(NASA-CR-168062) MOBILE RADIO ALTERNATIVE SYSTEMS STUDY TRAFFIC MODEL (General Electric Co.) 60 p HC A04/MF A01 CSCL 17B N84-10402

Unclas
G3/32 36099

MOBILE RADIO ALTERNATIVE SYSTEMS STUDY

Volume I

TRAFFIC MODEL

JUNE 1983

PREPARED FOR

NASA-LEWIS RESEARCH CENTER
CLEVELAND, OHIO

CONTRACT NAS3-23244

General Electric Company
Corporate Research and Development
Schenectady, New York

William T. Tucker
Roy E. Anderson

PREFACE

The Mobile Radio Alternatives Systems Study addressed the needs for mobile communications in the non-urban areas of the United States between the present and the year 2000, and considered two ways of fulfilling the needs: by terrestrial systems only and by a combination of terrestrial and satellite systems. Results of the study are presented in three volumes.

Volume I defines the functions and services that will be needed, and presents estimates of the mobile radio traffic that will be generated and the geographical distribution of the traffic.

Volume II describes and analyzes the performance and cost of terrestrial systems concepts for meeting the needs described in Volume I.

Volume III describes and analyzes the performance and cost of satellite-aided mobile radio systems concepts designed to serve that portion of the needs that may not be fulfilled by terrestrial systems. The volume includes a discussion of regulatory and institutional aspects of satellite land mobile communications.

A companion report, "Non-Urban Mobile Radio Demand Forecast," Final Report, June 25, 1982, was prepared by ECOsystems International Incorporated under a subcontract to the study. The report is available from the National Technical Information Service, Springfield, Virginia, 22161.

ACKNOWLEDGMENTS

Many persons participated in the Mobile Radio Alternatives Systems Study, or contributed directly to its performance. The efforts of the following persons are deeply appreciated:

General Electric Corporate Research and Development:

Roy E. Anderson
Howard L. Lester
William T. Tucker
Carolyn B. Morgan
Richard L. Frey
Richard J. Herbs

General Electric Space Division

John D. Kiesling
Charles C. Allen

General Electric Mobile Communications Division

Norman S. Cromwell
Ronald C. Sisson
John A. Mallen
Thomas R. Lusk

ECOsystems International

Peter A. Castruccio
James Cooper

Loats Associates

Harry Loats
Donald G. Lloyd

Comsat General Corporation

Frederick L. Hofmann

Telocator of America

Thomas Lamoureaux

United States Independent Telephone Association

Charles Demek

The staff at NASA-Lewis Research Center provided invaluable guidance and support throughout the study. Their friendly and cooperative participation is deeply appreciated. Staff members most closely associated with the project are:

Steven M. Stevenson
Jack A. Salzman
Bruce Leroy

TABLE OF CONTENTS

PRECEDING PAGE BLANK NOT FILMED

LIST OF ILLUSTRATIONS

LIST OF TABLES

Section 1

INTRODUCTION

The NASA-sponsored Mobile Radio Alternative Systems Study, Contract NAS3-23244, included the following tasks:

- Define traffic demand for mobile radio services in the non-urban areas of the United States from the present to the year 2000.
- Describe concepts for terrestrial systems that could meet the demand.
- Describe concepts for systems that use satellites in non-urban areas and terrestrial systems in urban areas (hybrid systems).
- Identify the regulatory and institutional aspects of the hybrid systems.

This report describes the results of the first task, the definition of the traffic demand. Consideration is limited to the non-urban areas of the United States with emphasis on the contiguous states. There is a large and growing demand for mobile radio services in non-urban areas, and within that demand are requirements for services and functions that are not likely to be met by a continuation of the traditional growth of terrestrial mobile radio systems.

Satellites offer a technical approach to satisfying the service and functional requirements. New terrestrial systems also offer means to improve services in non-urban areas; for example, mobile radio telephones that are compatible with the urban cellular systems may be installed in many mid-size and small communities.

The development of terrestrial and satellite systems concepts, and their evaluation, require definitions of potential market size and growth, identification of needed functions, geographical distribution of the market, and user willingness to pay for the services.

The traffic demand study identified a large market for mobile radio services that require long-range communications and functions that have not been readily available in the past. The geographical distribution of the demand is critically dependent on the population density that is assumed for the definition of the non-urban market. For example, if the mobile radio telephone market area is defined as those counties with population densities no greater than 20 persons per square mile, the demand is predominantly in the Western states. If the market is defined as counties that are not Standard Metropolitan Statistical Areas, the demand is greatest in the Midwestern and Eastern states. In order to provide a basis for satellite concepts the study considered a range of population densities and examined the geographical distribution for each of them. Separate estimates were made for each of the market categories.

Most of the data for the market analyses and many of the procedures for the analyses were provided by ECOsystems International, Inc. under a subcontract to this study with General Electric. The ECOsystems portion of the study is presented in a separate report:

"Non-Urban Mobile Radio Demand Forecast"
Final Report, June 25, 1982
Prepared for
General Electric Company, Schenectady , N.Y. 12301
Prepared by
ECOsystems International Inc., P.O. Box 225
Gambrills, Maryland, 21054

This report is available from the National Technical Information Service, Springfield, Virginia 22161.

Section 2

MOBILE SERVICES MARKET DEFINITION AND SCOPE

2.1 METHOD OF DEFINING MARKETS

Several market surveys provided a basis for the study. ECOsystems conducted surveys of public service users and business and industrial users of mobile radio. A survey for General Electric by Opinion Research Inc. addressed potential users of mobile radio telephone.

Interviews with representatives of business and industrial mobile radio users were conducted by ECOsystems and General Electric. Most of the interviews with General Elect were initiated by industry representatives, who described needs that are not met by present-day mobile radio technology. ECOsystems also interviewed public service users.

Three market categories were identified as a result of the surveys and interviews.

FCC licensing data were obtained for a significant number of randomly selected counties not in a Standard Metropolitan Statistical Area (SMSA). A computer tape with statistics on all counties was obtained from the Census Bureau. Correlations were found between demographic data on the tape and the licensing data for the randomly selected counties.

The correlations are assumed to hold for all counties of the United States. Based on the correlations, licensing data and demographic data were used to compute the mobile radio usage for each non-SMSA county of the contiguous United States. The usage was defined in terms of the number of users or subscribers and the radio traffic they will generate in ERLANGS.

The geographical distributions were tabulated and plotted by summing the county demands for each state and for each footprint of a postulated 100 beam satellite.

Market penetrations were estimated on the basis of information derived from surveys, interviews, and a literature search. Conservative, likely, and optimistic predictions were made for the years 1990, 1995, and 2000. Quality and price elasticities were estimated on the basis of the surveys and interviews.

The special needs of Alaska and Hawaii were addressed separately from those of the contiguous states.

2.2 MARKET CATEGORIES

The potential market for satellite-aided land mobile radio is divided into three categories:

- New services
- Commercial and public services*
- Cellular compatible mobile radio telephone

The study examined the total potential United States market for the contiguous states within each category. The new services market was estimated for only two sub-segments: the oil and gas industry and the inter-city trucking industry. In a more general study all potential users of the new services would have to be identified and a market survey performed. We believe that the selected sub-segments are two of the most important in terms of their needs and potential revenue. For the new services, the market quantification was made by employ-

* Also termed "private radio" because it is used under the purview of the FCC Private Radio Bureau.

ing ancillary statistics.

The commercial and public services market was determined by sampling FCC records and interviewing randomly selected licensees. A survey would be needed to finalize the potential non-SMSA or rural market.

The estimate of the mobile radio telephone service market was based on surveys made independently of this study. The surveys are referenced in the footnotes of Table 2-4. In order to be consistent with the analyses for the other two market segments, we employed ancillary statistics to quantify the market and used the survey results to assess the plausibility of the analysis.

Simple growth models were employed for all three segments to project the market requirements to the year 2000. The growth rates were taken from ancillary and historical information or were chosen to be consistent with anticipated future trends for the market of interest. The formulation was chosen for its ease of implementation and clear structure. It permits easy performance of "what if" studies. When backed by a market survey, it may yield the best possible quantification of a predicted market. Summaries of the three market segments follow.

2.2.1 New Services Market Scope

New services are herein defined as those for which there are expressed needs but which are not now met by any application of available technology. The functions required to fulfill the needs include voice, alphanumerics (printed messages), data at rates from 300 bits per second to 56 kilobits per second, and automatic surveillance of mobile locations.

The expressions of need were brought to NASA or to General Electric by representives of the industries that have the needs. They are unsolicited expressions of urgent, real needs. Discussions were held with representatives of the oil and gas well services industry and the trucking industry to get their perception of their total industry needs and willingness to pay for the new services. Other industries with expressed needs include mining, railroads, inland waterways, and information services. We present only the results of the discussions with the oil and gas well services industries and trucking industries because they are the most firmly quantified. The other industries are expected to add to the traffic demand and revenue.

The three largest suppliers of oil well services have presented their requirements for voice and data communications from well sites in the contiguous United States and the Gulf of Mexico. Together, the three suppliers provide about 50% of the oil well logging services in those areas. Independently of the oil well services suppliers, two companies that provide communications for oil and gas exploration and drilling described their present attempts to use C-band satellites and Marisat for communications from remote and off shore well sites. Logistic, cost and other problems severely limit the usefulness of those satellites for the application. A satellite designed for land mobile radio use would be superior.

Table 2-1 presents the results of the market analysis for the oil and gas service industry. The footnotes to the table identify the data sources and list the assumptions used in the analysis.

Four trucking companies have independently described needs that could be met by:

- Automatic position surveillance of trailers from a central location
- Automatic transmission of brief sensor data messages from trailers, either triggered by an event at the trailer or by interrogation from the central location

Table 2-1

CAPTURABLE[1] MOBILE RADIO MARKET (MOBILE UNITS) NEW SERVICES

Oil and Gas Industry[2]	1990[4]	(AAGR[5])	1995	(AAGR[5])	2000
Voice (Base of 16002[3])	35736	(3%[6])	41428	(3%[6])	48626
Data (Base of 3629[3])	7288	(3%[6])	8449	(3%[6])	9794

1. Capturable Market—The market for new mobile systems based on their provision of new services at prices comparable to current service charges for inferior or largely nonexistent services.
2. One of two market areas surveyed.
3. The base comes from a study done for NASA by ECOsystems International Inc. titled "Analysis of the Oil and Gas Industry Market for a Land Mobile Communications Satellite Service," January 18, 1982. ECOsystems forecasts a gross market of 28,000 units by 1985. This is equivalent to an average annual growth rate of 15% per year for the period 1981-1985. We employ this gross figure for our computations for the voice demand. However, since there has recently been a slump in drilling activity and most of the data requirements are for logging new wells we have performed a separate analysis for the data requirements. We assume that the average annual growth rate for the number of units is 12% for the period 1981-1985. This rate is equivalent to the growth in exploration units and equals the pre-1980 growth in active drilling rigs (cf. "Oil and Energy Trends," July 1982). For both voice and data we assume a common annual growth rate of 5% for the period 1985-1990 to obtain the number of units for the year 1990. (We assume that to some extent the drilling slump continues.)
4. We assume that there is essentially a 100% penetration of the market by 1990.
5. Average annual growth rate.
6. We assume that the market is approximately saturated in the period 1990-2000 and a common annual growth rate of 3% to the year 2000.

- Alphanumeric or voice communication with truck drivers

Discussions with an industry representative and with the American Trucking Association disclose that approximately 55 percent of the intercity common and contract carrier trucks operate in a dispatch mode over long distances. Generally, each driver is required to call a company dispatcher at least once each day. The calls are placed on WATS lines or are long distance calls. There is no way for a dispatcher to reach a driver directly. If dispatchers could reach drivers without delay, there could be a reduction in "deadhead" driving, without loads, and a resulting increase in operating efficiency.

If a ubiquitous mobile radio system can provide the enroute communications between drivers and dispatchers at a cost no greater than the present telephone costs, it is reasonable to expect that virtually all truckers who operate in a nationwide or regional dispatch mode would eventually adopt the satellite service because it would provide a significantly better service for a comparable price. On this basis the market was limited to carriers who operate over irregular long haul routes. The results are only for common and contract carriers for whom data are readily available. The importance of the private trucking market was not assessed but should be investigated. Some private trucking operations require dispatch communications like the common and contract carriers. Since deregulation some private carriers have become competitive with common carriers.

Table 2-2 presents the results of the trucking industry market analysis. The footnotes identify the data sources and list the assumptions used in the analysis.

Table 2-2

CAPTURABLE[1] MOBILE RADIO MARKET (MOBILE UNITS) NEW SERVICES

Trucking Industry[2]		1990[4]	(AAGR[5])	1995	(AAGR[5])	2000
Trailer	(Base of 153942[3])	168 439	(2%[6])	185 970	(2%[6])	205 326
Tractor	(Base of 79421[3])	86 900	(2%[6])	95 945	(2%[6])	105 931

1. Capturable Market – The market for new mobile systems based on their provision of new services at prices comparable to current service charges for inferior or largely nonexistent services.
2. One of two market areas surveyed.
3. The base comes from an analysis of financial and statistical data for the year 1979 from the Financial and Operations Statistics Manual published by the American Trucking Association and Moody's Transportation Volume. The total annual revenues of the common and contract carriers that engage in irregular long haul routes is $11,169,000,000 (general freight common, household goods, and special commodities common and contract; ATA manual). A random sample of 34 common and contract irregular route carriers as reported in Moody's shows total revenues of $1,516,000,000 for 20,895 trailers and 10,780 tractors. The revenue per trailer is thus $72,553 and there are 1.9383 trailers per tractor on average. Using these statistics and the total revenues one obtains the base.
4. We employ an annual growth rate of 2% (from a study done for NASA by ECOsystems International, Inc. titled, "Analysis of the Trucking Industry Market for a Land Mobile Communications Satellite Service," January 11, 1981) and an in-service factor of 88% (supplied by an industry representative) to obtain the number of units in 1990. Also based on the ECOsystems study we assume that there is essentially a 100% penetration of this specific market by the year 1990.
5. Average annual growth rate.
6. We employ a growth rate of 2%. See footnote 4.

2.2.2 Commercial and Public Services Market Scope

The commercial and public services market is drawn from the existing users of mobile radio in non-SMSA areas of the country. Most of the communications are in the dispatch mode: direct communications between mobiles and base stations. Most users are satisfied with the performance of their radios. A portion of the users express dissatisfaction with the coverage area of their radios because their communication range is too short or because terrain features block out their signals in portions of their service area.

Range is extended by the use of repeaters located on hilltops or towers. The repeaters receive the signals on one frequency and retransmit them on another frequency to relay signals between mobiles and base stations that are not within line of sight. Repeaters are also used to fill in service areas that are blocked by terrain features. When high-powered base stations are used with low powered mobile units, receivers may be installed at numerous locations throughout the service area. A high powered fixed transmitter is heard by mobiles directly, but the mobile signals are received by outlying receivers and are relayed over wirelines or microwave links to the base station. Several outlying receivers may relay a mobile signal. A voting device at the base selects the strongest signal. If the signal is fading, the voting device switches among the receivers and thus presents the strongest possible output signal all the time.

Repeater services are furnished in urban communities by Special Industrial Mobile Radio Service (SMRS) common carriers. In small communities, where there are few bases and mobiles, the users who need better range and coverage within their service area must depend on their own or community repeaters because the investment oy an SMRS is not justified. A satellite can aggregate the number of persons who need repeater service and thus justify provision of the service by SMSRs. The superior service that they would offer and their efforts to market the service would promote the penetration of the market.

Table 2-3 presents the results of the commercial and public services market study. The footnotes identify the data sources and list the assumptions used in the analysis.

2.2.3 Mobile Radio Telephone Market Scope

There is a substantial market for mobile radio telephone in thinly populated areas of the

Table 2-3

CAPTURABLE[1] MOBILE RADIO MARKET (MOBILE UNITS) COMMERCIAL AND PUBLIC RADIO SERVICES

Possible Base Market[2]		(AAGR[6]) (1980-1990)	1990	(AAGR[6])	1995	(AAGR[6])	2000
Conservative:	56 599 (5% of base)	(7%[7])	111 339	(7%[7])	156 159	(7%[7])	219 021
Likely:	169 798 (15% of base[4])	(10%[8])	440 412	(10%[8])	709 288	(10%[8])	114 2315
Optimistic:	264 884 (23.4% of base[5])	(18%[9] 1st 5 yrs) (10%[8] 2nd 5 years)	975 953[10])	(10%[8])	1 571 792	(10%[8])	2 531 371

1. Capturable Market — The nonSMSA and/or rural market for new mobile systems based on their provision of new services or improved services at prices comparable to current service changes.
2. Base market total in 1980 estimated as 6 mobiles/system × 186,664 systems or 1,131,984 mobile units in nonSMSA counties. Base data taken from ECOsystems study final report "Non-Urban Mobile Radio Demand Forecast," 1982, prepared for NASA by ECOsystems International, Inc. as part of a market study on the rural mobile radio market; 1980 count of nonSMSA counties employed.
3. Estimated from 1978 SIRSA membership report from survey taken on membership — 23.4% of respondents required additional coverage with 21.6% rate of return on a membership of 11,773 of 41,266 licensees in the Special Industrial Radio Service — by assuming Special Industrial is representative of all licensees, SIRSA membership is representative of Special Industrial Licensees, and survey coverage biased toward unacceptable service (.216 × 11773 = 2543 returns; (.234)(2543)/11773 = .0505)
4. Industry estimate of proportion of market that employs community repeaters with the assumption that this proportion requires improved service.
5. See footnote 3. Estimated by assuming no bias in respondents to SIRSA Survey and in relationship of SIRSA membership to total Special Industrial licensees and by assuming Special Industrial is representative of all licensees.
6. Average annual growth rate.
7. This growth rate taken for comparative purposes. See Footnotes 8 and 9.
8. Projected annual growth rate for 1980-1990 taken from International Resource Development, Inc. 1980 Report No. 156 "Mobile Radio Markets."
9. Average annual growth rate for 1975-1980 from "1981 Electronic Market Data Book" prepared by the Market Services Department of the Electronic Industries Association.
10. We assume that the recent past market performance continues into the near future (5 years) and after that the market grows at a lower rate. See footnotes 8 and 9.

ORIGINAL PAGE IS
OF POOR QUALITY

country. A market survey by Opinion Research Corporation[1] was used to estimate the number of persons who would subscribe to cellular compatible mobile radio telephone in the non-SMSA counties of the contiguous United States. The study was employed to verify the market projections for the mobile radio telephone service.

Table 2-4 presents the results of the mobile radio telephone service market study. The footnotes identify the data sources and list the assumptions used in the analysis.

1 "An Appraisal of a Mobile Communications Product for the Consumer" Conducted for Audio Electronics Department of General Electric Company, Prepared by Opinion Research Corporation, North Harrison Street, Box 183, Princeton, NJ 08540

Table 2-4

CAPTURABLE[1] MOBILE RADIO MARKET (MOBILE UNITS) MOBILE RADIO TELEPHONE SERVICE

Possible Base Market[2]		1990[6]	(AAGR[7])	1995	(AAGR[7])	2000
Conservative:	Population of 10,316,401[3] (Counties with ≤ 20 persons/ square mile)	51 582	(5%[8])	65 333 (.64% of base[11])	(5%[8])	84 021 (.81% of base[11])
Likely:	Population of 43,379,000[4] (Outside of towns > 1000 persons)	216 895	(7%[9])	304 206 (.70% of base[11])	(7%[9])	426 665 (.98% of base[11])
Optimistic:	Population of 57,562,000[5] (NonSMSA counties)	287 810	(10%[10])	463 521 (.81% of base[11])	(7%[9])	650 112 (1.1% of base[11])

1. Capturable Market — The nonSMSA and/or rural market for new mobile systems based on their provision of new services or improved services at prices comparable to current service charges.
2. Base market populations assumed constant for study (cf. footnotes 4 and 5). Base year taken as 1975.
3. Compiled from County and City Data Book, 1977. Counts for estimated 1975 data.
4. Statistical Abstract of the United States, 1981, page 14. Count from 1970 census — however, counts essentially constant for 1950, 1960, and 1970 censuses.
5. County and City Data Book, 1977, page 901. Count for estimated 1975 data — however, the revised count for the 1980 census based on 1980 SMSA's is 57,115,182 (cf. Statistical Abstract of the United States, 1981, page 919).
6. A market penetration of .5% of the population is assumed by the year 1990. This is consistent with AT&T, Motorola, and Telocator studies (cf. AT&T filing, FCC Docket CC 79-318, August 4, 1980; Motorola filing, FCC Docket 79-318, August 4, 1980; and "CMRS: Cellular Mobile Radio Telecommunications Service-Update on an Emerging Technology," Lehman Brothers Kuhn Loeb Research, May 7, 1982) and with an independent market study being prepared for NASA by ECOsystems International Inc. and Corporate Research and Development, General Electric Company.
7. Average annual growth rate.
8. Average annual telephone growth 1950-1979 taken from "Independent Telephone Industry in the United States," Telecommunications Journal, 1980, Vol. 47, page 392.
9. Average annual mobile telephone growth 1970-1979 taken from "Land Mobile Market Integration Study," Final Report NASA Contract NASW-2800, November 1, 1980, by ECOsystems International, Inc., page 24.
10. Increased average annual mobile telephone growth of recent years — see footnote 9, page 24 for references.
11. See explanation of footnote 6. These penetrations are for comparative purposes and indicate that the base market and growth assumptions give results that are consistent with the cited studies in footnote 6.

Section 3

MAPS AND TABLES OF MARKET DISTRIBUTIONS

3.1 COMMERCIAL AND PUBLIC RADIO AND RADIO TELEPHONE

The geographical distributions for Commercial and Public Radio and Cellular Compatible Mobile Telephone market categories are presented in Tables 3-1 through 3-4. Market demands were computed for each non-SMSA county of the contiguous United States, for each of one hundred postulated footprints of a multibeam satellite, and for each state. Demand estimates are thus available at three levels of geographical granularity. This report does not include the results at the county level because of the large volume of the data. The computer printouts of the individual county data were submitted to NASA.

Figure 3-1 is a county map of the contiguous states with the Standard Metropolitan Statistical Areas (SMSAs) outlined. The SMSA delineations were prepared by ECOsystems International, Inc. Except in New England, an SMSA is defined as a county that includes a metropolitan community with a population greater than 50,000 persons, or a county that contains an economically integrated set of communities with a total population greater than 50,000 persons and a county population greater than 100,000. In New England the SMSA boundaries do not necessarily conform to county boundaries. There are a total of 3110 counties in the contiguous states; 728 of them are SMSA counties as of the 1980 census. The total population (1980 census) of the SMSAs was 169,399,643 persons. The population of the non-SMSA counties was 57,115,182 persons.

The county map, Figure 3-1, has an overlay representing a probable set of satellite footprints. The pattern approximates the service areas of 100 beams of a large satellite in geostationary orbit at 90 degrees west longitude. While the footprint pattern may not depict the service areas precisely, it is adequate for depicting the geographical distribution of demand, and the proportionate loading of individual beams of a multibeam satellite.

Figure 3-2 presents the demand distribution for cellular compatible mobile radio telephone in non-SMSA counties as of the population that existed in 1975. This figure is an outline map of the contiguous states with the 100 footprint overlay. Within each footprint is a black square. The area of each square is proportional to the traffic demand in erlangs within the footprint. Actual values of demand are presented in Table 3-4. The footprints are numbered consecutively from the northwest, and the footprint numbers correspond to the numbers in the tables.

Figure 3-3 presents another possible demand distribution for cellular compatible mobile radio telephone. It shows the distribution for non-urban demand in counties with population densities 20 persons per square mile or fewer, again as of the 1975 population. Each dot within the outline of a state represents 25,000 persons who live in those 992 thinly populated counties. The total population is 10,316,000. Based on the conservative, likely, and optimistic market penetration assumptions derived from the survey results described in Appendix A, each dot represents 125, 250, or 375 potential subscribers. As each subscriber is expected to generate 0.028 erlangs of demand during peak hours, each dot represents a traffic demand of 3.75, 7.5, or 11.25 erlangs depending upon one's choice of the conservative, likely, or optimistic assumption of market penetration.

It is important to note that the geographical distributions of Figures 3-2 and 3-3 are significantly different. The geographical distribution of demand is critically dependent upon the population density that is selected for defining the non-urban population. Note that the choice of 20 persons per square mile results in the largest demand in the Western states. Choosing non-SMSA counties as the non-urban definition results in greatest demand in the

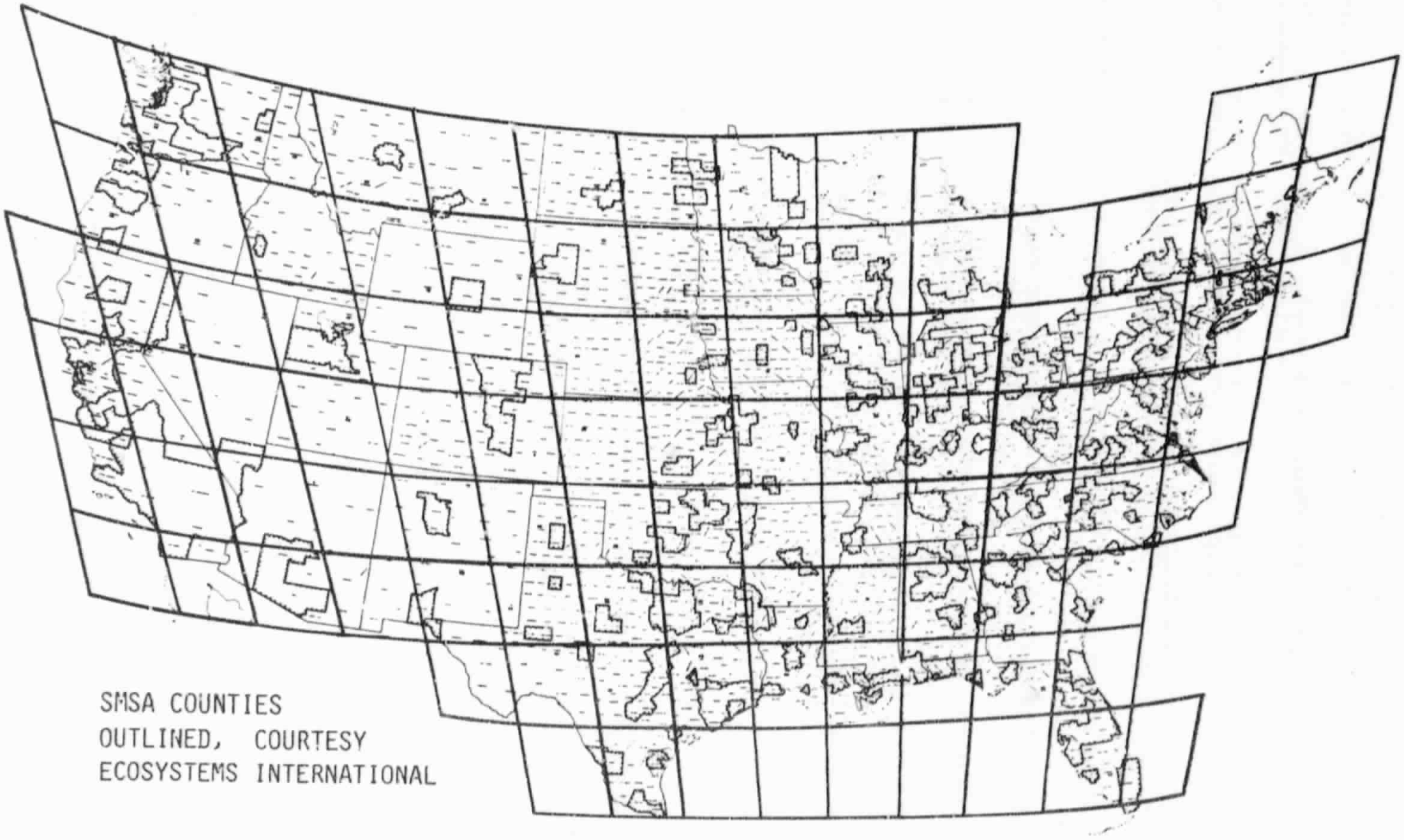

Figure 3-1. County Map with Overlay of 100 Satellite Footprints

ORIGINAL PAGE IS
OF POOR QUALITY

Table 3-1

MOBILE RADIO MARKET BASE
COMMERCIAL AND PUBLIC RADIO SERVICES
PRESENT USE OF MOBILE RADIO SERVICES PER STATE – NON-SMSA AREAS ONLY

State	Business Users[1]	Industry Users	Commercial, Public Users Total[2]	Business Erlangs[3]	Industry Erlangs	Commercial, Public Erlangs Total
Alabama	1,335	420	2,722	85.8	21.0	165.7
Arizona	625	228	1,325	40.2	11.4	80.0
Arkansas	1,563	558	3,291	100.5	27.9	199.2
California	1,016	458	2,286	65.3	22.9	136.9
Colorado	1,145	781	2,990	73.6	39.1	174.8
Conneticut	29	17	71	1.9	0.8	4.2
Delaware	182	52	363	11.7	2.6	22.2
Florida	[illegible]	285	1,880	59.5	14.3	114.5
Georgia	2,520	661	4,944	162.0	33.1	302.6
Idaho	1,195	509	2,645	76.8	25.5	158.7
Illinois	3,772	1,198	7,711	242.4	59.9	469.1
Indiana	1,979	534	3,902	127.2	26.7	238.8
Iowa	3,793	1,075	7,552	243.8	53.8	461.7
Kansas	3,426	2,050	8,501	220.2	102.5	500.7
Kentucky	2,350	537	4,478	151.0	26.9	276.0
Louisiana	2,240	753	4,644	144.0	37.7	281.8
Maine	473	129	934	30.4	6.5	57.2
Maryland	420	128	851	27.0	6.4	51.8
Massachusetts	146	36	283	9.4	1.8	17.4
Michigan	1,653	403	3,192	106.2	126.4	196.1
Minnesota	2,519	792	4,142	161.9	39.6	312.7
Mississippi	2,139	724	4,440	137.5	36.2	269.5
Missouri	2,527	794	4,154	162.4	39.7	313.6
Montana	1,154	1,275	3,769	74.2	63.8	214.0
Nebraska	2,197	1,339	5,485	141.2	67.0	323.0
Nevada	181	63	379	11.6	3.2	22.9
New Hampshire	[illegible]	57	439	14.5	2.9	27.0
New Jersey		86	602	19.4	4.3	36.8
New Mexico	1,[illegible]	673	2,925	78.0	33.7	173.2
New York	1,604	466	3,213	103.1	23.3	196.1
North Carolina	2,450	645	4,805	157.5	32.3	394.4
North Dakota	1,364	1,607	4,608	87.7	80.4	260.7
Ohio	2,299	656	4,583	147.8	32.8	280.2
Oklahoma	2,778	1,362	6,423	178.5	68.1	382.7
Oregon	959	427	2,150	61.1	21.4	128.8
Pennsylvania	2,105	588	4,176	135.3	29.4	255.5
South Carolina	963	290	1,943	61.9	14.5	118.5
South Dekota	1,325	1,243	3,980	85.2	52.2	228.6
Tennessee	1,483	352	2,847	95.3	17.6	175.2
Texas	7,133	3,529	16,545	458.4	176.5	985.1
Utaha	460	195	1,017	29.6	9.8	61.0
Vermont	351	89	682	22.6	4.5	41.9
Virginia	1,628	359	3,082	104.6	18.0	190.2
Washington	1,013	517	2,375	65.1	25.9	141.1
West Virginia	1,465	400	2,896	94.2	20.2	177.1
Wisconsin	2,022	525	3,952	130.0	26.3	242.4
Wyoming	747	525	1,974	48.0	26.3	115.2
Total	75,396	30,390	164,151	4,845.7	1,519.8	9,876.6

1. "Users" refers to the number of entities that hold mobile radio licenses regardless of number of base stations or mobiles.

2. Includes public service and other users in addition to business and special industry. See Section 1.1.

3. The imprecise but common use of "erlang" is total message transmission time divided by time. The numbers of channels required to carry the traffic is larger than the numbers shown.

Table 3-2

MOBILE RADIO MARKET BASE
COMMERCIAL AND PUBLIC RADIO SERVICES
PRESENT USE OF MOBILE RADIO SERVICES – NON-SMSA COUNTIES ONLY

Satellite Footprint (See Fig. 3-1)	Business Users[1]	Industry Users	Commercial, Public Users Total[2]	Business Erlangs[3]	Industry Erlangs	Commercial, Public Erlangs Total
1	78	16	146	5.0	0.8	9.0
2	576	173	1,161	37.0	8.7	70.9
3	885	547	2,223	56.9	27.4	130.7
4	546	440	1,530	35.1	22.0	88.6
5	240	388	975	15.4	19.4	54.0
6	805	1,079	2,922	51.7	54.0	164.0
7	1,056	929	3,080	67.9	46.5	177.4
8	498	118	958	32.0	5.9	58.8
9	336	68	627	21.6	3.4	38.8
10	76	12	136	4.9	0.6	8.5
11	137	43	279	8.8	2.2	17.0
12	0	0	0	0	0	0
13	490	141	980	31.5	7.1	59.8
14	289	181	728	18.6	9.1	42.9
15	525	227	1,169	33.7	11.4	70.0
16	449	290	1,147	28.9	14.5	67.3
17	328	315	997	21.1	15.8	57.2
18	425	619	1,604	27.3	30.5	89.7
19	1,542	863	3,728	99.1	43.2	220.7
20	2,360	664	4,693	151.7	33.2	386.9
21	1,593	400	2,951	96.6	20.0	180.9
22	970	218	1,846	62.3	10.9	113.6
23	0	0	0	0	0	0
24	730	212	1,462	46.9	10.6	89.2
25	935	237	1,817	60.1	11.9	111.6
26	82	22	162	5.3	1.1	9.9
27	294	124	648	18.9	6.2	38.9
28	176	89	411	11.3	4.5	24.5
29	69	38	166	4.4	1.9	9.8
30	329	145	720	29.6	7.3	43.2
31	384	156	838	24.7	7.8	50.4
32	519	396	1,421	33.4	19.7	82.5
33	758	768	2,366	48.7	38.4	135.2
34	1,791	653	3,793	115.1	32.7	229.3
35	2,699	795	5,421	173.5	39.8	330.8
36	1,968	629	4,030	126.5	31.5	245.1
37	1,873	546	3,755	120.4	27.3	229.1
38	1,936	570	3,888	124.4	28.5	237.3
39	1,983	551	3,929	127.4	27.6	240.5
40	570	174	1,155	36.6	8.7	70.3
41	103	25	199	6.6	1.3	12.2
42	123	58	280	7.9	2.9	16.8
43	231	79	481	14.8	4.0	29.2
44	85	34	185	5.5	1.7	11.1
45	142	64	320	9.1	3.2	19.1
46	456	197	1,015	29.3	9.9	60.8
47	289	295	906	18.6	14.8	51.7
48	1,644	1,204	4,421	105.7	60.2	257.4
49	1,782	846	4,080	114.5	42.3	243.3
50	1,419	442	2,888	91.2	22.1	175.8

1. "Users" refers to the number of entities that hold mobile radio licenses regardless of number of base stations or mobiles.

2. Includes public service and other users in addition to business and special industry. See Section 1.1.

3. The imprecise but common use of "erlang" is total message transmission time divided by time. The numbers of channels required to carry the traffic is larger than the numbers shown.

Table 3-2 (Continued)

Satellite Footprint (See Fig. 3-1)	Business Users[1]	Industry Users	Commercial, Public Users Total[2]	Business Erlangs[3]	Industry Erlangs	Commercial, Public Erlangs Total
51	2,663	801	5,374	171.2	40.1	327.7
52	1,832	443	3,608	121.0	22.2	222.0
53	2,449	622	4,766	157.4	31.1	292.5
54	1,539	365	2,952	98.9	18.3	181.8
55	570	163	1,139	36.6	8.2	69.5
56	150	74	348	9.6	3.7	20.7
57	0	0	0	0	0	0
58	86	39	194	5.5	2.0	11.6
59	177	39	335	11.4	2.0	20.7
60	337	153	759	21.7	7.7	45.5
61	465	409	1,357	29.9	20.5	78.1
62	1,499	907	3,730	96.3	45.4	219.9
63	1,448	581	3,148	93.1	29.1	189.5
64	849	270	1,737	54.6	13.5	105.6
65	1,547	544	3,240	99.4	27.2	196.5
66	1,260	280	2,392	81.0	14.0	147.4
67	1,462	314	2,757	94.0	15.7	170.2
68	1,733	493	3,456	111.4	24.7	211.1
69	596	158	1,169	38.3	7.9	71.7
70	0	0	0	0	0	0
71	113	48	250	7.3	2.4	15.0
72	196	82	432	12.6	4.1	25.9
73	234	105	527	15.0	5.3	31.5
74	366	200	876	23.5	10.0	52.0
75	1,563	745	3,581	100.5	37.3	213.7
76	1,156	613	2,746	74.3	30.7	162.8
77	1,247	448	2,631	80.1	22.4	159.1
78	860	269	1,755	55.3	13.5	106.6
79	1,304	493	2,787	83.8	24.7	168.3
80	781	244	1,590	50.2	12.2	96.8
81	1,212	322	2,386	77.9	16.1	145.8
82	584	179	1,185	37.5	9.0	72.1
83	97	49	226	6.2	2.5	13.5
84	399	225	968	25.6	11.3	57.2
85	613	384	1,548	39.4	19.2	90.9
86	823	330	1,789	52.9	16.5	107.7
87	1,309	458	2,740	84.1	22.9	166.1
88	1,291	373	2,582	83.0	101.6	157.7
89	365	104	727	23.5	5.2	44.5
90	1,017	298	2,042	65.4	14.0	124.5
91	167	40	322	10.7	2.0	19.8
92	76	39	179	4.9	2.0	10.6
93	742	349	1,694	47.7	17.5	101.1
94	152	77	355	9.8	3.9	21.1
95	0	0	0	0	0	0
96	0	0	0	0	0	0
97	0	0	0	0	0	0
98	0	0	0	0	0	0
99	516	181	1,081	33.2	9.1	65.5
100	26	9	54	1.7	0.5	3.3
Totals	75,396	30,390	164,151	484.6	1,519.8	9,876.6

Table 3-3

MOBILE RADIO MARKET BASE
MOBILE RADIO TELEPHONE

ESTIMATED NUMBER OF SUBSCRIBERS PER STATE, NON-SMSA AREAS

	0.5% Penetration[1]		1.0% Penetration		1.5% Penetration	
States	Subscribers	Erlang[2]	Subscribers	Erlangs	Subscribers	Erlangs
Alabama	6,962	194.9	13,924	389.9	20,886	584.8
Arizona	2,798	78.3	5,596	156.7	8,394	235.0
Arkansas	6,458	180.8	12,916	361.6	19,374	542.5
California	5,065	141.8	10,130	283.6	15,195	425.5
Colorado	2,452	68.7	4,904	137.3	7,356	206.0
Connecticut	450	12.6	900	25.2	1,350	37.8
Delaware	901	25.2	1,802	50.5	2,703	75.7
Florida	4,761	133.3	9,522	266.6	14,283	399.9
Georgia	10,085	282.4	20,170	564.8	30,255	847.1
Idaho	3,392	95.0	6,784	190.0	10,176	284.9
Illinois	10,425	291.9	20,850	583.8	31,275	875.7
Indiana	7,888	220.9	15,776	441.7	23,664	662.6
Iowa	8,635	241.8	17,270	483.6	25,905	725.3
Kansas	6,183	173.1	12,366	346.2	18,549	519.4
Kentucky	9,152	256.3	18,304	512.5	27,456	768.8
Louisiana	7,057	197.6	14,114	395.2	21,171	592.8
Maine	2,401	67.2	4,802	134.5	7,203	201.7
Maryland	2,082	58.3	4,164	116.6	6,246	174.9
Massachusetts	1,026	28.7	2,052	57.5	3,078	86.2
Michigan	7,524	210.7	15,048	421.3	22,572	632.0
Minnesota	7,038	197.1	14,076	394.1	21,114	591.1
Mississippi	8,667	242.7	17,334	485.5	26,001	728.0
Missouri	8 076	226.1	16,152	452.3	24,228	678.4
Montana	2,823	79.0	5,656	158.[illegible]	8,469	237.1
Nebraska	4,303	120.5	8,606	240.1	12,909	361.4
Nevada	575	16.1	1,150	32.2	1,725	48.3
New Hampshire	1,210	33.9	2,420	67.8	3,630	101.6
New Jersey	2,713	76.0	5,426	151.0	8,139	227.9
New Mexico	3,397	95.1	6,794	190.2	10,191	285.3
New York	8,541	239.1	17,082	478.3	25,623	717.4
North Carolina	12,721	361.8	25,842	723.6	38,763	1,085.4
North Dakota	2,147	60.1	4,294	120.2	6,441	180.3
Ohio	10,223	286.2	20,446	572.5	30,669	858.7
Oklahoma	5,766	161.4	11,532	322.9	17,298	484.3
Oregon	4,003	112.1	8,006	224.2	12,009	336.3
Pennsylvania	10,424	291.9	20,848	583.7	31,272	875.6
South Carolina	5,764	161.4	11,528	322.8	17,292	484.2
South Dekota	2,912	81.5	5,824	173.1	8,736	244.6
Tennessee	7,715	216.0	15,430	432.0	23,145	648.1
Texas	12,695	355.5	25,390	710.9	38,085	1,066.4
Utaha	1,272	35.6	2,544	71.2	3,816	106.8
Vermont	1,646	46.1	3,292	92.2	4,938	138.3
Virginia	7,526	210.7	15.052	421.5	22,578	632.2
Washington	3,553	99.5	7,106	199.0	10,659	298.5
West Virginia	5,573	156.0	11,146	312.1	16,719	468 1
Wisconsin	7,426	207.9	14,852	415.9	22,278	623.8
Wyoming	1,604	44.9	3,208	89.8	4,812	134.7
Totals	256,219	7,173.9	512,420	14,347.8	768,630	21,521.6

1. Based on 1975 population, but 1980 definition of SMSA counties.

2. The imprecise but common use of "erlang" is total message transmission time divided by time. The number of channels required to carry the traffic is larger than numbers shown.

Table 3-4

MOBILE RADIO MARKET BASE
MOBILE RADIO TELEPHONE

ESTIMATED NUMBER OF SUBSCRIBERS, NON-SMSA COUNTIES

Satellite Footprint	0.5% Penetration[1]		1.0% Penetration		1.5% Penetration	
(See Fig. 3-1)	Subscribers	Erlangs[2]	Subscribers	Erlangs	Subscribers	Erlangs
1	404	11.3	808	22.6	1,212	33.9
2	2,415	67.6	4,830	135.2	7,245	202.9
3	2,460	68.9	4,920	137.8	7,380	206.6
4	1,641	45.9	3,282	91.9	4,923	137.8
5	457	12.8	914	25.6	1,371	38.4
6	1,249	35.0	2,498	69.9	3,747	104.9
7	1,860	52.1	3,720	104.2	5,580	156.2
8	2,110	59.1	4,220	118.2	6,330	177.2
9	1,403	39.3	2,806	78.6	4,209	117.9
10	313	8.8	626	17.5	939	26.3
11	563	15.8	1,126	31.5	1,689	47.3
12	0	0	0	0	0	0
13	2,464	69.0	4,928	138.0	7,392	207.0
14	810	22.7	1,620	45.4	2,430	68.0
15	1,668	46.7	3,336	93.4	5,004	140.1
16	1,071	30.0	2,142	60.0	3,213	90.0
17	473	13.2	946	26.5	1,419	39.7
18	1,102	30.9	2,204	61.7	3,306	92.6
19	3,084	86.4	3,168	172.7	9,252	259.1
20	6,053	169.5	12,106	339.0	18,159	508.5
21	5,610	157.1	11,220	314.2	16,830	471.2
22	4,237	118.6	8,474	237.3	12,711	355.9
23	0	0	0	0	0	0
24	3,786	106.0	7,572	212.0	11,358	318.0
25	4,972	139.2	9,944	278.4	14,916	417.6
26	360	10.1	720	20.2	1,080	30.2
27	1,241	34.7	2,482	69.5	3,723	104.2
28	797	22.3	1,594	44.6	2,391	66.9
29	147	4.1	294	8.2	441	12.3
30	979	27.4	1,958	54.8	2,937	82.2
31	606	17.0	1,212	33.9	1,818	50.9
32	1,128	31.6	2,256	63.2	3,384	94.8
33	1,276	35.7	2,552	71.5	3,828	107.2
34	3,725	104.3	7,450	208.6	11,175	312.9
35	6,484	181.6	12,968	363.1	19,452	544.7
36	5,987	167.6	11,974	335.3	17,961	502.9
37	8,025	224.7	16,050	449.4	24,075	674.1
38	9,233	258.5	18,466	517.0	27,699	775
39	9,980	279.4	19,960	558.9	29,940	838.3
40	4,343	121.6	8,686	243.2	13,029	364.8
41	708	19.8	1,416	39.6	2,124	59.5
42	691	19.3	1,382	38.7	2,073	58.0
43	1,257	35.2	2,514	70.4	3,771	105.6
44	256	7.2	512	14.3	768	21.5
45	319	8.9	638	17.9	957	26.8
46	1,182	33.1	2,364	66.2	3,546	99.3
47	777	21.8	1,554	43.5	2,331	65.3
48	1,622	45.4	3,244	90.8	4,866	136.2
49	4,561	127.7	9,122	255.4	13,683	383.1
50	4,461	124.9	8,922	249.8	13,383	374.7

1. Based on 1975 population, but 1980 definition of SMSA counties.
2. The imprecise but common use of "erlang" is total message transmission time divided by time. The number of channels required to carry the traffic is larger than numbers shown.

Table 3-4 (Continued)

Satellite Footprint (See Fig. 3-1)	0.5% Penetration[1]		1.0% Penetration		1.5% Penetration	
	Subscribers	Erlangs[2]	Subscribers	Erlangs	Subscribers	Erlangs
51	7,120	199.4	14,240	398.7	21,360	598.1
52	7,819	218.9	15,638	437.9	23,457	656.8
53	9,358	262.0	18,716	524.0	28,074	786.1
54	7,320	205.0	14,640	409.9	21,960	614.9
55	2,452	68.7	4,904	137.3	7,356	206.0
56	994	27.8	1,988	55.7	2,982	83.5
57	0	0	0	0	0	0
58	426	11.9	852	23.9	1,278	35.8
59	851	23.8	1,702	47.7	2,553	71.5
60	1,495	41.9	2,990	83.7	4,485	125.6
61	962	26.9	1,924	53.9	2,886	80.8
62	1,915	53.6	3,830	107.2	5,745	160.9
63	3,463	27.0	6,926	193.9	10,389	290.9
64	3,611	101.1	7,222	202.2	10,833	303.3
65	6,521	182.6	13,042	365.2	19,563	547.8
66	6,249	175.0	12,498	349.9	18,747	524.9
67	8,942	250.4	17,884	500.8	26,826	751.1
68	9,493	265.8	18,986	531.6	28,479	797.4
69	2,641	73.9	5,282	147.9	7,923	221.8
70	0	0	0	0	0	0
71	421	11.8	842	23.6	1,263	35.4
72	847	23.7	1,694	47.4	2,541	71.1
73	909	25.5	1,818	50.9	2,727	76.4
74	838	23.5	1,676	46.9	2,514	70.4
75	1,734	48.6	3,468	97.1	5,202	145.7
76	1,502	42.1	3,004	84.1	4,506	126.2
77	3,615	101.2	7,230	202.4	10,845	303.7
78	3,207	89.8	6,414	179.6	9,621	269.4
79	5,792	162.2	11,584	324.4	17,376	486.5
80	4,496	125.9	8,992	251.8	13,488	377.7
81	4,978	139.4	9,956	278.8	14,934	418.2
82	2,854	79.9	5,708	159.8	8,562	239.7
83	151	4.2	302	8.5	453	12.7
84	356	10.0	712	19.9	1,068	29.9
85	1,367	38.3	2,734	76.6	4,101	114.8
86	2,240	62.7	4,480	125.4	6,720	188.2
87	3,870	108.4	7,740	216.7	11,610	325.1
88	4,173	116.8	8,346	233.7	12,519	350.5
89	1,640	45.9	3,280	91.8	4,92[illegible]	137.8
90	3,624	101.5	7,248	202.9	10,[illegible]	304.4
91	806	22.6	1,612	45.1	2,4[illegible]	67.7
92	220	6.2	440	12.3	660	18.5
93	1,204	33.7	2,408	67.4	3,612	101.1
94	291	8.1	582	16.3	873	24.4
95	0	0	0	0	0	0
96	0	0	0	0	0	0
97	0	0	0	0	0	0
98	0	0	0	0	0	0
99	2,864	80.2	5,728	160.4	8,592	240.6
100	229	6.4	458	12.8	687	19.2
Totals	256,210	7,173.9	512,420	14,347.8	768,630	21,521.6

Midwestern states with a much smaller proportion in the West.

The proportionate loading of the beams of a multibeam satellite is thus a matter that requires consideration of the minimum population density that is likely to be served by terrestrial systems. It would be advantageous to have approximately equal loading of all beams of a satellite. The independent growth of terrestrial installations can thus have an economic impact on the satellite by reducing its overall efficiency unless it is possible to design a satellite to match the geographical distribution of demand.

The geographical distributions of demand for the other market categories are not the same as the distribution for mobile radio telephone, although the distribution for Commercial and Public Services is similar. Figure 3-4 presents the demand distribution for Commercial and Public Radio. The area of the black square in each footprint represents the footprint's proportionate traffic demand in erlangs. The distribution is based on the demand in non-SMSA counties. Actual demand values are presented in Table 3-2.

Figure 3-4 depicts the actual present traffic load of all commercial and public mobile radio in non-SMSA counties. Figure 3-2 depicts the predicted demand for cellular compatible mobile radio telephone in non-SMSA counties. A unit area of a black square that represents an erlang of demand for commercial and public radio in Figure 3-4 is the same unit area that represents an erlang demand for cellular compatible mobile radio telephone in Figure 3-2 based on the conservative estimate for the population of the year 1975. It is apparent that the latent demand for quality mobile radio telephone service in non-urban areas approximates at least the total present usage of mobile radio in those areas.

The geographical distribution for commercial and public radio services depends critically on the population density that is chosen for defining the non-urban population because that selection determines the counties that comprise the market area.

The choice of SMSA counties as the definition of non-urban areas can lead to inaccurate results when the size of individual counties approaches the size of a satellite footprint. San Bernardino County in California nearly corresponds to footprint 57 on Figures 3-2 and 3-4. Most of the county has a low population density and it would be a candidate for satellite service, but the entire county is classed as an SMSA because the city of San Bernardino and its related metropolitan population are in the county. If the county were divided into several smaller counties, footprint 57 would likely show a need for non-urban mobile services.

3.2 OIL AND GAS SERVICES MARKET DISTRIBUTION

Because this is one of the new service markets, it is largely unpenetrated at this time and no base exists for study. The total market projection for this subsegment given in Section 2 was based on expressions of needs described by the three largest suppliers of oil well services. Also two companies that provide communications for oil and gas exploration and drilling described their present attempts to use C-band satellites and Marisat for communications from remote and offshore well sites. Logistics, cost, and other problems severely limit the usefulness of those satellites for the applications. The projection given in Section 2 assumes that overall costs are such that 100% penetration of the market occurs by 1990. This allows for straightforward computations but should be verified by survey before finalizing the potential oil and gas industry market.

We shall employ the database developed in Section 2 and distribute the market via ancillary data. Since no survey has been made and there is no existing database, we must assume a predictive relationship. One way to do this is to determine the pattern of oil and gas industry activity and make some assumption as to how the service will be employed.

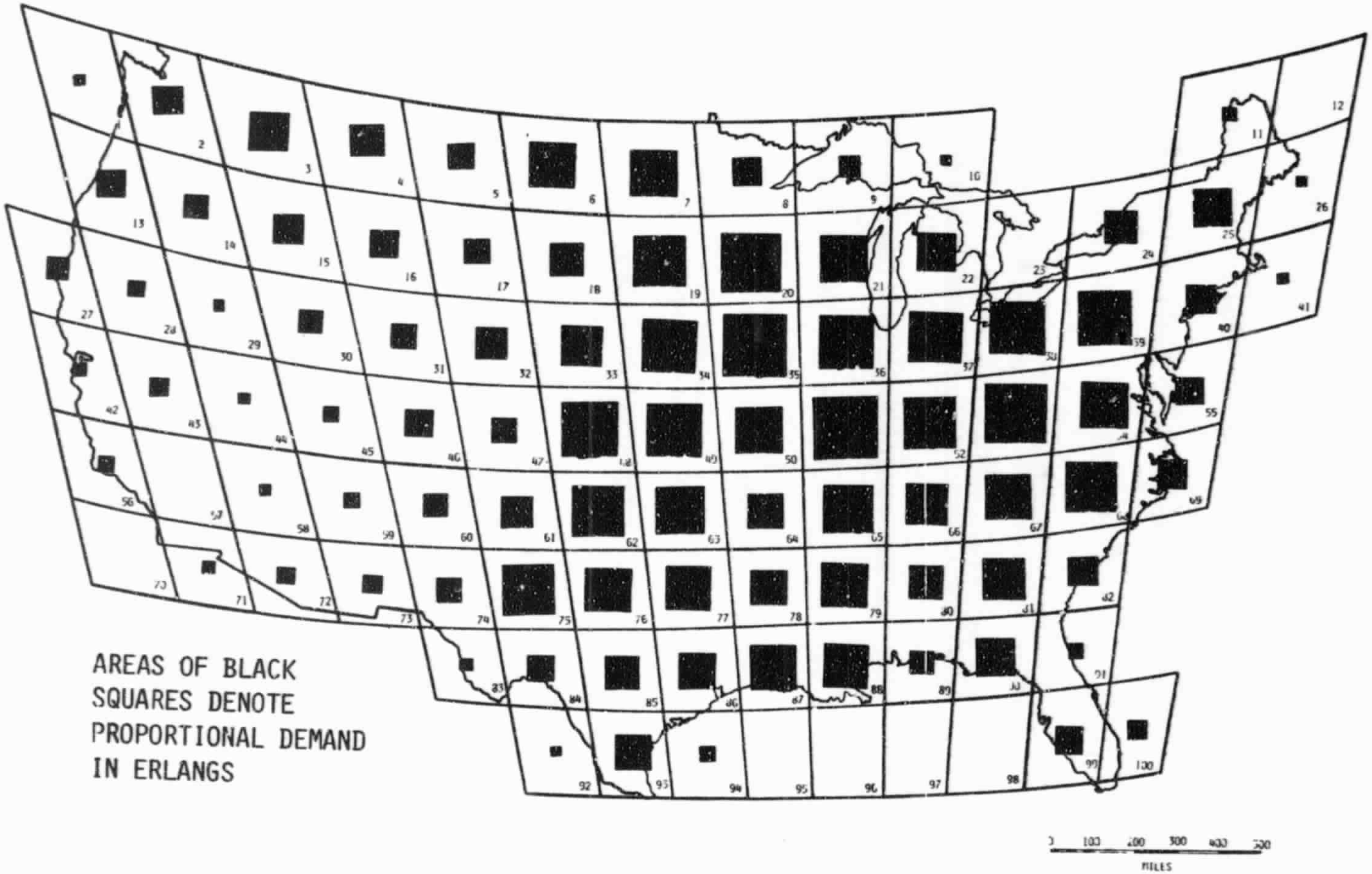

Figure 3-4. Demand Distribution for Commercial and Public Radio in Non-SMSA counties

We shall assume that every operator (service company or oil-gas company itself) uses the service in a similar manner so that the demand is proportional to the actual activity. Thus we are assuming that demand is proportional to rig activity.

As a measure of rig activity we take the estimated number of wells completed during the first half of 1982 as reported in the Oil and Gas Journal.[2] This reflects the recent slump in drilling activity and gives a current distribution of the market. The data are reported in Table 3-5. The total base voice market is 16002 mobile units and the total base data market is 3629 mobile units from Table 2-1, Section 2.2. Using the rig activity totals (shown in Table 3-5) to determine proportions gives the demand pattern shown in Table 3-6. Statewide totals are given in Figure 3-5. As might be expected this figure does not show great similarity to those developed for the Trucking market, Commercial and Public Radio market, and the Mobile Radiotelephone market.

3.3 TRUCKING INDUSTRY MARKET DISTRIBUTION

Because the trucking industry is one of the new service markets, it is unpenetrated at this time and no base exists for study. The total market projection for this subsegment given in Section 2 was based on expressions of needs described by four trucking companies and limited to carriers that operate over irregular long-haul routes. Also the results were for only common and contract carriers for which data are readily available. More importantly the private trucking market was not assessed. Since some private trucking operations require dispatch communications and compete with common and contract carriers, this segment should be investigated. Thus a survey is required to establish the potential trucking market.

We shall employ the same base as developed in Section 2 and distribute the market via ancillary data. Since no survey has been made and there is no existing data base, we must assume a predictive relationship. One way to do this is to determine the traffic pattern of the common and contract carriers that operate over irregular long-haul routes and make some assumption as to how the service will be employed.

We shall assume that every trucking operation uses the service in a similar manner so that the demand is proportional to the number of vehicles. Then we need only determine the traffic pattern of the vehicles. Data to accomplish this appear to be limited. Considerable statistical data on the trucking industry are kept: Census of Transportation, Federal Highway Statistics, American Trucking Association Statistical Tabulations, Moody's Transportation Volume, etc. Unfortunately, much of the data are economic in nature and to the writers' knowledge none have the exact traffic records required.

As a surrogate for the required traffic patterns we shall employ the highway use of special fuels for the year 1980 as given in Table MF-25, September 1981, of Highway Statistics 1980.[3] Special fuels are motor fuels other than gasoline and gasohol and consist primarily of diesel fuel, with small amounts of liquified petroleum gases. Therefore the use of the fuels reflects essentially all of the intercity long-haul trucking traffic as well as bus traffic. In employing these data we make the tacit assumption that the relative proportion of irregular long-haul route traffic does not vary throughout the contiguous United States. Then the traffic we need to estimate is just a proportion of the fuel consumption for a particular portion of the country.

Since the referenced data are totals by state for the year 1980, we develop a distribution by state. Furthermore, we assume that the year 1980 is representative of the span over which the baseline forecast was developed in Section 2. With these assumptions it follows that the

[2] OGJ Report, July 26,1982, Oil and Gas Journal, 163-171.

[3] U.S. Department of Transportation, Federal Highway Administration

ORIGINAL PAGE IS
OF POOR QUALITY

Table 3-5

ESTIMATED DRILLING ACTIVITY FOR 1982—U.S. AND CANADA

State district, province	First half estimates Total comp.	Wildcats	Field wells	Total ft (1,000 ft)
Alabama	101	40	61	757
Alaska	95	15	80	992
Arizona	2	2	0	8
Arkansas	541	80	460	2,731
Atlantic Offshore	3	3	0	–
California	1,737	305	1,432	5,347
Onshore	1,642	260	1,382	4,919
Onshore	95	45	50	428
Colorado	1,090	400	690	5,993
Florida	15	4	11	189
Georgia	2	2	0	13
Idaho	6	6	0	54
Illinois	1,357	325	1,032	3,738
Indiana	393	150	243	813
Kansas	4,217	1,208	3,009	13,665
Kentucky	1,500	360	1,140	2,145
Louisiana	2,862	542	2,320	19,948
North	1,600	167	1,433	5,776
South	777	280	497	9,032
Offshore	485	95	390	5,140
Michigan	430	250	180	1,960
Mississippi	325	150	175	2,942
Missouri	80	30	50	35
Montana	723	250	473	3,851
Nebraska	325	157	168	1,505
Nevada	13	11	2	70
New Mexico	1,353	224	1,129	7,273
East	903	137	766	4,889
West	450	87	363	2,384

State district, province	First half estimates Total comp.	Wildcats	Field wells	Total ft (1,000 ft)
New York	300	40	260	807
North Dakota	500	250	250	4,981
Ohio	1,238	33	1,205	4,158
Oklahoma	6,100	281	5,819	33,099
Oregon	11	8	3	71
Pennsylvania	1,139	100	1,040	2,657
South Dakota	45	25	20	139
Tennessee	230	133	97	398
Texas	14,442	2,846	11,596	77,519
District 1	1,266	221	1,045	4,923
District 2	470	189	281	2,995
District 3	1,377	325	1,052	11,437
District 4	755	340	415	5,480
District 5	365	81	284	2,339
District 6	684	130	554	5,321
District 7-B	2,150	434	1,716	7,228
District 7-C	1,251	276	975	6,762
District 8	1,603	159	1,444	9,321
District 8-A	1,354	267	1,087	7,804
District 9	2,248	324	1,924	7,762
District 10	795	50	745	4,966
Offshore	124	50	74	1,181
Utah	317	103	214	1,952
Virginia	20	2	18	119
Washington	2	2	0	40
West Virginia	900	60	840	3,766
Wyoming	1,178	300	878	9,354
Total U.S.	43,592	8,697	34,895	213,079
Western Canada	2,586	1,276	1,310	10,425
Alberta	2,200	1,054	1,146	8,952
British Columbia	90	65	25	557
Manitoba	40	15	25	133
North-Arctic	6	4	2	57
Saskatchewan	250	138	112	726
East Coast Offshore	3	3	0	51

Table 3-6

DISTRIBUTION OF OIL AND GAS ACTIVITY

State district, province	Voice	Data
Alabama	37	8
Alaska	35	8
Arizona	1	0
Arkansas	199	45
Atlantic Offshore	1	0
California	637	145
Onshore	602	137
Offshore	35	8
Colorado	400	91
Florida	6	1
Georgia	1	0
Idaho	2	0
Illinois	498	113
Indiana	144	33
Kansas	1548	351
Kentucky	551	125
Louisiana	1050	238
North	587	133
South	285	65
Offshore	178	40
Michigan	158	36
Mississippi	119	27
Missouri	29	7
Montana	265	60
Nebraska	119	27
Nevada	5	1
New Mexico	496	112
East	331	75
West	165	37
New York	110	25
North Dakota	184	42
Ohio	454	103
Oklahoma	2239	508
Oregon	4	1
Pennsylvania	418	95
South Dakota	17	4
Tennessee	84	19
Texas	5301	1201
District 1	465	105
District 2	173	39
District 3	505	115
District 4	277	63
District 5	134	30
District 6	251	57
District 7-B	789	179
District 7-C	459	104
District 8	588	133
District 8-A	497	113
District 9	825	187
District 10	292	66
Offshore	46	10
Utah	116	26
Virginia	7	2
Washington	1	0
West Virginia	330	75
Wyoming	432	98

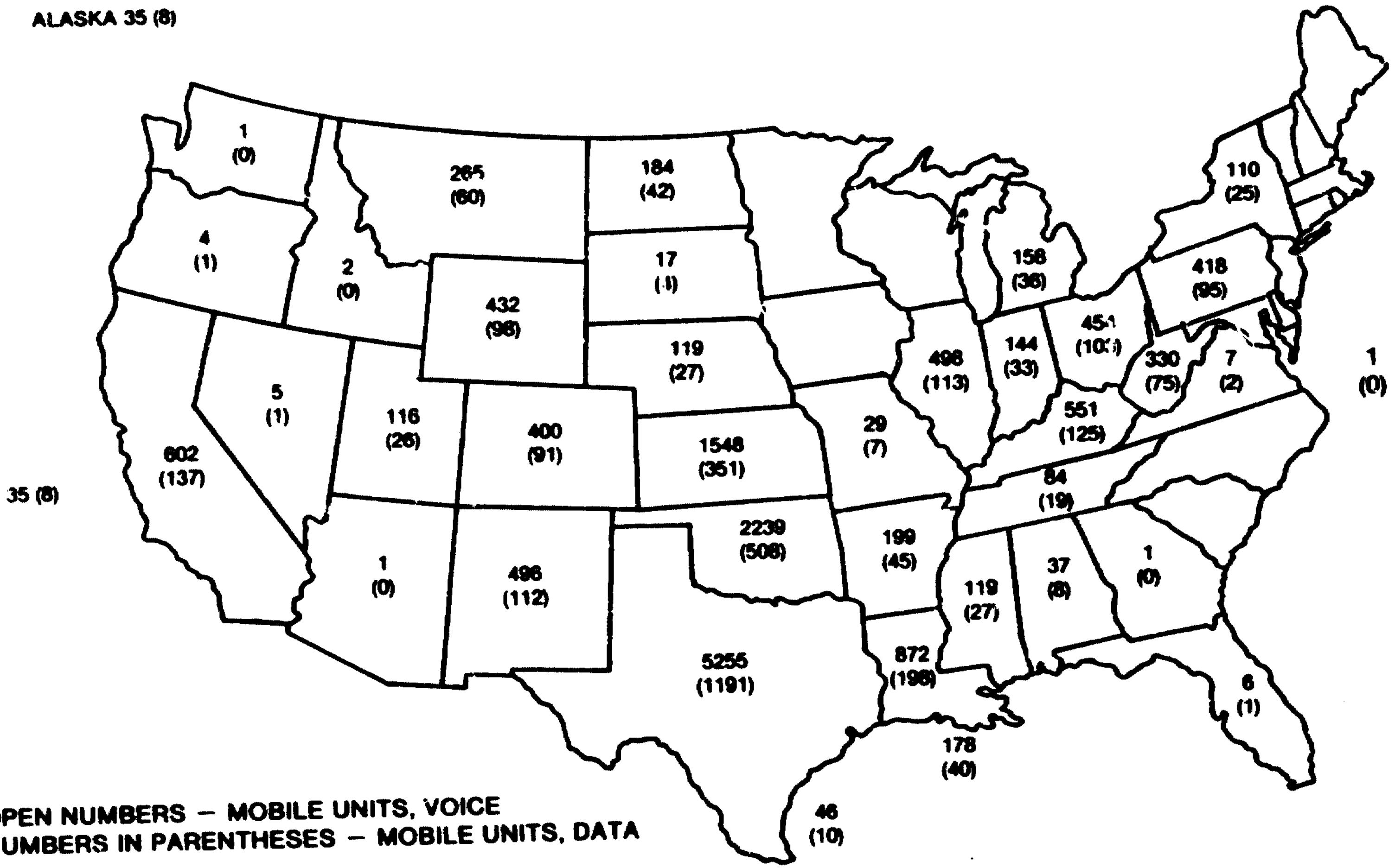

Figure 3-5. Distribution of Oil and Gas Activity

traffic distribution of the baseline market is proportional to the fuel consumption. The total trailer market is 153,942, and the total tractor market is 79,421, both from Table 2-2, Section 2.2. Using the state fuel totals shown in Table 3-6 to determine the state proportions gives the traffic pattern shown in Figure 3-6. We note the overall similarity of this figure and those developed for the Commercial and Public Radio market and the Mobile Radiotelephone market.

3.4 FACTORS AFFECTING FUTURE GEOGRAPHICAL DISTRIBUTIONS

Section 2 quantifies the market for each of the market categories and predicts the market growth up to the year 2000. Appendix A presents analyses of the geographical distribution of the markets, but only on the basis of present population, mobile radio usage, and distribution of activities that need new mobile radio services. Future changes in the geographical distribution are not presented.

No sound bases for predicting geographical distribution changes were determined. A prediction would require complex models that account at least for in-and-out migration. Factors that will modify the distributions include:

- Probable continuation of the trend toward increasing population in the Sunbelt and Western states with stable or slightly decreasing population in the Northeast and Midwest.
- Increased economic activity in the Rocky Mountain states, including but not limited to energy and mineral resource exploration and recovery.

The trends may be slowed by environmental limitations, such as the comparatively limited fresh water resources in the West and the development of high-technology industries in the Northeast that are replacing the traditional product lines that have moved away from the region.

3.4.1 Commercial and Public Radio and Radio Telephone

While demographic changes that have an effect on geographic distribution of mobile radio usage will certainly take place, their effect on demand will be small compared to the effect of market penetration on non-urban distribution of mobile services. This fact is dramatically demonstrated by comparing Figures 3-2 and 3-3. If the served non-urban market comprises the counties that have a population density of 20 persons per square mile or fewer, the geographic distribution is predominantly in the West. If the served non-urban market comprises those counties that are not SMSAs, the geographic distribution is predominantly in the East. It is reasonable to expect that if the served non-urban market comprises areas with population densities below some intermediate density, the geographical distribution of demand will be quite evenly distributed throughout the country. The total population of non-SMSA counties is 57,115,182. The total populations of counties with 20 persons per square mile or fewer is 10,316,000. Thus changes in distribution with market penetration are potentially so large compared to the changes that would result from future demographic changes that it is not worthwhile to attempt predictions of temporal changes in distribution.

It is important to note that, in the context of this study, the population density that distinguishes the non-urban market from the urban market is not an arbitrary choice or definition. The non-urban market is that population and those areas of the country that will not be served without special measures such as the implementation of a satellite system or a terrestrial system with a national architecture that serves nearly all of the nation's population and most of its land area.

Table 3-7

HIGHWAY FUEL CONSUMPTION OF SPECIAL FUELS 1980
(In Thousands of Gallons)

State	Total
Alabama	322.457
Alaska	46.132
Arizona	218.807
Arkansas	213.762
California	1,153.621
Colorado	141.087
Connecticut	104.213
Delaware	35.156
Dist. of Columbia	17.293
Florida	498.560
Georgia	449.287
Hawaii	19.169
Idaho	55.085
Illinois	604.245
Indiana	577.215
Iowa	268.905
Kansas	232.972
Kentucky	247.928
Louisiana	288.967
Maine	57.474
Maryland	165.740
Massachusetta	185.113
Michigan	304.285
Minnesota	252.877
Mississippi	212.544
Missouri	359.091
Montana	98.615
Nebraska	145.923
Nevada	78.064
New Hampshire	27.956
New Jersey	340.076
New Mexico	167.771
New York	332.853
North Carolina	382.817
North Dakota	79.070
Ohio	707.286
Oklahoma	305.944
Oregon	243.414
Pennsylvania	705.190
Rhode Island	27.187
South Carolina	228.847
South Dakota	73.557
Tennessee	383.751
Texas	1,199.933
Utah	111.133
Vermont	29.771
Virginia	318.037
Washington	235.020
West Virginia	123.976
Wisconsin	304.702
Wyoming	93.962
TOTAL	13,776.840

3.4.2 Trucking and Oil Services

Future distributions of mobile radio services for the trucking and oil services industries will continue to be dominated by economic activity. Traffic patterns for the trucking industry will continue to follow the total population distribution of the country, and thus will tend to shift to the Sunbelt and Western states. We do not have a valid basis for predicting the magnitude of the shift, but do not expect it to cause a major restructuring of the present distribution patterns.

Future activity in the oil and gas well servicing industry may increase in the Overthrust Belt along the eastern edge of the Rocky Mountain chain. Major activity is expected to continue in the Gulf states and the Gulf of Mexico with some increase in activity in gas well drilling in Michigan and the Northeast. The change in distribution of the mobile radio services to support the activities will reflect the geographical shift in emphasis, but no major restructuring of the present distribution patterns is expected.

Section 4

ELASTICITY OF DEMAND

4.1 DEMAND VERSUS SERVICE QUALITY

The ECOsystems report[4] presents an assessment of demand versus quality. The following is extracted from the report.

"By quality elasticity is meant the additional price which users are willing to pay in order to upgrade the performance of their systems from current to predetermined levels of improvement. The purpose of calculating this quantity is to assess the magnitude of the eventual 'premium' for performance which could be incorporated in the tariff structure of an eventual high-performance alternative system.

"The most reliable data to the effect of computing such premiums were found to be those furnished by SIRSA (Special Industrial Radio Service Association).

"With Special Industrial Radio Service having a nationwide growth rate in excess of 9% per year since 1977, SIRSA surveys showed a general decline in system satisfaction with 6.6% fewer users (primarily metropolitan users) willing to rate their communication system 'excellent' in 1979 as compared to 1977. In January 1979, SIRSA forwarded to its membership a survey designed to obtain reliable statistical information about this trend.

"For the purpose of classifying the survey data, SIRSA designated a system as 'rural' if its principal radio operations took place in a township, city, or county with less than 100,000 population. There were 1489 rural survey returns. System satisfaction indicated by rural users is shown in the following table.

RURAL SYSTEM SATISFACTION

Rating	Percent
Excellent	22.9
Good	48.6
Average	19.2
Fair	6.8
Poor	2.5

"The question, asked by SIRSA to its users, of interest in evaluating service quality elasticity was: 'Assuming your radio system satisfaction was average or below, how much would you be willing to pay to upgrade your system satisfaction to excellent?'

"The returns from the approximately 1300 rural SIRSA respondents to this question were as shown in the following table.

WILLINGNESS TO PAY TO UPGRADE SYSTEM SATISFACTION TO EXCELLENT

Willingness to Pay, $	Cumulative Percent Users	Average Percent Users	Willingness to Pay Per User	Cumulative Average
--	39.6	39.6	0	0
100	23.2	62.8	23.20	23.20
500	22.1	84.9	110.50	133.70
2,500	12.6	97.5	315.00	448.70
10,000	2.5	100	250.00	698.70

[4] Non-Urban Mobile Radio Demand Forecast, Final Report, June 25, 1982. Prepared for General Electric Company. Prepared by ECOsystems International Incorporated, Gambrills, MD. Pages 69ff.

"Figure [4-1] shows the amount that rural users are willing to pay in order to upgrade the quality of their system satisfaction to excellent.

"Figure [4-2] shows the prices which users actually pay for their base equipment. (Note that Special Industrial and Business Radio users are combined, because of their high degree of similarity.)

"Comparison of Figures [4-1 and 4-2] shows that the user's willingness to pay a 'premium for quality' is of order 7%."

4.2 DEMAND VERSUS COST

Potential business users of cellular mobile telephone systems in the Chicago metropolitan area were surveyed by Compucon, Inc. for Rogers Radio.[5] The following excerpt from the report is used with permission of Compucon.

"Four proposed monthly price levels ($60, $120, $180, $240) were proposed to equal numbers of respondents. They all were asked the following question:

'Not including long distance charges, if the cost of portable or mobile phone service including the equipment lease was $___ per month, how interested would you be in using this service?' Would you be:

Level	$60	$120	$180	$240
Very Interested	9%	3%	4%	6%
Somewhat Interested	25%	22%	14%	15%
Not Very Interested	17%	18%	25%	21%
Not at all Interested	47%	56%	55%	56%
Don't Know (was not read as a choice)	3%	1%	2%	2%

(One of the four price points was randomly selected by the computer and inserted in the blank.)

Those respondents who answered that they would be interested in leasing the service and equipment were then asked how many units they thought their companies would use at that price. The results obtained were as follows:

Number of Units	$60	$120	$180	$240
0	5%	10%	14%	18%
1	41%	25%	37%	20%
2	28%	33%	27%	33%
3	8%	6%	8%	16%
4	2%	10%	4%	8%
5	3%	4%	6%	0%
6 - 10	7%	6%	4%	0%
over 10	6%	6%	0%	4%

The average number of units per respondent was then calculated to each price point yielding the following results:

[5] "A Cellular Radio Market Study for the Chicago Metropolitan Area," May, 1982; prepared for Rogers Radio; prepared by Compucon Inc., 13749 Neutron Road, Dallas, Texas 75234

Price Point	Average Number of Units Per Respondent
$60	6.49
$120	4.90
$180	2.04
$240	4.24

The survey by Compucon was made in a large city and the respondents were business enterprises. While the results cannot be applied directly to thinly populated areas, it seems reasonable to expect that the businesses in non-urban areas would respond in approximately the same way. The survey conducted by Opinion Research Corporation for the Audio Electronics Department of General Electric Company, referenced in Appendix A of this report, was directed at households and thus reflects the private as well as the business and professional markets. Perusal of Table A-12 indicates that the overall response in the ORC survey was very nearly equivalent for the SMSA and non-SMSA respondents.

A combination of price and quality elasticity may be assessed from the ORC survey. One question addressed the price sensitivity of a consumer product that would use a mobile telephone in an automobile to communicate with a unit attached to the home telephone of the user. That unit would in turn connect into the wireline network. For a modest service charge the range of the vehicle would be extended by relaying its signals through a community repeater. The question and response were as follows: "If this product cost (a. $295), (b. $350), (c. $450) and the monthly service charge was $3.50, how likely is it that you would purchase this product for one of the vehicles in your household?"

ESTIMATES OF POTENTIAL MARKET SIZE AT THREE LEVELS OF PRICING

	$295	$350	$450
Percentage Base	(2509)	(2509)	(2509)
Potential Purchasers at Each Price	600	455	264
Potential Purchasers as a Percent of Total Sample	23.9%	18.1%	10.5%

Another question related to a mobile telephone system with price and performance similar to cellular mobile telephone: "If a much better mobile telephone system were available to you that operated in a much wider range in all directions, and had no limitations on message length and did not require a base station in your home, how likely is it that you would obtain such a system if the cost was $750 ($1000) and the monthly service charge was $50.00 ($75.00)? Would you ...?"

LIKELIHOOD OF PURCHASE OF A BETTER,
MORE COSTLY MOBILE RADIO TELEPHONE PRODUCT
($750 Mobile Radio Telephone
and $50 Per Month Service Charge)

	Total Drivers	Acceptors of GE Product
Percentage Base	(2509)	(600)
Intention of Purchase	100.0%[a]	100.0%[b]
Definitely purchase	0.6	1.3
Very likely purchase	0.9	2.0
Possibly purchase	4.4	9.8
Very likely not purchase	16.3	26.5
Definitely not purchase	76.2	58.3
Don't know/No opinion	1.5	2.0

(a) 5.9%, 149 respondents
(b) 13.1%, 79 respondents

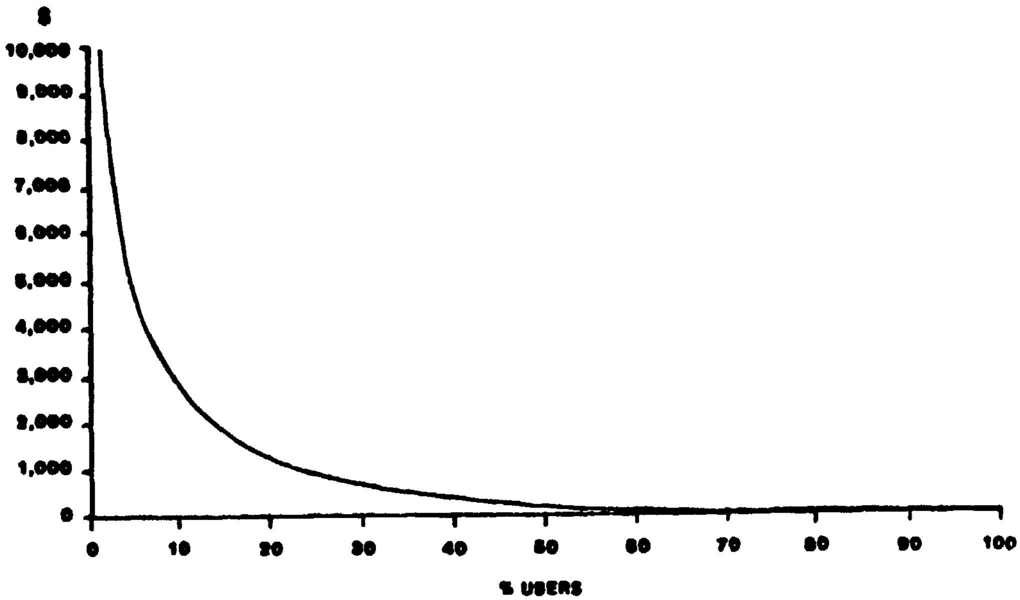

Figure 4-1. Users' Willingness to Pay to Upgrade System Satisfaction to Excellent (Cumulative by % of Rural Users)

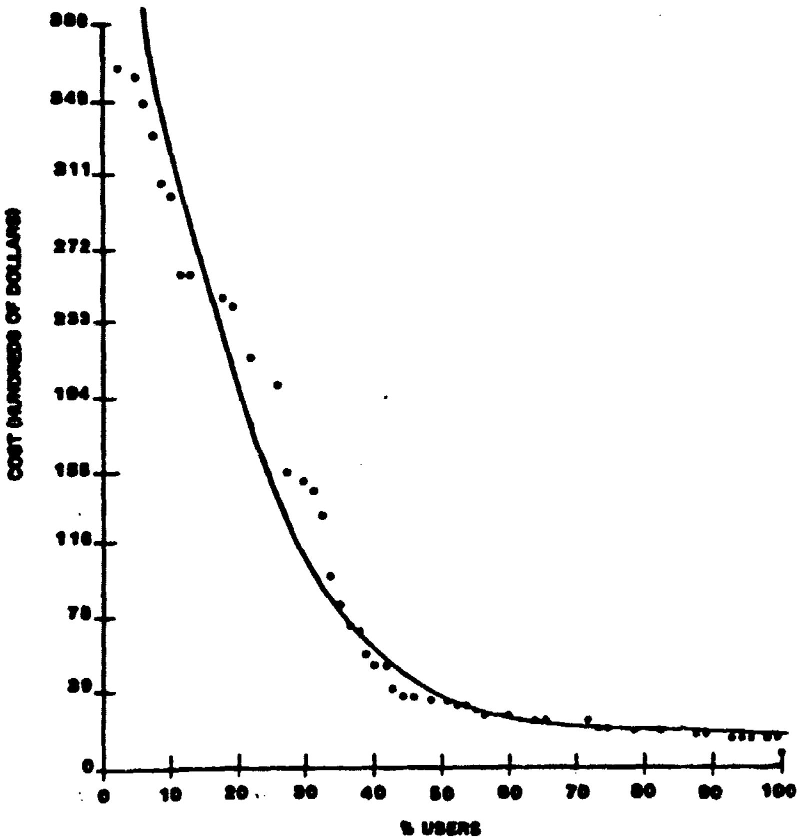

Figure 4-2. Business and Special Industrial Users' Base Radio Costs (February 1982)

Section 5

DISTANCE DISTRIBUTION OF MOBILE RADIO TRAFFIC

5.1 POLICE SYSTEMS

"The results of the ECOsystems survey[6] indicate that the distance requirements of police mobile radio traffic range from very low (a few kilometers) up to the maximum distance subtended by the corresponding political boundries. Only minimal traffic (of order 1% or less) is required to go beyond these boundries.

"The maximum ranges compute out as follows:

Territorial Area (County or State)	Average Maximum Range (km)	Absolute Maximum Range (km)
Average Eastern County	20-30	40-60
Average Western County	50-70	100-140
Median State	150-200	300-400

By average maximum range is meant the radius of coverage from geographic center to the furthermost territorial boundary. Absolute maximum range designates the longest distance between the furthest territorial boundries."

The requirements for police mobile radio as described above are assumed to be typical of county and state public services including highway maintenance and emergency medical service in rural areas.

Federal agencies require longer distance communication for applications such as law enforcement, illegal immigrant interdiction, and disaster control and relief. Disasters often occur where there are no telephone services. If telephone service is normally available, it may be destoyed by the disaster. If it is not destroyed, the system becomes saturated with calls and is often useless to the disaster relief agencies. The affected area may encompass several states in the region surrounding the disaster. Radio communication with ranges of several hundred to more than 1000 miles is essential in some of the applications.

5.2 SPECIAL INDUSTRIAL RADIO SERVICE

The Special Industrial Radio Service Association (SIRSA) conducted a survey in December 1977 to obtain information on the usage and performance of its members' mobile radio systems. The report includes the required communication ranges and the achieved ranges of its members.[7] Tables 6.1 and 6.2 are from the SIRSA report. SIRSA comments: "As expected, those industries that are primarily located in urban areas require shorter communication ranges as compared to those located in rural areas such as the petroleum services, agricultural services and mining industries. For example, 39.8% of those engaged in supplying services to the petroleum industry stated that they require a range of 51 to 75 miles, and 15.4% stated that more than 75 miles were necessary.

"Perhaps, more importantly, when these responses were tabulated by SIRSA's staff, it was found that 23.4% of the returns noted that more communication coverage was needed than presently achieved. Conversely, only 8.3% stated that they were achieving more coverage than they required from their two-way radio systems."

---

[6] Non-Urban Mobile Radio Demand Forecast, Final Report, June 25, 1982. ECOsystems International, Inc., Page 73.

[7] 1978 Membership Report of the Special Industrial Radio Service Association, page 19.

Section 6

RADIO TRAFFIC DEMAND SUMMARY

This section summarizes the numbers of mobile units and the traffic demands for each of the three market categories. Estimates are made of the radio traffic demand in order to determine the number of communication channels and thus define the size of the systems to meet the demand. Communication traffic is measured in erlangs. As used in the following assessment, an erlang is the traffic that will continuously occupy a voice bandwidth channel.

The channel capacity to handle the traffic is larger than the erlang demand because it must allow additional time on the channels for minimizing blocking of messages. If trunking is used, contol channels are needed in addition to the talking channels.

The ECOsystems study determined that the mean traffic generated by base stations is as follows:

Business	32.135 milli-erlangs
Special Industrial	25.004 milli-erlangs

ECOsystems emphasizes that the above values are only for the traffic generated by the base stations. An equal amount of traffic is generated by the mobiles in return; hence the total traffic is double the above. On the average, there are six mobiles per base station. For the purpose of estimating total traffic demand for dispatch services, we assume an average one way demand of 0.028 erlangs per base station, or an average of 0.0093 erlangs of two-way demand per mobile. The values are the average demand generated during the normal working hours of the users.

6.1 OIL AND GAS SERVICES

The capturable market in the oil and gas well services industry is summarized from Table 2-1.

Mobile Units

	1990	1995	2000
Voice	35,736	41,428	48,626
Data	7,288	8,449	9,794

On the assumption that the average demand for voice communications in the oil and gas well services industry is 0.0093 erlangs per mobile, the peak demand in erlangs is:

Erlangs (Voice)

	1990	1995	2000
Erlangs	322	385	452

A representative of a major oil and gas well service company stated that each day his company generates well logging data that would require 200 hours of transmission time at 4800 bits per second. He estimated that that is 15% of the total amount of logging data that is generated by the industry in the contiguous states and the Gulf of Mexico. Other industry representatives have indicated that new instrumentation will greatly increase, perhaps by an order of magnitude, the amount of data per wel site as the technology develops over the next decades.

Based on the assumption that the increase in demand will only follow the increase in the number of mobile service vans, the number of voice channel equivalent erlangs will be:

Erlangs (Data)

	1990	1995	2000
Erlangs	111	128.8	149.4

While the total demand for the data transmission is not large, the economic value of its transmission is emphasized by the industry representatives. One company is now offering the service through a domestic satellite for a $2400 setup charge and $800 per day.

6.2 TRUCKING INDUSTRY

The capturable market for the trucking industry as described in Section 2 is considered to be only the common and contract carriers on intercity irregular routes. Many other trucks may use a long range mobile radio service also, but the analysis is restricted to the portion of the industry whose represetatives have expressed a definite need. The desired functions are position surveillance of trailers, automatic data transmission from trailers, and communications with drivers. The numbers of mobiles in the market segment are summarized from Table 2-2.

Mobile Units

	1990	1995	2000
Trailers	168,439	185,970	205,326
Tractors	86,900	95,945	105,931

Voice or voice equivalent (alphanumeric) communications with the drivers will replace the long distance wireline calls that are now used for dispatching trucks. The average dispatch traffic demand per vehicle, 0.0093 erlangs, is assumed to apply to the trucking industry.

Erlangs (Voice)

	1990	1995	2000
Erlangs	808	892	985

The position fixing and low data rate communications will require short and infrequent messages from each trailer. A position fix can be accomplished in one second. Each status message will require only a fraction of a second transmission time at voice bandwidth rates. Guard time in the channels must be allowed because of the messages are transmitted at random times from the trailers. Messages are desired from many trailers when they are not attached to tractors because their status and load conditions are to be monitored. We assume five seconds of transmission per day from each trailer, or .00006 erlangs.

Erlangs (Data)

	1990	1995	2000
Erlangs	9.7	10.8	11.9

The attractivness of the position surveillance and data transmission will depend upon the cost of the units for the trailers. The cost of the functions will be low because a very large number of units can be accommodated in one voice channel. If the equipment cost is low, a few hundreds of dollars, it is likely that a very much larger portion of the nation's four million trailers will use the service.

6.3 COMMERCIAL AND PUBLIC SERVICES

Commercial and public radio services use voice in the dispatch mode of communications almost exclusively. The addressable market is summarized from Table 2-3.

	Mobile Units		
	1990	1995	2000
Conservative	111,339	156,159	219,021
Likely	440,412	709,288	1,142,315
Optimistic	975,953	1,571,792	2,531,371

The predicted traffic demand in erlangs for commercial and public radio to satisfy non-urban needs for longer range and better coverage is:

	Erlangs		
	1990	1995	2000
Conservative	1,035	1,452	2,036
Likely	4,095	6,596	10,623
Optimistic	9,076	14,617	23,541

6.4 MOBILE RADIO TELEPHONE

ECOsystems reports that the FCC sampled some 50 common carriers widely distributed throughout the United States and determined that the average mobile radio telephone generates .014 milli-erlangs of traffic. The number must be multiplied by two, since radio telephone service requires duplexing. The mobile traffic is thus .028 erlangs per subscriber. The addressable mobile radio telephone market is summarized from Table 2-4:

	Mobile Telephone Subscribers		
	1990	1995	2000
Conservative	51,582	65,833	84,021
Likely	216,895	304,206	426,655
Optimistic	287,810	463,521	650,112

Applying the estimate of .028 erlangs per subscriber to the above, the demand in erlangs is as follows:

	Erlangs		
	1990	1995	2000
Conservative	1,444	1,843	2,352
Likely	6,073	8,517	11,946
Optimistic	8,059	12,978	18,203

6.5 DEMAND TOTALS

The sums of the traffic demands in erlangs are:

	1990	1995	2000
Conservative	3,730	4,712	5,986
Likely	11,419	16,530	24,168
Optimistic	18,387	29,012	43,342

Section 7

MOBILE RADIO SERVICES IN ALASKA AND HAWAII

The populations of Alaska and Hawaii are small compared to the total population of the contiguous states. The mobile radio demand that they add to the total is not sufficient to seriously impact the size or capacity of a system with a national architecture. It is not fruitful to attempt more than an approximation of the total numbers of mobiles or the demand in erlangs. The separation of the two states from the others, the separation or isolation of communities within the two states, and the unique geographical characteristics of each of them present requirements that are quite different from those of systems within the contiguous states.

7.1 ALASKAN REQUIREMENTS

The large area of Alaska, its small and dispersed population, and its economic importance present commmunication challenges which are different from those of the contiguous states. Alaska has a land area of 591,004 square miles and a population of 401,851 persons. It has one Standard Metropolitan Statistical Area, Anchorage, with a population of 174,431 persons and an area of 1699 square miles. Fairbanks, population 22,645, and Juneau, 19,528, are the only other cities in the state with a population in excess of 10,000 persons. The state has many small, widely separated communities.

Present mobile telephone service in Alaska is of the IMTS type (Improved Mobile Telephone Service). All of the installations operate in the 150 MHz band. Radio Common Carriers have systems in Fairbanks, Anchorage, and Juneau. One system in Kenai (population 4,324) is operated by a Bell System company.

No survey of mobile radio usage in Alaska was attempted. Estimates of demand are based on extrapolations of use in the contiguous states. Gross estimates of demand for Alaska are sufficient for the purposes of this study because the number of units is small compared to the demand in the contiguous states and thus the Alaska estimates can have only a small effect on total system demand. More important than the numbers of units are the economic and societal needs for better, especially longer range, mobile communictions in the thinly populated, mountainous state.

Estimates of the numbers of commercial and public radio sets in the contiguous states range between seven and ten million, or 3.1% to 4.4% of the population. The SIRSA membership report referenced in Section 2 revealed that approximately 23% of the non-urban commercial and public radio users required additional coverage and range. If those factors apply to Alaska, the estimated number of commercial and public radio mobiles that would benefit from improved dispatch-type mobile services is about 3700. We estimate they would generate about 35 erlangs demand.

If a mobile radio telephone service were implemented in Alaska with no limit of range so that subscribers could have about the same quality of service that will be enjoyed by urban users of cellular systems, it is reasonable to expect that the market penetration would reach at least the one percent of the population that is estimated for the urban systems. In the Province of Alberta, which has a mobile telephone service available over 75 percent of its land area, the number of mobiles at the end of 1980 was 1.4% of the population. The number had been growing at 25% per annum for the previous seven years. Alaska may have many characteristics similar to Alberta. Both have large areas, much of which are thinly populated, and both have important energy resources with increasing exploitation activity. Based on one percent penetration, the number of subscribers in Alaska would be 4018. Radio traffic demand would be about 113 erlangs.

Alsaka shares in the need for new mobile services as well as for commercial and public radio and radio telephone. The state's energy, mineral, fisheries, and forestry industries would benefit from data communications and position surveillance functions if they were available. The geographical dispersion of the resources and the state's population require that the communications have long-range capability. A radio equipped vehicle should be able to communicate with a "home" base as it travels in its local area. It is also important that it be able to communicate over the long inter-community distances. Long distance communications are important to the fisheries industry as well as the land-based industries. High-frequency radio (2 - 30 MHz), the only presently availabe long-range mobile radio means, is frequently degraded by ionospheric disturbances in the Alaskan latitudes.

Specific needs for non-urban mobile communications in Alaska include:

- Dispatch and mobile telephone service in the local areas surrounding many small communities.
- Dispatch and mobile telephone service between vehicles and their home communities when they travel beyond local areas.
- Mobile and rural radio telephone service between widely separated communities including calls to major cities and to locations in the contiguous states.
- Dispatch communications and position surveillance for transportation services including trucks, trains, large and small aircraft, inland and coastal vessels.
- Data communications from energy and mineral exploration and exploitation sites to data processing centers in Alaskan cities and the contiguous states.
- Data communications from remote communities and settlements to medical and law enforcement centers in Alaskan cities and the contiguous states.
- Access from remote communities to information and data banks in Alaskan cities and in the contiguous states for educational purposes.

The needs listed above do not make a clear distinction between mobile radio and some fixed services. For small and isolated communities the communications equipment costs and service charges must be typical of mobile radio rather than of fixed services that require large antennas, costly equipment, and high service charges.

7.2 HAWAIIAN REQUIREMENTS

Hawaii differs from Alaska in total land area, but is similar in the total geographic area occupied by the state. The land area of Hawaii is 6471 square miles; its population is 964,691. Eight major islands extend westward about 400 miles from 155 degrees west longitude, and smaller islands in the chain continue on almost to the international dateline. In that long extent, the state has 12 cities that exceed 10,000 population. As in Alaska, there are separated, isolated communities.

Mobile radio telephone service of the IMTS type is provided by Radio Common Carriers in Hilo (population 35,629), Honolulu (City, 365,048; SMSA 762,874), Kaneohe (29,919), and on the island of Maui. Bell companies serve Hilo, Lihue (4000), and the island of Kauai.

The 150 MHz band seems the best available choice for terrestrial systems because of the mountainous terrain. Only in the largest cities, perhaps only Honolulu, would an 800 MHz cellular system be applicable. Inter-island communication and communication with the contiguous states must depend on HF radio (2-30 MHz), cable, and satellite. At the present time only HF radio is useful for inter-island mobile radio, and that mode is not reliable. Most requirements for inter-island mobile radio are for ocean vessels and aircraft that are enroute.

The needs for mobile radio in Hawaii are similar to those listed for Alaska. The total demand in Hawaii may be larger than that of Alaska in approximate proportion to its population.

Appendix A

STATISTICAL ANALYSIS OF POTENTIAL MARKETS AND THEIR GEOGRAPHICAL DISTRIBUTION

An important aspect of the potential markets is their geographical distributions throughout the contiguous United States. Ancillary data and correlational methods were used to obtain the distributions for the baseline (current) markets for the three segments. The three segments were chosen to be essentially independent for the current markets and to remain so.

The prediction of a future distribution requires a forecast of the ancillary data. The forecast of ancillary data coupled with the assumption that the predictive relationships remain constant over time allows forecasts of the distributed market to be made. Thus the analysis of the distributed market follows a cross-sectional econometric approach.

The cross-sectional approach differs from the one taken in determining the total market for the entire contiguous states for the three segments and the forecasts to the year 2000 as described in Section 1.2. The two approaches need not give identical results. Each has its advantages and disadvantages. A cross-sectional approach has the advantage of indicating relationships within a market (the basis for the market distribution) and can be the first step in determining cause and effect relationships. It has the disadvantage of requiring forecasts of the ancillary data in order to make market forecasts. The approach taken in Section 1.2 has the advantage that it is self contained and, hence, any analyses are simple and straightforward. However, it has no way of anticipating changes in growth rates or more importantly if a growth model continues to hold. By taking the two approaches we get two different views of the overall market.

Summaries of the distributions for the three market segments follow.

Distribution of the Commercial and Public Services Market

The fundamental data employed for the Commercial and Public Radio market analysis are derated counts for business and special industrial licenses in a set of sampled counties taken from a study performed by ECOsystems.[1] The counts for business and special industrial licensees were obtained directly from FCC records. The derating factor, defined by the FCC, corrects for frequency compounding and for users with more than one base station. Thus the derated counts represent the number of business and special industrial users of mobile radio. (See page 7 of the cited ECOsystems report for a further discussion of the derating factor.)

We also employed the results of a traffic survey made of the business and special industrial users in an initial sample of 13 users in a two-stage sampling scheme employed by ECOsystems. The survey comprised 77 business radio users and 32 special industrial radio users. The estimated mean milli-erlang demand for a business user is 2474.4/77 = 32.135 milli-erlangs and the corresponding estimated mean for special industrial users is 800.14/32 = 25.004 milli-erlangs. The estimates are obtained from data given in Tables 6 and 7 of the ECOsystems study.[2] The estimated means were multiplied by a factor of 2 because the erlang usages were on a one way basis.[3] It is assumed that the sum of the lengths of the average mobile messages associated with a base station is equal to the message transmission time of the base station. The assumption appears reasonable when complete transactions are con-

[1] Non-Urban Mobile Radio Demand Forecast, Final Report, June 15, 1982, ECOsystems International, Inc., Table 8, page 26

[2] Op. cit.

[3] Op. Cit. page 22

sidered. An initial message from a base is frequently longer than the initial mobile response. Succeeding mobile responses to the initial base station message are frequently longer than the corresponding base station response. The total demand is larger by some factor than the demand given in the ECOsystems study, and a factor of 2 is taken as the most likely.

The ECOsystems sampling was carried out in two stages because ECOsystems found no significant correlations[4] between erlang demand and available demographic data in the first sample. The initial sample consisted of 20 counties selected at random from the non-SMSA counties in the contiguous United States (CONUS). The second stage consisted of an additional 53 counties selected at random from non-SMSA CONUS counties. The total sample was used in our modeling process with the assumption that erlang demand is independent of an individual user selected at random. Since correlational models were developed only for the number of users within a county the sample remains a valid random sample.

The assumption is consistent with the ECOsystems findings and implies a compound distribution as a possible fundamental model. Compound distributions are widely used as models in situations analagous to this one. It is assumed that a random process generates the number of users in a given county and the demand for a particular user is given by a non-negative distribution. It is further assumed that the process that generates the users is independent of the process that generates the demand. An estimate of the mean demand for any county is obtained by multiplying the average demand per user times the estimated number of users in the county.

The first step in the procedure is to obtain estimates of the number of users for those counties that were not sampled. We employed demographic and economic data compiled on a county basis and published in the County and City Data Book.[5] The data are available on tape, and the tape version was used in the study. The data consist of statistical compilations for regions, divisions, states, counties, metropolitan areas, and cities.

County data are given under the general categories of: Population and Area, Vital Statistics, Labor Force, Employment, School Enrollment, Health, Income, Public Assistance and Social Security, Banking, Housing, Local Government Finances, Government Employment, Elections, Crime and Police, Manufacturers, Wholesale Trade, Retail Trade, Selected Services, Mineral Industries, Farm Population, and Agriculture. In all there are 195 individual data entries for each county.

From these 195 entries we sought to develop regression equations that would ascertain the number of mobile radio users in any given county. We were confronted with two conflicting objectives in the selection of an equation.

- To enhance the usefulness of the prediction the equation must include as many of the demographic and economic predictor variables as possible.
- Analysis with a large number of variables would be prohibitive in cost, and a large number of predictor variables generally results in a singularity in the regression equations.

It was necessary to make a sensible selection of initial variables and put the selection to a critical examination and analysis.

[4] Op. Cit. Page 22

[5] County and City Data Book 1977, U.S. Bureau of the Census, U.S. Department of Commerce.

The final model selection procedure employed stepwise regression. This is a widely used procedure that attempts to make the best of the opposing aims just discussed. An excellent discussion of the method and comparison with other methods is given in Draper and Smith.[6]

To begin, a small number of variables was studied in a usual regression analysis. Two things were discovered: the development of a "good" predictor would probably be difficult, and care would have to be exercised in selecting predictor variables from the 195 choices because not all variables are reported for all counties. An attempt was made to cover all factors that could contribute to the market. Of the general categories it was believed that population and area, employment, banking, manufacturers, wholesale trade, retail trade, selected services, mineral industries, farm population, and agriculture should be correlated with the business and special industrial users.

For the retail trade and selected services categories only certain totals, e.g., the number of establishments, are reported for all counties. Indeed even total receipts of all establishments for the selected services has missing data for Oliver, N. D., one of the sampled counties. Since these totals should be highly correlated with population and other variables we wish to include in the regression model we have included none of these totals in the analysis. Thus there are no direct representatives of retail trade and selected services in the model. The farm population category was also omitted because it is based on 1970 census data. Thus seven categories remained. One variable was selected from each category giving a total of seven predictor variables for the regression study.

The seven variables selected are total population as of July 1975 (item 3), total annual payroll for 1975 (item 36), total bank deposits for 1976 (item 65), manufacturing establishments with 20 or more employees from the 1972 Census of Manufacturers (item 110 x item 111/100), total wholesale trade establishments from the 1972 Census of Wholesale Trade (item 122), all mineral establishments (e.g., coal and ores, petroleum, gases, etc. and all related operations such as mining, drilling, quarrying, well operation, etc.) from the 1972 Census of Mineral Industries (item 162), and number of farms of 1000 acres and over from the 1974 Census of Agriculture (item 184).

In some cases other representative variables were investigated but were discarded either because there were missing data or because the included variable correlated better with the user counts. Table A-1 shows part of the output from the first step of the stepwise regression procedure for the regression of the business counts on the seven predictor variables.[7] Similar data are shown in Table A-2 for the regression involving the special industrial counts. The current error mean square is that associated with the fit of all seven variables shown in the two tables in their respective models. The incremental F-ratio is also the partial F and is the square of the partial t. The partial t is the test statistic reported in standard regression routines for testing the statistical significance of an independent (predictor) variable. The new mean square error is associated with the model that has the respective variable omitted. The variance inflation factor (VIF) is a measure of the near singularity of a model with all seven variables. An individual VIF is given by by $1/(1-R_i^2)$ where R_i is the multiple correlation of the i^{th} predictor variable with all other predictor variables.

Since the VIFs involve only the predictor variables, the two sets of VIFs are identical. Solving for the R_i^2 associated with payroll results in a value of 0.95585, so that about 95.6% of the variation of the payroll variable can be explained in a regression of payroll on the other

[6] Applied Regression Analysis, 2nd Edition, N. Draper and H. Smith (1981), John Wiley and Sons, Inc., New York

[7] The stepwise procedure employed STATPAC, a computer program developed at the General Electric Research and Development Center.

Table A-1

FIRST STEP OUTPUT – REGRESSION OF BUSINESS COUNTS

*Step No. 1
Test to Remove Old Variable
Current Error Mean Square: 749.1872

Var	Incremental Corr	Incremental F-Ratio	% Pt of F-Dist	New Error Mean Square	Incremental Error Mean Sq	Variance Inflation Factor
Manuf	0.1273	2.7082	89.53	768.5778	19.39053	6.934474
Bank	0.0686	0.7860	62.14	746.7577	−2.429520	10.11495
Payrol	0.1399	3.2687	92.48	774.9395	25.75231	22.65082
Minera	0.2347	9.2042	99.65	842.3157	93.12843	1.724372
Pop2	0.0392	0.2568	38.60	740.7515	−8.435753	14.83945
Farms	0.0175	0.0512	17.84	738.4174	−10.76980	1.455983
Wholes	0.2300	8.8423	99.59	838.2081	89.02087	5.868052

*Removed Farms 5.0000 is the specified value for deleting a variable.

Table A-2

FIRST STEP OUTPUT – REGRESSION OF INDUSTRIAL COUNTS

*Step No. 1
Test to Remove Old Variable
Current Error Mean Square: 95.68788

Var	Incremental Corr	Incremental F-Ratio	% Pt of F-Dist	New Error Mean Square	Incremental Error Mean Sq	Variance inflation Factor
Manuf	0.0162	0.0588	19.09	94.32339	−1.364497	6.934474
Bank	0.0749	1.2640	73.50	96.07059	0.3827066	10.11495
Payrol	0.0970	2.1172	84.95	97.30758	1.619699	22.65082
Minera	0.3068	21.1783	100.00	124.9427	29.25485	1.724372
Pop2	0.0211	0.1004	24.76	94.38356	−1.304325	14.83945
Farms	0.3032	20.6848	100.00	124.2272	28.53932	1.455983
Wholes	0.2234	11.2366	99.87	110.5291	14.84119	5.868052

*Removed Manuf 5.0000 is the specified value for deleting a variable.

predictor variables. A value of 10 for a VIF or R_i^2 of 0.90 is considered to be large by many analysts.[8]

Thus the VIFs indicate the presence of some linear relationships among the predictor variables. This is not unusual for this type of study. Since the program employed uses Gaussian elimination in double precision with pivoting, this amount of linear correlation does not unduly affect the matrix inversion required in estimating the model parameters and performing the analysis. Careful selection of the predictor variables avoided extreme correlation. Unfortunately, the most important predictor may have been missed in so doing, but there is no guarantee it was in the data given in the County and City Data Book.

In a further investigation of the correlation among the predictor variables the correlation matrix of the variables was obtained as shown in Table A-3. Inspection of that table indicates why the payroll variable has a VIF of 22.65 as well as the nature of the other VIFs. Payroll is reasonably correlated with the variables for manufacturing, banking, population, and wholesale trade. Moreover, the population variable is reasonably correlated with the variables for manufacturing, banking, payroll, and wholesale trade. Also the variables for minerals and farms are reasonably uncorrelated with each other and all the other variables. Perhaps the most striking feature in Table A-3 is the fact that certain predictor variables are better correlated with each other than with the business (BUSIN) and special industrial (INDUS) counts.

Finally, Tables A-1 and A-2 show the value of the *F* to remove (5.0). In addition a value of 6.0 was employed for the *F* to enter. These values are somewhat larger than the usual values and are chosen to allow for a simultaneous inference. This procedure is discussed at some length in the Draper and Smith reference in Chapter 6. The stepwise procedure was begun with all variables in the model. A check was then made to see if any variable could be removed. If not, the procedure would stop. For the business model, the farms variable was removed at the first step, and similarly for the special industrial model the manufacturing variable was removed. Before a step was completed all previously removed variables were checked to see if any could enter. The most promising was entered if it passed the enter test. For the first step the variables just removed were not entered. (We have *F* enter > *F* remove for this reason; see the Draper and Smith reference.) The process continued until no further model changes could be made.

Table A-4 shows part of the output for the last step of the stepwise procedure for the regression study of the business counts. Similar data are shown in Table A-5 for the regression study involving the special industrial counts. The results are quite interesting. For the business model the predictor variables are the mineral and wholesale trade variables. The partial correlations are of the order of the original correlations shown in Table A-3. The mean square error is 738.36 as opposed to the original value of 749.19. The multiple correlation coefficient is 0.766 with an index of determination (R^2) of 58.7%. The corresponding initial values were 0.782 and 61.1%. Thus the final model has almost the same predictive ability as the original model. We also note that the intercept term is not statistically significant at a level of confidence of 95% and for predictive purposes could possibly be omitted. However, we did not do so.

For the special industrial model the predictor variables are the mineral, wholesale trade, and farm variables. Essentially the same results that held for the business situation hold here. However, the final mean square error is increased over the initial mean square error and the predictive ability appears to be better than that for the business situation. Again the intercept term is not significant at the 95% level but again the full model was employed. As a

[8] "Some Aspects of Nonorthogonal Data Analysis, Part I" (1973), R. D. Snee, Journal of Quality Technology, 5, 67-79.

Table A-3

CORRELATION MATRIX OF THE VARIABLES

Variable	Manuf	Bank	Payrol	Minera
Manuf	1.0000000			
Bank	0.7530289	1.000000		
Payrol	0.8725226	0.9242528	1.000000	
Minera	−0.4568016E-01	0.1709728	0.2210834	1.000000
Pop2	0.8575606	0.9012138	0.9377864	0.9108305E-01
Farms	−0.3096322	−0.7431560E-01	−0.1768661	0.2014275
Wholes	0.6457256	0.8452297	0.8063513	0.2501952
Busin	0.2909841	0.5306697	0.5436417	0.5633043
Indus	0.2173732E-01	0.3521209	0.2586185	0.5599663

Variable	Pop	Farms	Wholes	Busin Indus
Pop	1.000000			
Farms	−0.1977446	1.0000000		
Wholes	0.8504550	0.9623977E-01	1.000000	
Busin	0.4869440	0.1689862	0.6438529	1.0000000
Indus	0.2514111	0.5600564	0.5481682	1.000000

consequence for some counties negative, but small, counts are predicted. In this case we set the predicted value to zero. This will produce results that are not too different from a re-estimated model with no intercept term.

In summary, the equations shown in Tables A-4 and A-5 were employed in predicting the number of users for each county in CONUS outside the 73 in the sample drawn by ECOsystems. For those we employed the observed data.

Inspection of the equations indicates that they are plausible. Business licenses can come from all areas of business and industry, while the special industrial licenses are restricted to seven general categories, the largest two of which involve agricultural endeavors. Apparently wholesale trade is a good indicator of general business and industry usage of mobile radio and the mineral variable improves the predictions. The strong agricultural bent of the special industrial licensees shows up in the farm variable being additionally included in this regression.

As a further test of the predictive ability of the two equations an additional set of ten counties was selected (but not at random) and the predicted values were compared to the observed values.[9] With the exception of one, these counties were selected from the borders of the states in CONUS or at places where large mobile radio activity was suspected. In this latter category are the three counties in California, one county in Iowa, and two counties in Ohio (one of which is an SMSA as of 1977). The one county in Mississippi (and possibly the border counties in Minnesota, North Carolina, and Texas) can be considered to be selected randomly. The observed data with summary statistics are shown in Table A-6.

[9] This additional data was compiled by ECOsystems but is not reported in the referenced study.

Table A-4

LAST STEP OUTPUT – REGRESSION OF BUSINESS COUNTS

Variables in the Equation:
Minera Wholes

Partial Correlations

Variable	Minera	Wholes
Busin	0.5429370	0.6286689

*Least Squares Estimate of the Fitted Equation

Mean = 3.461782
+ (0.4506807)*Minera
+ (0.6059895)*Wholes

Std Dev = 27.17275

Least Squares Estimates of Coefficients with 95% Confidence Limits

Var	Coeff	Estimate	Lower Limit	Upper Limit	Standard Error
Intr	C00000	3.461782	−6.152214	13.07578	4.820405
Minera	C00004	0.4506807	0.2845106	0.6168508	0.8331680E-01
Wholes	C00007	0.6059895	0.4272949	0.7846842	0.8959653E-01

Var	Coefficient	Variance Inflation Factor
Minera	C00004	1.066778
Wholes	C00007	1.066778

*Analysis of Variance

Source	D.F.	Sum of Sq's	Mean Sq
Regression	2	73498.85	36749.42
Error	70	51685.07	738.3582
Total	72	125183.9	

F-Ratio = 49.77181

The significance level of this F-Ratio is less than 0.001% which is the probability of a larger F value if the true regression coefficients are all zero.

*Other Statistics on the Fit

Standard Deviation about the Equation = 27.17275

Multiple Correlation Coefficient = 0.7662421

Index of Determination = 58.712690%

Maximum Log Likelihood = −344.6442

The mean, standard deviation, and variance of the sample of 73 counties are 35.79, 41.697 and 1738.6 respectively for the business counts and 15.27 17.295, and 299.12 respectively for the special industrial counts. The largest count for business is 279 and there are only five counties with counts above 100. The largest count for special industry is 95 and there are five counties with counts above 40.

If we compare these data with those presented in Table A-6 it does not appear that the ten selected counties are chosen at random from the county population (or from the same population as was the sample of 73). This is not unexpected in view of the way the 10 test counties were selected. The data for the test counties for business counts appear to be skewed to values that are on the average considerably larger than those of the original sample, while almost the opposite is true for the special industrial counts. However, in the case of the indus-

Table A-5

LAST STEP OUTPUT – REGRESSION OF INDUSTRIAL COUNTS

Variables in the Equation:
Minera Farms Wholes

Partial Correlations

Variable	Minera	Farms	Wholes
Indus	0.5260922	0.6123070	0.5784038

*Least Squares Estimate of the Fitted Equation

Mean = −1.980313
+ (0.1597106)*Minera
+ (0.9780157E-01)*Farms
+ (0.1937172)*Wholes

Std Dev = 9.963323

Least Squares Estimates of Coefficients with 95% Confidence Limits

Var	Coeff	Estimate	Lower Limit	Upper Limit	Standard Error
Intr	C00000	−1.980313	−5.918824	1.958199	1.974245
Minera	C00004	0.1597106	0.9770720E-01	0.2217141	0.3108026E-01
Farms	C00006	0.9780157E-01	0.6747307E-01	0.1281301	0.1520267E-01
Wholes	C00007	0.1937172	0.1281026	0.2593319	0.3289046E-01

Var	Coefficient	Variance Inflation Factor
Minera	C00004	1.104172
Farms	C00006	1.044730
Wholes	C00007	1.069276

*Analysis of Variance

Source	D.F.	Sum of Sq's	Mean Sq
Regression	3	14687.04	4895.681
Error	69	6849.479	99.26781
Total	72	21536.52	

F-Ratio = 49.31791

The significance level of this F-Ratio is less than 0.001% which is the probability of a larger F value if the true regression coefficients are all zero.

*Other Statistics on the Fit

Standard Deviation about the Equation = 9.963323

Multiple Correlation Coefficient = 0.8258086

Index of Determination = 68.195983%

Maximum Log Likelihood = −271. .030

trial counts the overall differences between the two sets of data are much less than in the case of the business counts. Also the special industrial counts for the test counties are much more clustered to smaller values than those for the original sample. This is somewhat unexpected in view of the fact that possibly six of the test counties were in locations where one might anticipate large mobile radio activity. In any event the test data obtained are the only data available for model validation.

Table A-7 shows the business and predicted business counts, and Table A-8 shows the same data for the special industrial counts. The P indicates a predicted value. Overall the pre-

Table A-6

TEST COUNTY DATA

County	Business	Business Derated*	Special Industrial	Special Industrial Derated*
Butte, CA	308	244	21	19
Nevada, CA	144	114	12	11
Imperial, CA	339	269	43	39
Beaufort, NC	35	23	19	17
Richland, OH	88	70	27	25
Crawford, OH	76	60	35	32
Clayton, IA	80	63	28	20
Star, TX	63	50	9	8
Kittson, MN	32	25	12	11
Prentiss, MS	17	13	4	4
Mean		93.6		18.4
Standard Deviation		90.5725		10.9565
Variance		8203.38		120.04

Note: Richland, Ohio became an SMSA as of 1977.

*Derated by a factor of 1.26 for Business, and 1.09 for Special Industrial. Industrial. The derating factor, defined by the FCC, corrects for frequency compounding and for users with more than one base station. Thus the derated counts represent the number of business and special industrial users of mobile radio.

Table A-7

PREDICTED BUSINESS USERS FOR THE TEST COUNTIES

List (Cty State Busin Pbusin)

Cty	State	Busin	Pbusin
Butte	CA	244.0	111.88817
Nevada	CA	114.0	25.852902
Imperi	CA	269.0	112.52465
Beaufo	NC	28.00	51.024335
Richla	Ohio	70.00	132.50706
Crawfo	Ohio	60.00	50.263037
Clayto	Iowa	63.00	47.683770
Starr	Texas	50.00	37.945053
Kittso	MN	25.00	28.152043
Prenti	MS	13.00	25.277404

Table A-8

PREDICTED INDUSTRIAL USERS FOR THE TEST COUNTIES

Cty	State	Indus	Pindus
Butte	CA	19.0	42.941700
Nevada	CA	11.0	6.7696286
Imperi	CA	39.0	47.616709
Beaufo	NC	17.0	14.624555
Richla	Ohio	25.0	39.983642
Crawfo	Ohio	32.0	14.005625
Clayto	Iowa	18.0	13.881360
Starr	Texas	8.00	19.781204
Kittso	MN	11.0	20.793924
Prenti	MS	4.00	6.9495376

dictions seem to follow the actual data. However, just employing the sample mean of the 73 counties for the predicted value might perform better for the special industrial data. In this context we note that the predictor equations were not developed for SMSA counties and Richland, OH, is an SMSA county as of 1977. Furthermore, Butte, CA, became an SMSA county as of the 1980 census and for our study is counted as an SMSA county. If these two counties are removed, the performance of the predictor equations improves greatly.

Table A-9 shows the error sum of squares obtained by employing the means of the 73 counties as predictors and also the predictor equations, both for the 10 test counties and for the eight non-SMSA test counties. Even though the variability and skewness is more pronounced in the test data than in the original sample for the business counts, for both the non-SMSA and complete data sets, the predictor equation still accounts for more than 50% of the variation (as measured by the error SS) as opposed to the original sample mean. This is consistent with the analysis obtained in developing this predictor equation. For the special industrial counts the predictor equation fares somewhat poorly for the complete data set. However,in the case of only the non-SMSA counties the predictor equation accounts for about 64% of the variation as opposed to the original sample mean. This is consistent with the analysis obtained in developing this predictor equation.

Therefore even though the model validation study was performed on additional data that were not selected at random the results indicate the appropriateness of the prediction equations. Thus we have no grounds to suspect performance statistically different from that observed in the original sample for the use of the predictor equations with non-SMSA counties. Indeed it may be that the predictor equations we have developed are valid for all counties. However, SMSA counties and especially those that have been recently so classified may have increased and/or widely varying levels of total business activity. This cannot be completely reflected in the County and City Data Book since the most recent entries are for the year 1976. Therefore the ancillary data we have employed may not be representative of the present business and industrial environment for some counties. This could in part explain the performance of the special industrial regression for the 10 test counties.

Now that we have two predictor equations that appear to be acceptable we need to employ them to form a prediction of total mobile radio usage in a given county. The business and special industrial licensees comprise 64.45% of the total existing mobile radio market.[10] For a

[10] Loc. cit. ECOsystems study.

Table A-9

ERROR SUM OF SQUARES OF PREDICTION

	Mean of 73 Counties B	Predictor Equation A	Ratio A/B
Business			
All Test Counties	107245.13	54780.621	0.510798
Non-SMSA Test Counties	62725.598	33419.953	0.532796
Special Industrial			
All Test Counties	1178.1205	1479.6792	1.25597
Non-SMSA Counties	1069.6416	681.96467	0.637564

given non-sampled CONUS county we estimate the number of business and special industrial users, rounded to an integer. The total of these is then divided by 0.6445 to ratio it up to a county level of activity, again rounded. Thus we tacitly assume that the business and special industrial users are representative of all users. The individual totals for business and special industrial users are each multiplied by their respective erlang demands to obtain an erlang demand for each. These two are summed and then divided by 0.6445 to obtain the county total demand. The procedure is similar for the 73 sampled counties except the observed number of users was employed. Complete county listings were reported to NASA. A summary by state is given in Table 1.3-1 and a summary by footprint is given in Table 1.3-2. (See Section 1.3)

In the referenced ECOsystems study a correlation equation for county police was developed. We did not employ that correlator for two reasons. First it was based on an initial sample of 13 from the ultimate total sample of 73 counties. Second it would be difficult to predict total police activity for a given county because ECOsystems obtained state police data only on a statewide basis. This is important since ECOsystems estimated that all police activity accounts for 4.99% of the total but gave no breakdown between state and county police. Thus we have no straightforward way to use the county police correlator.

Distribution of the Mobile Radio Telephone Market

The mobile radio telephone market is largely unpentrated at this time. The present subscriber base does not reflect its true potential. Since no significant base exists, our study is formulated on survey data. The survey was conducted by Opinion Research Corporation (ORC) for the Audio Electronics Department of General Electric Company (GE) and reported by ORC[11] and GE[12]

The purpose of the survey was to explore the potential consumer market of a mobile radio that would allow a customer to have mobile radiotelephone service via his own residential telephone. The survey also explored the possible market for a mobile radiotelephone system that could be cellular compatible, and we shall employ that portion of the survey in our analysis.

The survey was of households and was conducted by telephone on December 23-27, and 31, 1981. and January 1-2, 1982. The ORC report gives complete details and a copy of the questionnaire. However, in order to qualify for the survey the respondent had to be the head of household, regularly operate a private passenger vehicle (car, pickup truck, or van), and have in the household at least one passenger vehicle. Also all respondents were questioned about passenger vehicles that were primarily used in work-related activities excluding driving to and from work.

Thus the survey directly represents the private use of mobile radiotelephone services. However, commercial use is indirectly represented in that much of the commercial market (doctors, lawyers, managers, etc.) is included in the survey. Since 80% of the respondents (households) qualified for the survey, any underestimation of the market should not be significant.[13]

[11] "An Appraisal of a Mobile Communications Product for the Consumer," Opinion Research Corporation, North Harrison St., Box 183, Princeton, N. J., March, 1982

[12] "Supplemental Comments and Petition to Expedite Initiation of Rulemaking Proceedings," General Electric filing before the Federal Communications Commission, PR Docket No. 79-140. May 11, 1982

[13] Loc cit. ORC report.

Our investigation is based on a cross-tabulation study of question 32: "If a much better mobile telephone system were available to you that operated in a much wider range in all directions, and had no limitations on message length and did not require a base station in your home, how likely is it that you would obtain such a system if the cost was $750 ($1000) and the monthly service charge was $50.00 ($75.00)? Would you definitely purchase, very likely purchase, possibly purchase, very likely not purchase, definitely not purchase, or don't know/no opinion?" All qualifying respondents (2509) were asked question 32 with approximately one half at the lower cost (1254) and one half at the higher cost (1255).

By employing the respondents' zipcode,[14] a classification according to answer, price, and geographical location can be made.

The results are presented in Table A-10, in which we have grouped the answers "definitely purchase" and "very likely purchase." DEFIN denotes definitely purchase or very likely purchase; POSSIB denotes possibly purchase; VLNOT denotes very likely not purchase; DNOT denotes definitely not purchase, DONKNO denotes don't know/no opinion; CHEAP denotes the lower set of prices; and EXPENS denotes the higher set of prices. The totals differ from those previously given since 59 of the lower price respondents did not have their zipcodes recorded and 48 of the higher price respondents similarly did not have their zipcodes recorded. We assume that these missing data occurred at random.

[14] Supplied by Mr. Al Gauthier, Audio Electronics Products Department, General Electric Co.

Table A-10

CROSSCLASSIFICATION OF ANSWERS TO QUESTION 32

Price	Answer	SMSA	Non-SMSA	Totals
Cheap	DEFIN	15	5	20
	POSSIB	49	22	71
	VLNOT	156	63	219
	DNOT	638	232	870
	DONKNO	8	7	15
	Totals	866	329	1,195
Expensive	DEFIN	10	4	14
	POSSIB	28	9	37
	VLNOT	130	45	175
	DNOT	725	239	964
	DONKNO	14	3	17
	Totals	1,733	629	2,402

Perusal of Table A-10 indicates that the overall response for non-SMSA and SMSA respondents is very nearly equivalent. Also there appears to be a definite difference in response due to price. In order to investigate this further we made a number of two-way contingency table analyses of the data. The results are shown in Table A-11. The P-value is that level at which the given result would just be significant. The P-values for the various tests corroborate the results we obtained by inspection. It appears that location is independent of answer and price (at the usual statistical significance levels), and answer is independent of location for either price. Answer and price are not independent for SMSA respondents, and very nearly the same is true for non SMSA respondents.

This finding is important since it indicates that the potential market penetration is the same for SMSA and non-SMSA regions of the country. In addition, significantly different penetrations of the market can be expected on the basis of price. It appears (based on these data) that price is much more important in determining the market penetration than is market location. By way of comparison, Motorola[15] indicates that the capturable market as a percent of population will range between 0.5 and 1.5%, with the upper bound typically being for smaller markets with limited pay phone availability to respond to paging alerts.

To avoid any question of equivalence we base our further study only on the non-SMSA results. In order to be readily applied, the results for households need be converted into a population penetration factor. For this we employ the 80% qualification factor and 1980 Census data. The total population as of the April 1980 version of the 1980 Census is 226,504,825. Also the number of households as of the same version is 80,376,609.[16] Then the factor that converts an estimated proportion of households to a population fraction is

$$(.8)(80{,}376{,}609/226{,}504{,}825) = 0.283885.$$

For comparison purposes we determine a range of possible penetrations as indicated by the survey responses. The "definitely" and "very likely" purchase respondents represent a conservative market penetration. A likely market penetration is given by the conservative plus some portion of the "possibly purchase" respondents. We shall take 50% of these respondents as representative of a likely market penetration. Finally an optimistic market penetration is given by all respondents who indicated any desire to purchase. For each of these possible markets we estimate a penetration for each of the two prices. The results are given in Table A-12. We see that the penetrations range from 0.38 to 2.33% of the population. This covers the usually quoted range of 0.5 to 1.5% given in other studies and is consistent with these earlier findings.[17,18,19]

In the Lehman Brothers et al. report (written by J.S. Bain, W.E. Himsworth, and S.B. Bristol) a comparison of AT&T, Motorola, and Telocator forecasts is made. Unfortunately AT&T has not released great detail concerning its forecasts. However, by making very rea-

[15] "An Inquiry into the Use of the Bands 825-845 MHz and 870-890 MHz for Cellular..." Motorola filing before the Federal Communications Commission, CC Docket No. 79-318, August 1980, Appendix A.

[16] World Almanac and Book of Facts 1982, Newspaper Enterprise Association, Inc., New York.

[17] AT&T filing, FCC Docket CC79-318, August 1980

[18] Motorola filing, loc. cit.

[19] "CMRS: Cellular Mobile Radio Telecommunications Service— Update on Emerging Technology," Lehman Brothers Kuhn Loeb Research, May 7, 1982.

Table A-11

RESULTS OF TWO-WAY CONTINGENCY TABLE ANALYSIS

Two-Way Table	P-Value (%)
Price vs Answer and Location	0.16991
Location vs Answer and Price	>50
Answer vs Price and Location	1.09435
Answer vs Location Given Cheap Price	44.299
Answer vs Location Given Expensive Price	>50
Answer vs Price Given SMSA	4.0446
Answer vs Price Given Non-SMSA	6.2394

Table A-12

POSSIBLE MARKET PENETRATIONS AS A PERCENT OF POPULATION

Market Penetration	Conservative	Likely	Optimistic
Cheap Price	0.431%	1.38%	2.33%
Expensive Price	0.379%	0.852%	1.23%

sonable assumptions and essentially backtracking the published AT&T results, Bain et al. show that the AT&T forecasts are about 2.5 times as large as those of Motorola. Thus AT&T is operating with a penetration of 1.5 or higher. Furthermore AT&T believes that this penetration is immediate. All of this is consistent with the top end of our estimated penetration factors, and we believe that an ultimate penetration of about 2.0% of the population may be possible.

In order to determine the distribution of the market we decided to obtain results for the penetration factors 0.5, 1.0., and 1.5%. These figures will allow comparisons to be made and are representative of the potential penetrations. We employed the population data given in the County and City Data Book for the year 1975. Complete county listings have been reported to NASA. A summary by state is given in Table 1.3-3, and a summary by footprint is given in Table 1.3-4. (See Section 1.3)

The number of subscribers is obtained by multiplying by the appropriate penetration factor and then rounding. The erlang demands are obtained by multiplying the number of subscribers by an average demand of 0.028. This was obtained from the ECOsystems study. (We multiplied the ECOsystems value by 2 since their value was on a one-way basis and telephone usage requires duplexing.)

Appendix B

CONTIGUOUS STATES SMSA AREAS AND AREA VS. POPULATION DENSITY

The following list is derived from data in the County and City Data Book, 1977, U. S. Department of Commerce, Bureau of the Census. The areas of Standard Metroplitan Statistical Areas (SMSA's) in each state are as of the year 1980, but the population densities are the Census Bureau's estimates for 1977 as recorded in the Data Book. The areas in the list are the sums of areas with counties of the specified density, not the actual areas in each state with the indicated densities. The areas in some states with population density below 21 persons per square mile is larger than indicated, particularly in some western states where the counties are very large but are SMSA's because a metroplitan area lies within the county even though most of the county is sparsely populated.

STATE	SMSA AREA	STATE TOTAL	AREA UNDER 21/MI^2	NON-SMSA AREA OVER 20/MI^2
Alabama	14,493	50,708	7,839	28,376
Arizona	18,395	113,417	95,022	0
Arkansas	7,011	51,945	16,880	27,604
California	83,725	156,361	57,097	15,539
Colorado	16,379	103,766	87,008	379
Connecticut	4,348	4,862	514	0
Delaware	438	1,982	1,544	0
Washington, D.C.	61	61	0	0
Florida	26,273	54,090	11,519	16,306
Georgia	10,568	58,073	10,709	36,796
Idaho	1,043	82,677	70,748	10,886
Illinois	14,416	55,748	1,556	39,776
Indiana	13,306	36,097	0	22,791
Iowa	5,940	55,941	6,219	43,782
Kansas	5,313	81,787	59,792	16,682
Kentucky	5,045	39,650	0	34,605
Louisiana	9,961	44,930	5,142	29,827
Maine	6,481	30,920	18,870	5,569
Maryland	4,947	9,891	0	4,944
Massachusetts	6,575	7,826	0	1,287
Michigan	16,067	56,817	13,098	27,652
Minnesota	15,894	79,289	35,743	27,652
Mississippi	4,378	47,296	7,224	35,694
Missouri	9,466	68,995	25,300	34,229
Montana	5,303	145,587	136,957	3,327
Nebraska	1,674	76,483	62,423	12,386
Nevada	14,240	109,889	95,499	150
N. Hampshire	2,884	9,027	0	6,143
New Jersey	5,662	7,521	0	1,859
New Mexico	8,687	121,412	109,312	3,413
New York	19,647	47,831	4,849	23,335
N. Carolina	12,072	48,798	3,314	33,412
N. Dakota	6,732	69,273	60,497	2,044
Ohio	18,218	40,975	0	22,757
Oklahoma	13,562	68,782	36,784	18,436
Oregon	12,289	96,184	74,061	9,834
Pennsylvania	20,126	44,966	2,390	22,450
Rhode Island	1,049	1,049	0	0
S. Carolina	9,523	30,225	652	20,050
S. Dakota	813	75,955	66,018	9,124
Tennessee	10,541	41,218	1,874	28,803
Texas	50,378	262,134	177,864	33,892
Utah	10,579	82,096	70,343	1,174
Vermont	1,276	9,267	663	7,328
Virginia	11,897	39,780	2,838	25,045
Washington	18,763	66,570	38,017	9,790
West Virginia	3,561	24,070	4,547	15,692
Wisconsin	12,158	54,464	14,379	27,927
Wyoming	5,342	97,203	89,158	2,721
TOTALS	577,498	2,963,889	1,584,263	802,128