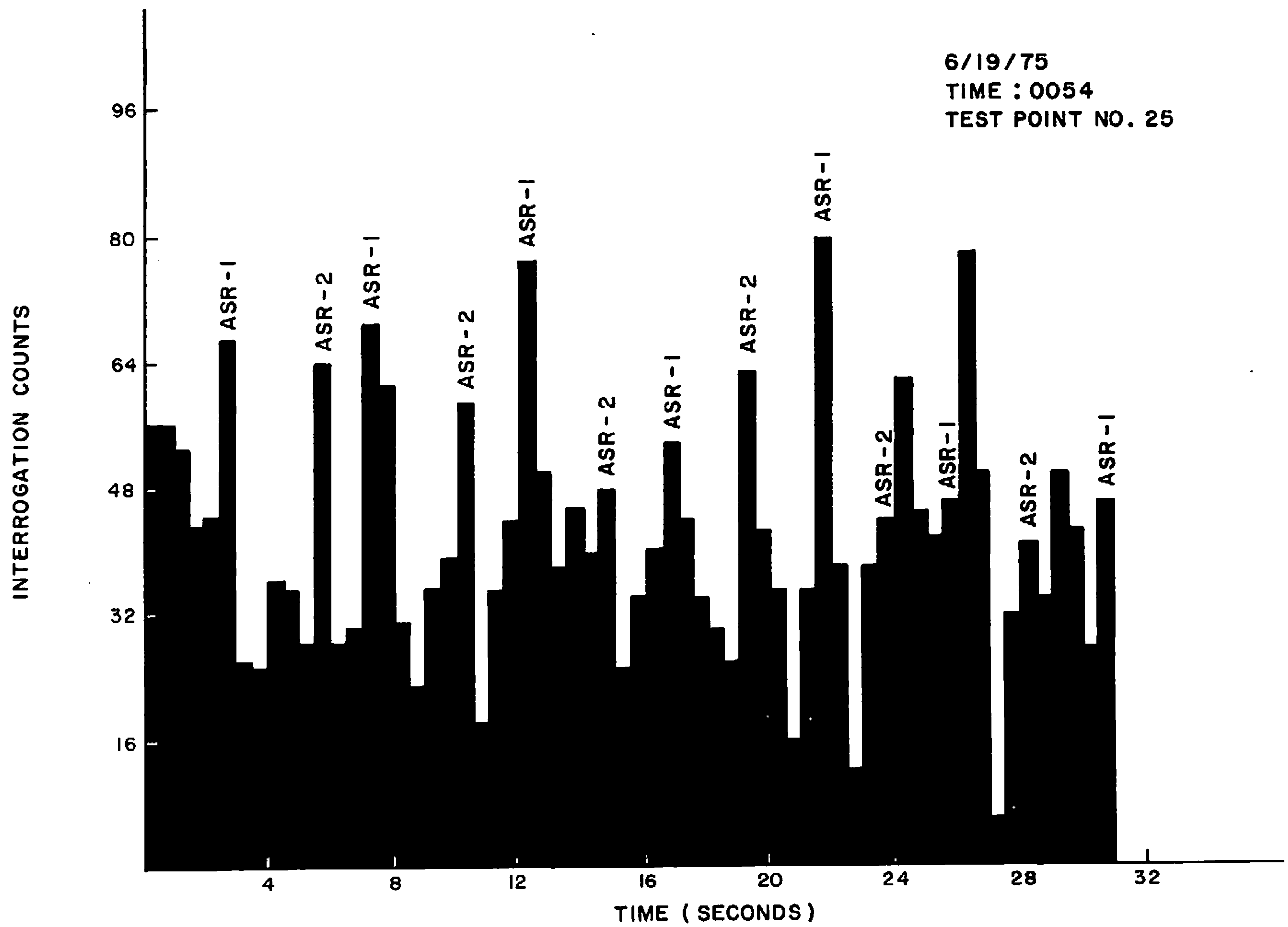

Figure 3-6 INTERROGATION HISTOGRAM FOR LOS ANGELES INTERNATIONAL AIRPORT SHOWING PHANTOM INTERROGATIONS

however, the clean environment between the bursts is now filled in by additional interrogations. Moreover, the replies per scan now appear to be larger than those indicated by Figure 3-5. Thus, it appears that the entire data is biased by 20 to 30 additional interrogations per second. This phenomenon could be caused by some form of omni interrogation signal operating at this low PRF.

At the outset of the second test period from 0020 to 0300 on June 19, the same omni interrogation effect was encountered. At 0100, however, the environment immediately changed; the omni interrogations disappeared and data similar to that shown in Figure 3-5 were obtained for the remainder of the test period. These values are shown in Appendix C. The dramatic change in the environment suggests that precisely at 0100 an interrogator was turned off thereby reducing the average reply rate from 80 per second to 24 per second. Time did not permit identification or location of the omni interrogator, however, it did remain off during the third and final test period on the morning of June 19.

3.3 COMPOSITE DATA SUMMARY

Table 3-1 provides a summary of the interrogation and SLS rates measured for the Logan, NAFEC, O'Hare, and Los Angeles airports. In each case the number of ASR and ARSR interrogators triggering surface transponder replies has been indicated. The average interrogation and SLS rates for each airport are listed with their respective standard deviations. These data were obtained using values measured at each airport's test locations.

The data in Table 3-1 show that the interrogation environments even for Los Angeles, which has often been suggested as a severe surface interrogation environment, are in fact very low when compared to airborne interrogation rates. In addition, it can be seen that the interrogation rates are very consistent over each airport as indicated by the low standard deviations of the interrogation rates. Thus, the interrogation rate for a surface transponder does not show large variations from one airport surface location to another. The average SLS rate is seen to be consistent with the number of interrogators triggering replies with the exception that those ARSR interrogators located at distances of 3 or 4 miles from an airport do not actively suppress surface transponders.

3.4 AVAILABILITY OF TIME FOR ASTC USE

To prevent mutual interference between ATCRBS and ASTC systems, the ASTC system is being designed to synchronize ASTC interrogations to occur only in the dead-time of the local ATCRBS equipment. Should

TABLE 3-1

SURFACE INTERROGATION DATA SUMMARY

AIRPORT	DATE	NUMBER OF TEST POINTS	NUMBER OF INTERROGATORS		AVG. INTERR. RATE PER SEC.	STD. DEV. OF INTERR. RATE	AVG. SLS RATE PER SEC.	STD. DEV. OF SLS RATE
			ASR	ARSR				
Logan	Dec. 1973	52	1	1	9.50	2.69	777	35
NAFEC	March 1974	45	2	1	13.18	2.53	753	5
O'Hare	June 1975	25	1	0	13.12	4.87	408	38
Los Angeles	June 1975	16	2	1	24.21	8.83	767	36

synchronization be required with additional sites, the available time for active ASTC use would be reduced resulting in a possible reduction in the ASTC update rate. As can be seen from Table 3-1, only one interrogator illuminates the O'Hare airport surface and as such synchronization would be required only to the local O'Hare ASR beacon interrogator. This synchronization would not affect the ASTC update since the system is being designed with this requirement in mind.

The environment at Los Angeles is somewhat more severe than that at O'Hare since there are 2 ASR interrogators and one ARSR interrogator illuminating the surface. It is unlikely that synchronization will be required with the ARSR since mutual interference with this site should be low due to its relatively remote location. Nevertheless there remains 2 ASR interrogators to which the ASTC system may have to be synchronized. If this is the case, and assuming the 2 ASRs are not synchronized to each other but are running at approximately the same PRF, the available time for ASTC use may be reduced by as much as one-half. This should not severely impact system performance, however, because sufficient margin has been allowed to provide necessary update rates even for this reduced ASTC PRF requirement. For example, the ASTC system is designed to provide a maximum of 14 interrogations per ATCRBS dead-time. If it is required to synchronize to a second ASR, only 7 ASTC interrogations may be available per equivalent ATCRBS dead-time. Initial estimates suggest, however, that only an average of 3 or 4 ASTC interrogations per dead time may actually be necessary to provide the required update rates. It therefore does not appear that the presence of 2 ASR interrogators at Los Angeles will in any way impact on the implementation of an ATCRBS-based ASTC system. Furthermore, it is not certain at this time whether it will even be necessary to synchronize to both radars.

4. CONCLUSIONS

The analysis and data presented in this report support the following specific statements concerning the surface interrogation environment at Chicago O'Hare and Los Angeles airports.

a. Results show only a single ASR interrogator at O'Hare triggering surface transponder replies. The average surface interrogation rate at O'Hare is 12.82 per second which is only slightly higher than the 9.5 per second measured at Logan airport. It is recommended that surface interrogation data be re-measured at Logan using the new portable equipment.

b. Results show that two ASR and one ARSR interrogators trigger surface transponder replies at Los Angeles. The average surface interrogation rate at Los Angeles is 24.21 per second which is considerably higher than Logan and O'Hare but, nevertheless, is much less than either initial expectations or typical airborne interrogation rates.

c. Although the nominal environment at Los Angeles consists of three interrogators as identified by 2 above, additional surface interrogations can occur from an unknown source. Extraneous interrogations were present during a portion of the tests at Los Angeles and appeared to be from an omnidirectional interrogator using a PRF between 30 and 40 per second.

d. Interrogation rates at both Chicago O'Hare and Los Angeles are very uniform for the respective airport surfaces, with little variation among the data collected for various surface locations.

e. Analysis of data indicates that sufficient time will be available for ASTC use at both Chicago O'Hare and Los Angeles airports. The ASTC system will have to be synchronized to only one ASR interrogator at O'Hare and at most two ASR interrogators at Los Angeles.

f. Data obtained from these tests have shown that the use of topographical maps is not a reliable technique for estimating the surface transponder interrogation environment at airports since analytical results can grossly overestimate the interrogation environment. These tests have clearly demonstrated the utility of field test data in making such determinations.

APPENDIX A

SPECIFICATIONS FOR PORTABLE INTERROGATION AND SLS MEASUREMENT EQUIPMENT

COUNTER ELECTRONICS

INPUT

Switch selectable for either interrogation or SLS suppression counts.

OUTPUT

Interrogation or SLS counts (depends on input switch selector setting) occurring during each sample interval. Data are output for each of 61 sample intervals. Total count is output in interval 62 and total SLS or interrogation count is output in interval 63. For example, if interrogation counts are output in each of the 61 intervals, then total interrogation count will appear in interval 62 and total SLS count will appear in interval 63 and vice versa.

OPERATOR FEATURES

Start - Manual by push button action

Stop - Automatic at end of 61 sample intervals

Reset - (a) Automatic at end of 61 sample intervals
(b) Manual by push button action at any time during data collection period

Readout - (a) Light emitting diode (LED) readout
(b) On-line paper tape printout

SAMPLE INTERVAL TIME PERIOD

Switch selectable in increments of 0.1 seconds from 0.1 seconds to 10.0 seconds.

DATA COLLECTION PERIOD

Dependent on sample interval selected. This period can range from a minimum of 6.1 seconds to a maximum of 610 seconds.

MEMORY

63 registers each containing 4 decimal digits used for storing data for LED readout at the completion of each data collection period.

PRINTER DISPLAY

a. On-line printouts of counts measured in each of the 61 sample intervals, plus total count in intervals 62 and 63.

b. Six column printout; four data columns plus two columns for interval number. Each column is one decimal digit.

c. Printer usable with sample interval time periods greater than 0.4 seconds. Printer not usable below 0.4 seconds due to speed limitations.

READOUT DISPLAY

a. Four digit LED readout for data plus two digit LED readout for memory location.

b. Readout of each of the 61 memory locations by sequence using push button.

c. Readout of memory location 62 by single push button action.

POWER REQUIREMENTS

12 volt supply with connection to either the vehicle cigarette lighter or directly to the battery.

ANTENNA

Stub type mounted on aluminum ground plane. Antenna assembly fastens to the roof of vehicle by two straps which are clipped over the rain gutter.

PACKAGING

Case measuring 18 inches by 12 inches by 8 inches.

TRANSPONDER

TYPE

KING KT-76

SENSITIVITY

-72 dbm

POWER OUTPUT

200 watts

POWER REQUIREMENTS

14 VDC, 1.3 Amps.

OUTPUTS

Interrogation	- Single pulse output whenever a mode A or mode C interrogation is successfully decoded.
Sidelobe	- Single pulse output whenever P_1 and P_2 pulses meeting suppression requirements are successfully decoded.
Transmitter	- Switch selectable for either standby or operative. This function is independent of interrogation or SLS outputs.
Receiver	- Output of transponder video available for viewing on an oscilloscope.

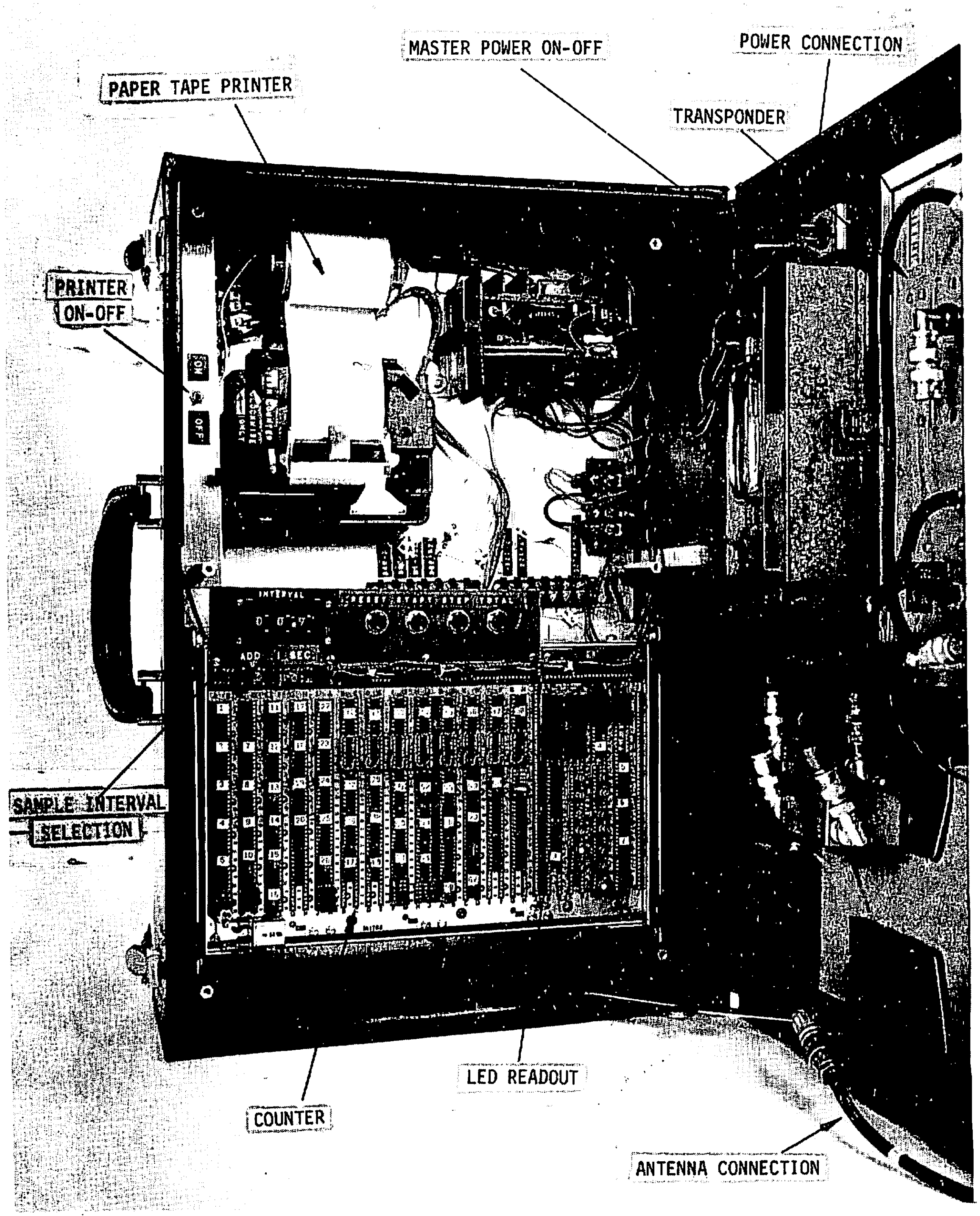

Figure A-1. Portable Interrogation and SLS Measuring Equipment

APPENDIX B

CHICAGO O'HARE DATA

TEST PERIOD I, JUNE 16

Test Point	Time-of-Day	Average Interr Rate per Second	Average SLS Rate per Second
1	1650	12.06	408
3	1703	13.33	405
4	1712	11.87	359
6	1721	11.29	411
8	1727	5.97	417
7	1740	16.39	406
9	1805	9.15	414
11	1816	10.78	412
13	1827	25.13	359
14	1857	15.93	375
15	1910	7.59	416
18	1920	15.35	416
16	1938	9.37	561
22	1958	9.45	413
21	2009	6.35	416
25	2020	14.07	406
24	2028	16.34	406
23	2033	14.99	335
4A	2045	11.64	485
		TEST PERIOD II, JUNE 17	
1	0106	13.30	406
3	0115	10.61	412
4	0121	9.71	392
6	0128	11.68	407
7	0136	9.26	413

APPENDIX B (Concluded)

TEST PERIOD II, JUNE 17 (Concluded)

Test Point	Time-of-Day	Average Interr Rate per Second	Average SLS Rate per Second
8	0145	9.50	413
9	0150	12.03	411
11	0157	10.10	412
13	0203	14.73	349
14	0210	30.18	483
15	0217	7.08	415
18	0223	11.34	405
16	0225	10.45	378
21	0230	6.77	415
		TEST PERIOD III, JUNE 17	
10	1141	6.00	417
2	1145	12.00	411
4	1149	10.79	381
5	1156	12.00	532
7	1203	8.49	419
11	1215	9.48	413
12	1223	17.80	406
14	1228	44.62	402
17	1236	7.46	415
19	1243	24.61	386
20	1253	17.40	328
22	1307	12.47	427

APPENDIX C

LOS ANGELES DATA

TEST PERIOD I, JUNE 18

Test Point	Time-of-Day	Average Interr Rate per Second	Average SLS Rate per Second
3	1600	20.43	751
2	1610	35.98	976
1	1620	56.33	928
6	1625	94.20	758
7	1636	98.85	746
10	1646	27.61	746
11	1654	81.84	861
12	1702	88.36	726
13	1711	103.60	772
14	1720	89.13	655
5	1732	83.33	690
4	1740	105.92	729

TEST PERIOD II, JUNE 18

3	1836	21.67	739
2	1843	52.61	747
1	1848	73.16	756
6	1942	90.72	713
16	1947	88.28	738
7	1950	91.74	781
8	1954	101.34	778
10	1958	20.07	754
11	2003	79.72	759
12	2007	78.62	791

APPENDIX C (Continued)

TEST PERIOD II, JUNE 18 (Continued)

Test Point	Time-of-Day	Average Interr Rate per Second	Average SLS Rate per Second
13	2013	84.10	754
14	2019	97.11	756
9	2024	24.54	780
15	2038	108.70	739
5	2043	98.11	747
4	2051	82.54	718

TEST PERIOD III, JUNE 19

Test Point	Time-of-Day	Average Interr Rate per Second	Average SLS Rate per Second
3	0020	37.31	704
2	0028	21.48	727
1	0037	86.57	786
6	0050	83.18	834
7	0054	83.25	776
8	0058	94.33	782
8A	0106	25.70	813
10	0109	26.39	962
11	0115	28.90	841
12	0120	27.27	862
13	0135	25.08	748
14	0140	21.57	755
9	0145	20.57	750
5	0152	26.12	748
15	0158	21.77	886
4	0205	25.67	677
3	0215	25.80	759
2	0218	8.90	762
1	0225	18.82	754

APPENDIX C (Concluded)

TEST PERIOD III, JUNE 19 (Concluded)

Test Point	Time-of-Day	Average Interr Rate per Second	Average SLS Rate per Second
6	0233	20.12	868
16	0236	22.52	710
7	0245	20.89	763

TEST PERIOD IV, JUNE 19

Test Point	Time-of-Day	Average Interr Rate per Second	Average SLS Rate per Second
3	1041	20.34	757
2	1047	19.85	750
1	1052	36.47	704
6	1056	20.58	764
16	1101	29.36	705
7	1106	23.50	754
8	1110	54.48	725
10	1116	24.62	660
11	1119	33.91	735
12	1123	29.02	693
13	1130	22.35	762
14	1135	29.13	746
9	1140	26.21	801
15	1149	19.38	767
5	1157	24.68	752
4	1205	23.51	746

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