PRELIMINARY

FEASIBILITY DEMONSTRATION OF CITIZEN ALARM SYSTEM: PHASE I

DEVELOPMENT REPORT

August 1973

Prepared by

COMPUGUARD SECURITY SYSTEMS
PITTSBURGH, PENNSYLVANIA

UNDER SUBCONTRACT 44326-V

For

LAW ENFORCEMENT DEVELOPMENT GROUP
THE AEROSPACE CORPORATION
El Segundo, California

Prepared for

NATIONAL INSTITUTE OF LAW ENFORCEMENT AND CRIMINAL JUSTICE
aw Enforcement Assistance Administration
U.S. Department of Justice
Washington, D. C.

Contract No. J-LEAA-025-73

PRELIMINARY

CITIZENS ALARM SYSTEM

PHASE I REPORT

August, 1973

SECTION 1

INTRODUCTION

1.1 OVERVIEW

The feasibility demonstration of the Citizens Alarm System (CAS) is being conducted in three phases. This report deals with the results of Phase I and is directed towards the understanding of the relationships between CAS and its environment. This environment includes users, response agents, the physical characteristics of the usage environment, and any other systems (e.g., burglar alarm systems) that may be used in conjunction with CAS.

The statement of work specifically outlines a number of tasks to be performed in Phase I (5.2.1 in SOW). These tasks include a definition of system requirements, an analysis of usage parameters, a study of response time requirements, and an assessment of user parameters (including a study of human factors, user attitudes, cost objectives, etc.). Phase I tasks also include a selection of two scenarios as potential sites for the feasibility demonstration of the system in Phase 3. The definition of these SOW tasks was considered by Compu-guard and defined on a specific task-by-task basis in the revised program plan which was accepted by the Aerospace Corporation following the kick-off meeting in El Segundo on July 12, 1973. This plan of work is also presented in Table 1.1.

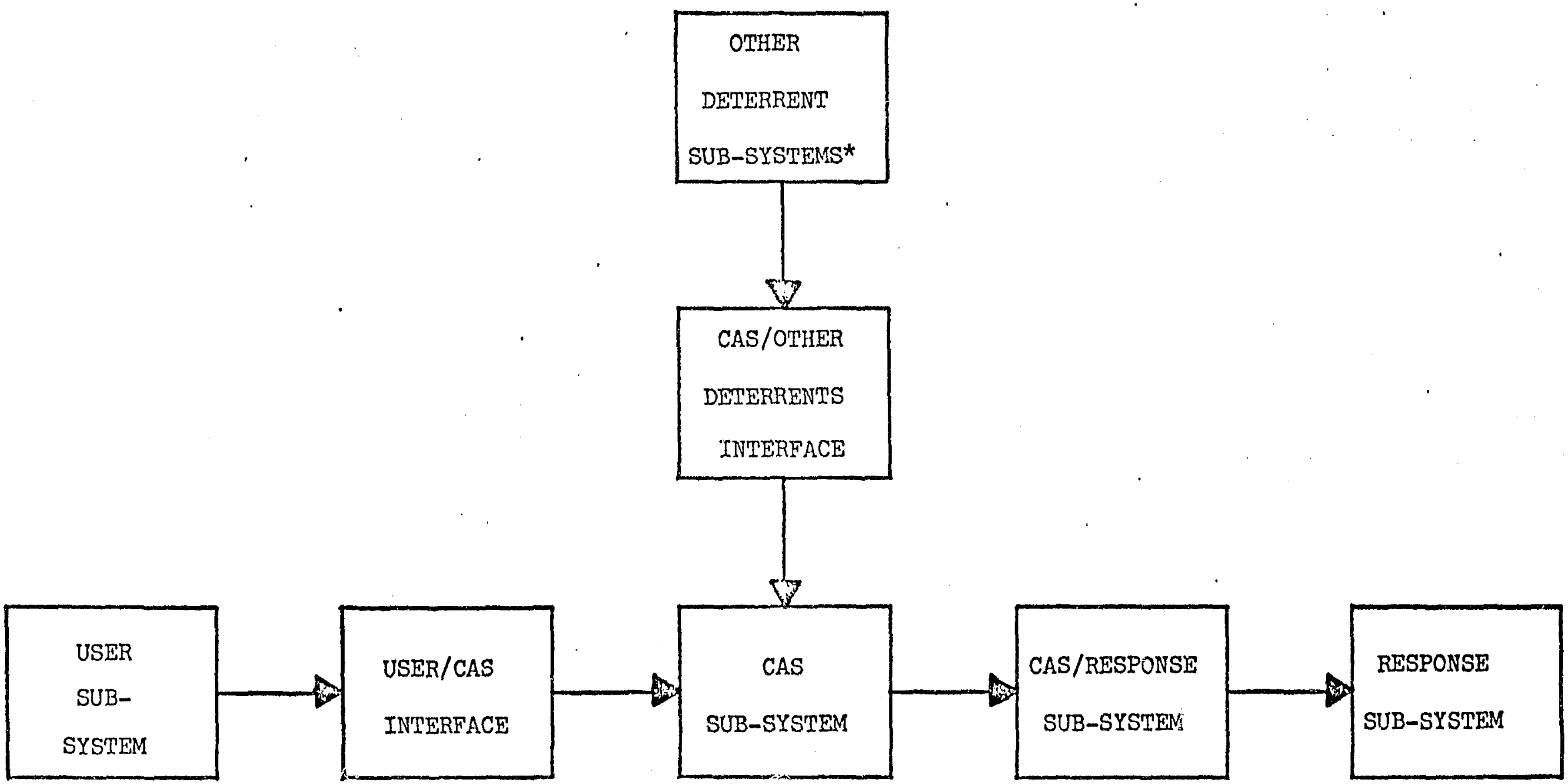
Compu-guard approached the actual implementation of Phase I by segmenting the total security systems environment into a number of sub-systems. The definition of the sub-systems and the interaction of each with the CAS sub-system are clearly indicated in Figure 1.1. The tasks defined in Table 1.1 are then directly related to the relevant sub-systems in the total security system and to the interactions between them.

Table 1.1
CAS UPDATED PROGRAM PLAN - Phase I

SOW ACTIVITY No.	TASK INPUTS (as defined on Pages 14,15 of CG Proposal)	ACTIVITY/OUTCOME	TIME SCHEDULE (1973)
5.2.1.1			
5.2.1.1.1	I-3,I-4,I-6,I-7,I-9	Review and analysis of information related to the user, community, and public-safety agencies	7/2 to 8/3
5.2.1.1.2	I-3,I-4,I-11,I-13	Analysis of threats and response patterns	7/2 to 8/3
5.2.1.1.3	I-9,I-11,I-12,I-13, I-14,I-15,I-16	Tabulation of requirements, development of simple parametric models related to response, false-alarms, effectiveness, reliability, and costs	7/16 to 8/17
5.2.1.2			
5.2.1.2.1	I-6,I-7,I-8	Analysis of user attitudes, motivation, and human factors	7/2 to 8/3
5.2.1.2.2	I-5	Analysis of the regulations and policies of relevant Government and private agencies	7/2 to 7/20
5.2.1.3	I-10,I-17	Analysis of operating scenarios, selection of scenarios	7/16 to 8/17

FIGURE 1.1: SUB-SYSTEM COMPONENTS IN THE

OVERALL SECURITY SYSTEM ENVIRONMENT



* Could include burglar alarm systems, citizen alarm systems for external use, etc.

1.2 OBJECTIVES

Prior to the actual implementation of Phase I, Compu-guard defined a basic set of objectives and goals in each of the areas of work related to Phase I activities. The specific objectives included the following:

a) The definition of each sub-system accompanied by an analysis of relevant, functional factors in each sub-system.

b) The analysis of published data, as well as that of original data gathered and assembled by Compu-guard. Sources of the latter included sister organizations such as Fidelity Security Systems, Inc., and other agencies with which Compu-guard has close working relationships.

c) Analyses of data in an effort to quantify relationships between parameters of interest.

d) The application of these analyses to the actual design and development of CAS hardware and software.

e) The consideration of such quantitative analysis as a basis for the development of models in the primary areas of effectiveness, false alarms, reliability, and response time.

f) The prediction of some of the effects of CAS upon its environment.

g) The analysis of the impact of CAS on other crime-deterrent sub-systems such as burglar alarm systems, deterrent systems for external use, etc. The objectives also included the development of a rationale for the selection of two scenarios. This rationale was then to be used in the procedure of selecting the actual scenarios and making arrangements for the use of these selected locations for the feasibility demonstration of CAS in Phase III.

1.3 METHODOLOGY

For the implementation of Phase I activities, Compu-guard developed a methodology that would allow the most effective means of task completion.

This methodology basically identifies the different steps to be applied in the analysis of each sub-system and the interfaces between sub-systems. These analyses then provide the input for the four models directly developed in this phase. A block diagram of the flow of Phase I work is given in Figure 1.2.

The results of Phase I modeling are applicable to Phase II of the CAS project. However, the actual design of the system is expected to be based not just on these four (false alarms, reliability, response, and effectiveness) but also upon a consideration of the potential market for CAS, and therefore, the manner in which CAS costs may change as a function of production quantity. The overall methodology leading to the design of CAS is shown in Figure 1.3.

1.4 PROJECT ORGANIZATION

The overall corporate organization of Compu-guard was presented to Aerospace in El Segundo on July 12, 1973. Within this overall organization, a special project team was established for the completion of Phase I activities. The Compu-guard organization for the implementation of Phase I is shown in Figure 1.4. As can be seen in Figure 1.4, the responsibilities for overall implementation of Phase I were distributed between three managers in three well-separated areas of work. Each had a number of object staff members working for them. The unusual feature of the organizational hierarchy lies in the fact that the same members of the project staff worked in more than one functional area depending, of course, upon their skills and expertise. Also, the project director and the three project managers participated directly in various functional areas.

Attention should be given to the fact that two different services groups were established as part of the CAS Phase I project organization. The computer services group had the responsibility of all operations

FIGURE 1.2: CAS PHASE I METHODOLOGY

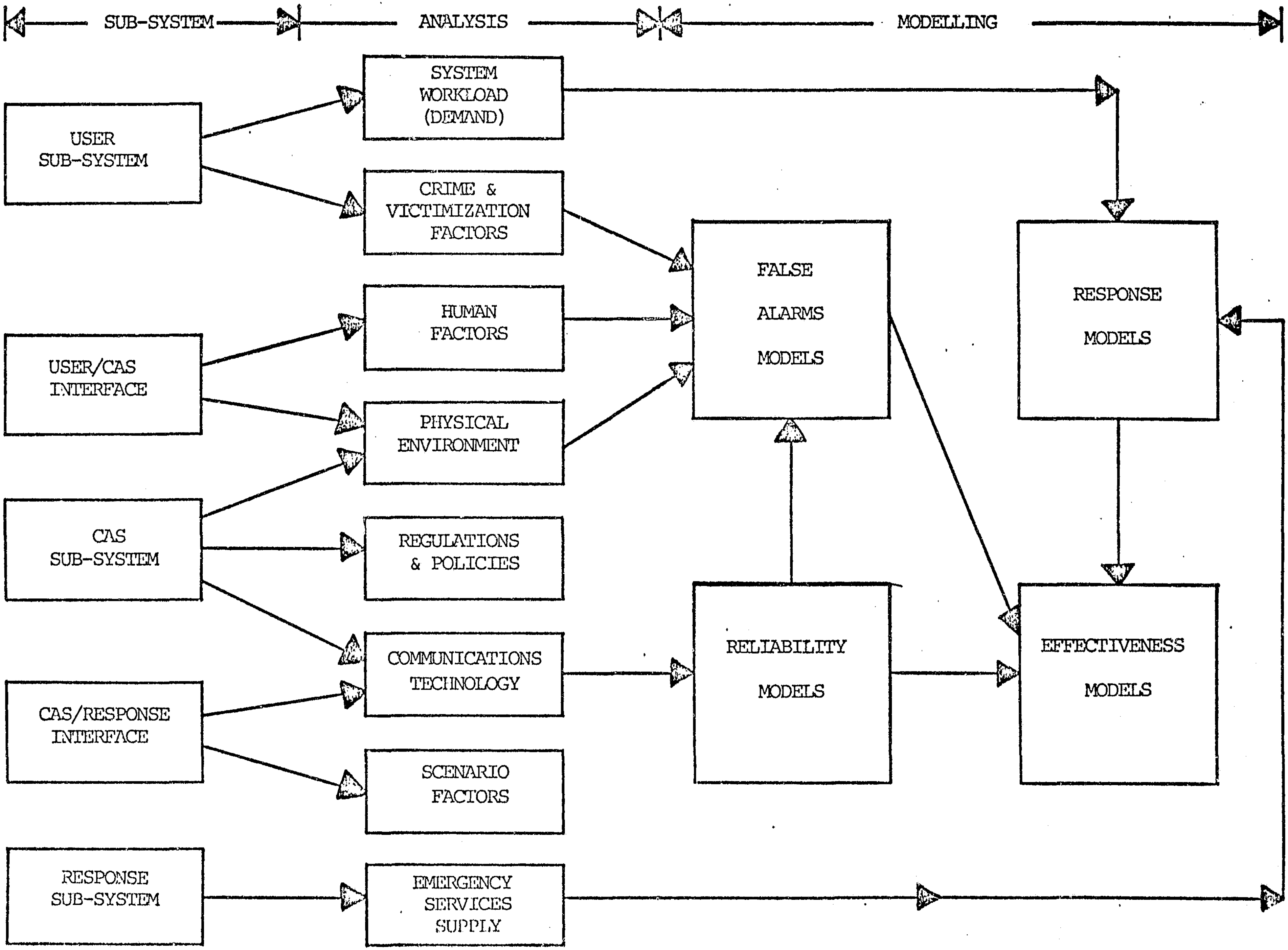


FIGURE 1.3: OVERALL CAS DESIGN METHODOLOGY

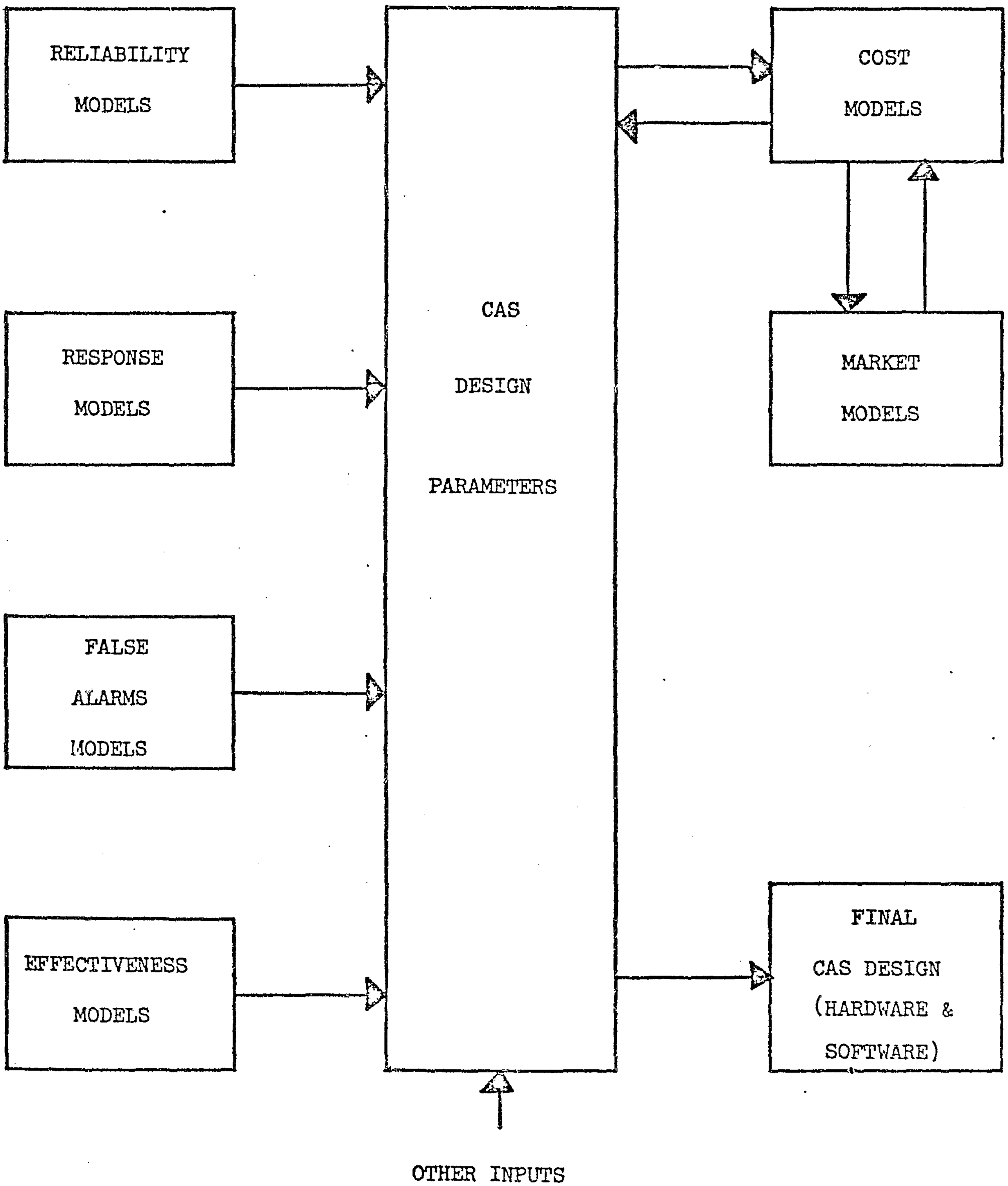


FIGURE 1.4: CAS PHASE I, COMPU-GUARD PROJECT ORGANIZATION

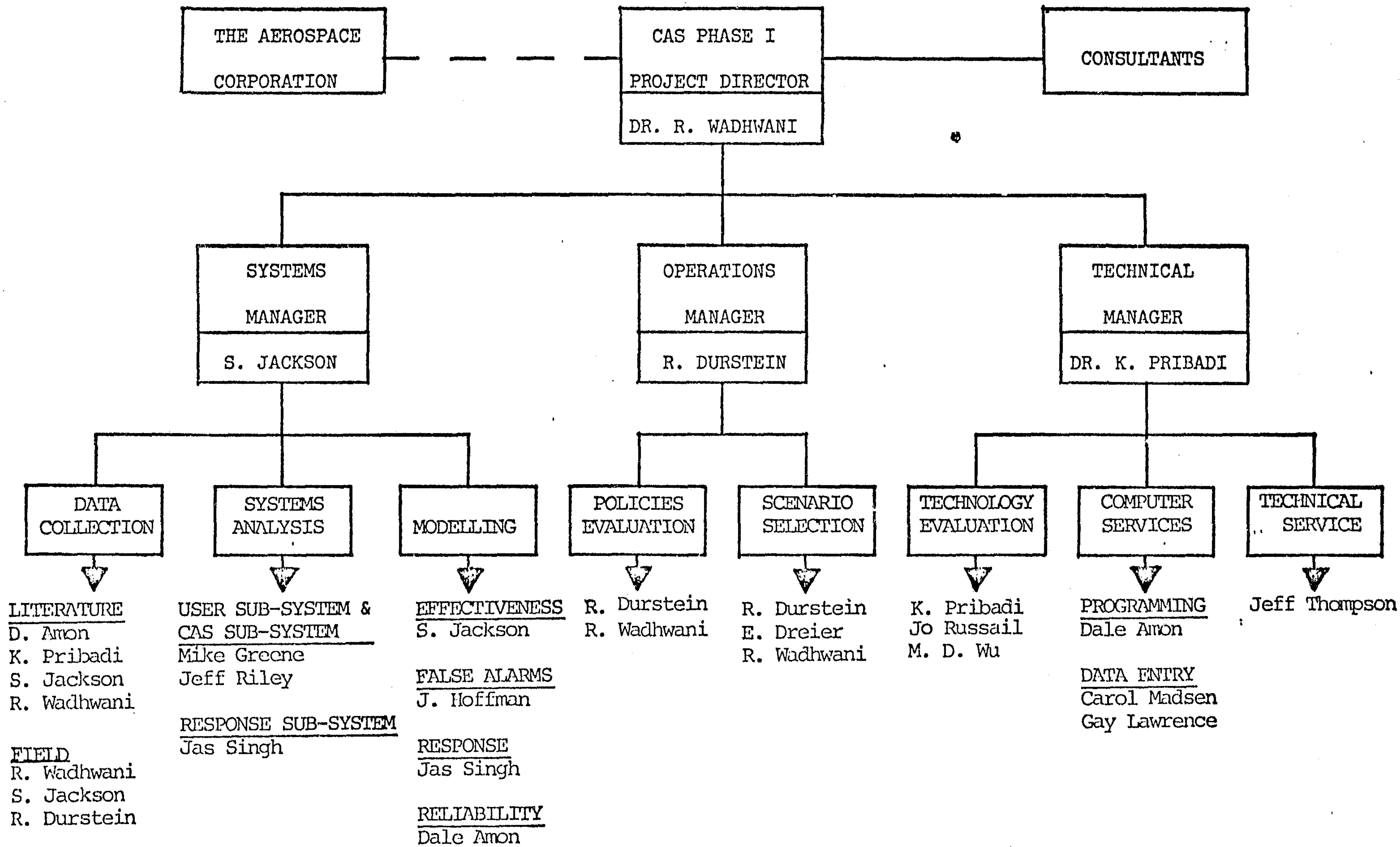


Table 1.2: PROJECT STAFF AND FUNCTIONS

FUNCTION	PROJECT STAFF
DATA COLLECTION:	D. Amon K. Pribadi S. Jackson R. Wadhwani R. Durstein
SYSTEMS ANALYSIS:	M. Green J. Riley Jas Singh
MODELLING:	S. Jackson J. Hoffman Jas Singh D. Amon
POLICIES EVALUATION:	R. Durstein R. Wadhwani
SCENARIO SELECTION:	R. Durstein E. Dreier R. Wadhwani
TECHNOLOGY EVALUATION:	K. Pribadi Jo Russail M. D. Wu
COMPUTER SERVICES:	D. Amon C. Madsen G. Lawrence
TECHNICAL SERVICE:	J. Thompson

related to data coding, data entry, programing, and computer operation. These services were invaluable in the evaluation of data collection for analysis and modeling. The computer was useful in assisting in the regression analysis on data collected in response to the Compu-guard questionnaire survey, the development of the reliability model, false alarms analysis of Fidelity data, etc. The technical services group was responsible for all work related to the development of mock-ups, proto-types, sketches, and other laboratory and workshop activities.

1.5 LOCAL RESOURCES

Compu-guard has close ties with Fidelity Security Systems, Inc. and the Center for Entrepreneurial Development at Carnegie-Mellon University. This working relationship with Fidelity led to a comprehensive analysis of six months of their false alarms data, the results of which are available in Section 10. In addition, Fidelity facilitated access to a number of agencies and people in the community whose perspectives on Phase I activities were very helpful.

The Center for Entrepreneurial Development was responsible for coordinating Compu-guard activities with the University, both in ascertaining the attitudes of the academic community to the system concept and in terms of inputs relating to the application of high technology. Compu-guard also established a good working relationship with the Bureau of Police, City of Pittsburgh, As a result of the support of Superintendent Colville, Chief Inspector de Roy, Inspector Palumbo, Inspector Gorshki, and Lt. Liscio, Compu-guard was given access to all Pittsburgh Police records and offered additional information that was helpful in Phase I.

1.6 COLLECTION OF PUBLIC DATA

One of the problems in the implementation of the various analytic and modeling procedures described later in this report is the paucity of reliable data. Compu-guard, therefore, had to make an extensive search of all relevant data available in this field. Compu-guard set about the task of first developing a list of relevant sources of information. This included the following agencies:

a. The National Institute for Law Enforcement and Criminal Justice
b. The National Criminal Justice Reference Service
c. Library, Law Enforcement Assistance Administration
d. School of Urban and Public Affairs, Carnegie-Mellon University
e. Department of Criminal Justice Administration, University of Pittsburgh
f. Library, Bureau of Police, City of Pittsburgh
g. Library, Police Academy, City of New York
h. National Technical Information Service
i. Government Printing Office
j. National Burglar and Fire Alarm Association
k. The Alarm Industry Committee for Combating Crime
l. The International Association of the Chiefs of Police
m. Police Departments in several cities
n. A T & T (Bell System)
o. FCC (Federal Communications Commission)
p. Utilities Telecommunications Council
q. Underwriters Laboratories, Inc.

With data from these and other agencies, a very comprehensive data base was established. This data was, of course, complemented by the existing data that Compu-guard had, as well as the data collected by Fidelity in its fourteen years of operation as a central station.

SECTION 2

CITIZENS AND CRIME

2.1 INTRODUCTION

In its most basic terms, CAS represents a low information, uncongested communications channel between the user and the police or other public-safety organization. The information transmitted includes the location of the incident and the identity of the caller; in specialized cases, a third signal may identify whether police, fire, or ambulance services are desired. The essential concept is for citizens to be able to report emergencies, primarily crimes, to the police in an unambiguous, inconspicuous, rapid and reliable manner. Such a reporting system is likely to have a profound effect on the citizen's risk of personal injury and loss of property resulting from having been the victim of a crime. By means of equipping citizens with CAS, it is intended that both the likelihood of their becoming victims of crime would be reduced and their fear would consequently be reduced. This would be a consequence of reduced police response time, given that shorter response time is associated with a higher probability of arrest.[1] Also, citizens tend to fail to report incidents in which they believe the police cannot make arrests, often because some delay has elapsed between the crime and the report. These crimes presently are ignored by the criminal justice system, but, as response time decreases under CAS, are likely to be reported. If there is any validity in the deterrent aspect of the criminal justice system, the increased likelihood of arrest should deter crime commission, although probably increasing the number of reported crimes.

The fear of becoming a victim is undoubtedly a major element in the lives of a large part of the population. The effect of CAS should be clear in user-reported perceptions of crime and its consequences.

[1] Task Force Report: Science and Technology, President's Commission on Law Enforcement.

2.2 CITIZEN'S PERCEPTION OF CRIME

The citizen's perception of crime risk is important both in how CAS is likely to be used and in how his attitudes are likely to change under CAS. In general, the fear of becoming a victim is considerably higher than the risk of crime. According to UCR (1965)[2], the probability of a serious personal attack on an individual in a given year is less than .002, and this includes attacks by family members, spouses, friends, or acquaintances as well as strangers. The National Opinion Research Center's "Criminal Victimization in the United States"[3] reported a slightly higher total using a broad-based sample of victims. This section deals at length with the NORC findings, basing most of its arguments upon NORC statistics rather than on the Department of Justice's Uniform Crime Reports. There are disadvantages, however, to the use of either. The NORC survey, the first and largest nationwide victim survey, is presently eight years old and becoming more dated as times goes on. Secondly, the NORC sample includes 3,000 subjects, so that projections based on the most infrequent Part I crimes, homicide, forcible rape and aggravated assault, are somewhat risky because of the small sample. UCR, however, represents an annual survey of all United States Police Departments, collecting and collating their data. Time trends are possible in UCR reports, but not in NORC. The NORC and UCR data is augmented, wherever possible, in this section by data from more recent polls, victimization surveys, and other studies.

The reliance on NORC findings is based on the extent of underreporting of crime to police that the NORC analysts presented; this was one of their major findings. As this section is more oriented to the needs and desires of the consumer (victim) rather than upon the police, the NORC report is the major evidence used.

Recent evidence suggests just how dated the "Criminal Victimization in the United States" report has become. For example, the 1972 Uniform Crime Report now

2 UCR, 1965, p. 51.
3 Philip H. Ennis, Criminal Victimization in the United States, NORC , May 1967.

shows the balance of reported homicide and aggravated assault is occurring between strangers rather than acquaintances. Whether this trend holds for the reported and unreported crimes also is not clear. Even so, as shown in Table 2.1, the estimated probability of experiencing a homicide, forcible rape, robbery or aggravated assault in 1965-66 was less than .005. The specific probability figures given in Table 2.1 can them be contrasted with those of Table 2.2, for which subjects were asked the likelihood of a person being robbed or attacked on the streets. The latter response is one order of magnitude larger, showing the massive difference between reality and perception.

Thus fear of crime is a key issue. The NORC national survey showed that victims tended to have somewhat more fear than non-victims about burglary or robbery, although women seemed to be more concerned about their safety than males, whether or not they had been victimized. Almost identical proportions, however, (57%) took strong household security measures.[4] Another study in Washington D.C. found that having personal experience with a crime was not correlated with respondents' attitudes toward crime and law enforcement.[5] Such studies led the President's Commission on Law Enforcement and the Administration of Justice to conclude that "people's perceptions of the incidence and the nature of crime and even to some extent, their concern about it may be formed in large part by what they read or hear about from others." The public, the report continued, fears the crimes that occur the least—the crimes of violence. And the fear of crimes of violence ultimately resolves itself into a fear of strangers. Finally, as they point out, the fear of strangers has greatly impoverished the lives of many Americans, restricting them to staying behind locked doors rather than risk walking the street at night.[6] NORC reported an affirmative answer to the question, "have you wanted to go somewhere recently

---

4 loc. cit.
5 Ibid., p. 87 (probably so few people become victims or witness crime.)
6 Ibid., pp. 87-88.

Table 2.1 Estimated Rates of Part I Crimes: 1965-66

CRIMES	NORC Sample Estimated Rate per 100,000 population	UCR Total per 100,000 population (residential or individual only)
Homicide	3.0	5.1
Forcible Rape	42.5	11.6
Robbery	94.0	61.4
Aggravated Assault	218.3	106.6
Burglary	949.1	296.6
Larceny (over $50.)	606.5	267.4
Vehicle Theft	206.2	226.0

Table 2.2 How Likely Is It That A Person Will Be Robbed Or Attacked On The Streets Around Here (per cent)

Response	White		Non White	
	Male	Female	Male	Female
Very likely	6	6	14	21
Somewhat Likely	14	15	25	30
Somewhat Unlikely	27	32	35	32
Very Unlikely	53	47	26	17

but stayed home because it was unsafe" for about 15% of the respondents.[7] Also, more than two thirds of the respondents reported that they walked in their own neighborhoods after dark less than a few times per week, or never.[8] Reiss found by surveying four police precincts in Boston and Chicago that 20 per cent of the citizens wanted to move because of the crime in their neighborhoods. Deserted shopping areas at night, people refusing to go to evening movies, theaters or restaurants, and the outmigration from certain areas of the city are to some degree a result of the fear of crime, especially fear of violent crimes.

This fear has had secondary effects. The President's Crime Commission noted that as the level of sociability and mutual trust is reduced, streets and public places can indeed become more dangerous. Not only will there be fewer people abroad, but those who are abroad will manifest a fear of and a lack of concern for each other. The reported incidents of bystanders indifferent to cries for help are the logical consequences of a reduced sociability, mutual distance and withdrawal.[10]

2.3 INCIDENCE OF CRIME

The NORC survey carefully distinguishes three areas:

1. The probability of becoming a victim (ACTUAL RISK)
2. The subjective estimate of the probability that someone or the respondent will become a victim (ESTIMATED RISK)
3. The subjective estimate that a) a target hardening (at various levels) or b) aversion behavior is justifiable (AVERSION)

---

7 Ennis, op. cit., p. 74 table 44.
8 Ibid., p. 74, table 43.
9 Albert J. Reiss, Jr. "Studies in Crime and Law Enforcement in Major Metropolitan Areas" (field Surveys III, President's Commission on Law Enforcemand and Administration of Justic e. Washington D.C., U.S. Government Print OH 1967. Vol. 1, p. 31.
10 President's Commission on Law Enforcement and Administration of Justice. "Task Force Report: Crime and its Impact—An Assessment. op. cit., p. 89.

Table 2-3. Concern of Victims And Non Victims About Burglary and Robbery[11]

Worry about burglary or robbery	% Victim	% Non-Victim
Males		
Worried	69%	59%
Not Worried	31%	41%
Females		
Worried	84%	77%
Not Worried	16%	23%

11 President's Commission on Law Enforcement and Administration of Justice, Task Force Report: Crime and Its Impact, An Assessment p. 87. Adopted from Norc.

As described above in this report, there appears to be an order of magnitude difference between these three states. The NORC tables do not break down estimated risk and aversion by demographic categories, so it is not possible to relate actual risk to estimated risk and aversion for each of these categories. It seems clear that estimated risk and aversion are highly correlated by the respondents to the survey. As mentioned previously, the incidence of violent crime, burglary and robbery is so low that it would be difficult to relate it to estimated risk and subjective behavior. But incidence is subject to significant demographic and socioeconomic variability. NORC's and other findings are now reviewed briefly.[12]

2.3.1.1 Robbery. Robbery is primarily an urban crime with the highest rates for the central sections of cities (207 per 100,000). The rates for the Northeastern United States and Northwestern United States are highest, probably because these are the most urbanized sections (139 per 100 K and 133 per 100K). Non whites with low income, $0-3,000, are the most common victims (278 per 100K), non-whites with incomes of $3000-5999 are next (at 240), and the non-whites over $6000 (121 per 100K). Whites then are next, those in the lowest income group dominating at 116 per 100 K, finally decreasing to 34 per 100 K at incomes over $10,000 per year. Non-white females (270 per 100 K) dominate non-white males (174 per 100 K), white males (97 per 100 K), and white females (43 per 100 K). Age seems to have little effect.

Non-whites, especially non-white females, report taking the heaviest load on this crime, although it appears that non-white males between 20 and 29 are also likely victims. Robbery strikes the poor disproportionately with respect to incidence. When asked where this crime occurred, non-white female response indicated primarily public buildings and public places. Non-white

---

12 P. Ennis, op. cit., 20 et passim. Note: categories in tables are not mutually exclusive.

males reported occurrences primarily near their own homes.

2.3.1.2 Residential Burglary. The western part of the United States again predominates with a rate of 1348 incidents per 100,000 population. Central city urban areas exceed suburbs and rural areas by a slightly smaller ratio than does robbery. The effect of race and income together follows the pattern established for robbery for whites, that is, decreasing incidence with increasing income (1310 per 100 K at $0-2999 to 1763 per 100 K at $10,000). However, this pattern is reversed for non-whites with the incidence rising with income. NORC attributes this to housing segregation keeping non-whites with high incomes in central city areas. Males dominate females, but this may be due to the fact that if a male is the head of the household that is burglarized, the male head is classified as victim.

However, these NORC findings conflict with the results of a 1970 LEAA victimization survey which revealed no significant difference in the rates of victimization between households with annual incomes under $10,000 and those over $10,000. Since both surveys were national, a further work may be necessary to resolve this inconsistency. It is certainly possible that major changes may have occurred in the pattern of victimization between 1966 and 1970.

Data from San Jose[13] showed that upper middle-class neighborhoods accounted for 18 per cent of house burglaries, whereas predominantly low-income and working-class neighborhoods accounted for 17 per cent of the incidents. Almost 40 per cent of the house burglaries occurred in apartment houses. Giertz,[14] studying Chicago, found that the burglary rate per hundred thousand population was negatively correlated with a number of factors: the median family income, the per cent owner occupied, median rent, value

---

13 Santa Clara Criminal Justice Pilot Program, "Burglary in San Jose," Technical Report, February 1972, p. 31.

14 J. Fred Giertz, "An Economic Analysis of the Distribution of Police Patrol Forces." Miami University, Oxford, Ohio, April 1970, p. 28.

of owner occupied house, and with percent foreign born occupants. It was positively correlated with percent non-white population, density and percent migrant. Scarr,[15] studying Fairfax County, Washington D.C., and Prince George County, found negative correlations between burglary rates and percent white, in all cases. Many of the correlations between social indicators and crime were not stable over time (for example, in Fairfax County percent black overcrowded and burglary frequency correlated .27 in 1967, .08 in 1968, and .02 in 1969). To summarize, the typical victim is more likely to be non-white male than a white male, and have a higher income than lower if non-white.

2.3.1.3 Aggravated Assault. Again the National Opinion Research Corporation demonstrated that the incidence is highest in the western part of the United States, almost twice that in the northeast and the south. Central cities and suburban areas have about the same rate of incidence per 100,000 population (293,286), whereas rural is one third of this rate. The remainder of the picture is somewhat inconsistent. Whites with income between $3000 and $5999 report the highest incidence at 289 per 100,000 for whites, while non-whites in the same income bracket reach the highest level also (420 per 100,000). The effect of age is very clear, the highest incidence occurring to men and women between 29 and 29 years of age, declining considerably as the subject becomes older. The incidence of the crime differs by sex and location as well. Fifty percent of white women and 40 percent of non-white women reporting occurrence in the home (presumably by a family member). White men reported that more than half of the incidents occurred in an outdoor public place.

---

15 Harry A. Scarr, "Patterns of Burglary," U.S. Department of Justice, LEAA. Washington U.S. Printing Office, February, 1972.

2.3.1.4 Rape. The incidence of forcible rape is about equal in the northeast and west at 139 and 133 per 100,000 population respectively, but is also primarily an urban phenomenon with rates of 83 per 100,000 population central city, 38 per 100,000 population suburban and a negligible rate in rural areas. Non-white women experienced 198 incidents per 100,000 population, whereas white women only represent 50 per 100,000. The incidence decreases with age, peaking in the age group 20 to 29 at 238 per 100,000. For white families, the rate per 100,000 population decreases with income, from a high 58 per 100,000 at 0-$2999 levels. For non-whites, there is no relationship with income. The location of the incident could not be determined with any certainty. The NORC data is summarized in Table 2.4.

In summary, Table 2.4 indicates (as well as is possible with the available data) the demographic and socioeconomic correlates of risk. Males, age 20-29 are the highest risks for burglary and aggravated assault, and as the rate for both of these crimes is considerably higher among non-whites than whites, it is likely that the rate for non-white males 20-29 exceeds the reported rates for both burglary and aggravated assault.

2.3.2 Summary based on the Report of the Violence Commission, 1969.

The Violence Commission submitted a report in 1969 identifying the chief characteristics of violent crime: murder, rape, aggravated assault and robbery. With one or two exceptions, these characteristics are also linked to burglary:

a. Violent crime in the United States is primarily a phenomenon of large cities.

b. Violent crime in the city is overwhelmingly committed by males.

Table 2-4 Most Likely And Least Likely Factors Associated With Victimization in A Part I Crime[16]

Rank	Robbery	Burglary *	Aggravated Assault	Forcible Rape **
1	Non-white income: 0-299 (278)	Male, age 30-39 (3649)	Male age 20-29 (824)	Female age 20-24 (238)
2	male age: 20-29 (257)	Male, age 20-29 (2782)	NW Male Income $3000-5999 (420)	NW Female " " (193)
3	Non-white income: 3000-5999 (240)	Male, age 40-49 (2365)	Male age 10-19 (399)	NW Female income 6000+ (121)
4	female age: 20-29 (238)	Male, age 60+ (2343)	NW Male Income $0-2999 (389)	NW Female income 0-2999 (111)
5	male age: 40-49 (210)	Male, age 50-59 (2297)	Male age 30-39 (337)	Female age 30-39 (104)
19	White Income 10,000 + (34)	White Income 10,000+ (763)	Female Age 60 (40)	White Female Inc. 1000+ (17)
20	White Income 6000-9999 (42)	White Income 6000-9999 (764)	Female Age 30-35 (52)	White Female Inc. 3000-5999 (46
21	White Female (43)	White Income 3000-5999 (958)	White Female (71)	Female Age 40-60+ (43)
22	Female Age 50-59 (60)	White Income 0-2999-(1310)	Female Age 50-59 (119)	White Female (50)
23	Male Age 10-19	Non-White Income 3000-5999 (1261)	Male Age 60 + (146)	NW Female Inc. 3000-5999 (60)

Numbers in parentheses are the rates per 100,000 population

[16] Adapted from Ennis, op. cit., Categories are obviously not mutually exclusive.
* Females excluded because too few in sample
** Males excluded

c. Violent crime in the city is concentrated especially among youths between the ages of 15 and 24.

d. Violent crime in the city is committed primarily by individuals at the lower end of the occupational scale.

e. Violent crime in the cities stems disproportionately from the ghetto slums where most Negroes live.

f. The victims of assaultive violence in the cities generally have the same characteristics as the offenders; victimization rates are generally highest for males, youths, poor persons and blacks. Robbery victims, however, are very often older whites.

g. By far the greatest proportion of all serious violence is committed by repeaters. (The Commission defined repeaters as persons with prior contacts with police.)

The Commission also indicated that burglary, a property crime, is less confined to central cities and less likely to be committed by non-white offenders than is violent crime.

2.3.3 The Location of Crime.

About 60 percent of all the violent crimes (murder, rape, assault, robbery) and 40 percent of the burglaries reported to the police in 1971 took place in cities with a population of more than 250,000. These cities represent only 20 percent of the U.S. population--suggesting the tremendous disparity in crime rates in different locations. Relevant information on the geo-distribution of crime is presented in Table 2.5, based on UCR data for 1968 and 1971. This shows that CAS is likely to be of much greater interest to the urban dweller than to the suburban or rural resident.

2.3.4 Modeling.

The NORC data would be useful to model the incidence of crime, that is,

Table 2.5 Violent Crime and Burglary
Known to the Police
(Rates per 100,000 Population)

	Urban (cities over 250,000)	Suburban	Rural
Crime Rate 1968:			
Violent Crimes	773.2	145.5	108.4
Burglary	1,665.8	761.0	387.2
Crime Rate 1971:			
Violent Crimes	1,047.5	205.7	133.4
Burglary	2,026.1	974.5	484.9
Percentage Increase:			
Violent Crimes	+35	+41	+23
Burglary	+22	+28	+25

modeling on the basis of victimization rather than on reported crimes. One might try to estimate coefficients on demographic and socioeconomic variables, using risk (the relative frequence of crime incidence) as the dependent variable. Specifically

$$P_i = f_i\ (d_j) \ldots\ldots (1)$$

$i = 1 \ldots n$, number of crimes
$j = 1 \ldots m$, number of demographic and socioeconomic variables

It is likely that the demographic and socioeconomic variables would enter in a highly non-linear way; that is, there appear to be interrelationships between variables such as race, income and age. The NORC survey suggests that people who have been victims of a crime engage in some target hardening or aversive behavior, and the President's commission report suggests that exposure to a crime (rare) or hearing information from others has some effect on behavior. This indicates a feedback loop in the model, i.e.,

$$P_{it} = G_i\ (P_{it}-1) \ldots\ldots (2)$$

where P_{it}, the probability of being a victim, is now time-subscripted. In an a priori sense, one would expect equation (2) to possibly be a negative exponential or some type of damping function. Equation (2) subsumes differential police or criminal justice system behavior as well. Equations (1) and (2) need to be estimated simultaneously because it is necessary to separate the effects of the demographic and socioeconomic variables from the feedback loop, as they are related to each other. Note that the probability of being a victim is related to the number of crimes analogous to a supply function. That is, the variables which are believed to be related to the level of criminal activity would be related to equation (1) as follows:

$$P_i = C_i/pop \ldots\ldots (3)$$

where C_i = total number of crimes of type i
pop = population in a region

$$C_i = h_i\ (d_j^*) \ldots\ldots (4)$$

where d* are a set of demographic and socioeconomic attributes of criminals or factors thought to be related to the incidence of criminal behavior, such as unemployment indices, population of various ages, average school years, etc. Equation (4) could be estimated independently of equation (1). Sjoquist[17] in a paper for the National Institute of Law Enforcement and Criminal Justice identifies and correlates several of these variables. Part of the correlation matrix is listed in Table 2.6. The remaining variables not included in the part of the table reproduced herein were essentially transformations of crime variables and punishment variables (i.e., sentence length, conviction probabilities, etc.) which were important in Sjoquist's risk modeling.

The simple correlation matrix of Table 2.6 illustrates the difficulties with the econometric modeling of crime production, or its analog, citizen risk. First, it should be noted that crimes (variables 9-12) correlate best with themselves, but variables one would expect to be interrelated are not strongly interrelated at all. For example, it seems logical that the percent of population in the age group 15-24 is related to crime frequencies both in the sense of providing victims (cf. NORC study) and offenders, and positive correlations of .248, .371, .278 and .187 are noted between this variable and various crimes as shown. The variable mean school years completed should bear a negative relationship to crime frequencies, and it does for robberies and auto thefts, even though the coefficients are almost too small to represent much beyond randomness. That the variables mean school years completed is positively correlated with larceny frequencies is surprising (.36). High residential density is another variable that is normally associated with crime and the correlation with robbery frequency (.326) is good, with burglary frequency not as strong (.132). It is surprising to find a positive correlation between density and auto thefts (.259), but then density and frequency of car

[17] David L. Sjoquist, "Property Crimes as an Economic Phenomenon," December 1970. pp. 116-119.

Table 2.6

Simple Correlation Coefilcients Between Socioeconomic and Demographic Variables and Crimes By Type

1. Unemployment	1.000											
2. Car registration/population	.068	1.000										
3. Retail Sales	.008	.077	1.000									
4. Pct. of Pop. Earning $3000	.056	.154	-.112	1.000								
5. Pct. non-whites	.004	.240	.094	.588	1.000							
6. Pct. of population 15-24	.282	.046	.091	-.010	.156	1.000						
7. Mean School Years Completed	.008	.017	.344	-.096	-.058	.132	1.000					
8. Density	.177	-.113	-.011	-.072	-.043	.044	-.358	1.0				
9. No. of Robberies/Pop.	.333	.014	.287	-.071	.458	.248	-.073	.362	1.0			
10. No. of Burglaries/Pop.	.356	-.036	-.021	.112	.396	.371	.046	.132	.719	1.0		
11. No. of Larcenies/Pop.	.124	.027	.313	-.033	.276	.278	.360	-.044	.573	.600	1.0	
12. No. of Auto Thefts/Pop.	.457	-.211	.156	-.210	-.189	.187	-.114	.259	.444	.537	.346	1.0

registration are negatively correlated, and frequency of car registration and auto theft a e also negatively correlated.

The search for a demographic, socioeconomic crime generating model makes intuitive sense, but poses many operational difficulties as noted above. The analyst becomes tempted to explain cause and effect, the signs on regression coefficients, coefficients produced by first, second or nth order correlations, or instability in the data. Explanations are easily developed to describe either sign on the data.[18] What is causing these difficulties is that crime is a relatively rare event, not well predicted by demographic variables, and subject to shifting patterns (such as narcotics availability, gang activity, etc.).

Let the probability of an incident of type k occuring = p_k, and assume that it is constant over time. This probability can be computed roughly as the frequency divided by the number of individuals. Considering a worst case, for example, the rate of burglary for a male age 30-39 is 3649 per 100,000 population[19] (NORC study) in a year, or p = .04. Some simple notions flowing from probability theory are as follows:

$$q_t = (1-p)^t \quad . \; . \; . \; . \; . \; . \quad (5)$$

where q_t is the probability that such a subject will remain free from burglaries from time o to time t.

$$r_t = (1-p)^{t-1}\, p \quad . \; . \; . \; . \; . \; . \quad (6)$$

where r_t is the probability that such a subject will remain free from burglary until the t^{th} year (and then be victimized in the t^{th} year), i.e., the probability that the waiting time is exactly equal to t. In Figure 2.1, the probability of being burglarized once or more as a function of time is shown for p = .01 and p = .04. The latter probability is an upward rounding of

---

18 cf. "The Prediction of Crime from Demographic Variables, A Methodological Note," Task Force Assessment, President's Commission on Law Enforcement and the Administration of Justice. pp. 207-211.

19 The proper unit is a household, not an individual, somewhat justifying the upward founding of the probability.

the rate shown for males 30-39 (3649 per 100,000) in the National Opinion Research Survey of Victimization. Rates are not segregated for non-white males in the same age or in the $6000+ income bracket, but those rates should at least be equal to .03649 if not much greater. The other probability shown, p = .01 is slightly higher than the overall burglary probability (949.1 per 100,000 population).

Figure 2.1 shows the large difference in the probability of becoming a victim of burglary as a function of time for different values of p. This distribution is a variant of the geometric distribution and is memory-less, that is, the probability is independent of past events. The theory involved in this plot is that the citizen "stations" himself at time equals zero year and looks ahead to determine how likely he is of becoming a victim at least once during the period. At five years, in the "low crime" neighborhood of p = .01, the probability of being a victim is slightly less than .05, whereas in the "high crime" area it is almost 0.19. Put in other terms, at the end of 5 years in man's circle of 20 male friends, we would expect one to have a story of a burglary in the low crime area. In the high crime area, there would be almost one every year. That the assumption of independent events is inadequate is shown in Table 2.7. This clearly suggests that the probability of becoming a victim more than once is considerably higher than predicted by a model which assumes (1) random interarrival times and (2) independence of events, assumptions made as well in the simplified model generating Figure 2.1. This confirms again the sizable difference in incidence between different age, economic, racial, and sex classes of Part I crimes as described earlier. The likelihood of being victimized twice is 5 times larger than would be expected under a random process.

Table 2.7

Actual Vs Expected Multiple Victimization

Number of Incidents	NORC Distribution of Multiple Victimization[20] (Actual process)	Predicted By μ =.063 Poisson Distribution (Random process)
0	.72	.940
1	.19	.057
2	.06	.013
3	.02	0
4	.01	0

[20] P. Ennis, op. cit., p. 40. The analysis supporting the conclusion from Table 2.7 is more illustrative than analytically correct. The proper strategy would be to segregate interarrival times or incidence statistics by age, sex, income and other variables, obtain a vector of μ's and then test for goodness of fit.

2.4 IMPACT OF CRIME ON CITIZENS

Table 2.8 condenses and contrasts the three states of risk: actual probability of becoming a victim, citizen's estimate of the probability, and a response to a question as to whether a citizen would be likely to change behavior (observed as a function of age and sex). These statistics, as mentioned previously in this report, show an order of magnitude difference between risk and fear. In summing up its report, the Task Force on Assessment made two key points. Firstly, the public fears most the crimes that occur the least: the crimes of violence. As Table 2.8 shows, people modify their behavior to guard against these rare instances. But the fear of crimes of violence is not a fear of death or injury alone. The amount of personal injury people face daily from many other sources, including occupational accidents, home accidents, vehicle accidents, greatly exceeds the 1.8 per 1000 rate of Index Offenses.[21]

Secondly, the crime of burglary, which involves a minute likelihood of violence to the victim, is a source of serious concern. In Table 2.8 half the respondents worried that their houses would be burglarized. The economic losses from crimes against property personally experienced by the victim are small as compared with the economic loss resulting from crimes against business establishments and government which pass their losses on to the general public in the form of increased prices and taxes.[22] Somehow, these numbers in Table 2.9 are inadequate to describe the fear engendered by these crimes. The Task Force on Assessment estimated annual expenses on burglar alarms, watchmen service and security equipment at $200 million plus for equipment and perhaps over $1 billion for personnel, although it is impossible to distinguish which costs are fixed (and should be capitalized) and which are for operations and

---

21 Task Force: Assessment. op. cit., p. 88.
22 loc. cit.

Table 2.8

Citizen's State of Risk By Type of Crime, Race, and Sex

STATE	CRIME TYPE	WHITE		NON-WHITE	
		MALE	FEMALE	MALE	FEMALE
Risk (rate per 100,000 pop.)	assault	.00297	.0071	.00305	.00386
	rape	N.A.	.0050	N.A.	.00193
	robbery	.0097	.0043	.00174	.00271
	burglary	.01517	.00236	.02045	.00771
Estimates of Risk	Responses likelihood of attack very likely or somewhat likely on street	.20	.21	.39	.51
	Concern about burglary high or some what high	.47	.52	.51	.62
Behavior	Responses Rarely walk in neighborhoods after dark.	.65	.81	.55	.73

Source; NORC Data N.A. = not applicable Risk = probability of becoming a victim

Table 2.9

Average Economic Impact of Index Crimes Against Citizen's[23]

Crime Type	NORC	Pres. Comm/UCR
Robbery	$271 per/incident $ 49 million	$254 per/incident $ 30 million
Burglary	$313 per/incident $450 million	$242 per/incident $284 million

[23] ibid., pp. 45-47.

maintenance. It is also impossible to distinguish which costs are borne by businesses and government and which by residences. Probably the most common security device, a dead bolt lock, is not even considered in this data. Another cost is that for overhead on insurance, estimated at $300 million annually (again much of this is for businesses).

The NORC survey indicates that about 37 percent of all households maintain firearms for protection of the household. This is an obvious method of protecting against burglary inspired by fear of personal harm from a burglar.

Citizen's reaction to robbery is not so pronounced; though robbery involves as great a loss per person, it does not occur anywhere near as frequently. According to NORC (Table 2.8) the main strategy is avoiding high risk areas after dark.

One attempt to integrate behavioral information and police statistics on crimes into a severity measure is the Sellin-Wolfgang Index.[24] It is listed in Table 2.10. The index was constructed to measure the seriousness of juvenile crimes. It was developed from the responses of several hundred people who ranked the seriousness of hypothetical situations against a base crime. The index purports to be a ratio scale where a single crime can be decomposed into a series of components and the values summed up for each component that occurred. For example, if a woman were robbed of $25, without the offender displaying a weapon, and then raped, the score would be 13 points. If she required hospitalization, the score for the particular incident would then increase to twenty points. If there were another victim in the same crime, the score would be increased to include the injury or loss experienced by the second victim.

---

[24] Marvin Wolfgang and Thorsten Sellin, "The Measurement of Delinquency," New York: J. Wiley and Sons, 1964.

Table 2.10

Sellin-Wolfgang Seriousness Index, Components and Survey

Component	Complaint			Score
Assault	Minor Injury			1
	Treated and Discharged			4
	Hospitalized			7
	Killed			26
Intimidation	Sex Offense	Without Weapon		10
		With Weapon		12
Intimidation	Non-Sex Offense	Physical or Verbal		2
		Weapon		4
Property Crimes	Forcible Entry			1
	Stolen Vehicle			2
	Value of Property Stolen		less than $10	1
			$10 - 250	2
			$251 - 2000	3
			$2000 - 9000	4
			$9000 - 30,000	5
			$30,000 - 80,000	6
			greater than $80,000	7

Usually, it is not possible to map crime statistics, (whether UCR's or NORC's) into the Sellin-Wolfgang Index. In Montreal, the basic police report form has been modified to permit rating crime according to the index. Heller and McEwen[25] recommend its use as an incident seriousness index in the deployment of patrol manpower.

The main contribution of the index is in relating injury, intimidation and property loss. Table 2.11 averages seriousness and seriousness components for St. Louis as reported by Heller and McEwen. The average rape, robbery and assault is three to seven times more serious in terms of the Sellin-Wolfgang Index (and, by implication, to the citizen) than property crimes. From NORC and UCR statistics, the likelihood of a burglary, robbery, assault, rape or murder is very small. The probability that forcible entry results in any other crime except burglary is very small, perhaps on the order of .05.[26] However, weighted by the potential loss or seriousness under the worst case assumptions, the situation becomes anything but trivial.

2.5 POTENTIAL BEHAVIOR UNDER CAS

In this section, the general parameters of CAS are considered with respect to, first, system needs and then user needs; the latter point to bring about some informed speculation as to the potential demand for emergency services given a CAS network. This speculation is supported by a survey conducted by Compu-guard and is described herein. Finally, institutional use of CAS is considered.

Beyond the technological problems and requirements by the system upon the citizens, a series of practice and psychological-sociological requirements

---

[25] Nelson B. Heller and J. Thomas McEwen, "The Use of an Incident Seriousness Index in the Deployment of Police Patrol Manpower," National Institute of Law Enforcement and Criminal Justice, January, 1972.

[26] When forcible entry is followed by a violent confrontation between the citizens and the offender, UCR considers this robbery, assault, or rape, even though the offender might have intended burglary.

Table 2.11

Average Seriousness and Seriousness Component for Actual Part I Offenses Occurring in One Week in St. Louis[27]

Type of Crime	Number	Average Seriousness			
		Injury	Intimidation	Property	Total
Homicide	38	28.97	3.32	0	32.39
Rape	75	3.24	11.87	.23	15.33
Robbery	651	1.44	3.34	1.66	6.43
Assault	462	5.40	4.28	.05	9.74
Burglary	2738	–	–	2.64	2.64
Larceny ($50)	4090	–	–	2.26	2.25
Auto Theft	1773	–	–	2.29	2.29

27 Ibid., p. 76

are made upon the user. The critical issues are false alarm control, intentional misuse of CAS, and the theft of a device. These issues have also been raised as conjectures by the Security Planning Corporation.[28]

2.5.1 False Alarm Control.[29]

A false alarm is defined operationally herein as triggering of the alarm due to:

a. malicious use
b. accidental error
c. equipment malfunction
d. user "perceptions" that fall short of a pre-defined threshold

Malicious use would either occur either by a user or by someone who was not a user obtaining possession of an actuator. The basic design of the system requires that the identification of the user be transmitted along with location information to a central computer. The system then has the potential to identify a user who transmits false alarms and to take action against the user should the false alarm continue, ultimately including service disconnection. It is extremely likely that malicious alarms are improbable as the identity of the offender is generally known. False alarms (malicious) in existing alarm systems are probably a function of the offender's estimate of being apprehended: false fire alarms from fire call-boxes far exceed false fire alarms by telephone.

Should a device be lost or stolen, there is a high probability of a malicious alarm or alarms. If reported as stolen, an alarm can be ignored by the central station; if not, the fact it was stolen should become known typically after the first malicious alarm. Subsequent alarms can be ignored.

Accidental error, where the user triggers the system by accident and is aware of this, could be treated in the same manner that central stations treat accidental burglar alarms. A user would be instructed to call the central station,

---

28 Security Planning Corporation, "Residential Security," submitted to LEAA, Contract No. J-LEAA - 007-72 draft April, 1973, p. 85.

29 See Section for a mathematical model of false alarms.

to report the accident and to identify himself by a code number, where satisfactory identification would result in cancellation of the alarm.

Equipment malfunction [30] and user over perception of situations are two causes of false alarms that are difficult to predict. Both argue for field experimentation.

It is too easy to become overconcerned with the false alarm issue. Proper evaluation requires a cost function, which should state the immediate opportunity costs of responding to a false alarm. Longer term effects concern lowering a citizen alarm in the dispatch queue by the police because of its supposed unreliability, i.e., losing system credibility.

Should actuator losses become a significant problem, it may become necessary to develop operational procedures to identify instead which units remain in service at any given time.

---

[30] et. Reliability Modeling Section, this report.

2.6 THE COMPU-GUARD QUESTIONNAIRE: CONCLUSIONS

In an attempt to identify user attitudes relative to the use of CAS, Compu-guard conducted a survey of about 500 people. This sample was not selected on any scientific basis, but was considered to be representative of the following:

a) Potential users of CAS.

b) Potential scenarios for the use of CAS.

The results of this questionnaire are now presented, together with some observations and conclusions. The questionnaire itself and the percentage of responses for each alternative it contains, is given as Figure 2.2.

2.6.1 Overview.

The results in Part I of the questionnaire indicate that the sample is reasonably representative. About 60 percent of the respondents were male, 40 percent female. Of these, about 75 percent were white, 15 percent black, 6 percent other--only 4.5 percent did not respond at all.

Sixty-five percent of the respondents live in single-unit houses, 20 percent in multi-unit houses. Only 5 percent of those sampled live in high rises or in institutions. For the place of work, however, 29 percent work in high rises, 20 percent in low-rise structures. Five percent work in banks, 6 percent in factories, 6 percent in warehouses, and over 7 percent in stores.

In terms of crime perception, the responses were as follows: in percent,

LEVEL OF PERCEIVED CRIME	AT HOME	AT WORK
High	9.8	12.9
Medium	26.1	31.8
Low	38.3	28.9
Negligible	23.7	15.1

Thus it is seen that over 35 percent of all respondents thought their neighborhood at home was a high or medium-crime area. This rose to nearly

CITIZENS ALARM SYSTEM (CAS) QUESTIONNAIRE

RETURN ADDRESS: COMPU-GUARD SECURITY SYSTEMS, INC.
5993 PENN CIRCLE SOUTH, PITTSBURGH, PA. 15206

This questionnaire is a vital part of a survey being conducted by the Center for Entrepreneurial Development, Carnegie-Mellon University. This survey is an analysis of attitudes and requirements relevant to the development of a new kind of emergency-calling system to assist any citizen in an emergency situation. CAS is being developed under contract to the Law Enforcement Assistance Administration of the U.S. Department of Justice.

The first part of this two-part questionnaire relates to your household and your neighborhood, and because of the personal nature of this information, do not include your name in this questionnaire. We are sending this questionnaire only to a small number of people, so your response will be deeply appreciated.

PART I.

CIRCLE YOUR CHOICE

1. SEX: M39.7% F59.3%
2. RACE: black15.1 white 76.6 other6%
3. TYPE OF HOUSING YOU LIVE IN:
   1) single unit house 64.8%
   2) multi unit house 20.1%
   3) high rise apartments 1%
   4) institutional (dormitory, 4.3% senior citizens home etc.)
4. TYPE OF FACILITY YOU WORK IN:
   1) high rise building 28.5%
   2) low rise building 19.6%
   3) factory 6.2%
   4) warehouse 6.2%
   5) bank 4.8%
   6) retail or wholesale store 7.4%
   7) other 20.3%
5. WHAT IS YOUR PERCEPTION OF CRIME IN YOUR NEIGHBORHOOD:
   1) high crime rate, causing substantial fear 9.8%
   2) medium crime rate, which causes concern, some fear 26.1%
   3) low crime rate, which causes concern but little fear 38.3%
   4) negligible crime rate, causing neither concern nor fear 23.7%
6. WHAT IS YOUR PERCEPTION OF CRIME IN THE GENERAL AREA OF YOUR WORKPLACE:
   1) high crime rate, causing substantial fear 12.9%
   2) medium crime rate, which causes concern and some fear 31.8%
   3) low crime rate, causing concern but little fear 28.9%
   4) negligible crime rate, causing neither concern nor fear 15.1%

FILL IN THE BLANKS (see Section 2.6 for Questions 7-12)

7. AGE: ______
8. APPROXIMATE ANNUAL INCOME: ____________
9. HOW MANY OTHER OCCUPANTS IN YOUR HOME:

   ______male ______female
10. HOW MANY PERSONS IN YOUR HOUSEHOLD HAVE MEDICAL PROBLEMS (cardiac, emphysema, failing eyesight, wheelchair etc.):

    ____
11. HAVE YOU OR ANY OTHER OCCUPANTS OF YOUR HOME OR OFFICE EVER WORRIED ABOUT A SITUATION WHERE HELP COULD NOT BE SUMMONED BY PHONE DUE TO LACK OF TIME, STRENGTH, PANIC, FEAR, ILLNESS, DISABILITY, ETC:

    ______no ______yes
12. WHICH SITUATION CAUSES THE MOST ANXIETY:

    HOME: ____________

    OFFICE: ____________

Figure 2.2

PART II.

The Citizens Alarm System (CAS) is intended to be an emergency-calling system for use in crime-related and other emergency situations. CAS includes an actuator which is a small device carried by each person who wishes to be protected by the system. It can be triggered in secrecy and with a minimum of effort, should an emergency arise. Each emergency call is transmitted automatically, in seconds, either to the police or some other public safety organization, telling them what type of emergency it is, where it is happening, and who sent the alarm.

1. THE ACTUATOR YOU WOULD CARRY FOR CALLING EMERGENCY ASSISTANCE COULD BE PACKAGED IN A NUMBER OF WAYS. WHICH OF THE FOLLOWING WOULD YOU PREFER: (circle as many as you wish)
   1) small attachment to a watchband 29.2%
   2) small attachment to a belt 15.3%
   3) a wristwatch 34.7%
   4) large ring 9.1%
   5) pendant 9.6%
   6) other 1.9%

2. DO YOU HAVE ANY SUGGESTIONS ABOUT THE SIZE, SHAPE AND STYLE OF THE ACTUATOR: ____________________

____

____

3. WHAT IS THE MAXIMUM PRICE YOU WOULD BE PREPARED TO PAY FOR THIS EMERGENCY CALL PROTECTION:

Total initial cost, per occupant protected (circle one)

1) $20-$25 67.7%	2) $26-$30 9.8%	3) $31-$50 7.2%
4) $51-$75 3.8%	5) $76-$100 3.1%	6) above $100 0.7%

Total Monthly Service for Maintenance and Monitoring, per Occupant Protected (circle one)

1) $2/month 57.4%	2) $3/month 13.8%	3) $4-$5/month 10.3%
4) $6-$8/month 4.1%	5) $9-12month 4.3%	6) above $12/month 0.7%

4. FOR WHICH OF THE FOLLOWING EMERGENCIES WOULD SUCH A DEVICE BE MOST USEFUL, NEXT TO MOST USEFUL, ETC., TO YOURSELF OR THERS: (number 1 to 8) (see Section 2.6)

___noise and disturbances
___holdup
___falls and accidents
___burglary
___fire
___medical emergencies other than accidents (e.g. heart attack)
___assault or attack
___other

5. THE ACTUATOR YOU WEAR MAY BE SUBJECT TO ABUSE. WHAT ARE THE WORST SITUATIONS YOU CAN THINK OF: (number 1 to 6) (see Section 2.6)

___accidental use by children
___soaking in a shower, bathtub, rain
___shock or vibration as in a fall
___other: ____________________
___other: ____________________
___other: ____________________

6. SINCE FALSE ALARMS DEGRADE SERVICE, RAISE COSTS, AND HURT EVERYONE, WHAT ONE OR MORE OF THE FOLLOWING PENALTIES WOULD YOU RECOMMEND AS A DETERRENT: (fill in one or more blanks)

a) Charge $______ for false alarms, with no charge for real ones. (remember it is often difficult to place the blame)

b) Charge $______ for every alarm, real or false.

c) Take the system away from the user responsible for more than _____ false alarms in a year.

d) Other: ____

CIRCLE ONE ANSER IN EACH OF THE 4 SCENARIOS BELOW

7. YOU'RE HOME ALONE LATE AT NIGHT WATCHING TELEVISION OR READING AND YOU HEAR A NOISE IN THE HOUSE YOU CAN'T IDENTIFY. YOU LISTEN VERY CAREFULLY AND YOU HEAR ANOTHER NOISE. YOU WOULD:

1) signal the police with your Citizen's Alarm System (CAS) 29.9%
2) telephone the police for help 10.7%
3) investigate the noise first yourself 54.1%

8. YOU'RE HOME ALONE, ITS LATE AT NIGHT. YOU'RE AWAKENED AND HEAR SOMEONE INSIDE YOUR HOME SEARCHING THE OTHER ROOMS OF YOUR HOUSE. YOU WOULD:

1) signal the police with CAS 69.1%
2) telephone the police for help and ask them what to do until help arrives 12.4%
3) try to frighten away the intruder by turning on lights or making noise. 14.1%

9. YOU'RE HOME ALONE AND YOU SEE SMOKE COMING FROM THE NEXT ROOM. YOU WOULD:

1) signal a firm alarm with your Citizen's Alarm System and leave the house. 43.5%
2) telephone the fire department, then leave 10.5%
3) investigate first to see if you can put the fire out yourself without assistance 41.6%

10. YOU'RE HOME ALONE LATE AT NIGHT AND YOU FALL DOWN THE STAIRS. YOU AREN'T SURE IF YOU'VE BROKEN ANY BONES, BUT MOVING HURTS. YOU WOULD:

1) signal an ambulance with CAS 72.5%
2) try to get to a phone 15.1%
3) yell for help and hope someone hears you 7.9%

45 percent for the place of work.

The age of respondents varied widely: 14 percent between 16 and 20 years old, 16 percent between 21 and 25, 14 percent from 26 to 30, 40 percent from 30 to 50, and 15 percent over 50.

The annual income of the respondents also enjoyed a wide representative spread: 25 percent below $2000, 13 percent from $2-5000, 16 percent from $5-8000, 13 percent from $8-10,000, 15 percent from $10-15,000, 14 percent from $15-25,000, and 2-5 percent over $25,000.

Most homes (77 percent) had at least one male, and 72 percent had at least one female. About 20 percent of the households had at least one person with some kind of severe medical problem. Over 40 percent of all respondents had worred about situations in which they would be unable to summon assistance by phone. This is a significantly high number.

2.6.2 Conclusions.

a) A wristwatch type actuator was found to be the most popular—preferred by 35 percent of all respondents. Next in popularity was a device attached to a watchband—15.3 percent. The ring was the least popular, with only 9.1 percent in its favor.

b) Though 68 percent of the respondents felt they would like CAS to be less than $25, initial cost per occupant, it is significant to note that nearly 10 percent were prepared to pay up to $30.

In terms of a continuing monthly service fee, 57 percent liked the figure of $2 per occupant, 14 percent were prepared to pay $3, 10 percent, $4 to $5, and almost 9 percent were prepared to pay more than $6.

c) Respondents were asked to rank the priority of different types of emergency situations for which they would consider CAS useful. The results are presented in Table 2.12. This table indicates that assault and medical emergencies both rank highest in user concern Hold-ups are given very low priority, probably because most users questioned do not work in a business

Table 2.12

PRIORITY RANKING OF EMERGENCY SITUATIONS

EMERGENCY SITUATION	NO RESPONSE	PRIORITY 1	2	3	4	5	6	7	8
Noise	25.6	3.6	1	.7	1.9	5	11.7	45.4	5
Hold-up	19.8	10.5	9.8	10.8	9.6	17.5	18.1	3.3	.5
Falls/Accidents	21.8	11.7	7.4	12.9	13.4	12.4	16.5	3.3	.5
Burglary	21.2	11.7	18.1	16.7	14.1	10.7	6.0	1	.2
Fire	20.3	15.5	18.7	16.0	14.1	8.6	4.3	1.9	.5
Medical	19.8	27.0	13.1	8.1	12.6	8.8	7.6	1.9	.7
Assault	19.4	25.6	7.6	8.6	7.6	10.0	8.8	10.7	1.4
Other	32.5	.2	.9	.7	1.0	.5	.5	5.5	58.1

susceptible to or subjected to hold-ups. Fire also ranked surprisingly low, with only 16 percent making it their first priority and 19 percent the second. Burglaries varied from 12 percent (1st priority) to 18 percent (2nd) to 16 percent (3rd).

d) The four scenarios (question 7-10, Part II of the questionnaire) were presented to get a crude feel for user awareness of the purpose of CAS. Obviously, user response in an emergency may be very different--but the questionnaire provides a measure of user understanding of system function. The results were quite positive. 69 percent of the respondents would use it if they heard an intruder in the home, 73 percent would use it in a severe medical emergency. Only 44 percent felt it would be useful in a fire, as compared to 42 percent who would first try to put the fire out themselves. However, in a situation involving unidentifiable noises, only 30 percent said they would use CAS--as compared to 54 percent who would investigate themselves.

This tends to suggest more than 30 percent would actually use CAS in "emergencies" involving noises.

e) In terms of actuator abuse, 27 to 28 percent of respondents felt that each of the three situations mentioned were of maximum importance.

f) In terms of penalties as a means of preventing false alarms, a majority felt that all alarm calls should be treated equally and billed for. This suggests that a charge should be levied for each alarm, true or false. This would tend to raise the threshold at which users would trigger alarms, thereby reducing false alarms.

2.7 OTHER CONCLUSIONS

The results presented in this section lead to a number of conclusions relative to the feasibility demonstration of CAS.

2.7.1 Crime-related Usage of CAS.

Given the basic characteristics of CAS, it readily lends itself to a number of typical applications. Some of these are presented in Table 2.13, based upon NORC, UCR, and other statistical findings. Five major applications of CAS are illustrated. From the user at home, the most likely type of alarms are for family fights, medical emergencies, and burglary. Family fights are extremely dangerous incidents for the people involved as well as for the police who intervene, often leading to aggravated assault and murder. The ease of transmitting a CAS alarm by one of the parties should be useful in this context. The likelihood of user overestimation of seriousness is high, but so is forcing a user to take whatever steps are necessary to cancel a call. It is probable that a call would be transmitted as early as the likelihood of impending physical violence reaches some threshold. Early response by police would be helpful in reducing injury.

Another major use for CAS would be for a suspected burglary. As the evidence suggests that burglars prefer unoccupied residences to occupied and avoid confrontations with their victims, it is believed that reports of actual burglaries will be rare. More likely, calls would be for prowlers, suspected burglars, suspicious noises, etc. CAS usage rules should perhaps indicate to users that the telephone be used for such incidents. In the rare case of a burglary in progress with the victim at home CAS offers the opportunity for the victim to notify the police without alerting the burglar. This should greatly increase the likelihood of apprehension of the offender. As a corollary to the point, a clear warning that a structure is CAS-equipped may serve as a deterrent.

The same notions apply to forcible rape, aggravated assault and robbery occurring at home. If the user is able to transmit an alarm early, the probability of arrest increases significantly.

2.7.2 Other Applications of CAS.

CAS is primarily intended to provide a response in a crime-related emergency. However, these subtleties are lost on a user confronted by any grave emergency--a cardiac arrest, a serious fall, a fire, etc. Thus, CAS is likely to be used by people in all kinds of emergencies--much as the 911 telephone number is used. This suggests several things:

a) The response agent must be able to respond to a variety of emergency situations--which may be criminal or medical in origin. The most appropriate agents would therefore be the police, a special well-trained guard force, or a public special-response unit set-up for this purpose.

b) Each user is likely to be confronted, at one time or another, by a non-crime emergency. If this emergency is sufficiently serious, the use of CAS must be allowed.

c) The actuator could be designed to allow the user one or more options in terms of the choice of response agent. The advantages of a multi-option actuator include: greater versatility and improved quality of response for the user, and a reduced workload for thepublic safety organization. The disadvantages include: likelihood of error in triggering the appropriate option, higher actuator cost, increased package size, slightly lower hardware reliability, and possible user confusion in an emergency. While final determinations are only possible in a large-scale field test, it is suggested that most of the actuators used in the feasibility demonstration can be single-option devices.

d) To prevent the use of CAS in non-crime situations which are also not serious enough, penalties should be established as a user-deterrent.

2.7.3 CAS as a Deterrent to Crime.

CAS is likely to present a significant deterrent against crimes such as rape, assault, robbery. It should also deter burglaries in situations in which it is obvious that the building or premises is occupied. CAS is not likely to be a deterrent against burglary in unoccupied premises, against larceny and auto theft, or against some kinds of vandalism. This deterrent is likely to be a function of the following factors:

a) The inconspicuous manner and ease with which the CAS actuator can be triggered by the victim.

b) The information conveyed to the response agent and the speed at which this is done.

c) The response time of the response agent to CAS-initiated calls.

SECTION 3

HUMAN FACTORS ANALYSIS

3.1 USER DIMENSIONS: PHYSICAL ABILITIES

The objective of the consideration of human factors is to produce a design that can be utilized by as large a segment of the population as possible without having to make several different configurations.

Most of the literature on human factors deals with the "average" person, and abilities are not described in terms of the percentile of the population capable of performing a given task. As an alternative, a survey was made of other manufactured items that must serve the public. These included public telephones, vending machines, television and radio sets, watches, calculators, and bank alarms. Manufacturers of these items were asked what percentage of the population was able to use their product and what problems did they have in serving particular handicap types.

As it turned out, little had been done in terms of designing the common products noted above. From this one might conclude that these products have been made in such a fashion as to make them useable to nearly everyone, or that handicap groups are not a large enough market to warrant specialized designs.

The response that Compu-guard got was that 97 percent of the population could use a public phone; 90 percent for vending machines; 98 percent television and radio sets; 85 percent for calculators and cameras. Significantly, 99 percent could use a watch. It wasn't clear that the manufacturers meant these were the percentages of all people that could use their product or if it was the percentage who came in contact with their product that were able to use it. There did not appear to be any control for reading level or comprehension of instructions nor attempt to explain what the unit did other than its expected service output.

The reliability of such data and the similarity of sample techniques is therefore in question. However, the responses do give a qualitative measure of the ability of the population to perform certain tasks.

Specifically the Citizens Alarm System actuator needs to have four major features:

A. Easy to operate, intentionally.

B. Difficult to operate, inadvertently.

C. As attractive or aesthetically desirable as a watch or necklace.

D. Useable by a maximum portion of the population.

Location of the actuator has been considered an integral part of the design. The choices available are either to have it carried in some external holder, e.g., a pocket or a purse; or to attach it to a limb, the body, or the head and neck.

Pocket or purse-carried actuators were rejected because of the variety of clothing and fashion, and the ease with which the actuator could be left behind when changing clothes, or forgotten.

Attachment to the head was rejected because it would be uncomfortable and the user couldn't see what he or she was doing, an important feedback.

Wristbands, belts, and necklaces were the remaining choices for attachment to a limb, the torso or neck respectively. Belts and necklaces are somewhat sex-specific, i.e., men seldom wear necklaces and many women's fashions are beltless. Thus the most common, least specific location was the upper limb, i.e., hand or wrist.

The actuator may be located to require one hand only to operate. Although the most common location is the wrist, it can also be attached to a belt, or necklace, or carried in a purse, facilitating one-hand operation. The housing and exterior design are fashioned along the lines of a wrist watch so as to be unobtrusive. Belt and necklace versions should be similarly styled so as to appear a natural part of the user's dress and accessories.

Hand dexterity is significant in the design of the actuator. Thumb-and-first finger dexterity is best, then thumb-and-second finger; first-and second-finger; thumb-and-ring finger; thumb-and-small finger; then other finger-to-finger combinations are equally poor. This suggest a pincer movement for the actuation of the trigger, using the appropriate finger-to-finger combination.

Wrist and belt locations were also considered highly advantageous along with an actuator that uses a rotary motion of the actuator mechanism, because it is relatively difficult to rotate one's arm about the wrist or one's body about the belt buckle.

3.2 USER DIMENSIONS: MENTAL ABILITIES

Average reading skills in the United States are about the sixth grade level. However, far more people use such devices as telephones and vending machines than can read the instructions on the devices. And it is assumed that virtually anyone can turn on a television set.

The actuation mechanisms seriously considered are two opposing buttons (pincer-movement), a dial and button, or two counter-rotating dials, any of which is easier than remembering a seven-digit telephone number and dialing or tuning a television set.

Correlation between mental capacity as measured by any verbal based test and ability to perform dexterity tasks is very low. Data in this area is so weak as to suggest that it is impossible to predict the usability of a product based on mental aptitude.

About all that can be said of the actuators proposed is that they require nothing more than basic motor skills to operate, skeletal and physiological functions that most people have by age four. So only the most severely retarded would be unable to perform the tasks necessary to operate an actuator.

3.3 PHYSIOGNOMIC PROFILE

Relative to the actuators considered, the average person has the following rank of skills relative to motion:

a. One hand to external object.

b. On hand to other hand or forearm.

c. Either hand to body where the person can see the hand.

d. Hand to face, unable to see the hand.

e. Hand to leg or foot, able to see the hand.

f. Hand to body, unable to see the hand.

g. Finger skills (including the use of the thumb).

h. Push/pull; thumb and first finger.

i. Push; thumb, first or second finger.

j. Rotate between thumb and first finger.

k. Rotate with the whole hand.

l. Push/pull; thumb and any other finger other than first.

Maximum finger or thumb load on a 1/8 inch diameter blunt cylinder is 6 ounces "with ease" or 9 ounces "without discomfort," an action such as a lever type switch, in which the cylinder is the lever.

Finger skills are also directionally specific. Most people have greater dexterity in a linear motion transverse to their forearm when using the other hand. But along the front of the body, vertical actions are easier than horizontal. Both of these refer to push/pull finger skills.

Rotation is not specific as to direction if the axis of rotation is normal to the body, assuming a rotation between thumb and first finger.

References: Measure of Man, Dreyfus.

Bio-physical Dimensions, NASA.

FIGURE 3.1

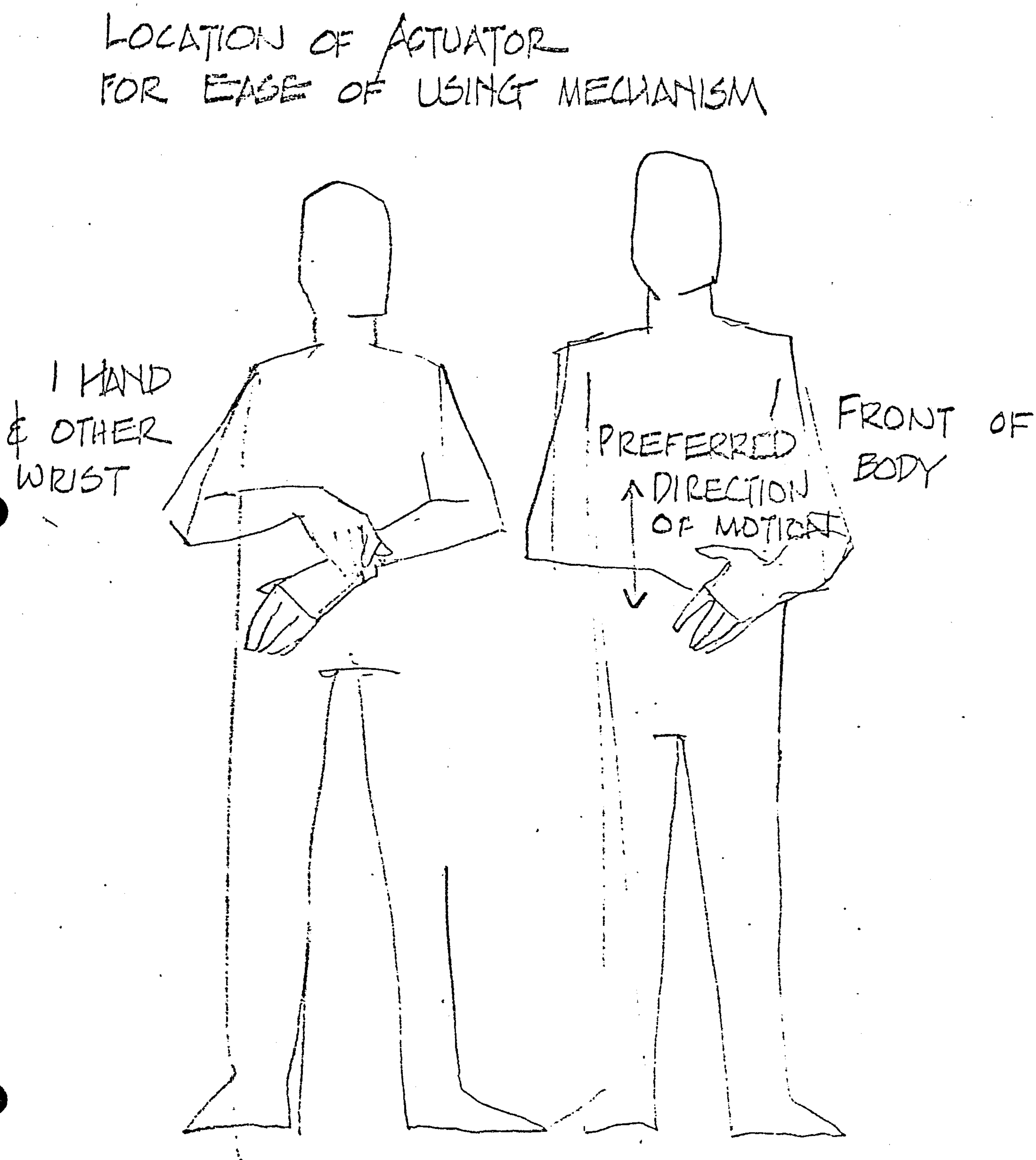
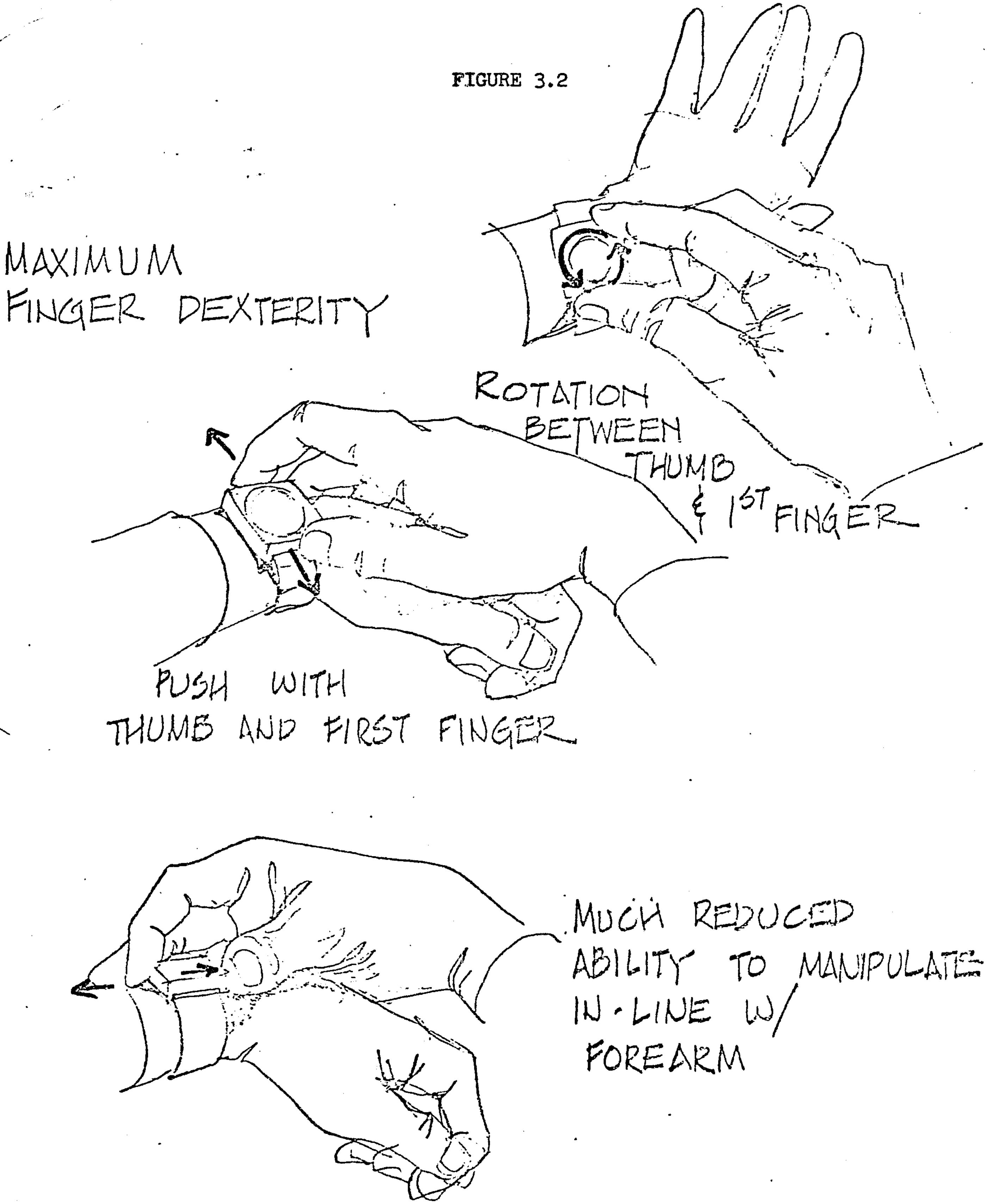

LOCATION OF ACTUATOR
FOR EASE OF USING MECHANISM
1 HAND
& OTHER
WRIST
PREFERRED
DIRECTION
OF MOTION
FRONT OF
BODY

FIGURE 3.2


MAXIMUM
FINGER DEXTERITY
ROTATION BETWEEN THUMB & 1ST FINGER
PUSH WITH
THUMB AND FIRST FINGER
MUCH REDUCED
ABILITY TO MANIPULATE
IN-LINE W/
FOREARM

3.4 CONCLUSIONS

a) In terms of the goals of the CAS actuator, a high priority is to make the mechanism easy to use intentionally, difficult to inadvertently trigger. Consequently, the most desirable actuation mechanism is one which allows a pincer-movement between fingers, or a rotating device at the wrist or belt requiring thumb and/or first finger.

b) Minimum false alarms can be accomplished by means of a double simultaneous-actuation mechanism such as a dial plus button; two dials to be rotated; or two opposed buttons (pincer movement).

c) Any of the designs shown can be styled to be worn on the wrist, as a pendant, or on the belt. They are all shown as worn on the wrist merely for comparative purposes. These devices can also be carried in a pocket or purse, if necessary.

3.5 RECOMMENDATIONS

a) It is suggested that two mechanical packages be developed as follows:

i. A multi-purpose actuator with a pincer-type actuation mechanism. Actuator to be about the size of a watch, and amenable for mounting on a wrist-band, waist-belt, or for carrying in a pocket.

ii. A watch-actuator, to be worn on the wrist, with a rotating actuation mechanism.

b) The ring has been considered as an alternative mechanical package for the actuator. To test the feasibility and desirability of its development, some mechanical packages were prototyped. The results of these exercises suggest that the ring is an undesirable alternative for the following reasons:

i. The cost of an acceptable package is too high.

ii. The probability of inadvertent triggering is high.

iii. The user dexterity required for an acceptable false-alarm preventive design is such as to restrict its use to a relatively small population.

iv. The size of the ring would be large enough to make it unacceptable to many potential users.

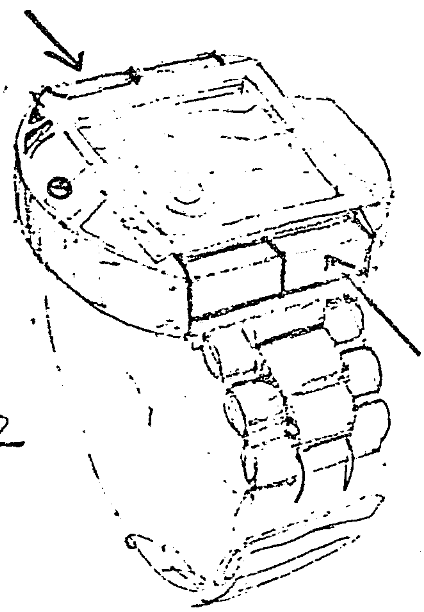
v. The ring could not be used in the winter or at other times if gloves were worn.

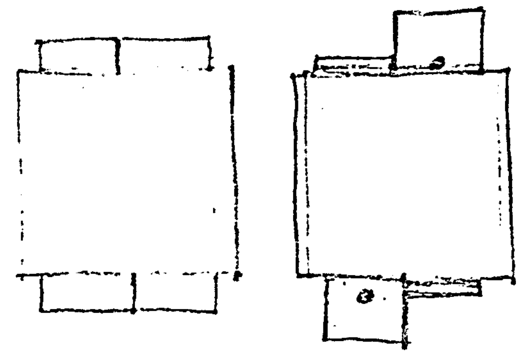
It is therefore recommended that the ring actuator not be developed.

FIGURE 3.3

ACTUATOR TYPES

TWO OPPOSING BUTTONS W/ INDICATOR LIGHT

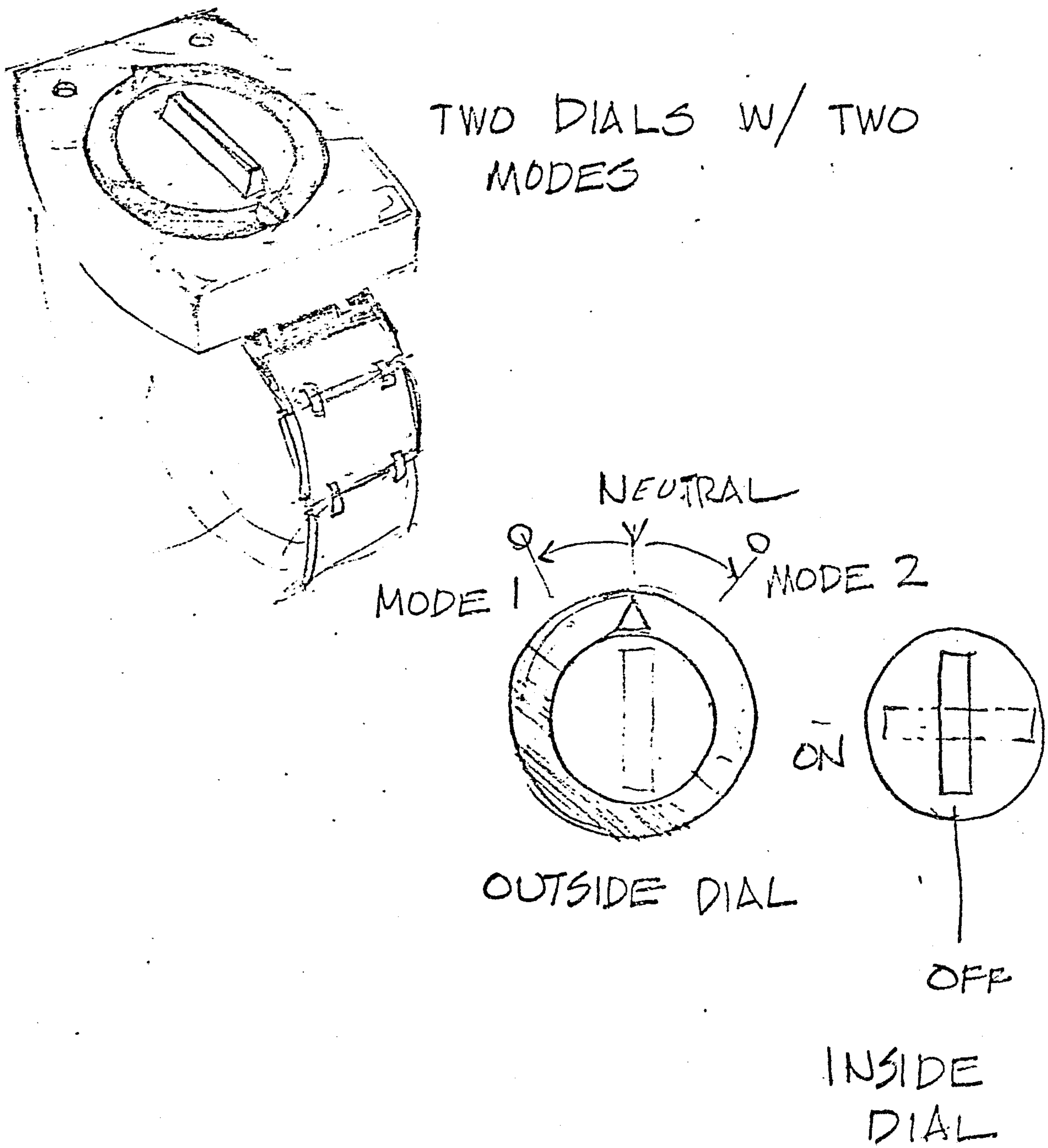




OFF ON

BOTH BUTTONS MUST BE SWITCHED "ON" TO ACTIVATE THE ALARM. BESIDES BEING ABLE TO SEE THE "ON" POSITION, A SMALL LIGHT IS ALSO IN THE CIRCUIT AND IS VISIBLE ON THE FACE OF THE ACTUATOR.

FIGURE 3.4



TWO DIALS W/ TWO MODES
NEUTRAL
MODE 1
MODE 2
ON
OUTSIDE DIAL
OFF
INSIDE DIAL

SECTION 4

ANALYSIS OF REGULATIONS AND POLICIES

4.1 INTRODUCTION

Prior to the final design of the CAS hardware and software, it is is important to consider the regulatory framework within which CAS must operate. Some of these regulations and policies are directly applicable, such as the FCC Part 15 regulations. Others, such as the guidelines of the power industry and the Utilities Telecommunications Council about the use of carrier frequencies, are not binding, but do require careful consideration for the purposes of system compatibility. Still others, such as the policies of A T & T may not be relevant today but may be of critical importance as the use of CAS proliferates.

4.1.1 Overview.

Many of the transmission techniques being considered as alternatives for the CAS system are such that their use is regulated by the FCC. This includes radio transmission by carrier along power lines, external transmission by radio or coaxial cable (CATV), etc. In an effort to understand the present regulations, and the policies likely assuming the widespread use of CAS, Compu-guard arranged a meeting with a team of experts in different functional areas from the FCC. This meeting was held at the FCC headquarters in Washington D.C. on the 1st of August, 1973.

4.1.2 Transmission from the Actuator.

It is likely that the technique used for RF transmission from the actuator will involve low power output at frequencies between 150 MHz and 450 MHz. The FCC regulations related to this kind of transmission are covered under Part 15 (Volume 2 FCC Rules and Regulations). Under Part 15, no specific licensing of each actuator would be necessary, However, from a systems standpoint, the FCC would need to be assured about the reliability of the actuator, its relationship to the public interest, and its compliance with the technical requirements covered under Part 15. The actuator would be defined by the FCC as a low-power communications device. Such a device may be operated in the frequency bands 10 to 490 KHz, 510 to 1600 KHz, 26.97 to 27.27 MHz, and over 70 MHz. The CAS system is covered specifically under Part 15.211 which relates to transmission from low power communication devices operating above 70 MHz. For devices such as the CAS actuator, the duration of each transmission should not be greater than one second and the silent period between transmissions should not be less than 30 seconds. The radiated field on any frequency above 1000 MHz should not exceed 500 microvolts per meter at a distance of 100 feet. The radiated field in any frequency above 70 MHz should not exceed the limitation specified in Table 4.1.

The devices should be packaged such that there are no external or readily accessible controls which may be altered to permit operations in a manner inconsistent with the provisions above.

4.1.3 RF Reception: Internal Receiver/Relay.

The receiver portion of the internal receiver/relay must also comply with FCC regulations. The field strength limitations necessary at a distance of 100 feet or more from the receiver are the same as those in Table 4.1.

4.1.4 Power-line Transmission at Carrier Frequencies.

The frequency of transmission signals along the power line in the CAS system is likely to be in the range of 100 to 500 KHz (carrier frequency). The FCC does impose certain limitations upon the strength of the field at a distance from the power line as this field may be a source of interference for other RF devices. For the frequency range between 10 and 490 KHz, this field strength should not exceed a value of $\frac{2400}{F(KHz)}$ at a distance of 1000 feet.

Table 4.1

FREQUENCY (F) (KHz)	DISTANCE (feet)	FIELD STRENGTH (micro V/m)
10-490	1,000	$\frac{2400}{F(KHz)}$
510-1600	100	$\frac{24000}{F(KHz)}$

For operations between 260 and 190 KHz, an alternative set of requirements may be applicable:

a. The power input to the final radio frequency stage should not exceed one watt.

b. All emissions below 160 KHz or above 190 KHz are suppressed 20 dB or more below the unmodulated carrier.

c. The total length of the transmission line and the antenna does not exceed 50 feet.

4.1.5 Special Telemetering Devices.

Since it is not yet known exactly how the CAS actuator will be classified and certified, it is also worth looking at the regulations that apply to other special-purpose, radio frequency, low-power communication devices (e.g., for biomedical telemetering). Such devices may be operated without the duty cycle limitations of 1 in 30 so long as they are in the frequency bank of 174 to 206 MHz. In such cases, the field strength of emission of the fundamental operating frequency should not exceel 150 microvolts per meter at 100 feet. The harmonic and other spurious emissions falling outside the band 174 to 206 MHz should be suppressed by at least 20 dB below the level of emission of the fundamental operating frequency. The receiver part of this biomedical telemetering device should be certified by the FCC.

A different set of standards applies to the radio control transmitters used in door openers. Though it is not yet known exactly what set of standards will apply to the CAS actuator, it is reasonable to expect that some of the presently defined standards will at least serve as guidelines in the certification of the actuator.

4.1.6 Special Class E Service.

The FCC has pending before it a notice of inquiry about the availability of a new class of citizens radio service called Class E service.

This service is likely to be offered at about 224 MHz and may prove to be appropriate for the transmission requirements of the CAS actuator. However, any FCC ruling on this issue is at least one year away. The notice of inquiry was introduced by the Electronic Industries Association.

4.1.7 RF Transmission from the External Receiver/Relay.

If RF transmission is to be considered as an alternative for the external receiver/relay, an operating license is likely to be necessary because of the high output power necessary for appropriate communications range. The FCC has a comprehensive set of regulations covering the operation of such devices. Though these regulations are too extensive to be discussed in this report, reference is made to Parts 89 and 91 of the FCC rules and regulations. The rules applicable depend on whether the external communications are base to base, mobile to mobile, or base to mobile.

Important note must be made of the fact that the FCC has in fact allocated 4 frequency bands around 950 MHz for primary use by the alarm industry. So far, the alarm industry (central stations, etc.) has not taken advantage of the availability of these channels. One of the reasons for this may be the high cost of communications equipment operating at this frequency. However, there is a possibility that the use of such channels may be of interest for external transmission of messages in CAS.

4.2 CABLE TV

4.2.1 Overview.

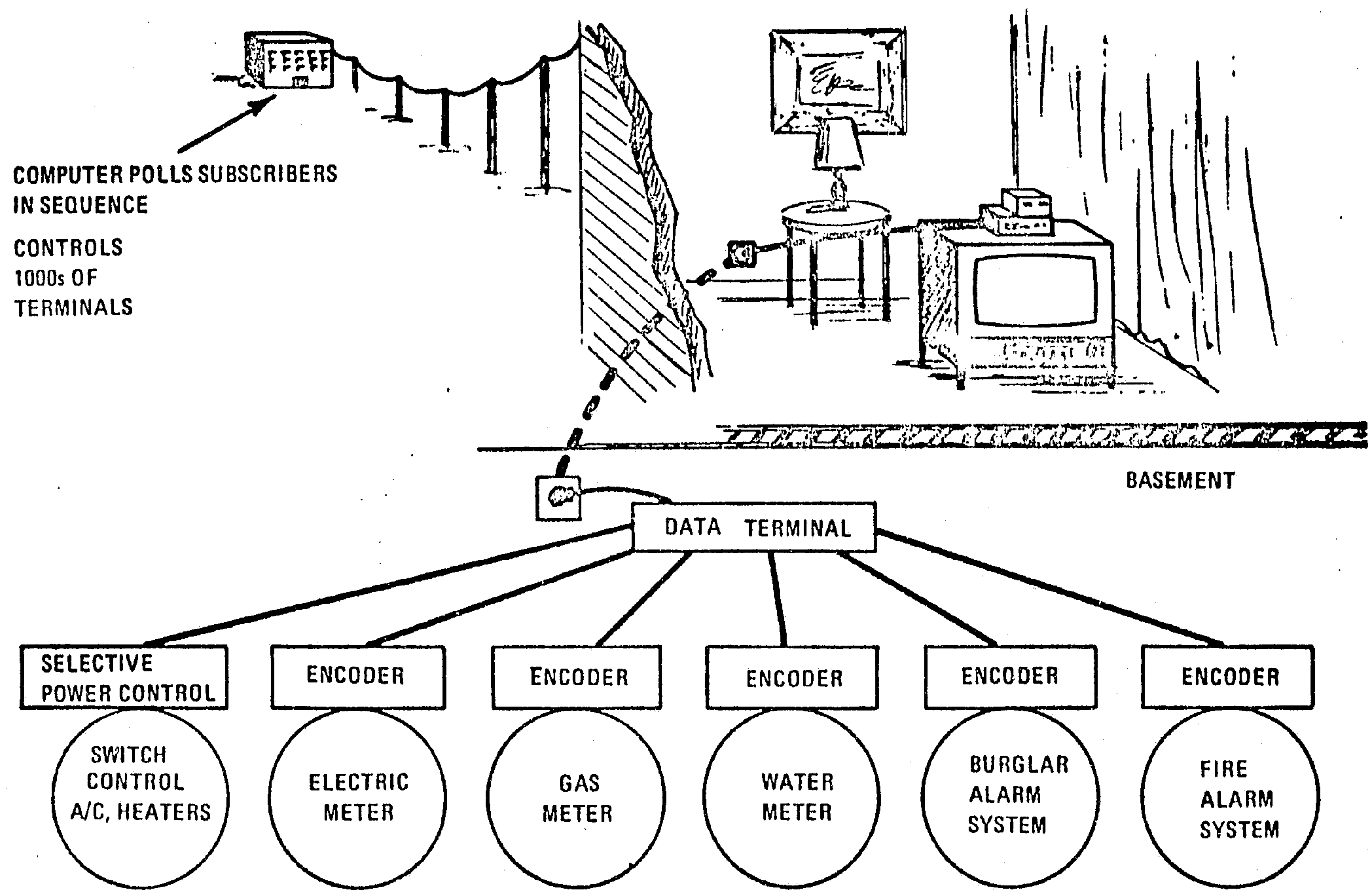
One of the alternative transmission media that may be used at the external receiver/relay and the central station is coaxial cable. Until March 1972, most of the cable TV systems installed had only a one-way transmission capability from the programming center to the subscriber. However, as a result of FCC regulations introduced then, all cabled systems built and installed since must have two-way transmission capability. With the two-way capability, it is possible to consider both the user and the response agent (e.g., police, ambulance service, etc.) as subscribers connected to the CATV Center. Alarm signals originating with the user are channeled through this center to the response agent.

An example of an applicable type two-way system based on publications issued by the National Cable Television Association is given in Figure 4.1. Before the 1972 FCC ruling on the use of CATV, there were a total of 3000 CATV systems, with only 10 percent in the top 100 TV markets. These television markets are almost exactly coincidental on a one-to-one basis with the top 100 metropolitan areas in the country. Thus, most of these systems were installed in rural scenarios. Since then, much higher percentages of all systems installed and planned will be located in these major metropolitan areas and will also have the required two-way communications capabilities. This makes CATV viable as an external communication alternative for CAS. Figure 4.2 gives a projection of the total number of new or proposed CATV systems that will be located in these top 100 areas. These figures suggest that a total population of almost 5.5 million people in these areas will be connected via CATV. Presently, CATV systems service a total of 5.3 million subscribers. By 1980 this figure is expected to increase to almost 30 million subscribers, representing half of all homes with televisions. Given this anticipated proliferation in the availability of CATV channels, the critical factors which will govern the use of such channels for CAS are the reliability and cost of the channels likely to be used on this application.

4.2.2 Class 3 and Class 4 CATV Channel Service.

Either a Class 3 or a Class 4 channel is applicable for communications use in CAS. Three types of telecommunication signals may be transmitted along these channels: image signals, audio signals, and data signals. The

Figure 4.1



TYPICAL TWO-WAY CABLE SYSTEM

M72-67

AUTOMATIC METER READING VIA CABLE

FRANK R. ELDRIDGE

PRESENTED TO
UTILITY TELECOMMUNICATIONS COUNCIL
ANNUAL MEETING
ANAHEIM, CALIFORNIA
JUNE 28, 1972

AUGUST 1972

THE MITRE CORPORATION
WASHINGTON OPERATIONS

Figure 4.2
TOP-100 MARKET SURVEY OF
NEW OR PROPOSED CATV SYSTEMS[1]

Of 128 new or proposed systems in the top 100 markets (as of 7/1/73) which have received our survey form requesting data on construction/operation dates and potential housing units/miles of plant, 74 (or 58%) have responded. Summary totals appear below:

* Category I--Operational Systems with Construction Completed

Systems	Communities Served	M.O.P.	Potential H.U.	Population
15	26	1,303	133,904	448,123

1 system began operation prior to 1972, 4 in early '72, 3 in late '72 and 7 in early '73. This category involved 15 top 100 markets.

* Category II--Operational Systems/Plant under Construction

Systems	Communities Served	M.O.P.	Potential H.U.	Population
30	58	6,358	706,719	2,296,511

3 systems began operation prior to 1972, 4 in early '72, 3 in late '72, 15 in early '73 and 4 in late '73. Construction is due to be completed on 10 systems in late '73, 4 in early '74, 2 in late '74 and 3 in '75. This category involved 28 top 100 markets

* Category III--Systems Under Construction

Systems	Communities Served	M.O.P.	Potential H.U.	Population
20	41	5,330	660,634	2,246,968

14 systems are scheduled to begin operation in late 1973, 4 in early '74 and one in late '74. Construction is due to be completed on 8 systems in late '73, 5 in early '74, 3 in late '74 and 3 in '75. This category involved 18 top 100 markets.

* Category IV--Systems Planned but not yet under Construction

Systems	Communities Served	M.O.P.	Potential H.U.	Population
9	10	1,177	103,830	446,961

8 systems are scheduled to begin construction in late 1973, 1 unknown. Construction is due to be completed on 1 system in late '73, 1 in early '74 and 4 in late '74. Operation is to begin for 2 systems in late '73 and 4 in early '74. This category involved 5 top 100 markets

[1]/Proposed new systems which have received Certificate of Compliance from the FCC since inception of the certificate requirement

distribution of the data signal for CAS purposes may be point to point (e.g., residential user to police) or multi-point to point (e.g., institutional user to emergency response agent). The signals would be transmitted in real time and the flow of data could be either unidirectional or bidirectional. The regulations covering the use of Class 3 and Class 4 channel services are covered under Section 76 of the FCC code.

Presently, subscribers pay an average of about $5.00 a month for CATV services. This figure is expected to rise to $15.00 per month for added services. Thus the marginal cost of providing a special communications channel for CAS is small only if the user already has a cable installed for other purposes. Otherwise, the communications cost would be excessive, relative to the cost targets established for CAS operation. Another factor which should be investigated in Phase II of this project is the cost of the interface between the CAS internal system and the cable termination hardware at the users end. Further information on the state-of-the-art in CATV and its effect on the development of CAS will be covered in a study of communications technology in Phase II.

4.3 POWER LINE COMMUNICATIONS

For external power-line communications, in addition to the FCC regulations (which are not hard to comply with), attention must also be given to the guidelines established by the power utility companies for signal transmission. Presently many utility companies do use carrier frequency signals on high voltage power lines. The primary function is usually protective relaying. Supplemental functions may include telemetering, such as the monitoring of demand meters, the switching of circuit breakers, and the reading of volt meters and megawatt meters. The frequencies normally used are generally between 30 to 300 KHz. Each channel modulated onto the carrier is usually a narrow-band channel with a band width of 1000 Hz or less.

In an effort to maximize the total number of communication channels on the total power system, the carrier frequencies are usually trapped on each line section within the system. Thus, the same frequencies may be used on different line sections.

While there are no regulations which prohibit the use of carrier signaling on external power lines for security communications, the present use of carriers for supervision and control limits the range of frequencies that may be used. Figures 4.2 and 4.3 indicate the carrier frequencies used by two different power systems on 765 kv lines for different applications. Additional applications that are likely in the future include automatic meter reading, distribution system monitoring, and the switching of power-factor equipment. Compu-guard is in close touch with the American Electric Power Company (one of the largest utilities in the United States), and with the Utilities Telecommunication Council. As soon as additional information is available on the frequency spectrum likely to be used by the power industry, arrangements may then be worked out to have communication channels available for the transmission of alarm signals. Regardless of the carrier frequencies used, it seems likely that narrow band transmission will be considered preferable. This will naturally limit the speed with which information bits can be transmitted down the line.

4.4 TELEPHONE LINE COMMUNICATION

Traditionally, the alarm industry has used telephone lines extensively in connecting alarm systems located in users premises to the central station. In most cases, the circuits used are not voice-grade lines but rather metallic 30 baud lines or the kind of party lines used by McCulloh circuits. As the use of these two kinds of lines has proliferated, telephone utilities have been faced with the problem of supplying these lines. The use of such lines is not only very poor from a cost-effectiveness standpoint and a reliability standpoint, but also the DC signals transmitted in a cable pair within a trunk may cause significant cross-talk and therefore interfere with neighboring cable pairs. Given these problems, the telephone utilities appear to be heading in a direction away from the use of metal lines and McCulloh lines and towards the use of voice grade telephone lines. For example, in some regions of the United States, the availability of direct lines is no longer assured, but rather the supply is on an "as available" basis. In other regions, central stations have been notified that the servicing of already-installed lines is subject to change with 90 day notice. As a third factor mitigating against the use of these lines, the rates for such lines are on the rise.

Based on this appreciation of the situation in the industry, Compuguard feels that the preferred approach is that of voice-grade telephone lines. Four different classes of voice-grade lines are available for the transmission of data. Class 1 channels are unconditioned and suitable for transmission speeds of up to 75 baud, but are not suitable for AC tone transmission. Class 2 channels, also not suitable for AC tones, allow up to 150 baud. Class 3 channels may be conditioned or unconditioned. Unconditioned lines allow AC signaling within a band width of 30 to 280 Hz. Conditioned lines allow an increase in this frequency range up to 3200 Hz and also provide improved performance on parameters such as delay distortion, etc.

Any interface equipment presently connected to voice grade telephone lines must use a Bell system coupler. Proposed rule changes by the FCC may make the use of such a coupler unnecessary in the future.

4.5 CONCLUSIONS

a) For the immediate future, the actuator will not need to be specifically licensed by the FCC. This implies that it must transmit at frequencies above 70 MHz, in compliance with Part 15 of the FCC regulations.

b) The actuator must meet FCC duty-cycle requirements of 1 in 30 i.e., each second of transmission to be followed by 30 seconds of silence. This implies that the coded identification message stored in the actuator must be transmitted repeatedly in less than one second.

c) At some point in the future, FCC approval may be desirable for the allocation of specific frequency bands for the use of CAS.

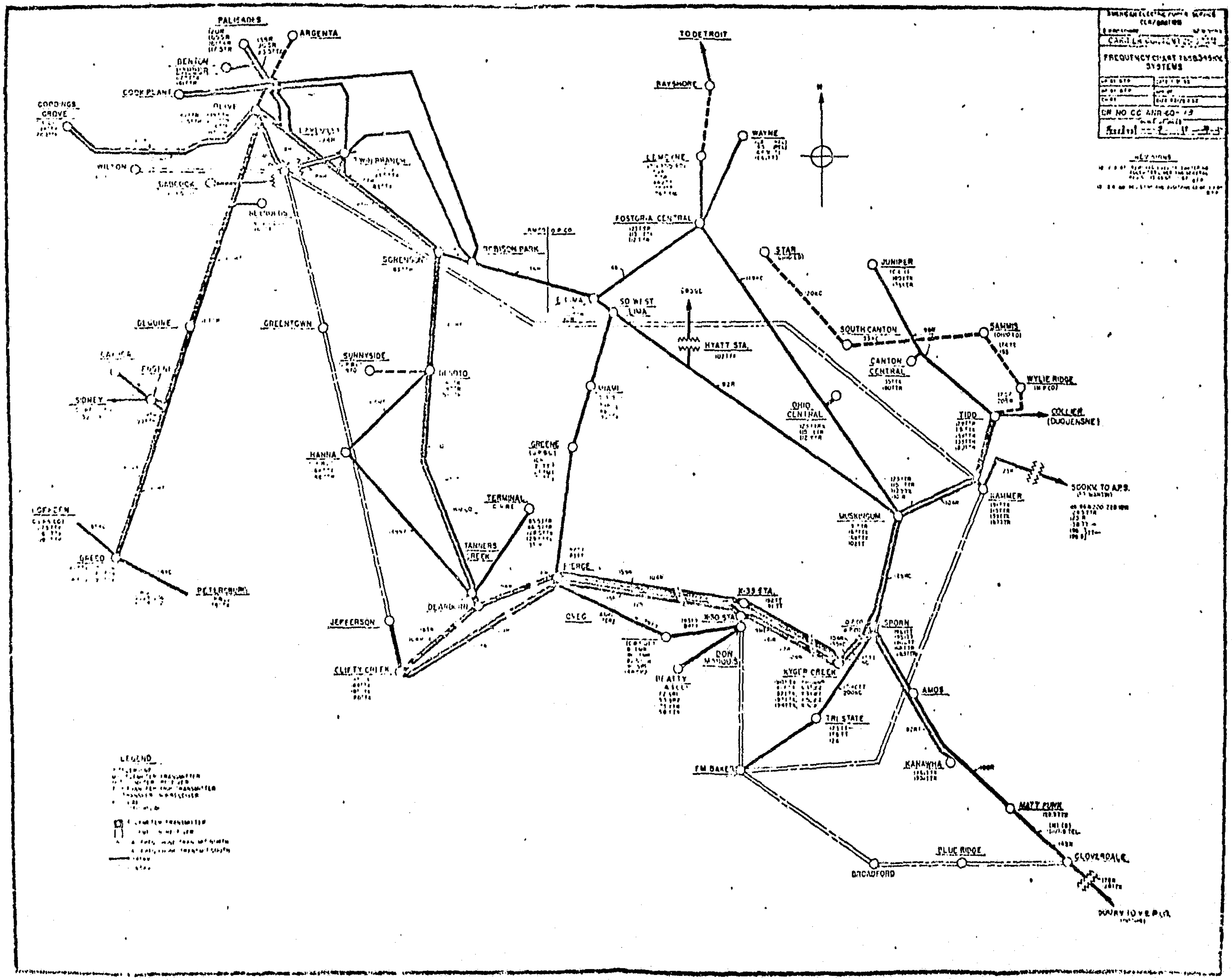
d) The use of carrier frequencies on internal power-lines is not likely to present any major problems with either the FCC or the utilities.

e) The use of external power lines for carrier transmission of CAS information is feasible, but the choice of frequencies needs to be worked out jointly with the Utilities Telecommunications Council.

f) The use of coaxial cable is presently limited to a very small fraction of all urban applications. This fraction is expected to increase rapidly in the next 10 years.

g) The use of coaxial cable for CAS will be cost-effective only if the user already uses the cable for TV or other purposes.

h) Based on the manner in which coaxial cables are generally laid and installed, they present an attractive alternative as a means for the external relaying of information for the outdoors use of a CAS-type system (e.g., street corners, parks, etc.).



FREQUENCY CHART 765&345KV SYSTEMS
N
PALISADES
ARGENTA
TO DETROIT
BAYSHORE
WAYNE
LEMOYNE
FOSTORIA CENTRAL
COOK PLANT
CODDINGS GROVE
OLIVE
TWIN BRANCH
WILTON
SORENSON
ROBISON PARK
E. LIMA
SO WEST LIMA
HYATT STA.
STAR
SOUTH CANTON
JUNIPER
SAMMIS
CANTON CENTRAL
WYLIE RIDGE
TIDD
COLLIER (DUQUESNE)
OHIO CENTRAL
DEQUINE
GREENTOWN
SUNNYSIDE
DESOTO
SIDNEY
MIAMI
GREENE
HANNA
TERMINAL
HAMMER
500KV TO A.P.S.
MUSKINGUM
TANNERS CREEK
PIERCE
BREED
PETERSBURG
JEFFERSON
DEARBORN
K-33 STA.
K-30 STA.
OVEC
SPORN
CLIFTY CREEK
DON MARQUIS
BEATTY
KYGER CREEK
AMOS
TRI STATE
KANAWHA
MATT FUNK
BROADFORD
BLUE RIDGE
CLOVERDALE
LEGEND

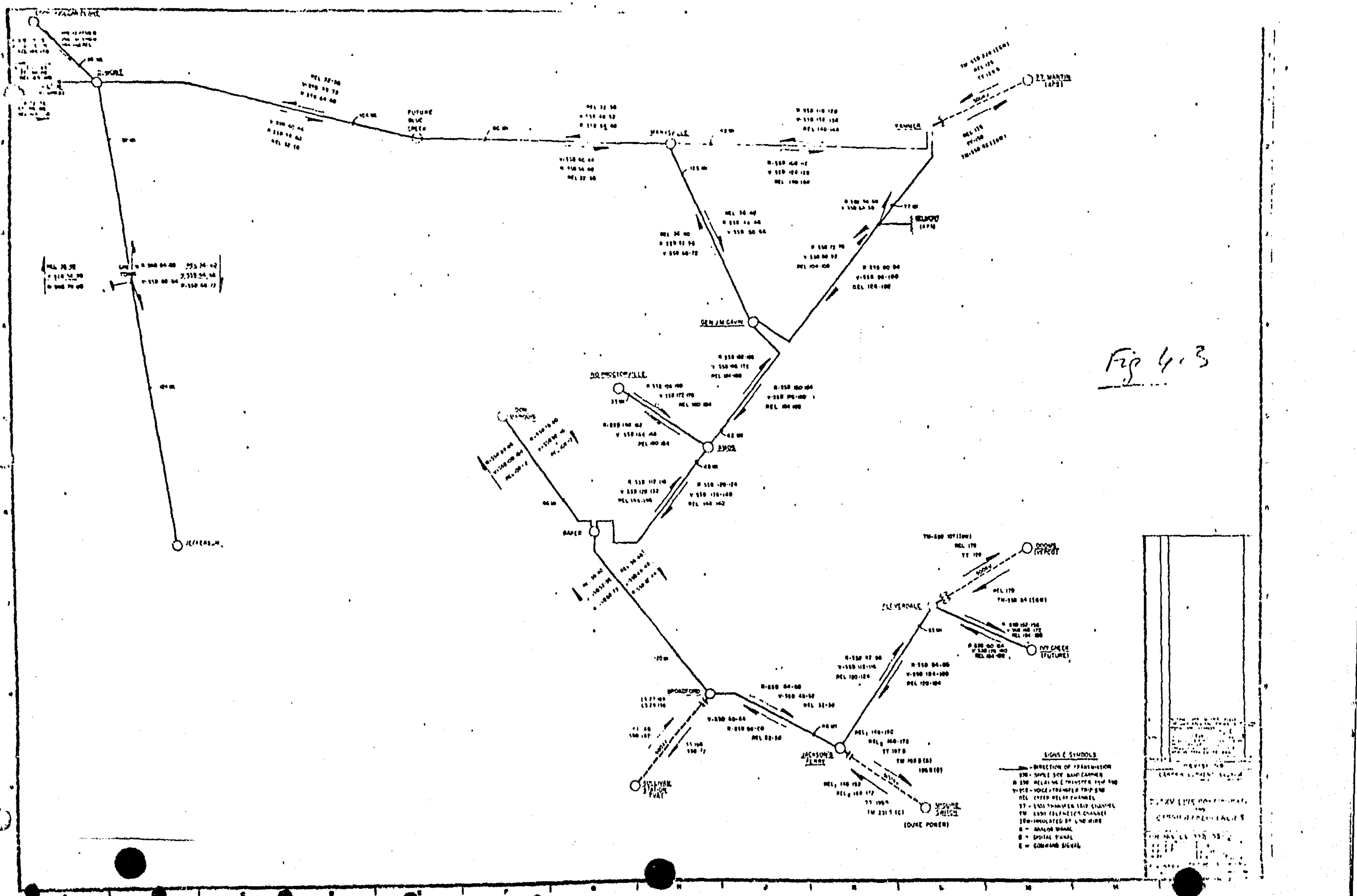


Fig 4.3

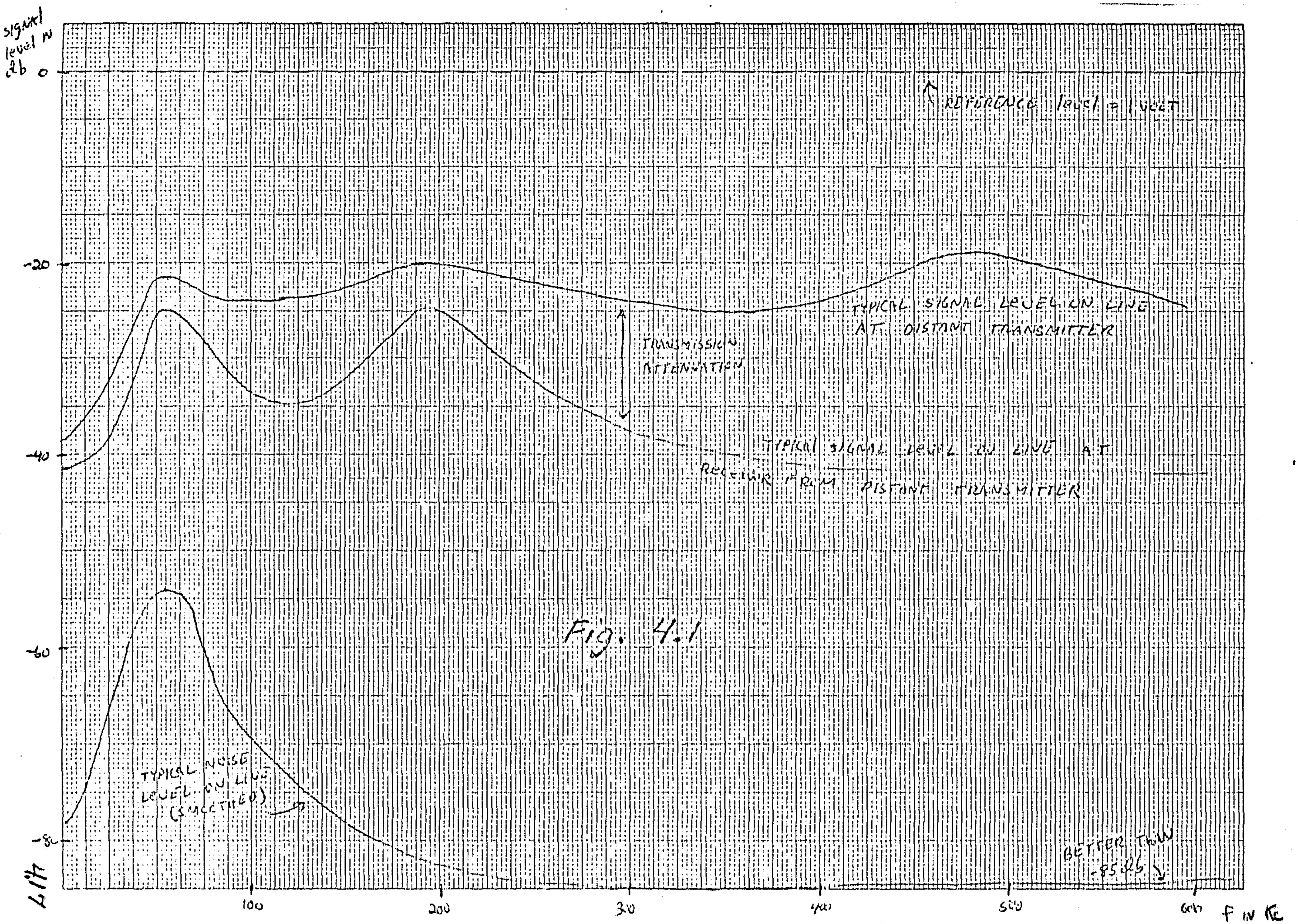

signal level in db
0
-20
-40
-60
-80
REFERENCE level = 1 VOLT
TYPICAL SIGNAL LEVEL ON LINE AT DISTANT TRANSMITTER
TRANSMISSION ATTENUATION
TYPICAL SIGNAL LEVEL ON LINE AT RECEIVER FROM DISTANT TRANSMITTER
TYPICAL NOISE LEVEL ON LINE (SMOOTHED)
BETTER THAN -85db
100
200
300
400
500
600
f in Kc

Fig. 4.1

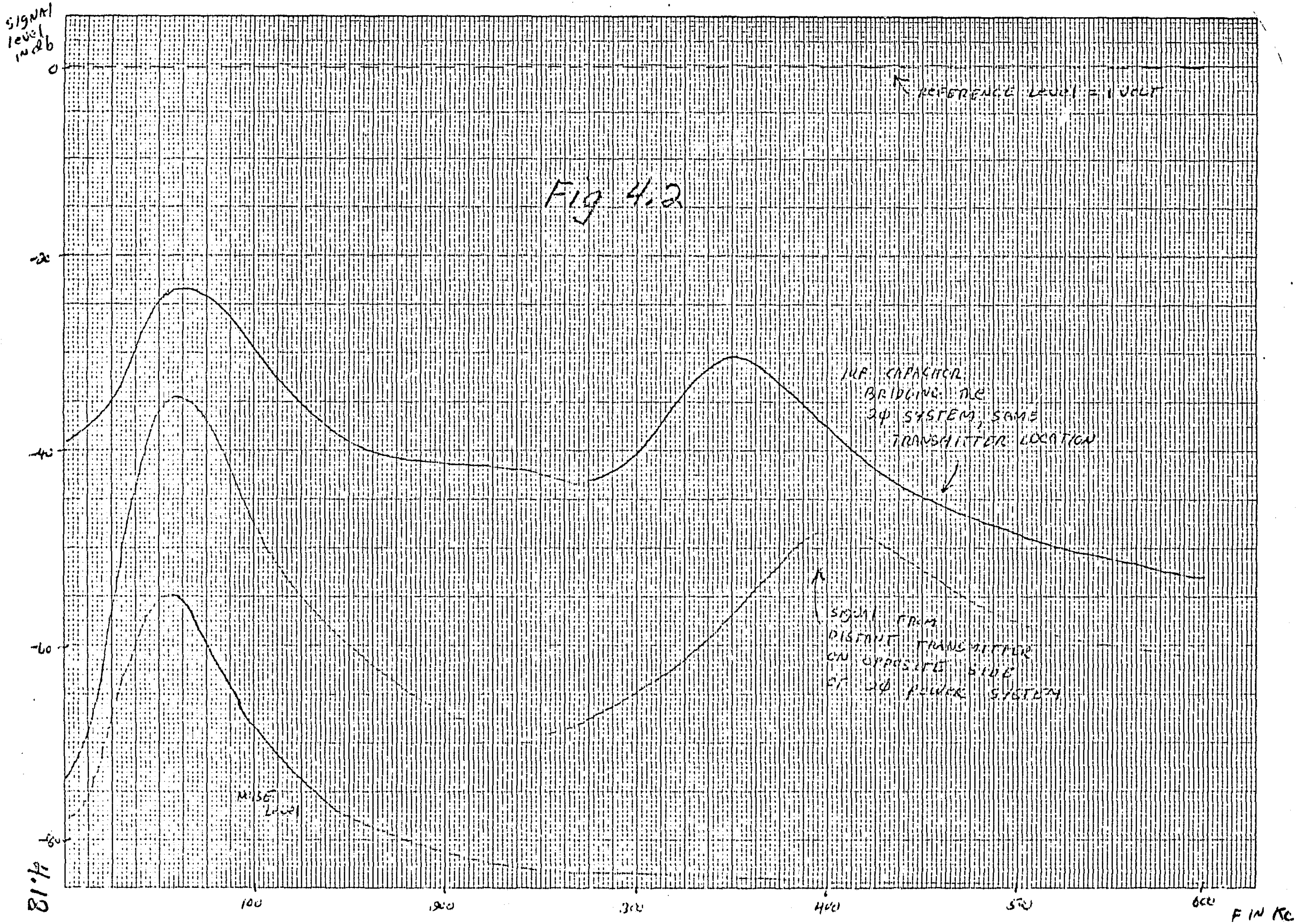

SIGNAL level IN db
0
-2
-40
-60
-80
100
200
300
400
500
600
F IN KC
REFERENCE LEVEL = 1 VOLT
1µF CAPACITOR BRIDGING THE 3φ SYSTEM, SAME TRANSMITTER LOCATION
SIGNAL FROM DISTANT TRANSMITTER ON OPPOSITE SIDE OF 3φ POWER SYSTEM
NOISE Level

Fig 4.2

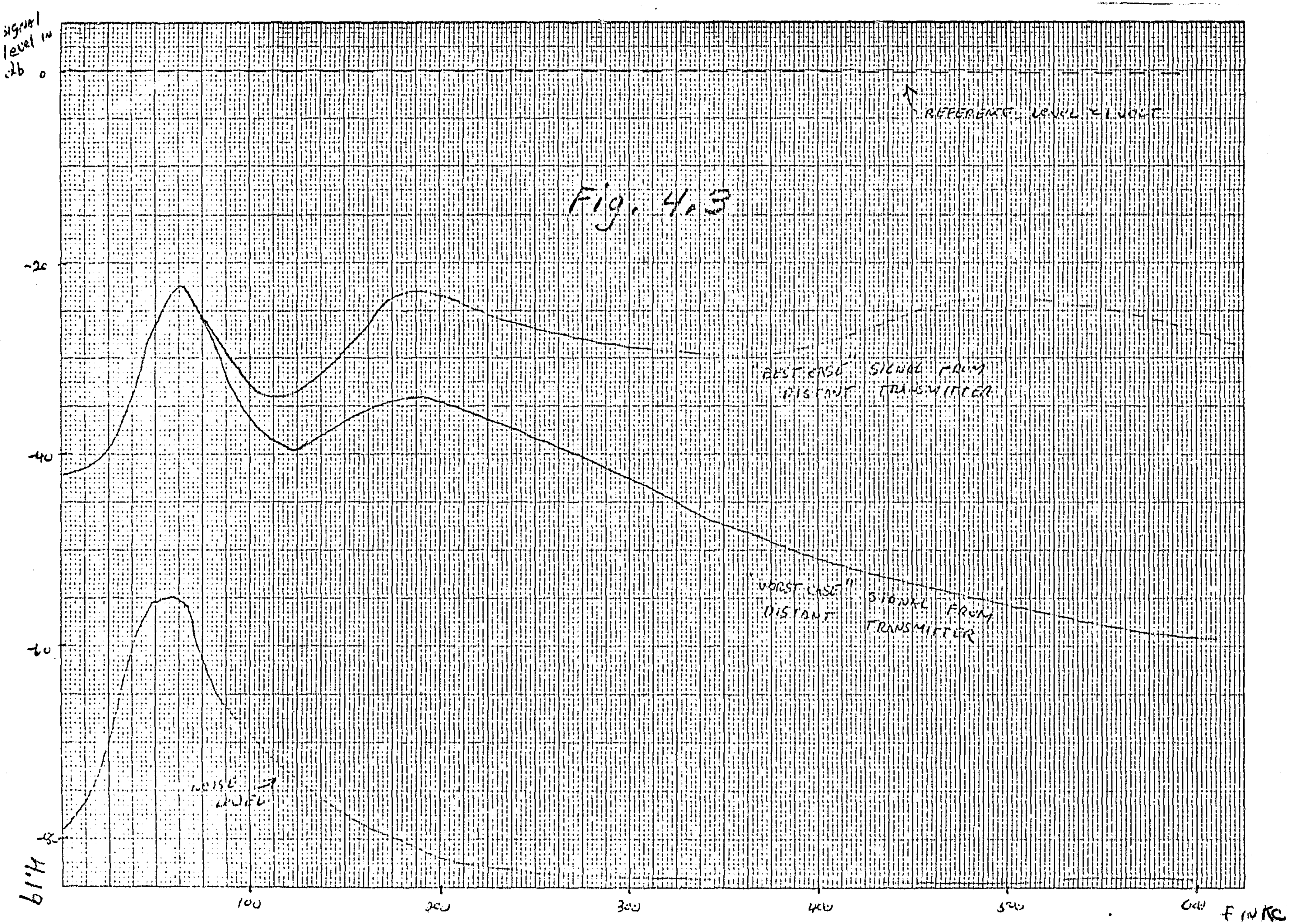

signal level in db
0
-20
-40
-60
-80
REFERENCE LEVEL = 1 VOLT
Fig. 4.3
"BEST CASE" SIGNAL FROM DISTANT TRANSMITTER
"WORST CASE" SIGNAL FROM DISTANT TRANSMITTER
NOISE LEVEL
100
200
300
400
500
600
F IN KC

Fig. 4.19

CONTINUED

1 OF 5

SECTION 5

SPECIAL POLICY CONSIDERATIONS

5.1 LEGAL ISSUES RELATIVE TO CAS USAGE

To understand more fully the questions concerning the legal liability of installers or monitors of CAS-type alarm signals, the existing central-station industry may be considered as a model.

Historically, there has been a conflict between the alarm industry on the one hand, trying to keep cost down, and the user on the other hand feeling the alarm companies have liability for losses incurred due to failure of the alarm service. This conflict has been resolved to a large degree in the following manner:

1) The insurance companies recognize monitored alarm systems through the granting of premium discounts of 20 to 70% depending on the type of service. This in itself is recognition of the fact that alarm service is not perfect since obviously the premiums would be zero, if the service were perfect.

2) The alarm companies have kept their service rates low by specifically stating that they are not insurers and are not liable for failure in service. This approach is now discussed further.

In some early court decisions where alarm companies had used a disclaimer clause, the courts either rules against the alarm companies, or found them partially liable. Because of this, the disclaimer clause was embellished with a further statement limiting the liability to some specific dollar figure; usually an amount equal to approximately 6 months of service under a lease-maintenance contract. Later, still another clause was added, which while affirming the fact that the alarm company was not an insurer, offered an option to the user to purchase liability coverage. Finally, because of some of the court's rulings concerning "fine print clauses," the industry either printed their exculpatory clause in bold type, or made specific reference to it near the client's signature.

We see then the evolution of the exculpatory clause which is used fairly generally throughout the alarm industry. The pertinent paragraphs are marked on the attached sample, Figure 5.1.

It is concluded that in order to keep costs to the average citizen to a minimum, the system installer, and the response or monitoring agent must be free of liability claims. Here it is worth noting the value of an accreditation and leasing agency; such as, Underwriters' Laboratories, Inc. While it is possible for inept installers to get into the business, it is difficult for them to become accredited, and even more difficult for them to stay in business if they are not performing on a generally satisfactory basis.

In conclusion, it is felt that the installers and monitoring agents for CAS should use the existing alarm company's approach to liability, and that the application of a viable accreditation and policing agency be invoked.

5.2 CRITERIA FOR CAS CERTIFICATION BY UNDERWRITERS LABORATORIES, INC.

5.2.1 Overview.

CAS is a system which will be used by a wide variety of people in a wide range of physical environments. One of the major factors in the acceptance of the system by the general public may lie in the perceived credibility of the system. Credibility here is used as a catch-all term to include all issues related to the sale, installation, servicing and monitoring of the system. Included also are the issues of liability in case of system failure. While Section 5.1 above has generally covered the legal issues, it is reasonable to expect that the accreditation of the system by a nationally known organization may contribute much to the accpetance of the system. Presently, Underwriters Laboratories, Inc. is the best known organization

Fig 5.1

for the accreditation of burglar-alarm systems. The value of their approval of a particular central station and a particular field system is reflected clearly in such things as reduced insurance premiums to users, greater likelihood of adequate system performance, etc. Given that Underwriters Laboratories has become a major and respected burglar-alarm accrediting agency, it becomes necessary to consider the value of getting CAS similarly certified. This would involve a clear understanding of Underwriters Laboratories requirements and procedures, so that appropriate parameters may be taken into account in CAS hardware and software design. With this in mind, Compu-guard arranged a meeting with the Underwriters Laboratories staff, at their headquarters in Northbrook, Illinois.

5.2.2 Underwriters Laboratories Accreditation Rationale.

The Underwriters Laboratories, Inc. has a special unit which deals with burglary protection devices and systems. This group has developed comprehensive standards in a variety of areas related primarily to property protection and to some extent in hold-up situations. These include the following standards:

U.L. 636: Hold-up alarm units and systems.

U.L. 609: Local burglary alarm units and systems.

U.L. 611: Central station burglary alarm units and systems.

U.L. 1023: Household burglary alarm system units.

U.L. 985: Household fire warning system units.

U.L. 864: Control units for fire-protective signaling systems.

U.L. has not developed any specific standards for systems similar to CAS. However, many of the standards that have been developed and reported in the above publications are applicable in the sense that they would be a guideline used by the U.L. staff in determining the possibility of accreditation of CAS. The U.L. staff was given a comprehensive description of the CAS system, including the technology and the components likely to be used, and the signaling techniques that are being considered as alternatives. Following this, a number of individual points relative to U.L. approval of CAS were considered.

1) U.L. did not see any major problem in the use of carrier currents over power lines.

2) It was suggested that any electrical, non-electronic components used in the receiver/relays (such as power cords, plugs, etc.) should be of a type already approved by U.L. It was suggested that if a power cord were to be used in connecting the internal or the external receiver/relay to the power line, a SP2 cord or SPT2 cord could be used.

3) U.L. requires that the total communication time between the triggering of the system and the receipt of the emergency message at the central station should not exceed 90 seconds. Since the expected response time of the alarm message from the CAS actuator to the CAS central station is likely to be of the order of 10 seconds, this suggests that the CAS total signaling time is almost an order of magnitude below the U.L. requirements.

4) The actuator which will send an RF signal to the internal receiver/relay is not likely to be supervised in the CAS system. Discussion on this point suggests that U.L. may not be critical about the supervision requirements of the actuator so long as the reliability of transmission between the actuator and receiver/relay can be successfully established.

5) Relative to power line communications, U.L. needs to be assured that there is no possibility of a power voltage appearing on the case or any other component such as to create a hazard or cause device failure or power-line short-circuit.

6) Any printed circuit board used within the system should be at least 1/16 of an inch thick and should withstand a dielectric test of 1240 volts.

7) At the external receiver/relay, any connections to the power line or to the telephone line should be such as to resist attack. Both the internal and external receiver/relays should be able to transmit messages through even when under attack and should resist attack for about one minute.

8) If an audible alarm is used at the external receiver/relay, it should be mounted in protective housing that resists attack for about two minutes. Also, the audible alarm must be clearly distinguishable from other sounds likely to be encountered in the physical environment. It was suggested that different types of audible sounds be used to annunciate the existence of different kinds of emergency situations. The audible alarm should have an acoustic intensity of at least 85 dB at 10 feet.

9) U.L. Has put out public listings of components which have been recognized as acceptable. These include relays, printed circuits, material for packages (e.g., plastics, sheet metal), etc. To the extent possible, these recognized components should be used in the assembly of CAS devices. For example, if plastics are used, the SE0 grade is acceptable. Many components which are not listed by U.L., such as integrated circuits, batteries, etc., should meet minimum standards of performance for acceptability.

10) If the power lines within a building are electrically distributed through more than one phase, then for proper carrier signaling through power lines it is necessary to connect these phases through high-pass filter circuits (e.g., a capacitive shunt). This provides electrical isolation of the different phases at power frequency (60Hz) but continuity of the signaling circuit (e.g., 100 KHz and over). U.L. is concerned about the filter circuit

and would like to be assured that the use of such circuits would not cause a short circuit across the power line.

11) In terms of the transmission link between the external receiver/relay and the central station, U.L. would approve any supervised link. This would include supervision along dedicated voice-grade telephone lines, coaxial cable, hard-wire, etc. However, the use of the regular switched telephone network (which is the lowest cost technique for homes and some buildings) would be acceptable only if the user/s system could be supervised adequately.

12) U.L. would be interested in insuring that radio frequency used by the CAS actuator would not cause interference with signals transmitted by RF components in existing burglar-alarm systems and devices.

13) U.L. would also like for the carrier frequencies used on power lines by the internal receiver/relay to be spaced sufficiently distantly from the frequencies used by intercom systems which also use the power lines as a communications link.

Based on this evaluation of requirements, Compu-guard feels that the various components of the CAS system could be designed to meet U.L. standards without any major changes in concept, kind of technology used, or packaging. Systems approval by the Underwriters Laboratores is likely to have a beneficial impact on its acceptability by the public.

5.3 ALARM ORDINANCES

As a result of the rapid increase in the use of alarm and signaling devices by the public for security protection, there has been some concern about the problems caused to the public safety organizations such as the police. Lacking any effective regulation pertaining to the quality of hardware, installation service, or monitoring service, the police have found themselves impotent to deal with the problems of false alarms and the abuse of security systems. As a result, many cities have attempted to cope with the problem by passing ordinances limiting the use of alarm systems. Presently these ordinances apply only to digital dialers and burglar alarm systems, but more comprehensive ordinances are expected in the near future. Their relevance to CAS is very clear.

The CAS concept seems to be appealing to police departments; this much is clear from the meetings held by Compu-guard with police officials in many cities. However, unless adequate safeguards are built into system design, the abuse of CAS could lead to a situation in which the police and the city would be pushed into limiting CAS usage. It is therefore useful to examine existing and proposed ordinances as a means of preventing such problems as may relate to CAS. Ordinances from five cities, model legislation proposed by the Rand Corporation for the installation and use of burglar alarm systems, and a very comprehensive model "police alarms" ordinance proposed by the International Association of the Chiefs of Police have all been examined and considered for their relevance to CAS design and operation.

5.4 CONCLUSIONS

a) The legal issues related to the use of CAS do not appear to pose a major problem. The approach suggested for consideration is that presently used by central station operations with users of burglar alarm and hold-up systems.

b) Preliminary indications are that a CAS system, with appropriate design modifications, may be acceptable to Underwriters Laboratories, Inc. for accreditation purposes. Such an accreditation may be desirable to enhance the acceptability of the system by the lay public.

c) The impact of ordinances being introduced in several cities relative to the restricted use of burglar alarm systems has been examined for relevance to CAS. No major conclusions will be possible until a large-scale field test of the CAS system has been conducted. Such a test will be necessary to establish the credibility of CAS with municipalities, police departments, etc.

SECTION 5

ANALYSIS OF REGULATIONS AND POLICIES

5.1 Introduction

Prior to the final design of the CAS hardware and software, it is important to consider the regulatory framework within which CAS must operate. Some of these regulations and policies are directly applicable, such as the FCC Part 15 regulations. Others, such as the guidelines of the power industry and the Utilities Telecommunications Council about the use of carrier frequencies, are not binding, but do require careful consideration for purposes of compatibility. Yet others, such as the policies of AT&T may not be relevant today but may be of critical importance as the use of CAS proliferates.

5.1.1 Overview

Many of the transmission techniques being considered as alternatives for the CAS system are such that their use is regulated by the FCC. This includes radio transmission from the carrier along power lines, external transmission by radio or coaxial cable (CATV), etc. In an effort to understand the present regulations, and the policies likely assuming the widespread use of CAS, Compu-guard arranged a meeting with the team of experts in different functional areas from the FCC. This meeting was held at the FCC headquarters in Washington D.C. on the 1st of August, 1973 and was chaired by Mr. Garlan, Chief of the RF Devices Branch of the FCC. Also representing the FCC at that meeting were Mr. Murray (RF Devices Branches), Mr. Turner and Mr. Brumbaugh (Safety and Special Radio Services Branch), and Mr. Monroe (CSTV Bureau) the impace of FCC regulations and policies on development of CAS is now presented.

5.1.2 Transmission from the Actuator

It is likely that the technique used for RF transmission from the actuator will involve low power output at frequencies between 150 MHz and 450 MHz. The FCC regulations related to this kind of transmission are covered under part 15 (Volume 2 FCC Rules and Regulations). Under part 15, no specific licensing of each actuator would be necessary, however, from a systems standpoint, the FCC would need to be assured about the reliability assurance of the actuator, its relationship to the public interest and its compliance with the technical requirements covered under part 15. The actuator would be defined under section 15 as a low power communications device. Such a device may be operated in the bands 10 to 490 KHz, 510 to 1600 KHz, 26.97 to 27.27 MHz, and over 70 MHz. The CAS system is covered under part 15.211 which relates to transmission from low power communication devices operating above 70 MHz. For devices such as the CAS actuator, the duration of each transmission should not be greater than one second and the silent period between transmissions should not be less than 30 seconds. The radiated field on any frequency above 1000 MHz should not exceed 500 microvolts per meter at a distance of 100 feet. The radiated field in any frequency above 70 MHz should not exceed the limitation specified in Table 5.1.

The devices should be packaged such that there are no external or readily accessible controls which may be attached to permit operations in a manner consistent with the provisions above.

5.1.3 RF Reception: Internal Receiver/Relay

The receiver portion of the internal receiver/relay must aslo comply with FCC regulations. The field strength limitations necessary at a distance of 100 feet or more from the receiver are the same as those in Table 5.1.

5.1.4 Power-line Transmission at Carrier Frequencies

The frequency of transmission of signals along the power line in the CAS system is likely to be in the range of 100 to 500 KHz (carrier frequency). The FCC does impose certain limitations upon the strength of the field at a distance from the power line as this field may be a source of interference for other RF devices. For the frequency range between 10 and 490 KHz, this field strength should not exceed a value of $\frac{2400}{F(KHz)}$ at a distance of 1000 feet.

For operations between 160 and 190 KHz, an alternative set of requirements may be applicable:

a. The power input to the final radio frequency station should not exceed one watt.

b. All emissions below 160 KHz or above 190 KHz are suppressed 20 dB or more below the unmodulated carrier.

c. The total length of the transmission line and the antenna does not exceed 50 feet.

5.1.5. Special Telemetering Devices

Since it is not yet known exactly how the CAS actuator will be classified and certified, it is also worth looking at the regulations that apply to other special purpose, radio frequency, low-power communication devices (e.g., for biomedical telemetering). Such devices may be operated without the duty cycle limitations of 1 in 30 so long as they are in the frequency band of 174 to 206 MHz. In such cases, the field strength of emission of the fundamental operating frequency should not exceed 150 microvolts per meter at 100 feet. The harmonic and other spurious emission falling outside the band 174 to 216 HMz should be suppressed by at least 20 dB below the level of emission of the fundamental operating frequency. The receiver part of this biomedical telemetering device should be certified by the FCC.

A different set of standards applies to the radio control transmitters used in door openers. Though it is not yet known exactly what set of standards will apply to the CAS actuator, it is reasonable to expect that some of the presently defined standards will at least serve as guidelines in the certification of the actuator.

5.1.6 Special Class E Service

The FCC has pending before it a notice of inquiry about the availability of a new class of citizens radio service called Class E service. This service is likely to be offered at about 224 MHz and may prove to be appropriate for the transmission requirement of the CAS actuator. However, any FCC ruling on this issue is at least on year away. The notice of inquiry was introduced by the Electronic Industries Association.

5.1.7 RF Transmission from the External Receiver/Relay

If RF transmission is to be considered as an alternative for the external receiver/relay, an operating license is likely to be necessary because of the high output power necessary for appropriate communication range. The FCC has a comprehensive set of regulations covering the operation of such devices. Though these regulations are too extensive to be discussed in this report, reference is made to Parts 89 and 91 of the FCC rules and regulations. the rules applicable depend on whether the external communications are base to base, mobile to mobile, or base to mobile.

Important note must be made of the fact that the FCC has in fact allocated 4 frequency bands around 950 MHz for primary use by the alarm industry. So far, the alarm industry (central stations, etc.) has not taken advantage of the availability of these channels. One of the reasons for this may be the high cost of communications equipment operating at this frequency. However, there is a possibility that the use of such channels may be of interest for external transmission of messages in CAS.

5.2 Cable TV

5.2.1 Overview

One of the alternative transmission media that may be used at the external receiver/relay and the central station is coaxial cable. 1 Until March 1972, most of the cable TV systems installed had only a one-way transmission capability from the programming center to the subscriber. However, as a result of FCC regulations introduced then, all cabled systems built and installed since must have two-way transmission capability. With the two-way capability, it is possible to consider both the user and the response agent (e.g., police, ambulance service, etc.) as subscribers connected to the CATV Center. Alarm signals originally with the user are channeled through this center to the response agent.

An example of an applicable type two-way system based on publications issued by the National Cable Television Association is given in Figure 5.1. Before the 1972 FCC ruling on the use of CATV, there were a total of 3000 CATV systems, with only 10% in the top 100 TV markets. These television markets are almost exactly coincidental on a one-to-one basis with the top 100 metropolitan areas in the country. Thus, most of these systems were installed in rural scenarios. Since then, much higher percentages of all systems installed and planned will be located in these major metropolitan areas and will also have the required two-way communications capabilities. This makes CATV viable as an exterior communication alternative for CAS. Figure 5.2 gives a projection of the total number of new or proposed CATV systems that will be located in these top 100 areas. These figures suggest that a total population of almost 5.5 million people in these areas will be connected via CATV. Presently, CATV systems service a total of 5.3 million subscribers. By 1980 this figure is expected to increase to almost 30 million subscribers, representing half of all homes with televisions. Given this anticipated proliferation in the availability of CATV channels, the critical factors which will govern the use of such channels for CAS are the reliability and cost of the channels likely to be used on this application.

5.2.2 Class 3 and Class 4 CATV Channel Service

Either a Class 3 or a Class 4 channel is applicable for communcations use in CAS. Three types of telecommunication signals may be transmitted along these channels: image signals, audio signals, and data signals. The distribution of the data signal for CAS purposes may be point to point (e.g., residential user to police) or multi-point to point (e.g., institutional user to emergency response agent). The signals would be transmitted in real time and the flow of data could be either unidirectional or bidirectional. The regulations covering the use of Class 3 and would like to be assured that the use of such circuits would not cause a short circuit across the power line.

11) In terms of the transmission link between the external receiver/relay and the central station, U.L. would approve any supervised link. This would include supervision along dedicated voice-grade telephone lines, coaxial cable, hard-wire, etc. However, the use of the regular switched telephone network (which is the lowest cost technique for homes and some buildings) would be acceptable only if the user/s system could be supervised adequately.

12) U.L. would be interested in insuring that radio frequency used by the CAS actuator would not cause interference with signals transmitted by RF components in existing burglar-alarm systems and devices.

13) U.L. would also like for the carrier frequencies used on power lines by the internal receiver/relay to be spaced sufficiently distantly from the frequencies used by intercom systems which also use the power lines as a communications link.

Based on this evaluation of requirements, Compu-guard feels that the various components of the CAS system could be designed to meet U.L. standards without any major changes in concept, kind of technology used, or packaging. Systems approval by the Underwriters Laboratores is likely to have a beneficial impact on its acceptability by the public.

5.3 ALARM ORDINANCES

As a result of the rapid increase in the use of alarm and signaling devices by the public for security protection, there has been some concern about the problems caused to the public safety organizations such as the police. Lacking any effective regulation pertaining to the quality of hardware, installation service, or monitoring service, the police have found themselves impotent to deal with the problems of false alarms and the abuse of security systems. As a result, many cities have attempted to cope with the problem by passing ordinances limiting the use of alarm systems. Presently these ordinances apply only to digital dialers and burglar alarm systems, but more comprehensive ordinances are expected in the near future. Their relevance to CAS is very clear.

The CAS concept seems to be appealing to police departments; this much is clear from the meetings held by Compu-guard with police officials in many cities. However, unless adequate safeguards are built into system design, the abuse of CAS could lead to a situation in which the police and the city would be pushed into limiting CAS usage. It is therefore useful to examine existing and proposed ordinances as a means of preventing such problems as may relate to CAS. Ordinances from five cities, model legislation proposed by the Rand Corporation for the installation and use of burglar alarm systems, and a very comprehensive model "police alarms" ordinance proposed by the International Association of the Chiefs of Police have all been examined and considered for their relevance to CAS design and operation.

5.4 CONCLUSIONS

a) The legal issues related to the use of CAS do not appear to pose a major problem. The approach suggested for consideration is that presently used by central station operations with users of burglar alarm and hold-up systems.

b) Preliminary indications are that a CAS system, with appropriate design modifications, may be acceptable to Underwriters Laboratories, Inc. for accreditation purposes. Such an accreditation may be desirable to enhance the acceptability of the system by the lay public.

c) The impact of ordinances being introduced in several cities relative to the restricted use of burglar alarm systems has been examined for relevance to CAS. No major conclusions will be possible until a and Class 4 channel services are covered under section 76 of the FCC code.

Presently, subscribers pay an average of about $5.00 a month for CATV services. This figure is expected to rise to $15.00 per month for added services. Thus the marginal cost of providing a special communications channel for CAS is small only if the user already has a cable installed for other purposes. Otherwise, the communications cost would be excessive, relative to the cost targets established for CAS operation. Another factor which should be investigated in Phase 2 of this project is the cost of the interface between the CAS internal system and the cable termination hardware at the users end. Further information on the state-of-the-art in CATV and its effect on the development of CAS is covered in the section on communications technology.

SECTION 6

THE PHYSICAL ENVIRONMENT AND THE NEED FOR CAS

6.1 INTRODUCTION

In the normal course of a typical day, the average urban resident spends between 50 and 70 percent of the total period within a structure of some type, be it a house, office, factory or institution.[1] The quality of life, a subjective measure at best, can be reasonably said to vary widely across the United States. If "quality of life" is defined by economic factors, and housing stock data, without the inclusion of other more empirical sociological measurements, a direct and negative correlation seems to exist between it and the rate of crime. As centers of poverty, unemployment, and to some extent high density[2] are spread across the urban environment, so too are the incidents of criminal and illegal activity, generally with the same epicenters.

Recently, research has been undertaken by Peek, Newman, Proshansky, Jacobs and others in order that the effects of architecture, urban design, and the juxtaposition of one upon the other upon the existing fabric of human activity within the city could be more clearly assessed. While this work is still in its infantile stages, it appears that building and urban morphology do indeed play a part in a person's perception of himself, and in the perception of the individual by others. The work of Newman in this regard is germane: "Architectural design can make evident by the physical that an area is the shared extension of the private realms of a group of individuals. . . Design can make it possible for both inhabitant and stranger to perceive

1 United States Census 1970, Department of Commerce, United State Government Printing Office, Washington, D.C., a compilation of data by the author.

2 Sociologists have yet to show that there are intrinsic problems with high densities, the reverse is however also true. The economics of land and construction often dictate that high density buildings replace time-worn lower density buildings in a given urban area. Lacking more concrete sociological data than has hithertofore been gathered, economic factors are generally controlling.

that an area is under the influence of a particular, that they dictate the activity taking place within it, and who the users are to be. This can be made so clearly evident that residents will not only feel confident, but that it is incumbent upon them to question the comings and goings of people to ensure the continued safety of the defined areas. Any intruder will be made to anticipate that his presence will be under question, and open to challenge; so much so that a criminal can be deterred from even contemplating entry."[3]

Few new residential buildings are built to the above criteria. Those which have been built with those spatial concepts in mind are quite successful in fostering a community which provides a sense of mutual protection; examples which came readily to mind are Chatham Village in Pittsburgh, and Radburn in New Jersey. While the final data is not yet in, Columbia, Maryland and Reston, Virginia seem to be successful in this and other respects.

Unfortunately, monetary restraints, zoning and building codes, and a popular lack of empathy with the problem do not allow for wholesale changes in those buildings which do not conform with man's territorial requirements.

Of the small amount of research contemplating the interface between man, his structures, and his society, the vast majority has been empirical and centered upon residential use. "No one has ever deliberately designed buildings or urban areas to foster crime and induce fear. Yet, in a number of respects, the architecture of American cities does both. The design of housing in this country, Ada Louise Huxtable has written, has demonstrably increased tendencies toward crime, violence, and social isolation, at a social and monetary cost that is insupportable."[4]

---

3 Defensible Space, Oscar Newman, The Macmillan Co., New York, N.Y., 1972, pp 2-3.

4 Residential Security, Security Planning Corp., National Institute of Law Enforcement and Criminal Justice, LEAA, United States Government Printing Office, Washington, D.C., April 1973, pp 90-91.

This attitude is beginning to show signs of change as planners and design professionals become more aware of the probable social ramifications of a given building type. However, the social sciences have yet to reach the stage where the benefits to the individual or to society of a particular geometric configuration in a living, working, or institutional environment can be well enough calculated to offset the additional cost of providing a given design. As many times happens, the municipality, the corporation, and the entrepreneur pass off such design initiatives as capricious and will not pay the extra cost. To further cloud the issue, municipal and federal law has a tendency to inhibit the very design initiatives which could make the urban environment a more attractive place to live.

"This is not to suggest that design is a panacea for the problems of fear and crime. While the physical environment influences behavior, the extent of its influence is largely unstudied, outside of specific institutional settings such as schools, libraries, hospitals and mental institutions. This country made the mistake in the 1950's of assuming that remaking the physical environment would solve social problems; the urban renewal program, based in part on this assumption, proved that social problems were much more intractable and complex than that. Similarly, the impact of design improvements on security may turn out to be smaller than currently imagined. Even if this is the case, however, many security design concepts may contribute to socialization processes within apartment buildings, housing developments, and neighborhoods--a possible behavioral consequence of independent value."[5]

6.2 STRUCTURES AND CRIME

Studies have shown that crime occurs more often in some places than in others. Due to the different characteristic patterns of interaction, the most

---

[5] Ibid. p. 91.

likely location of attack varies between men and women. A study carried out in Chicago classified by sex the types of premises in which crimes against persons occurred. The street and home dominate as the most likely locations. Men are victimized most often in the street, and women in the home. Due to drinking the tavern is third most likely assault site for men, while men and women most frequently arouse conflicts between themselves at home. Details are given in Figure 6.1 and Tables 6.1 through 6.4.

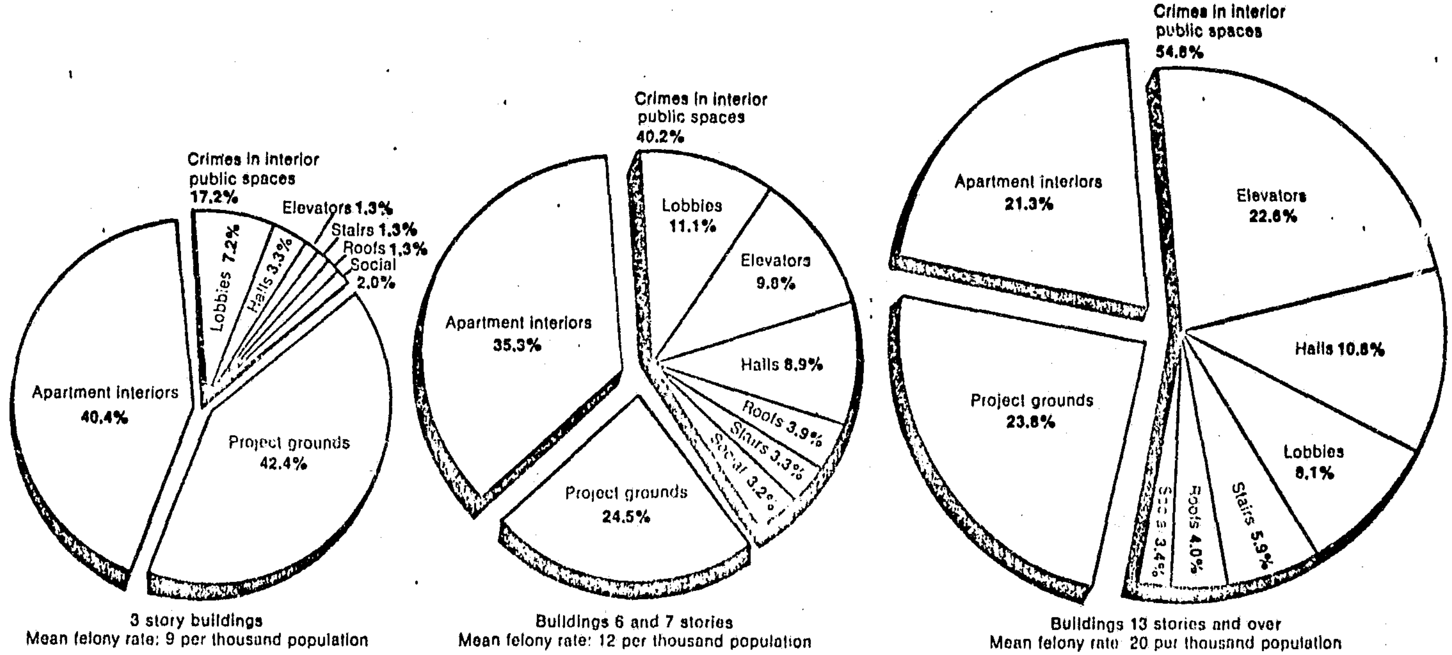
Burglars surprised in the act account for a considerable number of attacks. The confrontations can be quite volatile due to the territorial instincts aroused. The victim reacts to invasion of his personal space with sometimes illogical passion, while the burglar, in unfamiliar territory, is at a disadvantage and reacts protectively. In the case of personal attack, by either party, the advantage of surprise often separates victor from victim.

Although the home, be it high-rise apartment, garden apartment or single-family house, is thought of as a safe refuge, many situations advantageous to the attacker are designed in. Elevators, stairwells, laundry rooms and other such public spaces provide ideal places for concealment in an apartment building even though the unit is high in the air, thereby prohibiting window access.

The commonly-used security system of intercome and remotely-actuated door locks can be easily circumvented by either "voiding" the lock with a credit card or pushing all door bell buttons until someone, often in exasperation, releases the door lock. Once inside, access to the entire building is simple and quick via elevators and stair towers.

A doorman or security guard is an effective, though expensive, block at the entrance. He can require all people entering the building to identify themselves and their destinations and clear entry with the tenant by telephone. Cost prohibits 24 hour service in all but apartment buildings for the very well to do.

Figure 6.1



Place of occurrence of crimes in buildings of different heights
Source: New York City Housing Authority Police–1969 data

Table 6.1

CRIMES AGAINST PERSONS (EXCEPT HOMICIDE)

(In Percent)

Place of occurrence	Victims of major crimes against person: Male	Female
School property	3.2	2.4
Residence	20.5	46.1
Transport property	1.4	.4
Taxis and delivery trucks	2.6	-
Businesses	3.2	1.1
Taverns and liquor stores	5.7	2.8
Street	46.8	30.7
Parks	.8	.5
All other premises	16.0	16.0
Total percent	100.0	100.0
Total number	(8,047)	(5,666)

SOURCE: Special tabulation from Chicago Police Department Data Systems Division for period September 1965 to March 1966, adapted from Reiss studies.

Table 6.2

PERCENTAGE DISTRIBUTION OF PLACE OF ENTRY BY TYPE OF STRUCTURE ENTERED IN BURGLARIES

Types of Structures	Percent	Place of Entry			
		Door	Window	Roof	Other
Residence (Anywhere on premises)	100.0	61.4	33.7	.2	4.7
Retail Store	100.0	49.2	39.3	4.6	7.0
Warehouse or plant	100.0	45.1	41.7	4.0	9.2
Public Building (School, Library, etc.)	100.0	38.8	52.9	.9	7.4
Gas Station, Garage, etc.	100.0	39.7	53.6	.9	5.7
Business or Professional Office	100.0	53.1	37.6	1.6	7.7
Bank (Savings and Loan, etc.)	100.0	56.1	34.1	2.4	7.3
Other (Boxcar, Private Clubs, etc.)	100.0	60.0	27.2	1.6	11.2
Total Burglaries	100.0	53.6	38.3	1.7	6.4

Note: Due to rounding may not add to 100 percent.

Source: Patterns of Burglary by Dr. Harry A. Starr
Report LEAA N I 70.064

Table 6.3

PERCENTAGE DISTRIBUTION OF MEANS OF ENTRY
WASHINGTON, D.C. AND PRINCE GEORGE'S COUNTY

Means of Entry	D.C. 1968	D.C. 1969	Prince George's County 1967	Prince George's County 1968	Prince George's County 1969
Break glass	23.0	19.8	24.4	27.6	25.8
Force lock	49.3	53.0	30.8	26.9	31.0
Open unlocked door/window	8.6	6.2	10.6	10.0	10.2
Use key to unlock door	2.4	2.4	2.7	3.5	3.2
Other	5.6	3.6	15.1	15.4	15.2
Unknown	11.2	15.1	16.4	16.2	14.7
Total	100.0	100.0	100.0	100.0	100.0
Number	16,446	22,480	2,365	2,192	2,263

Source: Patterns of Burglary by Dr. Harry A. Starr
Report LEAA N I 70.064

Table 6.4

Location of crime* — all projects*

General Space Category	Exact Location	Total Crime	Total FMO's†	Total Felonies	Assault	Bur-glary	Mur-der	Rape	Rob-bery	Lin-gering	Mailbox (all incidents)	Drugs (all incidents)	Malicious Mischief (all incidents)
Interior Private Space	Apartment	21680	5692	2321	54	2087	7	16	62	29	22	195	2561
Interior Public Space	Lobby	9746	4103	682	18	7			591	3321	2267	207	828
	Elevator	5451	2165	1549	10	1		13	1490	58		12	537
	Stairway	4572	2129	347	14		1	14	286	1460	1	230	1568
	Hallway	7379	2419	817	40	3	1	5	718	1720	6	185	1263
	Roof and Landing	1395	396	72	3	3		39	7	446	3	210	143
	Other Inside	3894	1351	319	14	197		2	73	309	4	80	777
	Subtotal	**32437**	**12563**	**3786**	**99**	**211**	**2**	**73**	**3165**	**7314**	**2281**	**924**	**5116**
Non-Tenant Space	Social Facility	1639	610	227	2	213			3	32	1	5	271
	Commercial Facility	285	144	55		38			15	11	1	1	41
	Subtotal	**1924**	**754**	**282**	**21**	**251**			**18**	**43**	**2**	**6**	
Exterior Project Public Space	Project Grounds	15031	4649	1990	107	3	2	8	1419	719	7	660	432
Exterior Nonproject Public Space	Contiguous to Project	763	358	229	11		1		175	4		67	3
	Off-Project and Other	24	7	3		2			1	1		1	1
	Subtotal	**787**	**365**	**232**	**11**	**2**	**1**		**176**	**5**		**68**	**4**
Total		**71859**	**24023**	**8611**	**273**	**2554**	**12**	**97**	**4840**	**8110**	**2312**	**1853**	**8425**

*All incidents reported to NYCHA Police in 1969, excluding intrahousehold incidents.
†Felonies, misdemeanors, and offenses.

Single-family residences don't have the problems of concealment in public spaces within the building, but the yard, garage, and car-port offer hiding places within a few steps of the front door. Another common technique is forced entry when the doorbell is answered.

Office building security is a very difficult problem due to the continuous flow of salesmen, job seekers, and friends of employees, as well as the normal occupants of the building. A high-rise office building has all of the hiding places of an apartment building and none of the common security practices. Locked doors and interrogation at the entrance are bad business practices.

Hospitals and prisons are similar in that there is considerable control over access to elevators, corridors and stairwells (more so in prisons, of course), but even prisons have to deal with the public, and that means an acceptance of strange faces, at least in the less secure areas.

Virtually all buildings suffer from the same traffic control problem, and that is the multiplicity of exitways needed for emergencies (generally fire). The number and locations of exitways, be they corridors, stairwells or doorways exiting directly to the outside, are determined by codes. Generally speaking, 100 feet is the maximum allowable distance that an individual may be from a stairway, door, or fire and smoke resistant corridor, although 50 feet is not an uncommon maximum .

These areas are a haven of safety in case of a fire, but can become a source of terror for the victim of an attacker. Once entry is gained, a large building provides untold numbers of hiding places and escape routes. Fire stairs are a particular problem, as they are rarely used except in an emergency and therefore the intruder's risk of discovery is low. He can wait in the stair until a potential victim approaches either by stair or adjacent corridor, make his attack and be gone, the stairway hiding his escape. He has access to any other floor or to the exterior.

Attempts to thwart this misuse of the fire exits are often circumvented by the tenants themselves. A common technique is to disable the door hardware so that entrance to the stair can be made in an emergency from the dwelling floors only, but re-entry to any floor impossible. This eliminates the use of the stair as a circulation device for the tenants, who often tape the bolt or prop the door open so that they can move freely in their chosen (usually convenient) routes, but making it easier for intruders as well. Determined intruders can use these same methods.

A study of Public Housing in New York City, cited in Newman's Defensible Space, shows that 10 to 20 percent of crimes in the projects studied occurred within the elevator cab. The exact percentage rose directly with the height of the project. Elevator crimes are probably the simplest and least susceptible to discovery. A victim isolates himself from outside aid when he steps alone into the elevator with a potential attacker. A simple push of the red emergency stop button instantly brings the elevator to a halt between floors. The victim can't escape and help is locked out. Other than the elevator alarm button (easily ignored and therefore ineffective), the only available actions are resistance or submission, neither very attractive.

After completing the mugging, robbery or whatever he has in mind, the attacker releases the emergency stop and the elevator proceeds on its way. The threat of violence is normally enough for him to escape at whichever floor he chooses. Another elevator (if available) or the stairway effects escape from the building.

The victim requires considerable time to sound an alarm with currently available systems. He must exit from the elevator and find a telephone. This may in itself be a major problem. If there is a building security guard or doorman, he can be of help, but it takes time to get to the first floor and locate him.

Once the police are called, it may take several minutes for them to reach the scene and several more to ascertain the nature of the crime and a description of the assailant. At this point they must try to locate the attacker if he is still in the premises. Most large buildings (especially multi-story) have a minimum of three exits, the lobby and at least 2 fire stairs. Even though one fire stair may exit through the lobby, multiple exits from the lobby itself are not uncommon. This leaves even a 2-man patrol car shorthanded if they attempt to seal the building for a search (although it is unlikely that the attacker would still be there).

Since police response time is relatively fixed, and the vast majority of buildings cannot afford a permanent security force, it is obvious that a method of signaling for help at the location of the crime, perhaps even at the instant the attack is initiated, would be the most effective method of reducing the amount of time required to ask for and receive aid. This reduced response time would also increase the likelihood of apprehension, especially if the alarm were not apparent at the crime site. If this decreased response time can be combined with a reduction of possible escape routes, the advantage reverts to the side of the law.

6.3 SOCIAL DESIGN

The city of Pittsburgh has, for the most part, phased out its beat policemen , replacing them with two patrolmen in a car. Since this change has taken place, Pittsburgh has shown a decrease in reported crime and an increase in apprehension and conviction. Nonetheless, the city's neighborhoods have perceived, due it would seem to the fact that patrol cars are faceless, a decrease in the quality of police protection.[6]

---

6 Unpublished research by the authors.

An interesting phenomenon is thus presented, and a transfer phenomenon may be postulated: perception of crime need not bear a real relationship with the fact of crime's existence; and may be a focusing of the apprehensions arising from the dangers throughout a person's neighborhood or city on the one space entirely within his own control; and as a corollary, it may well be that perceived betterment, and this is important, coupled with actual improved security beyond a person's domicile, may well increase the sense of security within the home. This takes on the aspects of a mandela, the crucial question being where to enter, and how to influence the spiral.

Figure 6.2 (from Newman), while based upon a public housing model, gives an excellent picture of the areas within several multi-family residential structure types which are settings for such criminal activity.

"Muggings form 95 percent of (all) crimes committed in interior public areas, (whereas). . . burglaries form 90 percent of apartment interior crime. Note that not only does the. . . location change, but the total number of felonies in each category goes from nine per thousand in three story buildings to twenty per thousand in buildings thirteen stories and over.

"The specific area within a high rise building that is most vulnerable—the elevator—is a prime example of an area lacking surveillance. Thirty-one percent of all robberies (muggings) in all housing projects occur within elevators.

"Evidence indicates that those spaces which people must use on a continuing basis to get from the public area outside the project to the safety of the interior of the apartment are particularly dangerous if screened from natural observation and from formal patrol. In this light, the elevator is a space public in nature, but totally screened from an observation. For the interval of the ride, it provides the optimal situation for a criminal. . . . It should be remembered that vertical travel in elevators can run to 1200 FPM.

At this speed, exposure time in the elevators is substantially reduced."[7]

Entrance lobbies are not much safer, and account for 12 percent of all robberies. This is very often the result of the peculiar design convolution of the lobby layout. The elevator bank is usually required to be located at the center of the corridor of the typical apartment floor. In answering this requirement, architects sometimes have difficulty resolving the positioning of elevators at ground level. It is not uncommon for them to produce circuitous passageways and hidden double turns in linking up the entrance lobby to the elevators.[NB]

"There is still another problem area worth singling out for special discussion: the fire stairs and secondary exits. Because of the multitude of fire stairs required in servicing large, double locked corridors, and because the fire code(s) requires they be designed as vertical concrete boxes with little or no windows, they are continually used by criminals as places to waylay or bring victims. More importantly, (and this is not a phenomenon which appears in the statistics) the profusion of fire stairs and exits, plus the difficulty of keeping activities within them under surveillance, makes pursuit of a criminal next to impossible. There are so many potential evasion routes open, and so many different possible exits, that it would take a contingent of policemen to apprehend a criminal even if they knew for sure that he was in a particular building. More important than apprehension, however, is the fact that a criminal covering a scene will perceive at a glance the number of escape options open to him and realize his risks are minimal. A building, through its basic design, can

---

7 Newman, Op. cit. pp 33-34.

NB This configuration is not one normally found in office buildings, where for reasons of economy and business visibility it is imperative that elevators be immediately accessible from the entrance lobby; the latter generally open to all, with various commercial establishments fronting upon it.

make evident to criminals either that they will be seen everywhere they go and have only one avenue of escape, or, as in the case of the double loaded corridor, high rise, elevator building that they will be out of site continuously and have a vertical maze in which to hide and escape."[8]

6.4 PHYSICAL ABUSE

The CAS system must be built with the thought in mind that no building is a totally rigid structure. Standing waves will move through the structure as a result of the mechanical equipment's function; additionally, periodic waves may result by virtue of the building's placement, e.g., vibrations from trolley cars, subways, trains, trucks and the like.

Also, the internal receiver/relay must be able to withstand a certain amount of physical abuse if it is placed within public reach or view. In offices, schools, hospitals and the public portion of apartments, it may be placed above the hung ceiling or in a lighting fixture withpower delivered from the nearest mechanical chase, or electrical socket.

6.5 BUILDING CONSTRUCTION AND DESIGN TRENDS

Currently popular design trends in large public buildings do not vary greatly in basic concepts or layouts from those of the past 25 years. Most of the changes have revolved around more sophisticated structural techniques and newly developing materials, but the basic layouts of office buildings and apartments, the most common large structures, remain fairly simple.

The following sketches, Figures 6.2 through 6.8, illustrate several basic ways of providing circulation space, elevators, and fire stairs for both low rise and high rise structures.

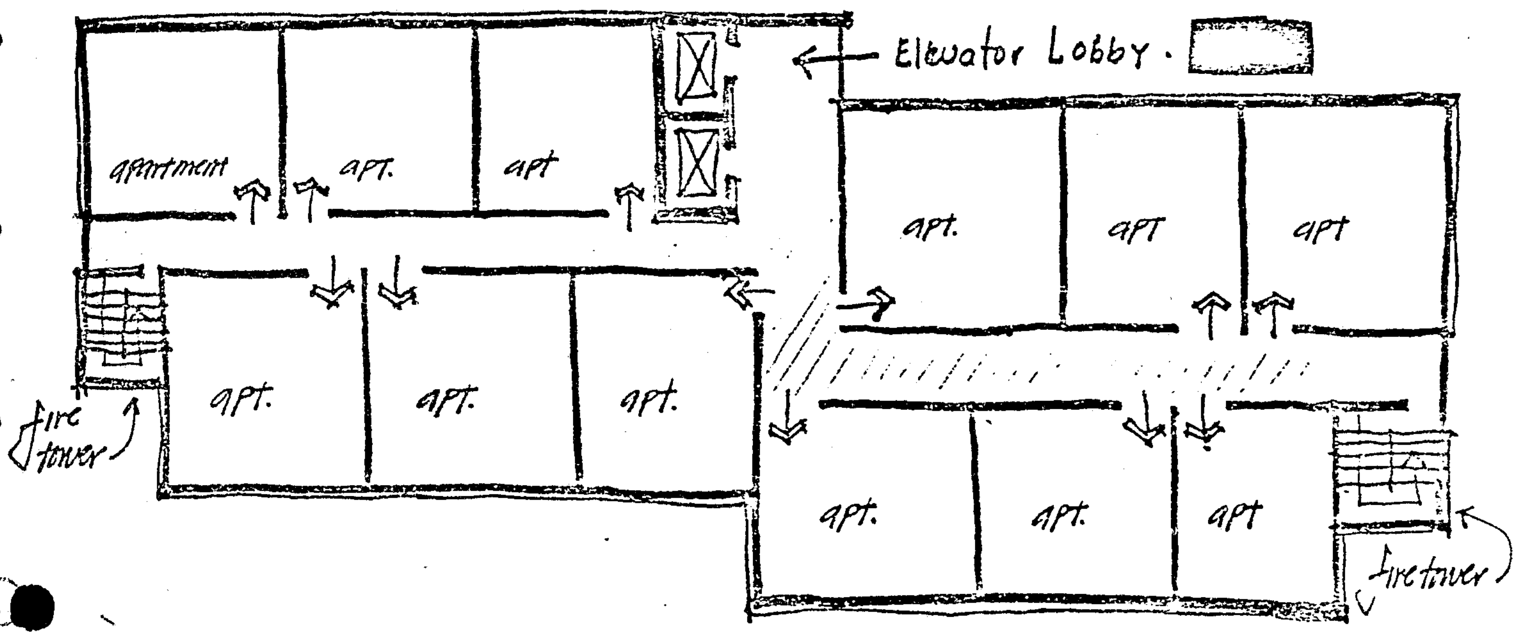
Office buildings are almost always finished with a suspended acoustical ceiling, due to the changing requirements for lighting, air conditioning, and

---

8 Newman, Op. cit., p 34.

Figure 6.2

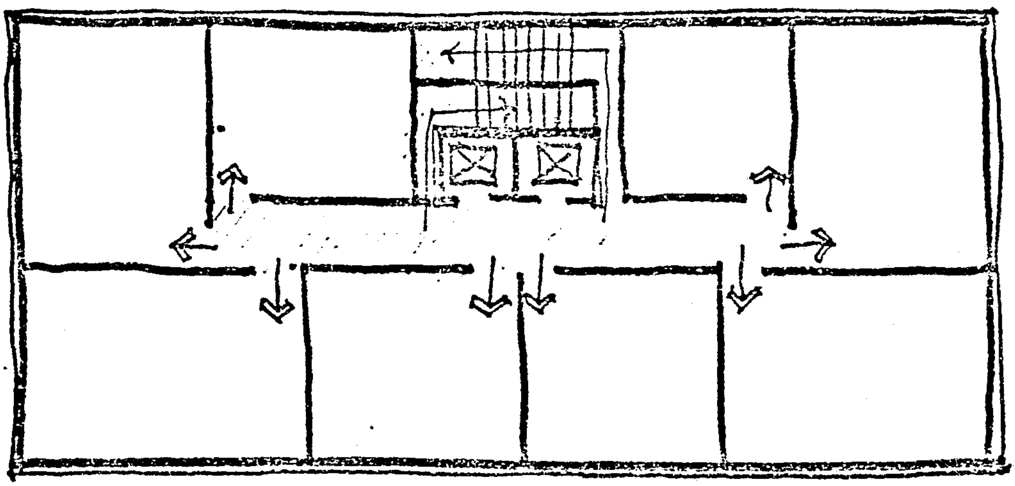
HIGH RISE APARTMENT COMPLEX



"Hi-rise central vertical core with stair wells near extremities" Double loaded corridors. This type of floor plan could also apply to hospitals or even schools (substituting stairs for elevators). Elevator lobby is isolated from corridors and is considered a good circulation pattern by many architects.

Figure 6.3

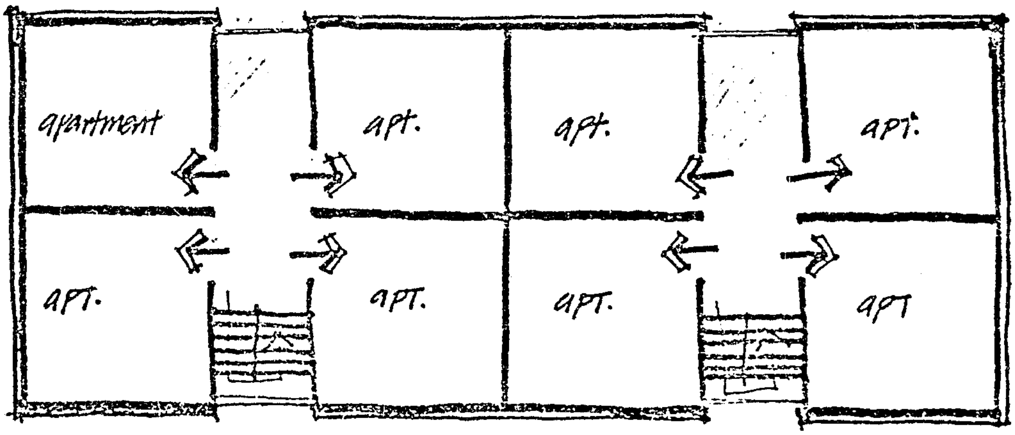
PUBLIC HOUSING MODEL



"Central vertical core and stairs." Short corridors are advantageous, but stair arrangement is under going criticism due to fire hazards.

Figure 6.4

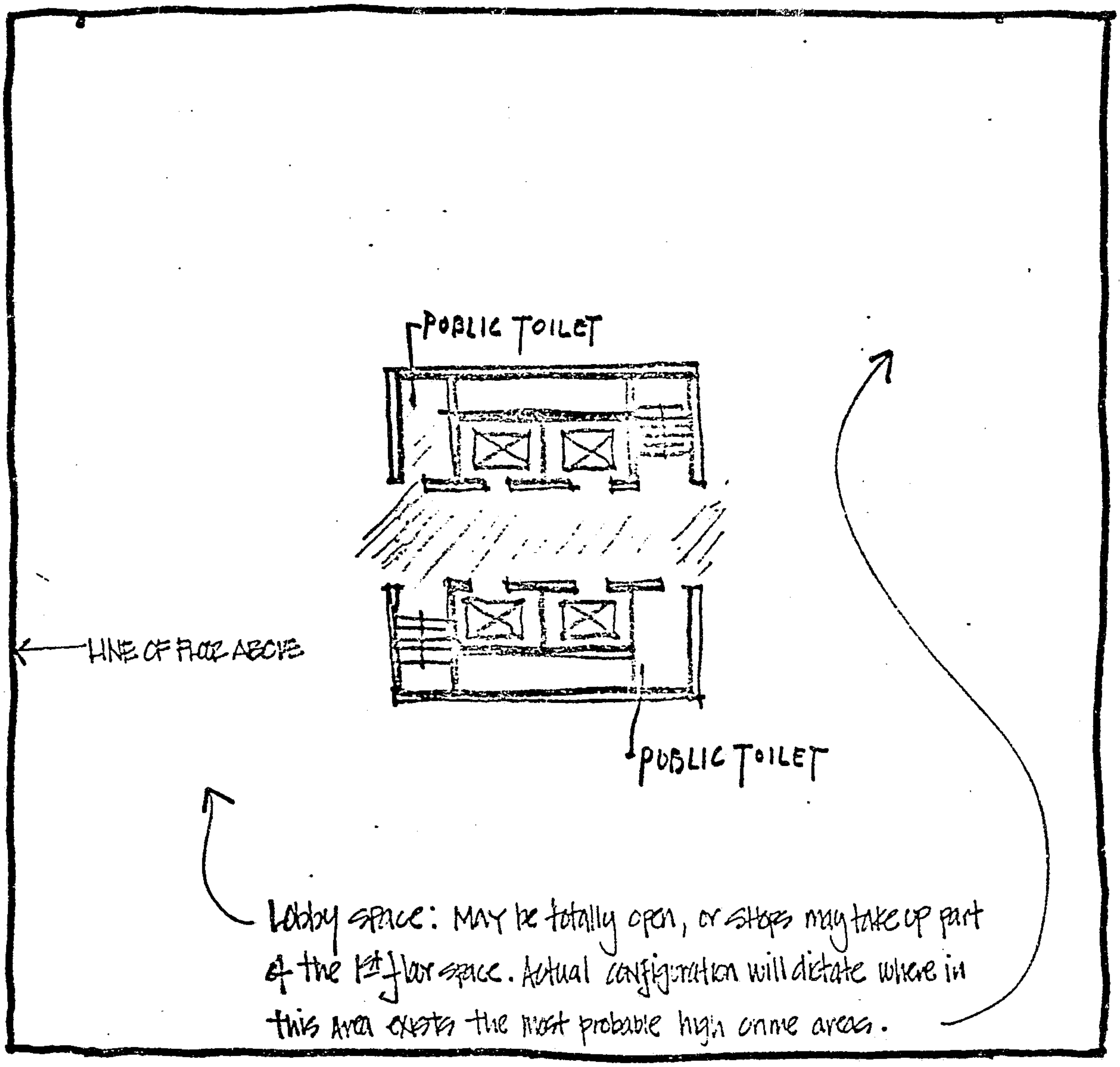
LOW RISE APARTMENTS



"Low Rise"
"Cluster Corridor" The apartments are clustered around their own stairwells and provide a sense of territoriality that is missing in corridor buildings. A minimum number of families are served by each stairwell (4 - 6 per floor for two or three floors) makes strangers easier to spot and minimum chance for surprise.

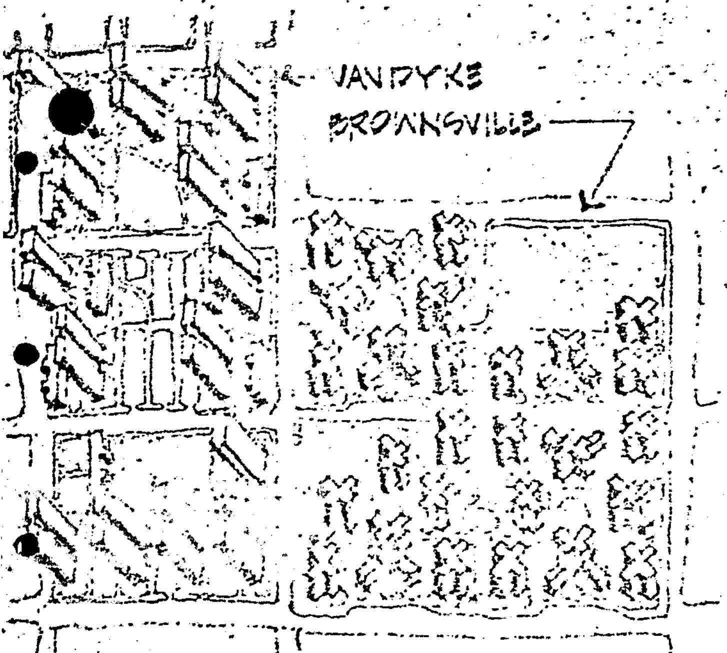
Figure 6.5

HIGH RISE OFFICE BUILDING
IIIG



"Hi-rise office building" The raw space around the elevator and service core is divided up as to tenant needs. Final layouts vary from full floor open space by a single tenant, to a maze of small offices with corridors serving them.

Figure 6.6 HOUSING COMPLEXES



Comparison of crime incidents

Crime incidents	Van Dyke	Brownsville
Total incidents	1189	790
Total felonies, misdemeanors and offenses	432	264
Number of robberies	92	24
Number of malicious mischief	52	28

SOURCE: New York City Housing Authority Police Records, 1968.

Comparison of maintenance

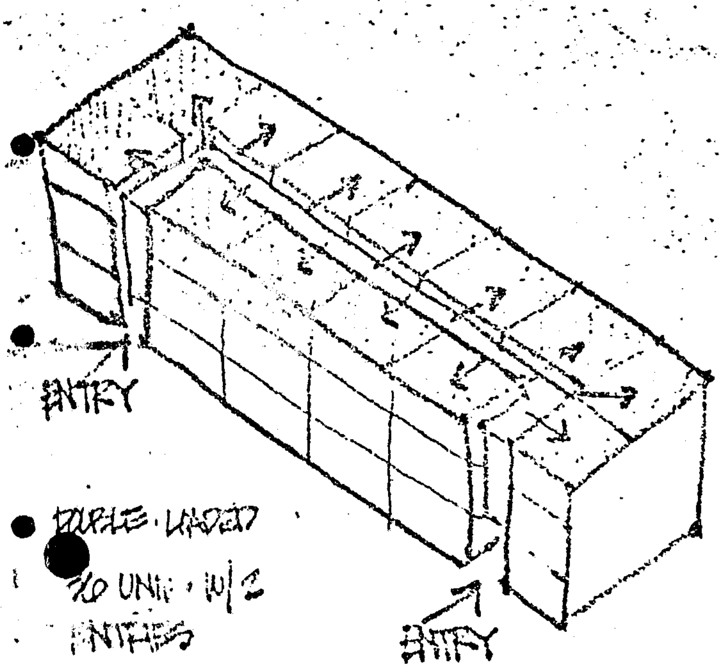
Maintenance	Van Dyke (constructed 1955)	Brownsville (constructed 1947)
Number of maintenance jobs of any sort (work tickets) 4/70	3301	2376
Number of maintenance jobs, excluding glass repair	2643	1651
Number of nonglass jobs per unit	1.47	1.16
Number of full-time maintenance staff	9	7
Number of elevator breakdowns per month	280	110

SOURCE: New York City Housing Authority Project Managers' Bookkeeping records.

A comparison of physical design and population density

Physical measure	Van Dyke	Brownsville
Total size	22.35 acres	19.16 acres
Number of buildings	23	27
Building height	13–14 story 9–3 story	6 story with some 3 story wings
Coverage	16.6	23.0
Floor area ratio	1.49	1.39
Average number of rooms per apartment	4.62	4.69
Density	288 persons/acre	287 persons/acre
Year completed	1955 (one building added in 1964)	1947

SOURCE: New York City Housing Authority Project Physical Design Statistics.



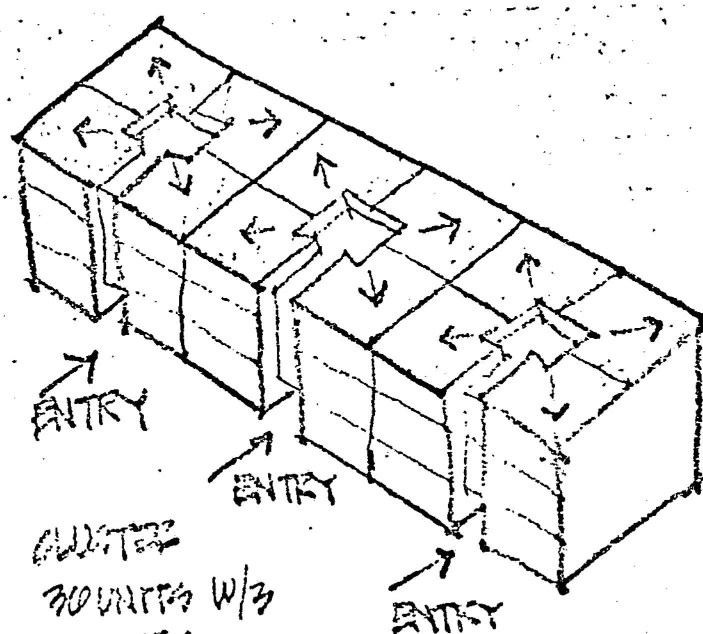
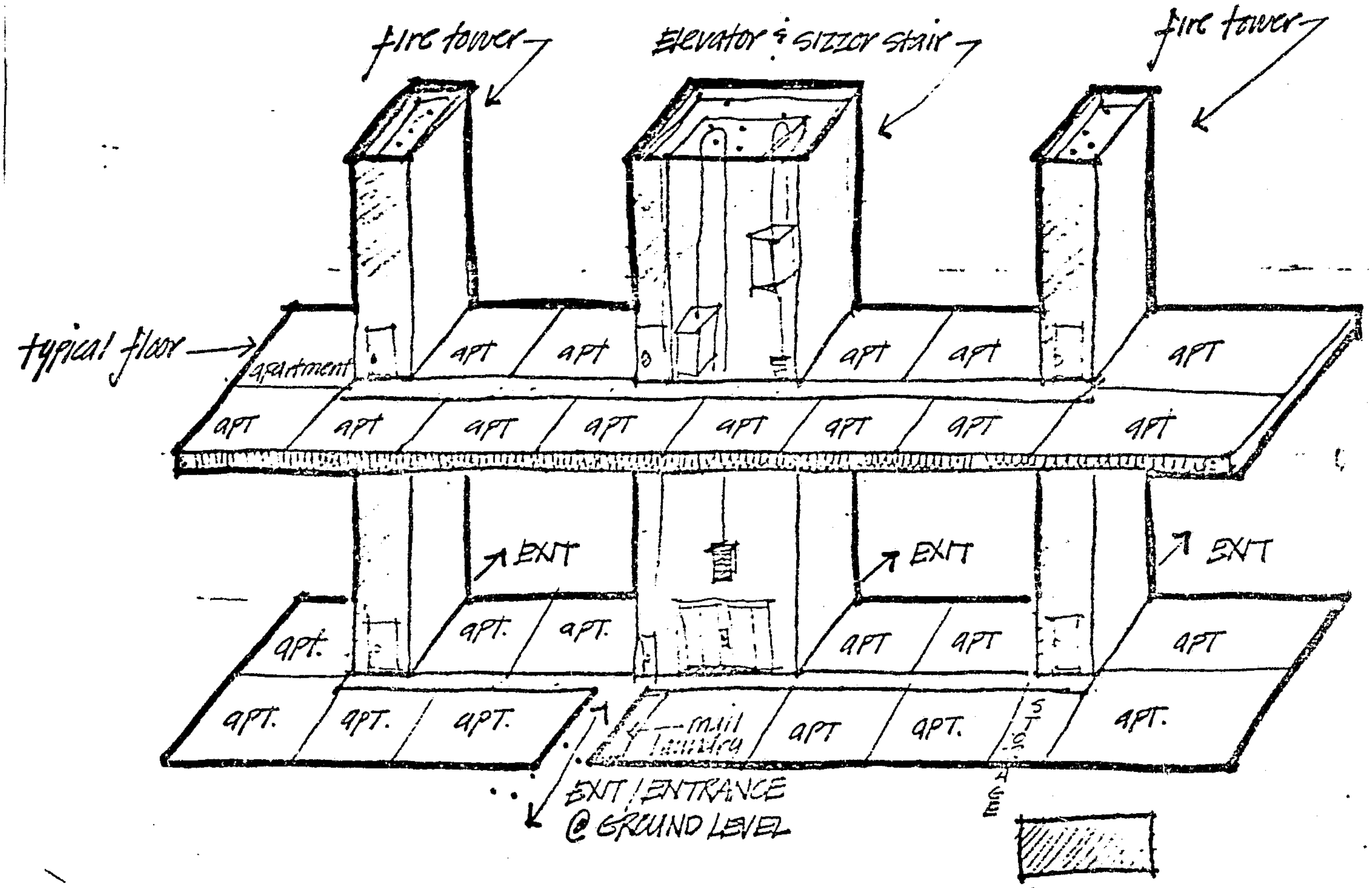
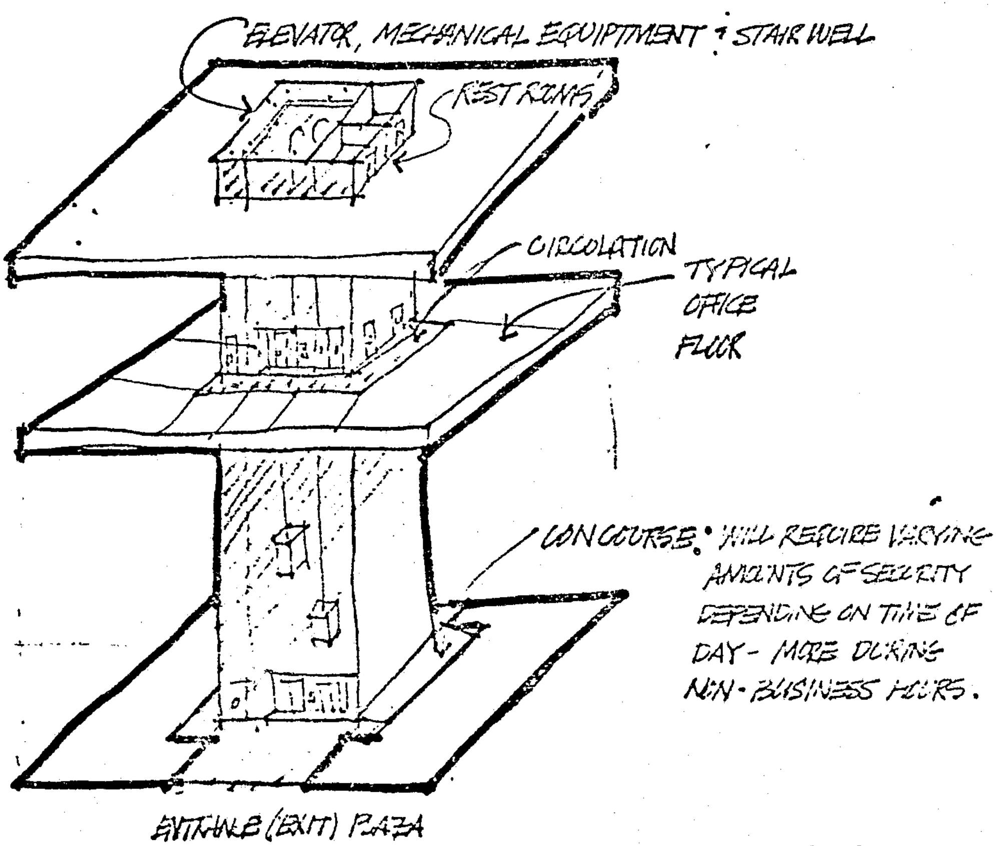


Figure 6.7



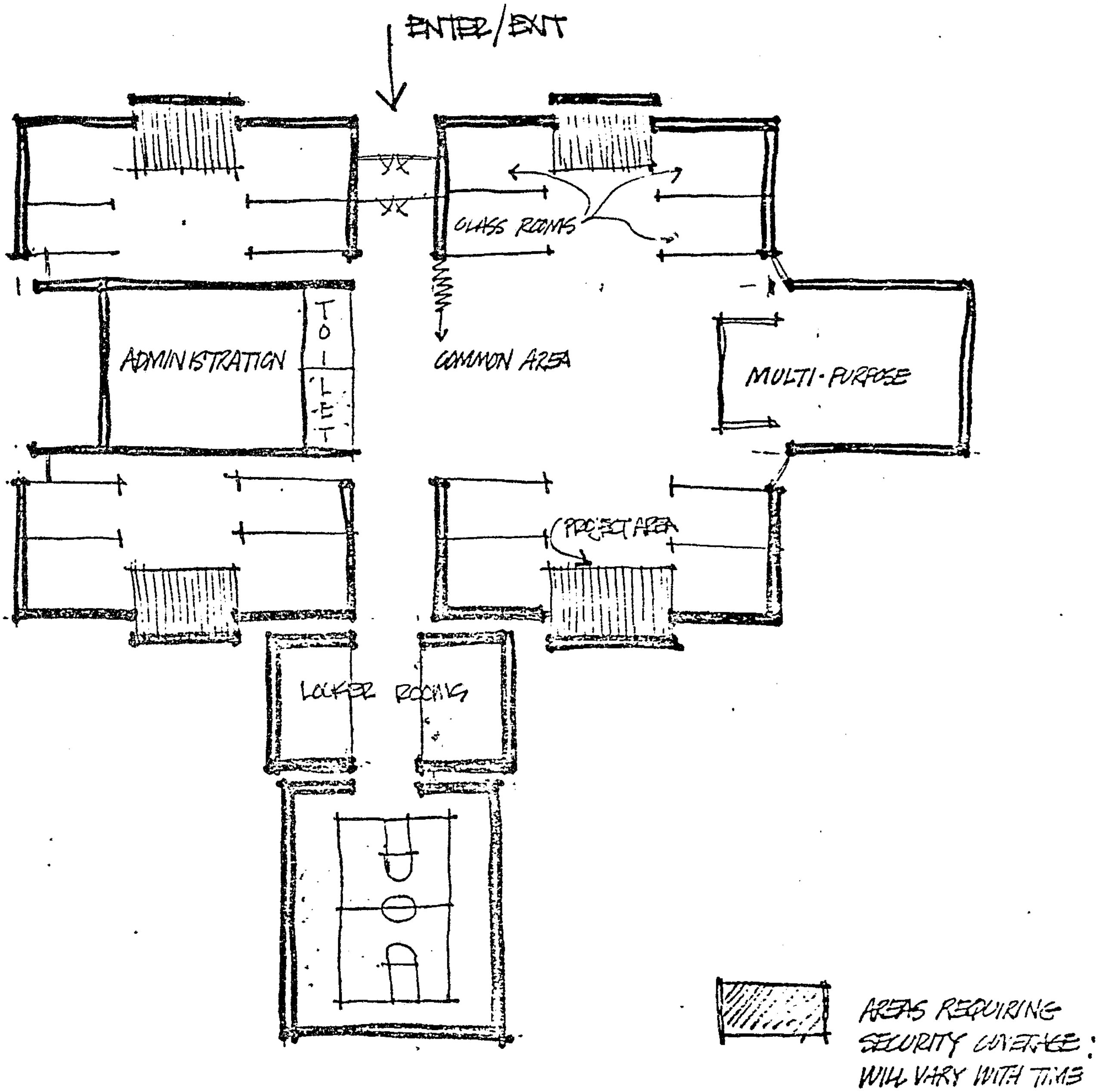
TYPICAL SCHEMATIC OF A HIGH-RISE APARTMENT

Sketch (right) of a typical high rise apartment scheme, with mailboxes and elevators hidden from all surveillance, multiple egress routes and anonymous corridors. Even in three story walk-up units, such as an existing dormitory at Sarah Lawrence College (below, left), the possible elimination of corridors through clustering (below, right) serves to increase the sense of common responsibility felt by the resident. Newman's study team observed that, in the dormitory schema represented, girls had become "loners"; no sense of either community concern or behavior code existed. Together with an open-door policy which allows for an occasional overnight guest in the college dorm rooms, this lack of identity has made the girls vulnerable to pressures by boys to extend their stay. Other nearby dormitories have strongly developed "house" identities, and corresponding interrelationships that exert group influence on behavior. These older units have their own internal hall, stairways and codes of ethics.



TYPICAL HI-RISE OFFICE BUILDING

Figure 6.8



SCHEMATIC: OPEN PLAN SCHOOL

partitions. Hospitals and schools are moving in this direction, also due to increasing flexibility requirements.

Apartment buildings are generally constructed by the above method or as follows. Precast concrete plank may be used for finished ceiling, thus eliminating hidden space above the false ceiling. Even in thisinstance, the corridor ceilings are commonly furred down with an acoustic ceiling in order to conceal piping, dustwork, and wiring that are routed through this service area.

Hospitals in the past were designed, like office buildings, apartments, and schools, around a double loaded corridor (individual rooms along both sides of a public corridor). This is changing as new health care techniques and ever-changing requirements have forced hospitals to become extremely flexible. The latest designs include 6' to 7' high spaces between the ceiling and the floor above. Workmen have access to these areas to enable constant rearranging of plumbing, wiring, and special equipment.

Older hospitals suffer often from tortured circulation due to constant additions and remodelings, making it difficult for a stranger to find his way.

Schools, too, have been traditionally based on a double loaded corridor, with the teacher standing at the front of the room. Several variations on this theme have been used recently, but a definite trend to a radical view approach is apparent. Open plan school are cropping up all over the country, essentially, a traditional school with larger classrooms and less defined circulation.

The large rooms enable four or five groups to explore their own interests in various areas of the classroom. Walls are minimized and interaction among the students is maximized. Structural systems vary, but again, hung ceilings predominate.

Prisons are very special cases. They range from the urban walled megastructure to minimum security prison farms that are essentially garden apartments. This is a very difficult building type to generalize about and might best be left to study on an individual basis.

As can be seen by the above descriptions, almost all buildings offer myriad locations for the concealment and wiring of security devices. Hung ceilings, access panels to vertical chases, locked maintenance closets and mechanical spaces conspire to hide devices and prevent their vandalism. If concealment is absolutely impossible, installation in a vandal-proof box is a minor design problem.

6.6 CONCLUSIONS

a) The use of CAS may be viewed in a spatio-temporal sense. Since the average urban resident spends 50 to 70 percent of his time within a building, these numbers also represent the time he or she could be protected by CAS, given its widespread use. If CAS were to be complemented by a compatible system for outdoors protection, this could provide protection for most of the time remainder. The location of crimes against the person depends on the sex of the individual, split almost 50-50 between indoors and outdoors. For women, almost 70 percent of all crimes against the person occur indoors. Thus, it seems that the development of an alarm system for outdoors use, compatible with CAS, is also a necessity.

b) In public housing (based on statistics from New York City), the percentage of crimes occurring within the apartments varies from 40.4 percent for 3 story buildings, to 35.3 percent for 6-7 story buildings, to 21.3 percent for buildings 13 stories and over. For these projects, crimes on the project grounds (outdoors) varied, respectively, from 42.4 percent to 26.5 percent to 23.8 percent. Thus the need for an outdoor system is at least as great as that of one which protects within the home.

c) For these public housing buildings, the percentages of crimes in elevators rose from 1.3 percent in 3 story buildings to over 27 percent in buildings 13 stories and over. This suggests the importance of using CAS to over-ride the elevator control system in the case of a crime-related emergency in an elevator, and bringing the elevator immediately to the lobby--where a response agent could be waiting.

d) The high percentage of crimes committed inside the lobbies of these buildings (7 to 10 percent) suggests that CAS be complemented by a compatible system which limits access to the building and restricts it to residents and bona-fide visitors.

e) Over 90 percent of all felonies in the public spaces of such housing projects are directed against the person, primarily rapes and robberies. The use of CAS would be invaluable, and suggests the extensive location of internal receiver/relays in all critical public places.

f) The use of CAS in the public spaces of most institutions such as schools, hospitals, etc. should be highly beneficial in the apprehension of the criminal and the ultimate reduction of the crime rate in these scenarios.

SECTION 7

EMERGENCY SERVICES SUPPLY ANALYSIS

7.1 SUPPLY AS A FUNCTION OF EMERGENCY

Practically all the Part I crimes mentioned in Section 2 of this report, i.e., murder, rape, robbery, assault, and burglary, all represent emergency situations from the victim's point. In addition, emergency situations arise because of fires, accidents, and the need for ambulance service—whether these needs are crime-related or not.

It is important to note that a crime situation may or may not be described as an emergency situation depending upon the definition criteria used. In fact, of all police radio calls only about 10 to 15 percent are emergency calls, which include fire alarms (about 1.0 percent) and ambulance assistance calls (3 to 10 percent). In addition, the total amount of services supply time spent on Part I crime-related emergencies is only about 9.5 percent, as shown in Table 7.1 for the Mission District, City of San Francisco.

It must be noted that the data for the other cities is comparable. Miscellaneous public services, including patrol time, consume about 80 percent of police time. Therefore, it is not surprising that no systematic relationship exists between the total police services supplied in direct response and the number of crime-related emergency situations. Table 7.2 illustrates the relationship between the total size of the police force and the number of selected Part I crimes for seven major U.S. cities. The total number of crimes are listed in increasing order, along with total number of police officers employed. The absence of any significant relationship between the two is obvious.

Table 7.1

ALLOCATION OF SERVICES SUPPLY TIME (IN PERCENT)

MISSION DISTRICT, CITY OF SAN FRANCISCO[1]

Part I Crimes	9.5%
Part II Crimes	5.3%
Other Crime-related Calls	4.9%
Misc. Public Services	70.9%
Traffic Violations	9.6%
TOTAL	100,0%

[1] R. J. McCormack and J. L. Moen, "San Francisco's Mission Police District: A study of Resource Allocation," Center for Planning and Development Research (Working Paper 95), University of California, Berkeley.

Table 7.2

RELATIONSHIP BETWEEN SELECTED PART I CRIMES[2] AND NUMBER OF POLICE OFFICERS EMPLOYED
7 MAJOR U.S. CITIES, 1971

CITY	NUMBER OF SELECTED PART I CRIMES*	TOTAL NUMBER OF POLICE OFFICERS
	12,587	998
	14,297	1,661
	19,432	2,720
	28,563	1,927
	76,055	13,172
	106,122	6,994
	308,071	30,865

2 Crimes include only murder, rape, robbery, aggravated assault, and burglary, *i.e.*, only crimes relevant to the use of CAS.

7.2 SUPPLY OF POLICE SERVICES AS A FUNCTION OF DEMOGRAPHIC VARIABLES

In determining the response variants related to the use of Citizens Alarm System it is useful to know how police officers are distributed throughout the country and within particular cities. This sub-section presents figures which relate the size of cities to the number of crimes per capita and number of crimes per police officer. Similar statistics for Chicago, Los Angeles, New York and Pittsburgh also demonstrate resource allocations between police districts. The attempt by city police forces to equalize crimes per officer between districts is noted and related to the need for a Citizens Alarm System.

Table 7.3 gives approximate figures on police department employees per 1,000 people in the listed population groups. It demonstrates a commonly suspected relation: the larger the city, the larger the number of police per capita. More police are supplied because of the generally higher crime rates. However, these figures are useless by themselves. It may be more useful to consider equalizing the number of crimes per officer (given present totals), suggesting perhaps 5 officers per thousand population in the largest cities, but only one officer per thousand in the smallest cities (below 10,000 population).

While specific procedures for better allocation are not brought up here, Table 7.3 shows how this problem is dealt with in a general manner. There is a strong ordinal relationship between city size, crime rate and the number of police officers. There is, however, a large range in the number of crimes per officer. The smallest cities, with 5.1 crimes per officer have better protection quantitatively than do larger cities whose officers each handle over twice as many crimes. Similar tables giving appropriate statistics for Chicago, Los Angeles, New York, and Pittsburgh show how police resource allocation is related to crime rates within cities.

Table 7.3

CRIME RATES AND POLICE ALLOCATION, 1971

Type of City	Total Pop.[3]	# Police Officers[4] # per 1000 pop.[5]/Rank	# Crimes[6]/# per 100,000 pop./Rank	# Crimes per Officer/Rank
Total Cities	125,171,000	260,350/2.1	2,471,416/1970	9.5
Group I Over 250,000 pop.	42,663,000	120,821/2.8/1	1,313,499/3080/1	10.9/2
Group II 100,000-250,000	14,079,000	28.469/2.0/2	323,570/2300/2	11.4/1
Group III 50,000-100,000	18,221,000	30,443/1.7/4	281,678/1540/3	9.2/3
Group IV 25,000-50,000	17,705,000	28,218/1.6/5	227,996/1290/4	8.1/4
Group V 10,000-25,000	19,378,000	29,381/1.5/6	207,293/1070/5	7.1/5
Group VI Under 10,000 pop.	13,125,000	23,018/1.8/3	117,380/ 895/6	5.1/6

---

3 Based on 4,958 cities with a total population of 125,171,000.
4 Based on 5,673 agencies serving a total population of 150,666,000.
5 These population figures differ from those in the first column because the latter is based on different statistical observations.
6 Includes homicide, rape, robbery, assault, and burglary.

Table 7.4 shows the relationship between the number of police officers allocated to each district in the city of Chicago and the district population density, and number of crimes. In the case of Chicago there seems to be little relationship between the number of police assigned to a district and the population of the district. Population density is correlated more strongly with number of police and the number of index crimes is the closest of the three in determining the distribution of police.

For Los Angeles, however, there appears to be a relationship between the number of police officers in a district and the corresponding population, density, and number of crimes, as shown in Table 7.5. The relationship between police and number of crimes is again the closest of the three.

As shown in Table 7.6, similar data on the precincts in New York indicates that both the population and the number of felonies are related to the allocation of police. The latter case is especially evident if the figures for Queens and the Bronx are separated. The population density figures show a very low correlation with the number of police.

Table 7.7 gives the corresponding figures for Pittsburgh, The population of a district seems unrelated to its allotment of police, while the number of crimes is rather highly correlated. Population density figures were not available.

Further statistics for the City of Chicago consider the hypothetical distribution of the police force by equalized-per-capita service, by equalized density per unit area, and by the proportion of the city's total number of index crimes to be found in a district. Equalized-per-capita service would neglect socioeconomic conditions and split up the force simply based on the number of inhabitants of a district. Equalized density of service has the same problem in its allocation of equal numbers of police per square mile. Table 7.8 presents these figures.

Table 7.4

ALLOCATION OF CITY POLICE OFFICERS AMONG DISTRICTS
CHICAGO, 1965

District	Number of Police Officers	Population	Pop. Density/ Square Mile	Part I Crimes/ Rank
2	444	134,000	33,500	6,297/2
3	400	165,000	27,500	4,302/6
18	378	131,000	32,750	4,655/4
7	369	163,000	23,285	3,850/9
11	357	154,000	30,800	4,837/3
10	323	180,000	25,714	3,194/10
21	313	135,000	27,000	3,924/8
12	307	125,000	20,833	4,106/7
20	291	299,000	24,916	2,134/13
1	283	22,000	7,333	13,695/1
13	275	133,000	26,600	4,370/5
9	237	183,000	14,076	2,094/15
19	226	193,000	32,166	2,536/11
5	211	175,000	8,750	2,510/12
14	207	194,000	24,250	1,822/17
15	203	205,000	17,083	1,806/18
16	185	203,000	7,250	1,133/21
4	182	168,000	6,461	1,952/16
8	180	236,000	9,833	1,589/20
6	176	159,000	9,937	2,100/14
17	138	167,000	15,182	1,747/19

Table 7.5

ALLOCATION OF CITY POLICE OFFICERS AMONG DISTRICTS
LOS ANGELES

District	Number of Police	Population (Thousands)	Pop. Density/ Square Mile	Part I Crimes/ Rank
1	272	160	10,795	16,814/2
10	244	208	11,647	22,286/1
7	184	219	13,298	15,359/3
6	163	179	6,533	14,747/4
11	141	88	10,526	10,226/5

Table 7.6

ALLOCATION OF CITY POLICE OFFICERS AMONG DISTRICTS
NEW YORK CITY

District (Precinct)	Number of Police (Cars)	Population (Thousands)	Pop. Density (Per Sq. Mile)	Number of Felonies
(Queens) 103	22	126	8,870	8,800
(Queens) 105	20	207	14,730	5,310
(Queens) 107	18	165	16,200	4,170
(Bronx) 41	17	161	64,300	10,350
(Queens) 109	16	147	15,220	3.160
(Queens) 111	15	142	12,500	2,600
(Bronx) 43	15	198	30,400	4,100
(Bronx) 45	9	67	8,620	990

Table 7.7

ALLOCATION OF CITY POLICE OFFICERS AMONG DISTRICTS
PITTSBURGH

District	Number of Police	Population (Thousands)	Pop. Density (Per Sq. Mile)	Selected Part I Crimes (murder, rape, assault, robbery, burglary)	
9	145	84		2530	
1				710	
	126	36			2441
2				1731	
5	125	73		2177	
8	107	109		1853	
4	93	36		1474	
7	93	63		1352	
6	79	72		1929	
3	74	48		1367	

Table 7.8

COMPARATIVE ALLOCATIONS OF POLICE MANPOWER
CHICAGO 1971

District[7]	# of Police Officers (N) (Actual)/Rank	N Equalized Per Capita (Assumed)/Rank	N for Equalized Density Per Unit Area (Assumed)/ Rank	Part I Crimes Per 100,000/Rank
2	487/1	295/14	137/19	604/2
7	450/2	295/15	195/12	476/5
3	422/3	329/9	161/15	396/9
18	411/4	255/17	127/20	577/3
11	378/5	235/20	141/18	765/1
10	361/6	322/10	215/11	470/6
13	337/7	268/16	154/16	503/4
21	335/8	248/18	148/17	416/8
12	332/9	241/19	188/13	463/7
20	330/10	550/1	342/8	208/13
9	105/11	335/7	389/6	161/16
19	291/12	389/4	168/14	262/10
15	271/13	376/5	349/7	235/11
14	264/14	349/6	228/10	208/14
5	263/15	335/8	290/4	228/12
8	241/16	449/2	698/3	121/19
4	241/17	322/11	778/2	168/15
6	224/18	309/13	376/5	161/17
16	224/19	396/3	838/1	114/20
17	167/20	322/12	309/9	161/18

[7] District 1 is eliminated because it is a business district with only a small stable population and would distort the figures.

This table also shows that the actual distribution of officers in Chicago is not done in order to equalize per capita service or the number of police per square mile. There is a much closer relationship between number of police and the Part I crime rate in a district.

For the United States as a whole there is a rather high correlation between the number of crimes in a population group and the number of police employed. The correlation is almost as high between the size of the group and the number of officers. The number of crimes per officer ranges from 5.1 in the smallest cities to 11.4 in Group II cities, with a national average of 9.5. This suggests that large cities need more police (per 1000 crimes) to compare favorably with the smaller cities. For each of the four cities studied, Chicago, Los Angeles, New York and Pittsburgh, there is a distinct tendency for more police to be assigned to areas with more crime. Especially in the big cities there is a need for more police to raise the level police services per 1000 crimes to that of the smaller cities.

7.3 SUPPLY AS A FUNCTION OF LOCATION OF EMERGENCY

The police have three primary functions: response in emergencies, patrol, and investigation (follow-up). By performing such functions, it helps prevent and therefore control the number of crimes in society. Total deployment of the force, given everything else constant, should be and is related to the type of crimes as discussed in earlier sub-sections. To the extent that these crimes are related to location there must be a consistent relationship between total police deployed in such areas and the total number of crimes committed in the corresponding areas. It must be noted that patrolling a commercial property is easier than a residential property because of concentration. Also, 55 percent of the robberies are committed on the streets. There would be a bias in the direction of commercial areas if these crimes are committed on commercial streets rather than residential streets. It must also be noted that the rates of day and night-time burglaries and robberies are substantially different and therefore the deployment in the same shifts will not be similar.

Data is scarce in the case of police deployment as a function of land use parameters. Table 7.9 gives the total number of radio monitored patrol cars assigned to areas having business establishments. There appears to be no relationship between the assigned police and the number of business establishments. However, the density of such premises (i.e., the land-use factor) is important along with various other factors.

7.4 RESPONSE TIME

The overall response time from call for service to arrival at the scene consists of two major components: communication center response time (the time required in the communication center from the receipt of a telephone call to transmission of a dispatching message) and field response time (the time between the receipt of dispatch message by the patrol unit and arrival at the scene). The response time may also be increased significantly if a call is not considered urgent and the dispatching is intentionally delayed.

In Table 7.10,[9] for emergency calls in Los Angeles, the overall police response time is seen to average 6.3 minutes for those cases involving crime, subsequently not cleared. The average is only 4.1 minutes for cases in which the police were able to make an arrest. A similar situation holds for the calls classified as non-emergency. Thus shorter response time correlates with ability to make an arrest.

A similar picture is presented in Figure 7.1 which shows the arrest probability as a function of response time for all emergency radio calls.

---

[9] Task Force Report: Science and Technology, President's Commission on Law Enforcement

Table 7.9

RELATIONSHIP BETWEEN RADIO MOTORIZED POLICE CARS AND NUMBER OF BUSINESS ESTABLISHMENTS

Precinct	No. of RMPs Assigned	Business Establishments and Licensed Premises
45	9	1,398
43	15	3,328
111	15	19,805
109	16	26,132
41	17	5,201
107	18	25,602
105	20	35,832
103	22	55,623

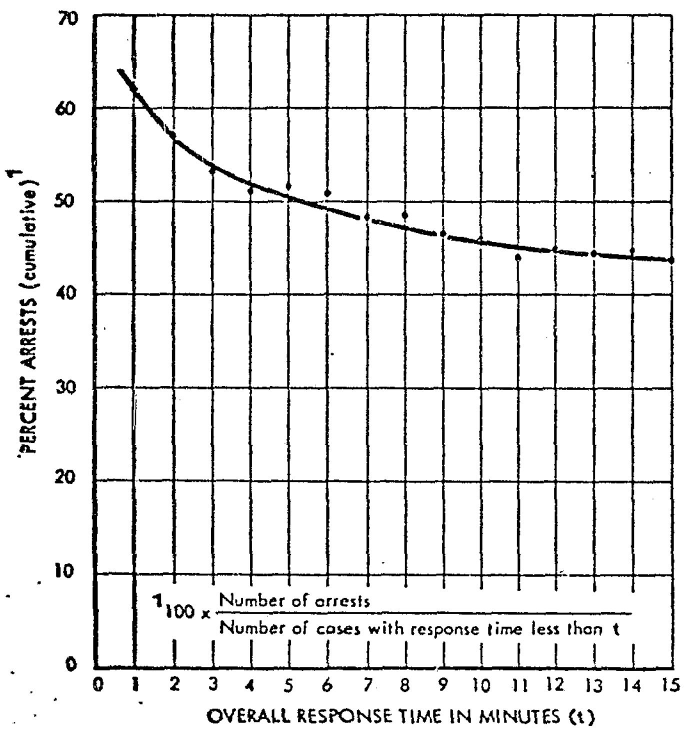
Table 7.10

RELATIONSHIP BETWEEN RESPONSE TIME AND ARRESTS[10]

Type of Call	Average Response Time in Minutes		
	Communication Center	Field Response (Travel Time)	Total
Emergency:			
Crimes Cleared	1.9	4.4	6.3
Arrests Made	1.1	3.0	4.1
Non-Emergency, Urgent			
Crimes Cleared	3.8	4.0	7.8
Arrests Made	2.6	2.7	5.3
Other Non-Emergency			
Crimes Cleared	7.3	12.9	20.2
Arrests Made	5.6	4.6	10.2

10 Ibid.

Figure 7.1



70
60
50
40
30
20
10
0
PERCENT ARRESTS (cumulative)[1]
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
OVERALL RESPONSE TIME IN MINUTES (t)
1 100 x Number of arrests / Number of cases with response time less than t

When the response time was one minute, 62 percent of the cases resulted in arrests. When all cases with response times under 14 minutes were grouped together, only 44 percent led to arrests.

Up to this point, arrest probability has only been shown to be correlated with response time. As in any correlation, the relationship may be one of cause and effect or it may have developed through some uncontrolled third factor to which both arrest and response time are related. It has been pointed out earlier, for example, that the police force may respond more rapidly to incidents in which arrest is recognized to be more probable. This is a major benefit to a system such as CAS which is likely to allow improved arrest probabilities.

Very little data is available on response time as a function of the type of emergency. Some data collected over a seven-day period in 1966, for the city of Boston, has been located and is discussed in Section 9 of this report.

7.5 SUPPLY OF PRIVATE POLICE AND GUARD SERVICES

7.5.1 Current Roles and Functions.

The major functions of private guards are to prevent, detect, and report criminal acts on private property; to provide security against loss from fire or equipment failure; to control access to private property; and to enforce rules and regulations of private employers. Generally these are the services that public police either do not perform because of resource limitations or cannot perform because of legal constraints. In a few instances, however, private guard services supplement public police services. For example, private guards are deputized by local law enforcement to provide limited police services, such as traffic direction and traffic direction in the immediate surroundings of the private property on which they work, because local public law enforcement agencies cannot spare the resources. As another example, private guards are often hired by citizen groups to patrol public streets in residential neighborhoods in the hopes of deterring street crimes, because the residents feel that the quality and/or quantity of public force protection is inadequate.

Private armed-car guards and services provide for the secure transfer of valuables between locations; public police generally do not. In this case, the public and private police are complementary. Private patrolmen often must use public streets in the course of regular patrols to prevent and detect crime on private premises. Their presence on public streets is incidental rather than primary and they are complementary to public police forces. But to the extent that crime is deterred by visibility of any security personnel on the street, private patrol services supplement public police in that all citizens in the area derive direct benefit.

Reliable alarm systems and central-station alarm operations generally complement the functions of public police because they are intended to prevent crimes (if the alarm system is conspicuous), to detect crimes, and to report crimes that occur on private premises where they are installed. Central stations turn out to be an effective means for channeling calls for assistance received via alarm systems to private guards, public police, or other public-safety organization. Central-station screening of calls tends to cut down the false-alarm rate.

7.5.2 The Extent and Place of Employment of Security Forces.

In the public sector, 395,000 persons (49 percent of all security personnel in the U.S.) were employed as policemen or detectives at all levels of government and about 120,000 (15 percent) worked as government guards or watchmen. The remaining 290,000 (36 percent) were employed in the private sector. Most of the latter (260,000) were private guards or watchmen; the remainder (32,000) were private detectives or investigators.

Thus the ratio of total private police-sector crime-related security personnel to total public sector law enforcement and guard personnel was 4 to 7. Or if government guards are included with private security forces, because most guards and private investigators do not have public peace-officer powers, the ratio of security personnel with peace-officer powers to those without was about 1 to 1.

In 1969, between one-fourth and one-third of all privately employed guards and investigators worked for contract security firms; the remainder were in-house employees. In 1967, there were over 4000 private establishments providing contract guards and investigative services, but four firms (Pinkertons, Burns, Wackenhut and Globe), with less than 6 percent of all establishments, accounted for half the revenues.

The list below gives the employment breakdown of private security forces.

Industry	Percent Employed
Manufacturing	46
Transportation	12
Wholesale and trade	3
Finance, Insurance and Real Estate	6
Services (Not including contract firms)	21
Educational services	7
Agriculture, forestry, etc.	5

It should be noted that real estate captures less than 5 percent of the market, whereas the biggest chunk goes to manufacturing.

Market Segment	Percent
Financial, Commercial, and Retail	35
Industrial and Transportation	50
Institutional	13
Consumer[11]	2

Once again, the consumer use of security equipment is substantially low even though 60 percent of burglary, a major portion of assault, rape, and murders are against the individual and residences. Therefore there exists a need for a security system which is cheap and reliable and available to the consumer for protection against crime and its effects.

7.6 CONCLUSIONS

The analysis of the data presented in this section leads to a number of conclusions that are both interesting and relevant.

a) The supply of services to the public in response to specific requests for assistance constitutes a major portion of the total police workload. Of this total supply, on 10 to 15 percent is in response to crime-related emergencies. This indicates that police resource allocation, and hence response time, may be determined by factors other than crime-related emergencies.

b) Present policies for the relative allocation of police officers between districts in a city seem to imply a positive correlation with the relative number of crimes in each district. This correlation is far less marked with the district population, and there is no correlation at all with density of officers per unit area.

c) Crime rate is directly proportional to the size of the city: the larger the population, the greater the crime rate. The number of crimes per police officer also increases with the city population.

---

[11] Private residences, persons, and automobiles.

d) The police tend to respond more rapidly to those crime-related emergencies which offer the highest probabilities of criminal arrest. This is a self-perpetuating cycle, but one that is beneficial to a system such as CAS which offers the potential of high arrest probability.

e) Police response seems to be a function of the type of emergency (whether or not crime-related), but accurate documentation of this does not seem to be available.

f) CAS emergency calls will represent only a fraction of all crime-related emergency calls. These in turn represent only 10 to 15 percent of all calls for assistance. Calls for assistance themselves only occupy about 20 to 25 percent of the total police workload (Reference: Pittsburgh Police statistics, 1972). Thus the time spent by the police in response to CAS calls is a very small fraction (perhaps less than 0.2 to 0.5 percent, for 10 percent coverage ratio) of the total police workload. As a result, police response time to CAS emergency calls is more likely to be limited by factors outside of CAS.

g) Private guards and private police are not utilized in residential and many commercial complexes in a manner commensurate with corresponding crime-related personal and property losses.

h) Private guards, private police, and manned central stations all offer good alternatives as potential CAS dispatching/response agents—depending on specific scenarios and the specific central-station capabilities available.

SECTION 8

EMERGENCY SERVICES DEMAND ANALYSIS

8.1 NATURE OF THE EMERGENCY

All Part I crimes other than larceny and auto theft require a quick counter-action either by the intended victim or the police in order to prevent them. In cases of murder, rape, aggravated assault, and robbery, the life of the victim may be in danger. If the act has already been committed, the need for an ambulance may be urgent. Table 8.1 shows the crime rate for these five crimes in seven major United States cities.[1]

Table 8.2 is presented to indicate that various police departments may sometimes treat murder, aggravated assault, and commercial burglary incidents as non-emergencies, possibly because the act has already been committed. And as discussed later, criteria of emergency vary during busy and lean periods of police service.

Following is a brief description of the details of the nature of the five crimes listed above.

8.1.1 Murder.

An analysis of types of murder weapons used shows that in 55.1 percent of the cases firearms were used. The other weapons used included knives (19 percent), club or poison (6.5 percent), and personal weapons (8.6 percent). The police are generally powerless to prevent a large number of these crimes, which is readily apparent from the circumstances or motives which surround a criminal homicide. The significant fact emerges that most murders are committed by relatives of the victim or persons acquainted with the victim. It follows, therefore, that criminalhomicide is to a major extent a national social problem beyond police prevention, unless

[1] Uniform Crime Reports, FBI, 1971.

Table 8.1

Crime Rate Per 100,000 Population in 7 Cities,
5 of the 7 Part I Crimes
(1971)

City	Population (millions)	Murder	Forcible Rape	Robbery	Aggravated Assault	Burglary
Total U.S.	220	8.5	20.3	187.1	176.8	1148.3
Chicago	7.05	13.1	27.4	373.6	236.0	921.6
New York	11.61	13.6	22.3	790.4	307.6	1820.5
Pittsburgh	2.382	4.1	17.7	148.4	118.3	814.4
Los Angeles	7.06	10.4	51.3	348.5	384.3	2209.0
St. Louis	2.36	12.7	31.2	266.1	203.5	1494.7
San Fransisco	3.1	9.4	39.7	403.4	235.6	2247.6
Cincinati	1.4	8.4	19.5	165.8	103.6	1191.7

Nonemergency Dispatching Problem Calls: Breakdown of Types of Cases [2]

	From call information						Totals (112)		
	Appeared to be "suspect-on-scene" (57)			Appeared to be "possible crime" (55)					
	At arrival:			At arrival:			At arrival:		
Type of crime	Take report	Suspect gone	Suspect-on-scene	Take report	Suspect gone	Suspect-on-scene	Take report	Suspect gone	Suspect-on-scene
Murder						1			1
Aggravated assault	3	1		1			4	1	
Sex offense		1						1	
Burglary	12	6	2	8	1		20	7	2
Robbery	1	1		1			2	1	
Grand theft	2						2		
Petty theft	3	3		1		2	4	3	2
Grand theft—auto				6			6		
Simple assault						1			1
Malicious mischief	4	4	1	23	2		27	6	1
Other	2	2	1	2	2	3	4	4	4
Unknown [1]			8			1			9
Total	27	18	12	42	5	8	69	23	20

[1] Type of crime omitted in data collected.

Table 8.2

[2] Task Force Report: Science and Technology
The President's Commission on Law Enforcement
p 94.

police can be notified whenever the danger is perceived. The effectiveness of a CAS type system in such cases would, therefore, be limited to cases in which the attempt was obvious to the victim and allow time for action and response.

8.1.2 Aggravated Assault.

Most aggravated assaults occur within the family unit, among neighbors or acquaintances. The victim-offender relationship, as well as the very nature of the attack, makes the crime one in which the separation of real alarms and false alarms would be difficult.

8.1.3 Rape.

Only 55 percent are cleared, perhaps because the suspect cannot be identified and arresed and because the rape is reported after it has taken place. A system like CAS can notify the police as soon as the danger is perceived, and there is a higher probability of the suspect being caught. Also, CAS would probably result in a greater incidence of reports of attempted rapes.

8.1.4 Burglary.

If the police are informed quickly the suspect perhaps can be arrested on the scene as it takes some time before the felony can be completed. The arrest probability decreases exponentially with total signaling and response time. Reporting with CAS is possible only if the premises under attack are occupied, or if the crime-in-progress is observed by others.

Not all the crime-related cases reported to the police are considered of an emergency type as shown in the results of the radio calls analysis presented in Table 8.3.

Table 8.3

Radio Calls and Reported Crimes
(Los Angeles)

Type of Call	All Radio Calls	% of Total	Radio calls with Crimes Reported	% of Radio Calls
Emergency	724	16.5	179	24.7
Non-Emergency but urgent	274	6.3	67	24.4
Non-Emergency	3378	77.2	1368	40.5
TOTAL	4376	100	1614	37.0

8.2 RADIO CALLS ANALYSIS

Table 8.4 shows the nature of a sampling of radio calls which are obtained by some police stations in Los Angeles. It should be noted that the overall number of crimes reported, given a radio call is 1614 of 4376 (or 37 percent). The emergency calls however show that only 24.7 percent are crime related. This is low primarily because fire alarms and some non-crime related incidents are considered urgent.

About 90 percent of nonemergency calls with crime reports are only to take crime reports after the crimes have been committed (such as burglary). It must be noted that in 40.5 percent of presumably nonemergency calls, a crime is reported. It is possible that some of the nonemergency calls should be considered emergency calls.

8.3 DEMAND AS A FUNCTION OF TYPE OF PUBLIC SAFETY ORGANIZATION

Public service organizations or emergency service organizations such as police departments, fire departments and ambulance services have several different functions, although it is clear that these are often closely related. In the main, fire departments answer calls sent by telephone and from call boxes, and proceed to the scene of the fires. Ambulance services transport injured and extremely ill persons to hospitals. The police receive calls to investigate crimes in progress, crimes that are completed but only recently discovered or reported, plus assist in many non-crime instances such as missing persons. Other non-crime incidents attended to by police officers include fires and many incidents requiring ambulance services, such as traffic accidents and general injuries. Police department figures may therefore be used in some cases to determine the demand for fire department and ambulance services.

Clearance of Radio Calls With Crimes Reported [3]

Type of call	Uncleared crimes	Arrests made	Other clearance	Total cleared	Total radio call crimes
Emergency (all blue)	116	53	10	63	179
(Percent)	(65)	(30)	(5)	(35)	(100)
Nonemergency but urgent (white/ Code 2)	38	23	6	29	67
(Percent)	(57)	(34)	(9)	(43)	(100)
Nonemergency (other white)	1, 138	151	79	230	1, 368
(Percent)	(83)	(11)	(6)	(17)	(100)
Total	1,292	227	95	322	1, 614
Percent	(80)	(14)	(6)	(20)	(100)

Table 8.4

3 Task Force Report: Science and Technology
The President's Commission on Law Enforcement
p 93.

Statistics on fire alarms may be examined as an example, based on reports from the cities of New York, San Francisco, and Pittsburgh. For each city, figures concerning the number and type of fire alarms shall be examined and compared to the population. Where statistics are available, notably in the case of New York, a more detailed analysis of resource allocation in fire departments will be made, including the types of fires, dispatch time (the time between a telephone report and the commencement of action in the fire-house itself), travel time, and time spent at the fire, related to time spent by police at the scene of fires and other types of incidents. Following this section on fire department services we shall look at the likely demand for ambulance services, based on Police Department statistics. These analyses are important because they examine the situations which absorb a significant fraction of the response resources available. They are also important because CAS, if available, is likely to be used in such situations even if they are not crime related.

Table 8.5 shows the number of alarms serviced by the fire departments in New York City, San Francisco, and Pittsburgh and lists rates per 100,000 population. It is likely that the rate is high for cities with large numbers of old run down buildings and for cities with high population densities. As time goes on the number of alarms per year may increase as a function of these variables.

For the entire city of New York in 1968, about 27 percent of all alarms were false. Thirty-five percent were car fires, rubbish fires and other minor problems. Eighteen percent were termed emergencies (such as gas leaks or smoky incinerators). Only 20 percent were fires in buildings.

Table 8.5

FIRE ALARM CALLS

City	Year	Population	Number Fire Alarms	Rate/100,000 population	Total Number Calls to Police	Percent represented by fire calls
New York	1970	7,782,000	260,000[1]	3,250	--------	--------
San Francisco	1966	600,000	5,200[2]	866	435,240	1.2%
Pittsburgh	1972	450,000	5,368[3]	1,193	258,250	2.1%

1. An increase from the 66,000 alarms in 1956
2. Police Department figures. This is an estimate based on 11 calls in a week for a presumably "average" district, The Mission Police District, one of 9 in San Francisco.
3. Police Department Figures.

When an alarm box is used to report a fire, information gets to the proper station immediately and one may assume that the trucks are moving within one to two minutes. When alarms are phoned into a dispatching office, an additional half minute is required for the dispatcher to determine the correct company signal. The average travel time seems to be approximately two minutes, so it can be supposed that fire-fighting begins from three to four minutes after the fire is reported.

Regarding the time spent at a fire, it was found that the companies would be back at their quarters about ten minutes after they left in the case of a false alarm. On most rubbish fires all but one engine would return immediately, while the remaining unit would stay for five and twenty minutes. For structural fires requiring three engines and two ladders, the first-arriving engine and first-arriving ladder will stay for about the same amount of time. The second engine works longer than the second ladder but for less time than the first engine.

The reports submitted by the police can be used to approximate the demand for ambulance services by choosing certain types of cases. The Pittsburgh Police Department noted 31,551 aided-injury reports in 1970 and 4,338 cases of animal bites. These represent about fourteen percent of the 258,250 total calls (12.22 percent and 1.67 percent respectively), certainly showing a significant demand for health-related ambulance services.

In the week reported for San Francisco's Mission Police District there were sixteen aided-injury cases and two dead-on-arrival incidents, amounting to 2.25 percent of the 930 calls (2 percent and 0.25 percent respectively).

It is clear that fire and ambulance services are vital to the life of a community. A minute or two delay in the response of the fire department may mean not only a great amount of added damage to the structure the fire began in, but also possible damage, which could have been avoided, to adjacent structures. A delay in the arrival of an ambulance may make the difference between life and death. These assertions coupled with the statistics presented in this section indicate a strong likelihood of significant popular demand for an effective Citizen Alarm System for situations that are not crime-related. They further demonstrate that a properly designed system may cut down on the workload of emergency service organizations, especially fire departments, by reducing false alarms. The extent to which CAS provides specific location information will greatly determine the quality of response: both by reducing total response time, and by allowing the public safety organization to better cope with the situation.

8.4 DEMAND AS A FUNCTION OF POPULATION, LAND USE, AND TIME

8.4.1 Population Density.

Crime depends upon a large number of factors including population density, income of victims and offenders, total population, composition of population, etc. Table 8.1, which gives the total crime rates for different cities in the U.S., shows that a large population does not necessarily mean a larger crime rate. Rates of rape per 100,000 people in Los Angeles and San Francisco are much greater than in New York, even though New York is more densely populated and has a larger population. Rates of burglary and robbery are, however, greater for bigger metropolitan areas.

The crime rates in various districts in Chicago are shown in Table 8.6. The rates of homicide, rape, assault, robbery, and burglary appear to be positively correlated with density, as shown in Table 8.7.

Table 8.6

RELATIONSHIP BETWEEN DENSITY AND CRIME
-- STUDY IN CHICAGO DISTRICTS

Density per square mile	Population (000)	District Number	Total Crime* Index/100,000
6461	168	4	1952
7250	203	16	1133
7333	22	1	13695
8750	175	5	2570
9833	236	8	1589
9937	159	6	2100
14076	183	9	2094
15182	167	17	1747
17084	205	15	1806
20833	125	12	4106
23285	163	7	3850
24250	194	14	1822
24916	299	20	2134
25714	180	10	3194
26600	133	13	4370
27000	135	21	3942
27500	165	3	4302
32100	193	19	2536
32750	131	18	4655
33500	134	2	6297

* Includes Thefts and Larceny

Table 8.7

SIMPLE COEFFICIENT OF CORRELATION
BETWEEN VARIABLES AND DENSITY
(Chicago Districts)

Homicide	Rape	Assault	Robbery	Burglary
0.63	0.64	0.71	0.64	0.76

8.4.2 Land Use.

Patrol to prevent commercial crimes such as robberies and burglaries is easier than in residential crimes, partly because commercial property is generally more concentrated than residential property. For example, in Chicago there are about 35 miles of commercial property. Given 592 commercial burglaries, this works out to 17 commercial incidents per linear mile per year. However, there are about 150 linear miles of residential property with only 7½ residential incidents per linear mile per year. Therefore the observability of crime from a patrol car may be higher for commercial property per unit resources allocated.

Increased patrol should theoretically increase the chances of detecting a burglary in progress. However, only about 3 percent of commercial burglaries are detected in progress. Another tactic which could be used to reduce commercial burglaries is more active patrol of alleys behind commercial property. The detectability of rear entrance can be assumed to be the same as the front entrance. Approximately the same number of entrances are made in the rear as in the front, but almost twice as many exits are made in the rear.

8.4.3 Residential Property.

In 1971, 70 percent of the residential burglaries occurred in apartments and 20 percent occurred in single-family dwellings. Nationally 46 percent of residential burglaries occurred at night, primarily in single-family dwellings. In buildings with four floors or less, 47 percent of the burglaries occurred on the first floor, while only 31 percent occurred on the second floor and 21 percent on the third floor.

In high rises (buildings with at least five floors) the data indicates that burglary is less likely at higher floors. The percentage of first floor burglaries is low, perhaps because many high rises have no first floor apartments.

Only in 13 percent of the cases is the owner or victim at home. In all other cases the offender has a free hand in committing the crime. In such cases CAS, by itself, would be of no help. However, complemented by a modular and compatible burglar-alarm system, the crime could be detected and assistance summoned in the other 87 percent.

8.5 DEMAND AS A FUNCTION OF DEMOGRAPHIC CHARACTERISTICS

Crime rates in cities are related quite closely to certain characteristics of the population. Districts with large numbers of nonwhite inhabitants and those with low median property values, for example, are found to have high crime rates. We shall look at certain statistics concerning the ethnica backgrounds, incomes and several other variables and relate these to crime rates in New York, Los Angeles, and Chicago. This section should show which characteristics of the population of an area are important in determining the need for a Citizens Alarm System.

In New York City (Table 8.8) the ten precincts with the highest homicide rates showed the following characteristics:

85%	nonwhite
$4950-$10,996	median income
0.74	homicides per 1000 population
26.20	robberies " " "
34.66	burglaries " " "

The ten precincts with the lowest homicide rates showed:

10%	nonwhite
$10,003-$20,865	median income
0.02	homicides per 1000 population
5.80	robberies " " "
10.60	burglaries " " "

TABLE 8.8 : DEMOGRAPHIC CHARACTERISTICS AND CRIME RATES BY PRECINCT OR POLICE DISTRICT

New York City, 1972

Precinct	% Nonwhite	Median Family Income	% Families with Income over $25,000	Homicides per 1,000 pop.	Robberies per 1,000 pop.	Burglaries per 1,000 pop.
(Manhattan)						
1	13.6%	$ 9,030	5.2%	.32	32.57	119.86
5	66.2%	6,799	2.0%	.53	10.78	18.89
6	10.1%	13,592	21.4%	.22	18.11	40.93
7	60.5%	6,399	1.7%	.14	16.76	20.56
9	49.8%	6,695	3.8%	.60	20.30	31.80
10	31.7%	9,282	6.5%	.45	15.91	35.44
13	14.0%	15,224	18.7%	.18	16.50	40.39
Midtown South	19.6%	10,996	20.2%	.93	93.52	175.72
17	8.9%	20,705	39.7%	.05	11.11	45.21
Midtown North	23.3%	9,819	16.0%	.55	42.34	120.00
19	6.7%	20,865	40.8%	.04	7.86	20.95
20	22.7%	13,293	23.5%	.27	16.75	30.35
23	47.3%	8,888	18.1%	.29	13.47	19.32
24	44.1%	10,019	11.4%	.38	19.42	30.50
25	84.3%	5,447	1.1%	.57	27.56	24.42

TABLE 8.8 : New York City, 1972 Cont.

Precinct	% Nonwhite	Median Family Income	% Families with Income over $25,000	Homicides per 1,000 pop.	Robberies per 1,000 pop.	Burglaries per 1,000 pop.
26	65.8%	$ 7,920	4.7%	.36	20.44	24.48
28	98.4%	5,658	0.6%	2.03	62.19	35.69
30	87.0%	7,567	1.7%	.58	23.70	26.60
32	98.7%	6,539	1.1%	1.00	26.40	22.11
34	36.3%	9,033	4.3%	.14	11.75	12.31
(Bronx)						
40	91.2%	5,440	0.7%	.51	15.46	36.48
41	94.0%	4,950	0.4%	.59	15.28	25.50
42	84.2%	6,212	1.2%	.45	18.61	26.10
43	33.8%	9,822	3.4%	.13	5.99	10.42
44	55.2%	7,906	2.1%	.27	14.99	26.48
45	13.8%	11,021	3.9%	.04	3.15	8.79
46	27.6%	8,551	3.0%	.18	10.96	6.96
47	27.8%	10,535	3.9%	.05	4.49	10.71
48	80.1%	5,958	1.1%	.49	17.80	24.09
50	10.3%	13,387	14.0%	.01	4.12	12.65
52	5.5%	10,458	4.4	.08	5.08	10.60

CONTINUED

2 OF 5

TABLE 8.8 : New York City, 1972 Cont.

Precinct	% Nonwhite	Median Family Income	% Families with Income over $25,000	Homicides per 1,000 pop.	Robberies per 1,000 pop.	Burglaries per 1,000 pop.
(Brooklyn)						
60	16.3%	$ 9,285	4.9%	.16	8.56	16.76
61	4.7%	11,373	6.4%	.04	1.74	9.41
62	5.8%	10,003	3.0%	.02	1.53	6.73
63	4.7%	12,655	9.5%	.03	2.16	8.87
66	8.0%	9,306	3.0%	.04	1.95	10.01
67	25.6%	10,320	4.7%	.19	8.85	16.29
68	14.5%	10,468	5.4%	.04	2.14	10.19
69	21.1%	10,881	4.0%	.10	5.16	9.39
70	7.9%	11,452	9.0%	.02	2.77	10.99
71	58.7%	8,782	3.1%	.14	6.42	17.74
72	28.2%	8,613	2.3%	.11	4.41	17.73
73	93.6%	5,501	0.5%	.61	16.90	21.01
75	59.7%	7,484	1.3%	.25	11.55	20.29
76	49.3%	7,521	2.4%	.20	4.30	16.29
77	90.3%	6,760	2.1%	.52	17.14	24.58
78	58.4%	7,132	4.4%	.33	16.14	30.26
79	96.4%	6,094	0.6%	.43	13.18	20.01
81	96.3%	6,089	1.0%	.43	16.13	20.86
83	63.5%	6,554	0.8%	.23	8.73	22.60
84	43.8%	9,750	9.8%	.15	23.16	31.06
88	75.1%	6,869	2.1%	.44	20.05	22.43

TABLE 8.8 : New York City, 1972 Cont.

Precinct	% Nonwhite	Median Family Income	% Families with Income over $25,000	Homicides per 1,000 pop.	Robberies per 1,000 pop.	Burglaries per 1,000 pop.
90	69.7%	$ 5,886	.9%	.31	10.32	21.86
94	18.0%	8,594	1.7%	.09	3.53	14.53
(Queens)						
100	15.2%	10,939	9.3%	.17	4.03	13.92
101	17.9%	10,511	6.5%	.19	7.93	22.56
102	6.9%	11,668	5.9%	.05	3.95	8.79
103	73.1%	9,610	2.7%	.28	17.44	23.63
104	2.4%	10,198	1.9%	.04	3.09	9.03
105	38.9%	12,236	5.4%	.10	6.53	18.31
106	14.7%	11,108	4.4%	.05	3.95	9.31
107	11.4%	13,404	12.3%	.05	3.98	13.72
108	23.8%	9,789	3.5%	.12	5.93	16.31
109	12.5%	12,283	7.6%	.01	2.54	9.61
110	30.6%	10,798	5.2%	.06	4.21	13.37
111	7.0%	14,153	12.7%	.01	1.95	8.65
112	8.1%	13,194	11.1%	.05	3.17	9.82
114	21.3%	10,030	3.1%	.04	3.38	9.91
(Staten Island)						
120	15.1%	11,131	5.3%	.06	3.04	13.89
122	5.9%	12,778	6.1%	.02	1.04	7.99

TABLE 8.8 : New York City, 1972 Cont.

Precinct	% Nonwhite	Median Family Income	% Families with Income Over $25,000	Homicides per 1,000 pop.	Robberies per 1,000 pop.	Burglaries per 1,000 pop.
123	8.9%	$12,224	3.9%	0.00	0.93	10.79

The ten precincts with the highest median income:

0.16	homicides per 1000 population			
13.83	robberies	"	"	"
32.48	burglaries	"	"	"

The ten precincts with the lowest median income:

0.57	homicides per 1000 population			
19.00	robberies	"	"	"
22.00	burglaries	"	"	"

The 19th precinct:

40.8%	of families earn more than $25,000			
6.7%	of residents are nonwhite			
0.04	homicides per 1000 population			
7.86	robberies	"	"	"
20.95	burglaries	"	"	"

The 23rd precinct:

18.1%	of families earn more than $25,000			
47.3%	of residents are nonwhite			
0.29	homicides per 1000 population			
13.47	robberies	"	"	"
19.32	burglaries	"	"	"

The 25th precinct:

1.1%	of families earn more than $25,000			
84.3%	of residents are nonwhite			
0.57	homicides per 1000 population			
25.56	robberies	"	"	"
24.42	burglaries	"	"	"

For New York City, then, it seems that the homicide rate per 1000 is correlated negatively, and quite strongly, with income levels. The correlation with percentage nonwhite is also strong (negative). The results are the same for robbery, but not as accurately for burglary. It is likely that burglars more than murderers and robbers go to wealthier neighborhoods in order to maximize their bounty.

In the case of Los Angeles (Table 8.9) we relate the rate of crimes to the assessed property value per capita. The property crime rate appears to be correlated to property value, while the personal injury crime rate seems to be a bit more responsive. The total crime rate is another poor indicator, though. It is likely that other factors are felt in Los Angeles which increase crime rates in more affluent communities relative to the rates in poorer districts.

Table 8.10 shows correlation coefficients between demographic variables and crime rates for Chicago, using the 1960 census figures and 1965 crime figures. There is a strong correlation (.81) between total crime and the percentage of the population which is nonwhite. This is to be expected since the 1965 arrest rate for Blacks was four times than for whites. The coefficients of correlation for crimes against persons (homicides, rape, and assault) and percentage nonwhite are generally much higher than the coefficients between property crimes and nonwhite population. This indicates that the percentage of nonwhite persons in a district is more closely associated with crimes against persons than with property crimes. This finding is supported by arrest data (not supplied) which shows a much higher divergence between arrest rates for Blacks and whites for crimes against persons than the difference in arrest rates between the races for property crimes.

Table 8.9

DEMOGRAPHIC CHARACTERISTICS AND CRIME RATES BY PRECINCT OR POLICE DISTRICT

Los Angeles, 1967

Police District	Population	Property Crimes per 100,000 (Includes Larceny and Auto Theft)	Personal Injury Crimes Per 100,000 (excludes murder)	Assessed Property Value Per Capita	Total Number Index Crimes	Crime rate per 100,000 Population
1	160,000	9,738	666	$3,272	16,814	10,500
6	179,000	7,947	303	2,691	14,747	8,210
7	219,000	6,507	397	2,332	15,359	6,990
10	208,000	8,388	1,282	1,072	22,286	10,710
11	88,000	9,913	1,712	1,707	10,226	11,620

Median family income of the districts and crime rates are correlated very strongly in a negative direction for Chicago. The results show that high income districts are less likely to suffer from all types of serious crime than the poorer districts. This can be seen from the very high negative coefficients of correlation between median family income and all types of crime. Personal injury crimes are again more strongly correlated with income than are the property crimes.

The percentage of homes in a district which are owner-occupied is also negatively correlated with crime. The results for this variable, which may be interpreted as a measure of the stability of a neighborhood, show that the higher the percentage of owner-occupied homes, the lower the level of crime is likely to be. Correlation between rent and crime and value of owner-occupied homes and crime also show negative correlations, but less strong ones. The percentage of foreign-born inhabitants of an area also showed a negative correlation with crime. It may be hypothesized that neighborhoods with substantial numbers of foreign-born inhabitants are more stable, rather than less, than other parts of the city. Instability today is more a function of immigration within the country than the immigration from foreign nations and we see moderately high coefficients for percentage of migrants (those who have changed county within the U.S. within the past five years) and crime.

We see, then, that those who suffer most from crimes are those with low incomes. Black areas have especially high crime rates, notably for crimes against persons in lower income areas, and for crimes against property in all areas. Areas with unstable populations are also in need of such systems.

8.6 CONCLUSIONS

a) CAS is likely to be useful in potentially homicidal situations only if the intended victim is aware of imminent attack, and triggers the CAS actuator in time to summon assistance.

b) Given the nature of the relationship between the offender and the victim in many cases of rape and aggravated assault, separation between real and false alarms is likely to be very difficult.

c) The use of CAS is likely to increase the number of reported cases of rape, and is also likely to sharply increase the clearance rate for rape and other personal crimes reported with CAS.

d) CAS will be useful in burglary situations only if the premises under attack is occupied and the occupants are alert, or if the crime is observed by others while in progress. Only 13 percent of all burglaries occur while the owner or victim is on the premises. Thus CAS should be complemented with a compatible modular and low-cost burglary-alarm system for protection in the 87 percent of such cases, and in the cases in which the premises is occupied but the user is not alert.

e) CAS is likely to be used in emergency situation other than crime-related ones, e.g., fires, falls, accidents, etc. Since a user with CAS is likely to place great faith in the system, and is likely to use the actuator in a grave emergency--regardless of its origin, an appropriate response is desirable. Thus the CAS interface with the response sub-system must take into account not only crime-related emergencies but also others in which CAS will be used, regardless of its intended usage.

f) The ability of CAS to provide the specific location of the emergency will be a major benefit to public-safety organizations in directing their efforts and in better coping with the situation.

g) Crime rate seems to correlate with a number of demographic variables: ethnic background, income, etc.--based on an analysis of data available for New York (1972), Los Angeles (1967), and Chicago (1965).

SECTION 9

RESPONSE MODELING

9.1 INTRODUCTION

In Section 7 and 8 of the report it was pointed out that the criteria for an emergency are functions, among other things, of whether the police can respond in time to save a life or arrest an offender in the case of a felony. Therefore, these criteria are different in each case of burglary, murder, rape, aggravated assault, robbery, and fire. They also depend upon whether the burglary was in a residential or commercial area. Some preliminary research along these lines has been performed, but the currently available empirical information is not adequate as the foundation for the selection of a policy for optimal resource application. The relevance of such allocation procedures to CAS is obvious from the effect of such changes as response time.

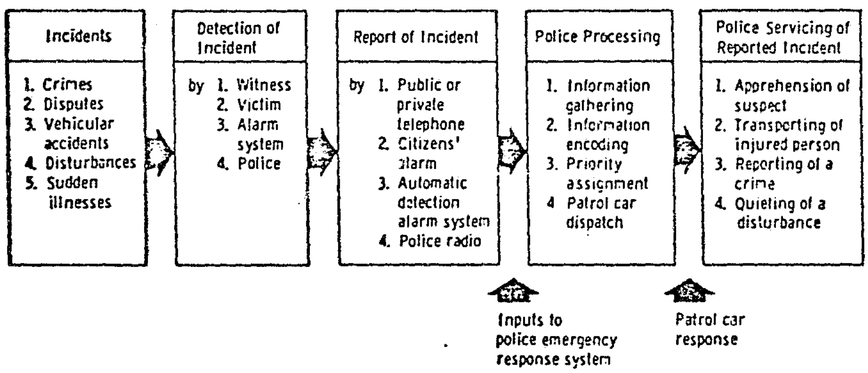
In the first part of this section, the police emergency system is described. Then the results from various response studies are presented. The importance of a quick response has already been discussed in Section 7 on the supply of police forces. The results from some models developed for the Chicago Police are also discussed for relevance to CAS.

9.2 POLICE EMERGENCY RESPONSE SYSTEM

The police emergency response system is shown in Figure 9.1. The system responds (efficiently or otherwise) whenever a citizen communicates the need for police service to a police communication center. A typical call is handled in the following manner:

9.2.1 Incident Occurrence.

At time t equals zero, a particular incident such as robbery, burglary, etc. commences and requires police attention.



Aggregated flow diagram of the police emergency response system.

Figure 9.1

9.2.2 Police Detection

At time t_1, the police or a person or a device that will report the incident to the police, detects the crime.

9.2.3 Initial Attempt to Communicate With the Police

If detection at time t_2, is by an automatic device, this delay may be small . Otherwise, if a call is made from a telephone or call box, this delay $t_2 - t_1$ would depend upon the proximity of a telephone or call box. In case of central-station burglary alarm systems, the system usually notifies a centeral-station operation which may dispatch its own units and guards to be scene to notify the police or both. On the other hand, victim-triggered robbery alarms are often wired directly to the communication center and given top priority

9.2.4 Contact With Police

At time t_3 contact with the police is made. Therefore, $t_3 - t_2$ represents the time delay in queue waiting for an available complaint clerk to receive the call. Based on New York City data for Friday and Saturday evenings, 40 percent of these calls received suffer a delay of 30 seconds or more. The delays of course, depend on the number of complaint clerks receiving calls. Again, in New York City, the headquarters may receive over 1500 calls per hour during evening hours, requiring more than 40 complaint clerks. The delay depends also upon the manner in which calls are taken at the switchboard. For example, a first-come first-served system produces the least delay to an individual, but disregards the urgency of the need for response.

9.2.5 Information Gathering

Assuming that all relevant information is received by time t_4, the initial information gathering time is $t_4 - t_3$. For any call, the clerk gathers information about the incident and ascertains priority for the call.

If the clerk decides that the incident does not require the dispatch of a patrol car, he may choose to terminate the call at that time or transfer the call to back-up operators who handle non-emergency calls. The clerk, in assessing the priority, may indeed make mistakes with serious consequences. On the other hand, if too many calls are accepted as requiring on scene service, the patrol force may become saturated.

The average time for such a call requiring police service is 20 to 30 seconds. Average time for other calls varies between 40 to 120 seconds.

9.2.6 Information Processing

The information is coded on a complaint ticket or incident report. Say this activity terminates at time t_5.

9.2.7 Transmitted to Dispatch

This activity involves transferring the call to the dispatcher of the patrol cars and ends at t_6. It usually takes 10 seconds.

9.2.8 Entrance to Dispatcher Queue

The incident report leaves dispatchers queue at time t_7. The queue gets formed when incident reports arrive in a flurry, faster than the dispatcher can handle them. The delay ($t_7 - t_6$) typically varies from a few seconds to a few minutes, but rarely exceeds 10 minutes.

Much more important is the second source of delay, that caused by the entire patrol force being busy. These delays can exceed one hour. In some cases they comprise 90 percent or more of total police response time.

9.2.9 Dispatch of Patrol Unit

The dispatcher selects a patrol unit to be sent to the scene of the incident and transmits the necessary information to the unit. This activity takes a small amount of time and ends at t_8.

9.2.10 Arrival at the Scene

The assigned patrol unit then travels to the scene at speeds determined by the nature of emergency. The unit arrives at time t_9. This travel time, $t_9 - t_8$, may vary from a normal range to 3 to 7 minutes, to over 15 minutes in some cases.

9.2.11 Completion of Service

A typical call takes 25 to 45 minutes to service and ends at time t_{10}.

9.2.12 Results of Response Models

The sum total of dispatcher queue amd processing time and the travel time of a police car to the scene comprises between 50 to 90 percent of the total response time, $t_9 - t_1$. The dispatcher is a prime decision maker in the emergency response system, He can delay a dispatch or even preempt one of the low-priority calls. Table 9.1 presents response time data from the Boston Police Department for different kinds of emergencies. The travel time does not seem to vary much. However, the time, $t_8 - t_4$, varies considerably with the type of incident.

Studies in New York City show that the average time between the receipt of a call and dispatch of a patrol unit may vary between 2.4 minutes to 15 minutes. (See Table 9.2) The smaller values are due to time required for recording information, to transfer information to the dispatcher, and to dispatch an available patrol unit. The larger values occur when most patrol units are busy and no car is available in the vicinity of an incident. Figure 9.2 shows that larger communication delays occur when the patrol units are relatively busy. In this study, the precinct tours which experienced largest average dispatch delays averaged 46.2 percent unavailablity of cars for dispatching. The precinct tours which experienced smallest average dispatch delays averaged 31.7 unavailability. Yet this relatively small range of

Table 9.1

Response Time Data from the Boston Police Department

Incident Type	Elapsed Time from Termination of Telephone Conversation until Dispatch of a Patrol Unit		Time Required for Patrol Unit to Travel to Scene of the Incident		Service Time at the Scene of the Incident		Sample size
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	
Vehicular Accident	1.05	1.00	3.98	3.09	54.25	25.97	44
Medical Case	1.73	3.01	5.35	3.38	40.38	24.74	225
Other Offense	1.74	2.04	5.41	4.03	22.68	18.19	97
Drunk	2.31	3.83	5.34	4.26	25.31	25.89	71
Burglary	2.39	4.24	6.45	5.05	51.76	31.36	33
Investigation	2.61	5.23	5.94	4.53	31.30	23.56	509
Larceny	2.79	4.34	7.58	5.52	31.74	15.57	38
Vandalism	3.42	5.85	6.90	4.40	36.14	24.23	118
Minor Disturbance	3.46	6.11	5.95	3.64	24.39	18.56	406
Auto Theft	4.83	8.08	7.09	4.35	35.54	21.87	94

Note: Delay units are minutes. Data were collected at the Boston Police Department over the seven-day period June 6–12, 1966.

Table 9.2

TYPICAL RESPONSE TIME COMPONENTS
(New York City)

	Average	Median
Between dispatch of a unit and receipt of a call ($t_8 - t_4$)	2.4-15 minutes	5.8
Patrol Unit travel time to the scene ($t_9 - t_8$)	3.6-9.8 "	6.2
Average distance traveled	0.78-2.91 miles	1.62
Average service time ($t_{10} - t_9$)	16.6-19.3 minutes	27.5

unavailability does not explain a larger variation in delays. This may be due to uneven distribution of police force between peak and average demand times of the day.

Some good data has been collected on the different components of response time, and on the service time, for the police in New York City. The cumulative distribution functions for each of these factors are presented in Figures 9.3, 9.4 and 9.5. Figure 9.3 shows that the probability of the total delay in the communication center ($t_8 - t_3$) being less than 5 minutes to 6 minutes is only 0.5 . The range is large, varying from over 2 minutes to well over 15 minutes. Surprisingly, the total travel time varies much less: from 3 to 10 minutes. There is a 0.5 probability of this delay being less than about 6 minutes. Total service time (Figure 9-5) may vary from 15 to 50 minutes, with a 0.5 probability of it being less than 25 minutes. Thus it is seen that the total response time may vary significantly, depending on the nature of the emergency, its location, the availability of patrol cars for response, and other factors. Once a car arrives at the scene, it is tied up for 50 minutes (more or less) and is unable to service any other call (even a higher priority call) in this period.

Data from the same New York study on the average recorded travel distance is presented in Figure 9.6. This distance depends on section size, street layout, number of cars per unit area, land use patterns, etc.

Some work has been published in recent years on the use of modeling and simulation techniques in the allocation of police resources for improved response time. In particular, the work of Larson and the Rand Corporation is outstanding. Various kinds of queueing dispatching, car location, and other models have been developed but their use is presently quite limited. A recent simulation study for the City of Chicago resulted in some very interesting conclusions

---

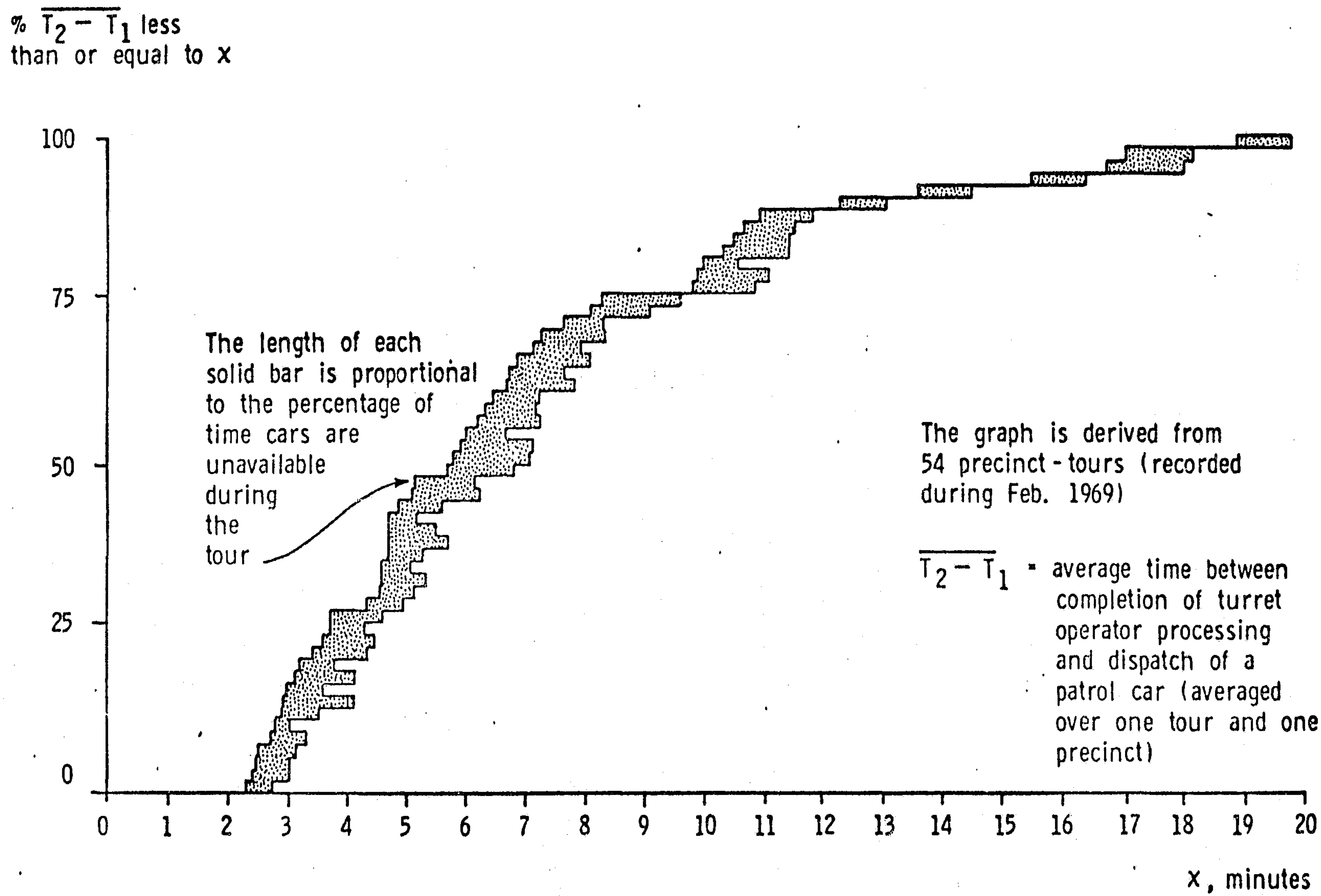
1.

2.

3.

Figure 9.3

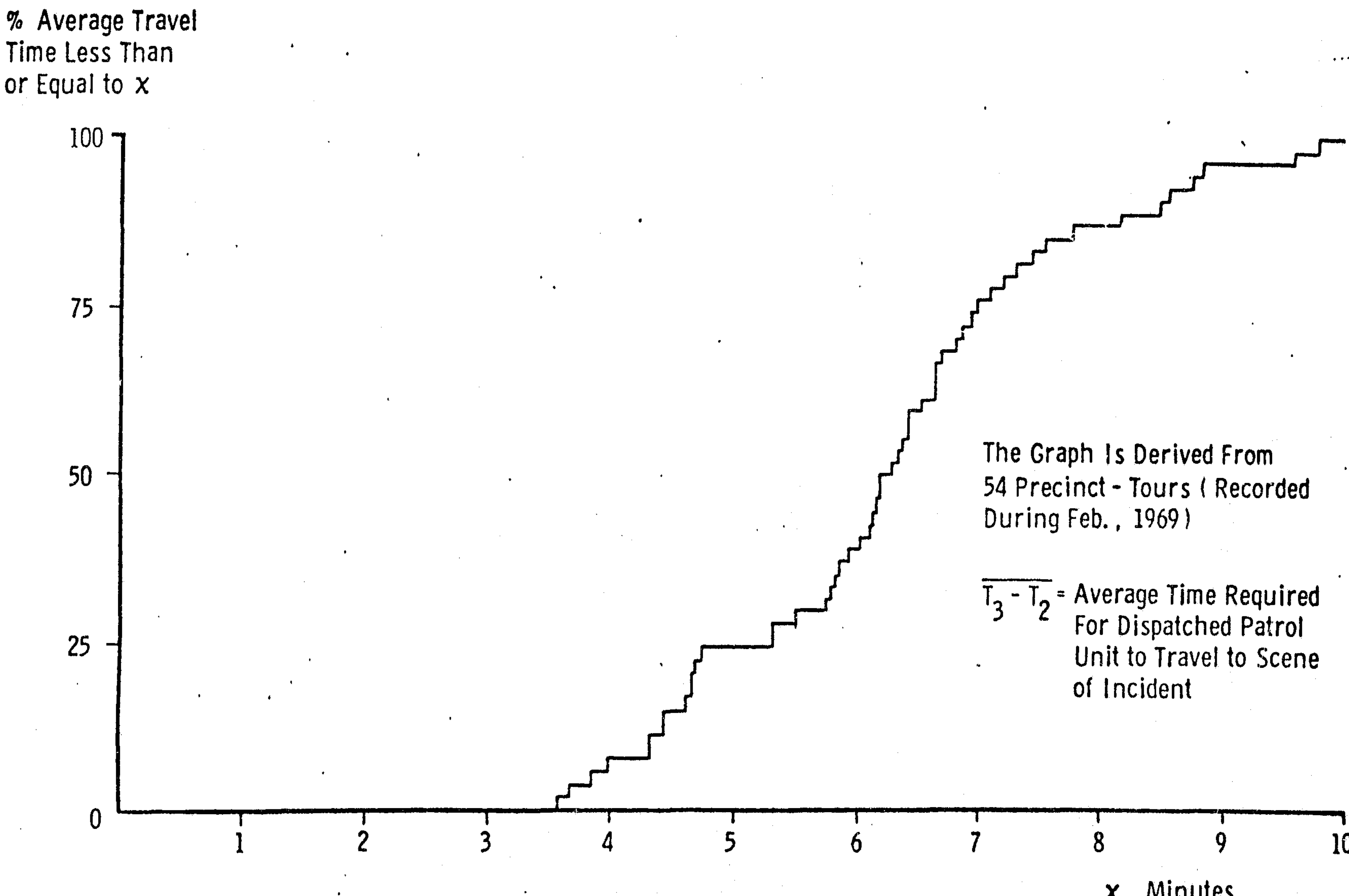
CUMULATIVE DISTRIBUTION OF AVERAGE RECORDED COMMUNICATIONS ROOM TIME, $\overline{T_2 - T_1}$
(AVERAGED BY TOUR AND BY PRECINCT)



(New York City)

Figure 9.4

CUMULATIVE DISTRIBUTION OF AVERAGE RECORDED TRAVEL TIME, $T_3 - T_2$
(AVERAGED BY TOUR AND BY PRECINCT)

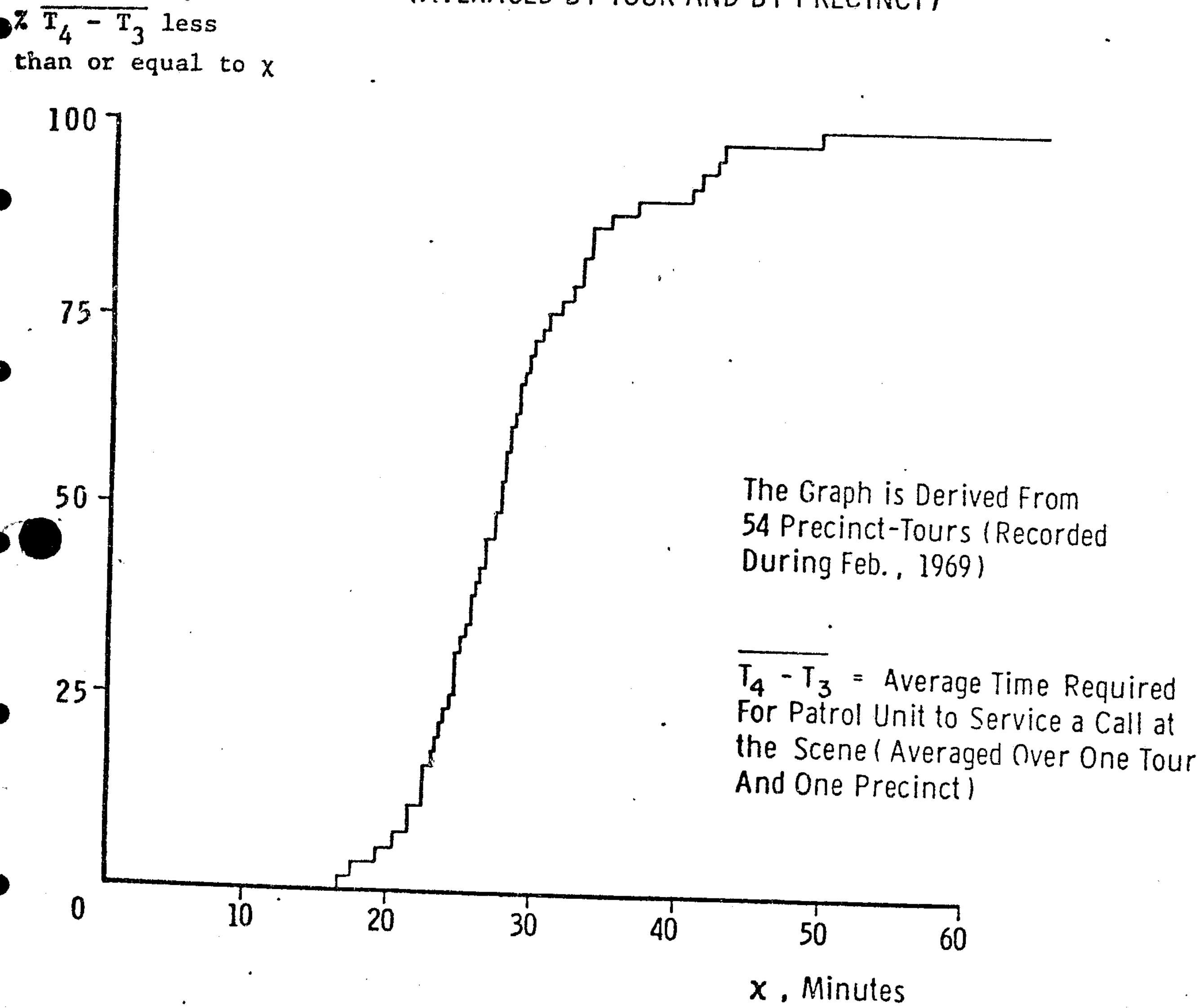


(New York City)

Figure 9.5

CUMULATIVE DISTRIBUTION OF AVERAGE RECORDED SERVICE TIME AT THE SCENE OF THE INCIDENT, $T_4 - T_3$

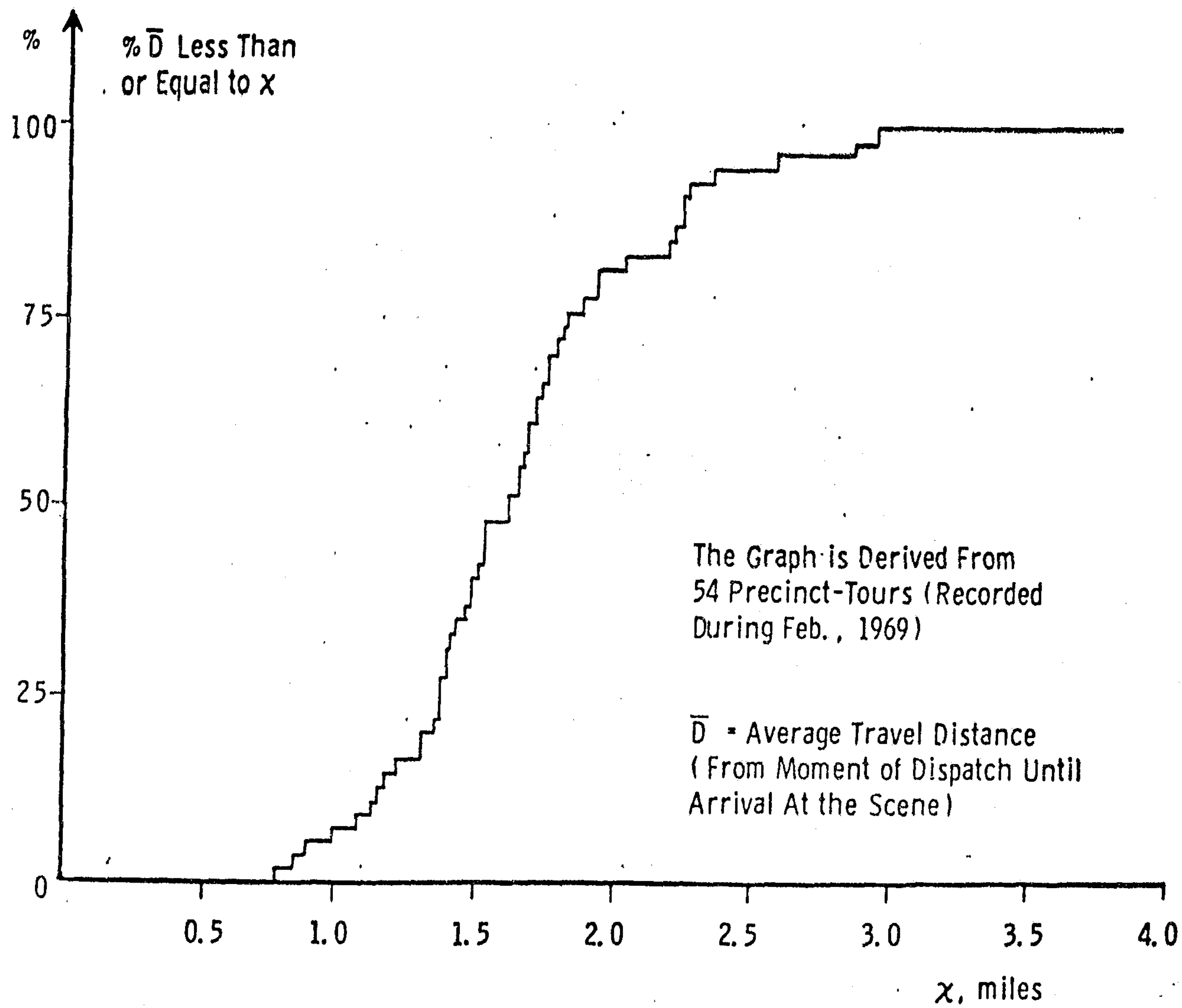
(AVERAGED BY TOUR AND BY PRECINCT)



(New York City)

Figure [illegible].6

CUMULATIVE DISTRIBUTION OF AVERAGE RECORDED TRAVEL DISTANCE (AVERAGED BY TOUR AND BY PRECINCT)



(New York City)

9.12

related to service time, the rate of receiving emergency calls, allocation of priorities, and the number of police cars required. These results are presented in Figures 9-7 through 9-10 which are self-explanatory. It is seen that with the adequate deployment resources, the unavailability factor can be cut down to a few seconds.

9.3 CONCLUSIONS

a. Total response time for the police may vary widely depending on various factors related to the type of emergency, its location, the availability of police resources, and the criteria for their location.

b. Total response time may vary from a mean of 5 minutes (vehicle accident) to 7 minutes (medical emergency) to 9 minutes (burglary), as measured in a Boston study. New York City statistics are simular showing a range from 6 to 25 minutes, with a median of 12 minutes. Los Angeles statistics show a range from 4 minutes for emergency call (arrest made) to 8 minutes for non-emergency but urgent calls (no arrest made).

c. The total response time is made up os a number of components. The more significant components include:

I Time to establish communication with police or other public-saftey organization.

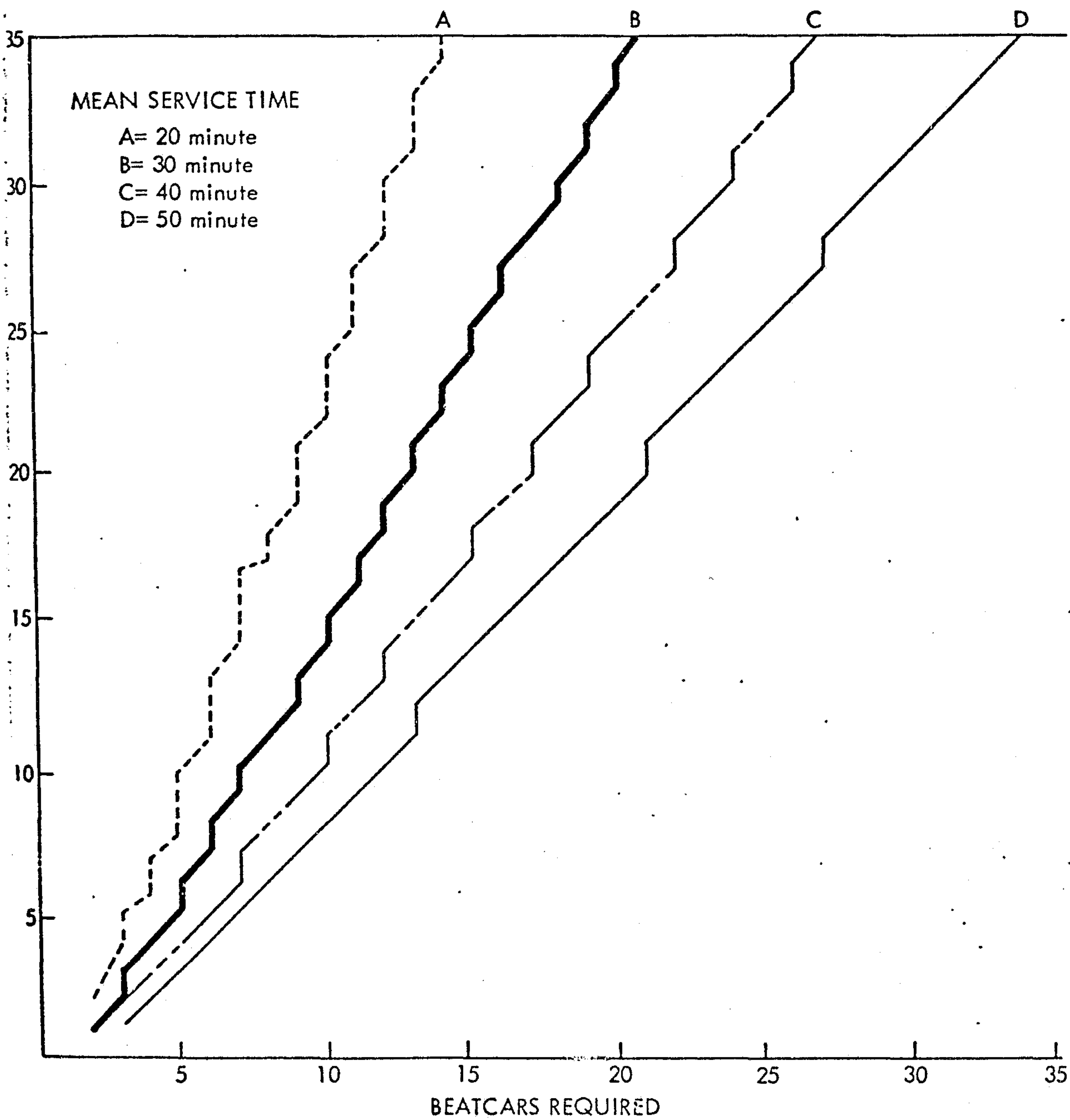
II Processing time at Police Communication Center

III Dispatch delay

IV Patrol car travel time to scene of emergency.

Figure 9.7

Number of cars needed to limit average wait for available car to five minutes.



(City of Chicago)

Figure 9.8

Number of cars needed to limit average wait for available car to 2.5 minutes.

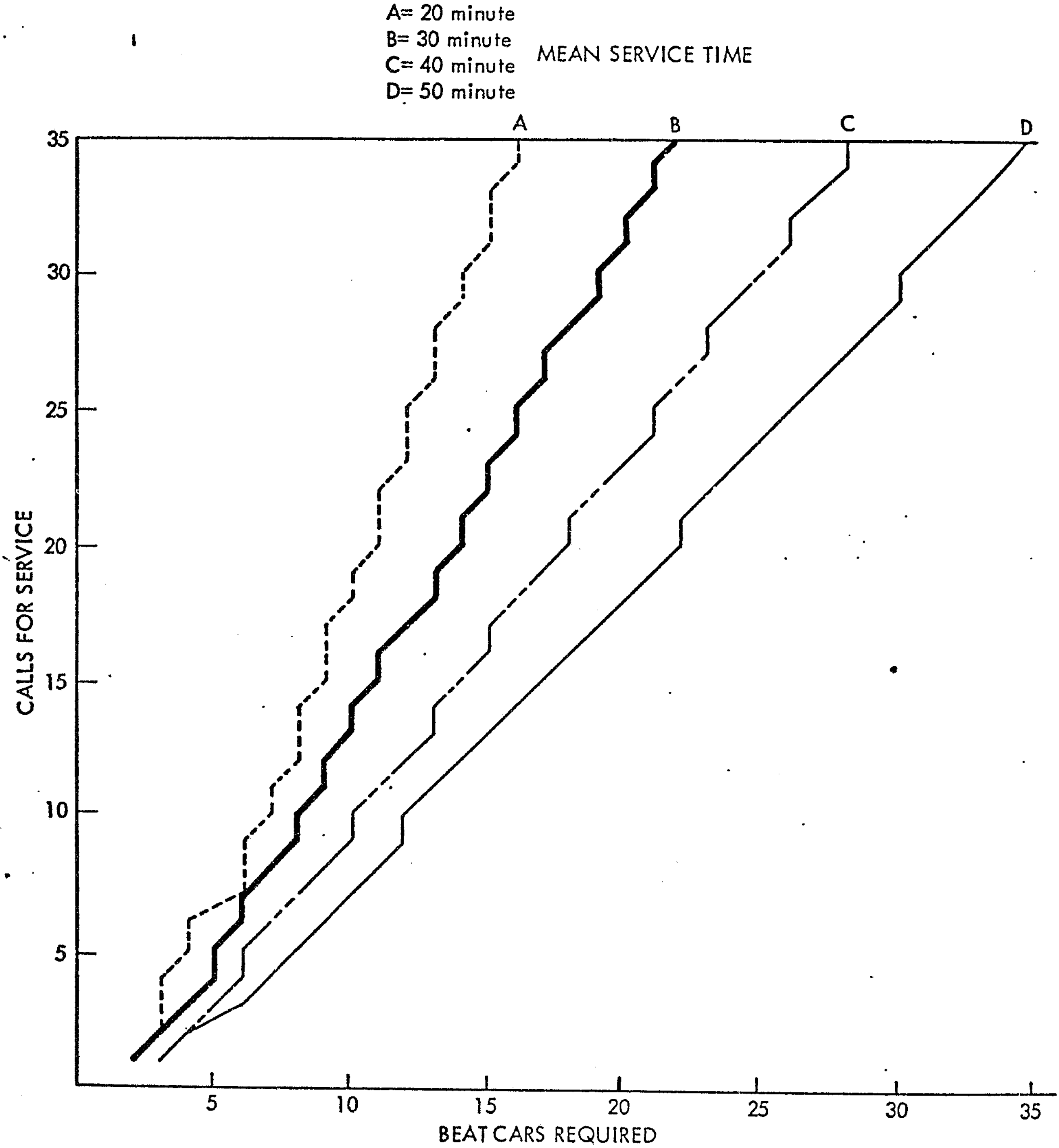


Figure 9.9

. Number of cars needed to limit average wait for available car to 0.10 minutes (6 seconds)

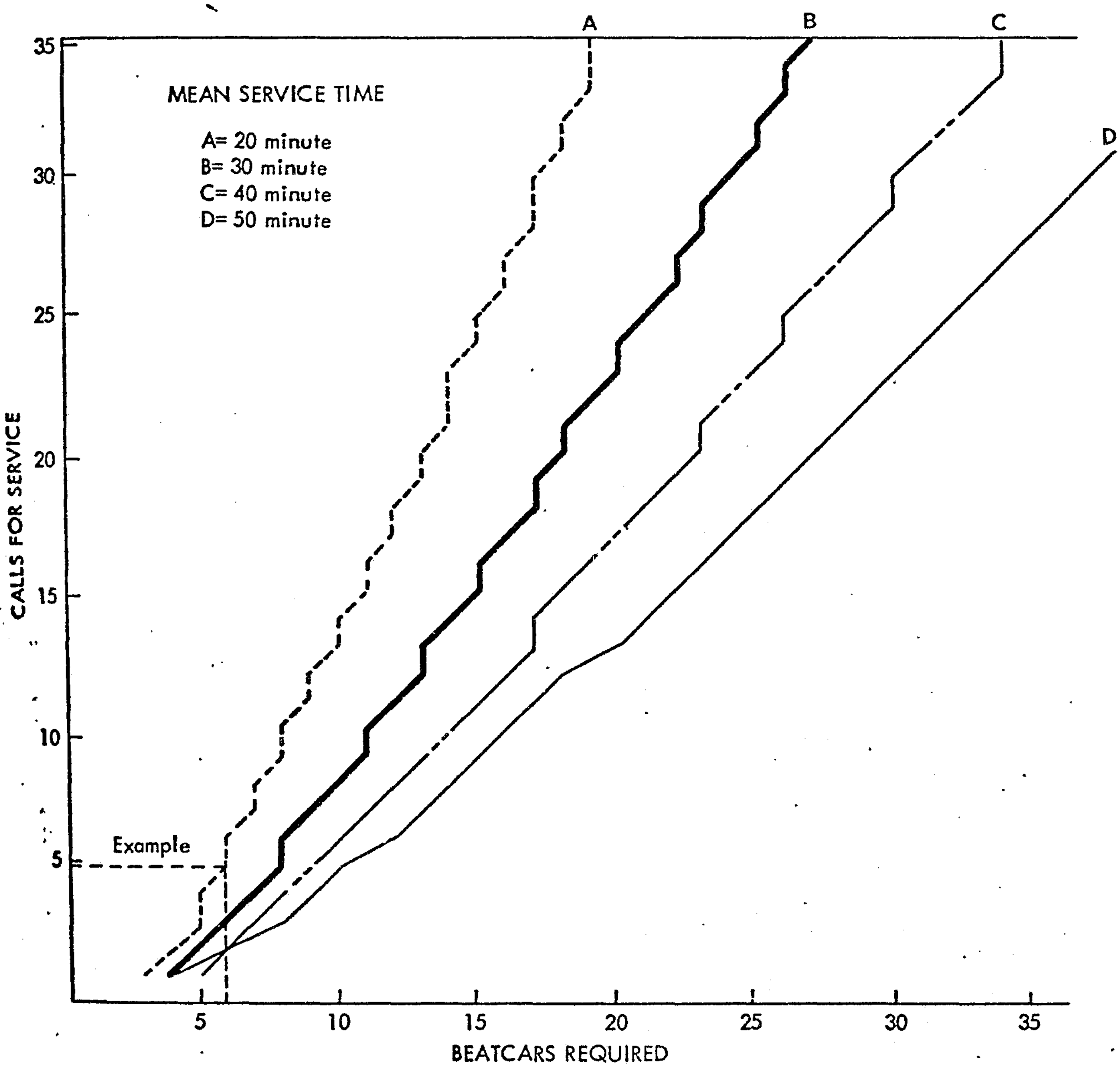
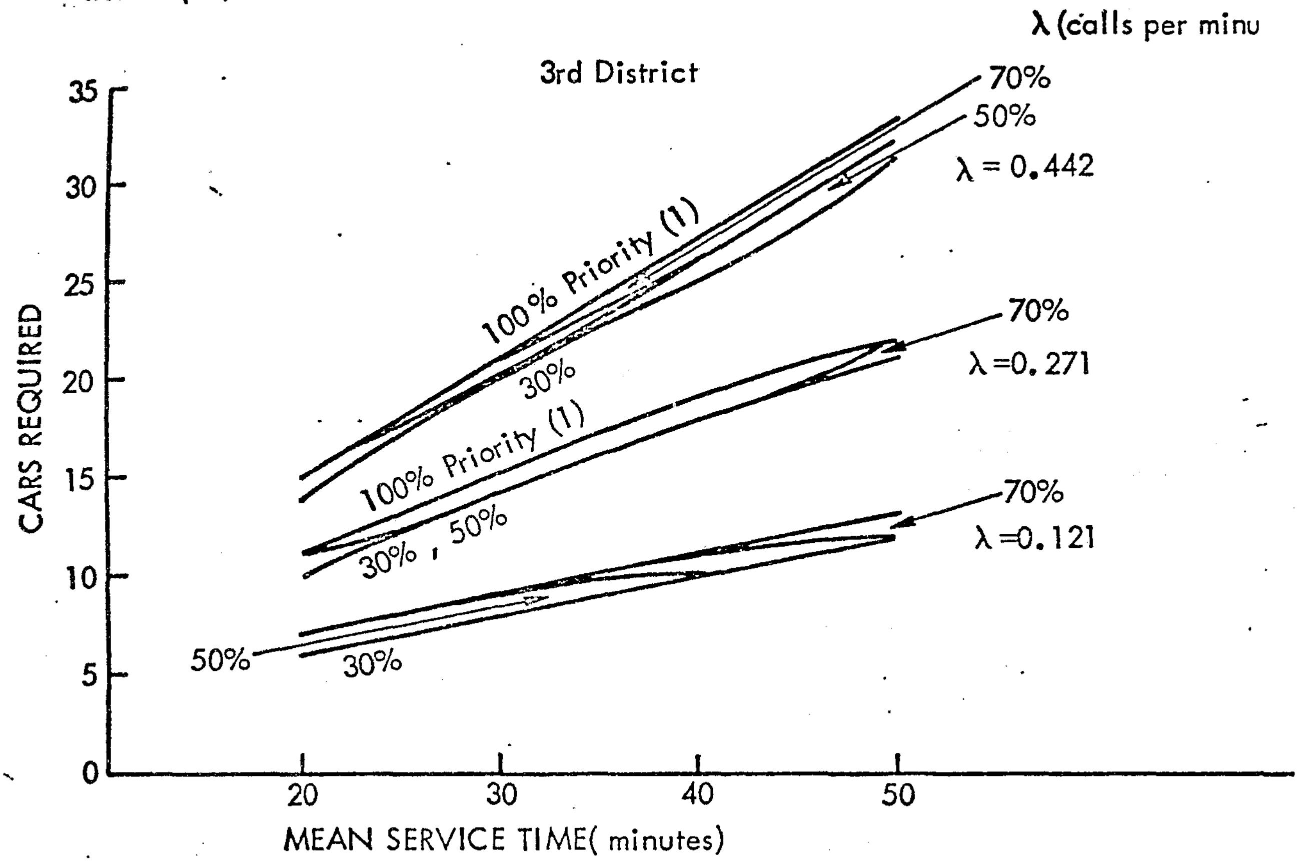
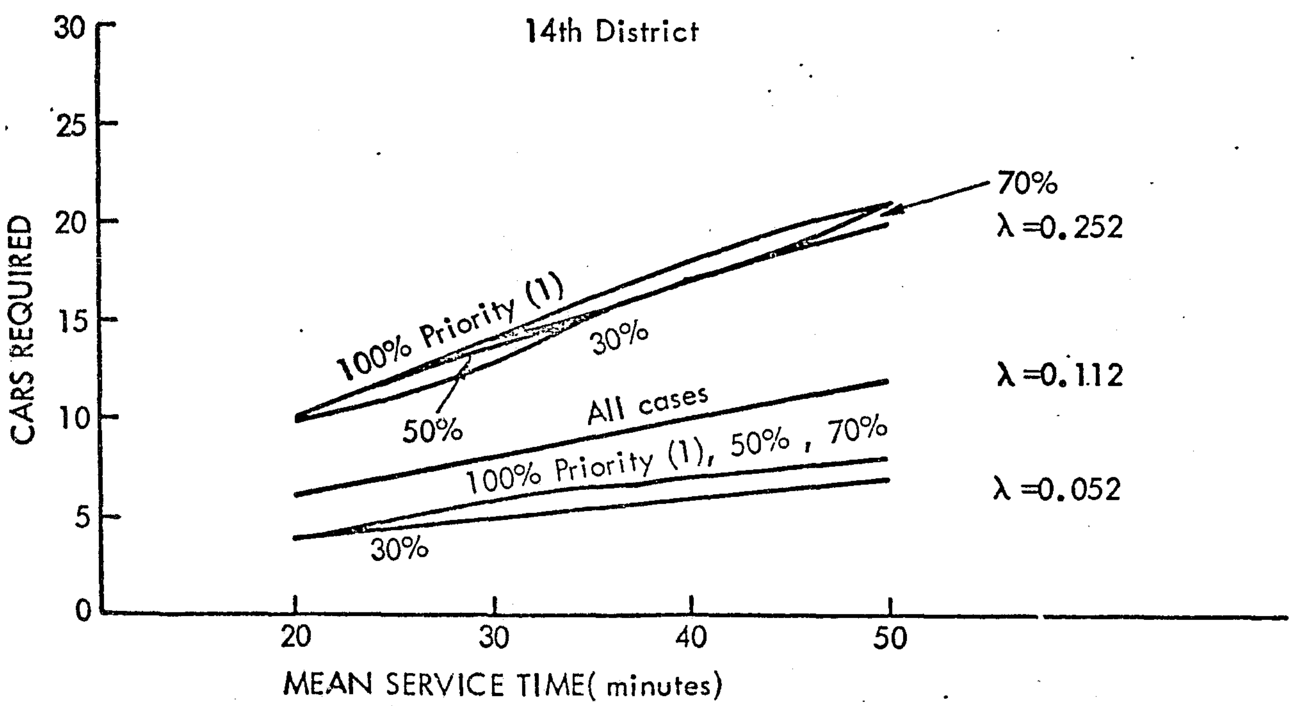


Figure 9.10

Cars Required to Insure An Available Car for all Priority (1) calls within (10) seconds





d. The use of CAS virtually eliminates the time to transmit a call for assistance to the police or other response agent.

e. Work-scheduling and allocation algorithms are presently available to help reduce the other components of response time, but are not in widespread use.

f. With present resources and allocation procedures, it is unrealistic to expect a total response time of less than 4 to 5 minutes, for the highest priority calls, assuming an average urban police district.

g. There is a wide variation in response capabilities between situations of average and peak workloads. In the latter case, response times may degrade significantly (by an additional factor of 10 minutes or more) because of the unavailability of police cars.

h. Significantly improved response time is desirable for a personal protection system such as CAS, especially when it is noted that an average robbery may last less than 5 minutes. This implies the use of guards and other response agents located close to large population clusters (e.g., housing complexes, communities, etc.), to support the capabilities of the police.

i. Response time is related to arrest probability in the manner shown in Section 8.

SECTION 10

ANALYSIS OF FALSE ALARMS

10.1 INTRODUCTION

The analysis of false alarms is an issue which has been explored by a number of different agencies. Most police departments have conducted "an analysis of false-alarm data" in an effort to understand the problems caused by the incorrect operation of alarms and security systems. Some data has also been collected by alarm industry organizations, such as The Alarm Industry Committee for Combating Crime. The parameter that is usually examined in such studies is the false-alarm ratio. General experience shows that the false-alarm ratio is almost always in excess of 90 percent and may approach 98 percent to 99 percent for systems which include automatic, digital dialers. There are three major problems with this present approach to the analysis of false alarms data. Firstly, the data collected by different organizations is collected in different formats, and the error in the data is large enough that the use of such data for any sophisticated analysis is questionable. Secondly, this data is usually collected over short periods of time, e.g., over a two week or four week period. This naturally limits the ability to relate the occurrence of false alarms to causes which may change with time and time-related variables. Thirdly, the false-alarms ratio can hardly be considered an adequate parameter for analysis. This is because, depending on location and circumstances, a system which is both effective and reliable may have a high false-alarm ratio merely because the number of real alarms is extremely small. To pick an absurd example, if a system with ten installations, over a period of five years causes a total of two false alarms and no real alarms, the false-alarm ratio is 100 percent even though the system may be more than adequate for a practical standpoint.

More recently, efforts have been made to consider parameters such as the false-alarm rate and the mean-time between false alarms. The Mitra Corporation recently released a report in which an analysis was performed of a burglary alarm network. The false-alarm ration was related to parameters such as the false dispatch ratio (dispatches made by the police to false alarm calls), and to the mean-time-between-false-alarms (MTBFA). It has been suggested in this report that the MTBFA may be a good measure of theperformance of an alarm network. The advantages and disadvantages of such an approach will be discussed in the following section.

10.2 FALSE ALARMS ANALYSIS OF FIDELITY DATA

Fidelity Security Systems, Inc. is a UL approved central station. Fidelity is in the business of installing alarm systems and monitoring the signals received from these systems. Fidelity is an independent operation which in the last five years has tripled in size. Fidelity's operation is different from other operations its size in a number of ways. First, most of its central station alarm systems are supervised on direct telephone lines (the Bell System), as compared to McCulloh systems. Over 95 percent of Fidelity's business is in burglary alarm installations, i.e., a very small fraction is in fire and other alarm systems. Another factor which distinguishes Fidelity is the nature of the area served by it. Pittsburgh is a city with a small core population, with a large number of its working force residing in the suburbs outside the city. Topographically, the city is hilly. The intersection of three rivers and the presence of a large number of bridges introduces unusual factors in the response of the police or guards to an emergency. Fidelity has comprehensive records on its alarm data, both real and false alarms, dating back two years. In an effort to take a more serious look at the false alarm data maintained by central station operations and the relevance of such data to CAS development, Compu-guard decided to perform an analysis of six months of Fideltiy data.

The six month period from January through June 1973 was considered. Data on real alarms, false alarms, repair calls, guard response time, and police response time was taken directly from the central station logs, runner dispatch cards, and service call sheets. The analysis was aimed at finding the number and causes of alarms, the time interval between alarms, and any correlation between the number of alarms and temporal variables.

The alarm data was coded, key punched and entered onto a data file on the Carnegie-Mellon University IBM 360/67 computer system. The analysis was done on the 360 and many of the outputs were plotted directly on computer. Prior to an actual discussion of the results, it may be worth examining some definitions. Real alarms were considered to be classified in nine different ways: burglaries, hold-ups, parking lot violations, fires, vandalism, attempted burglaries, arson, medical accidents, and others. False alarms were classified as being those alarms in which a runner (guard or police) was dispatched to the scene of the emergency, but no evidence was found of an attack on the system. False alarms can be classified as belonging to one of three groups depending on the origin of the false alarm call: whether it originated from a burglary alarm system, a hold-up system, or from a failure in the test of the system. This third classification requires some explanation. Often when an alarm system must be tested and set, either during the opening in the morning or the closing in the evening, the system may not function correctly. In such cases there are two alternatives. If the central station recognizes that it is a system malfunction, then the situation is treated as a repair call. However, if the central station is unable to recognize this, a guard (also known as a runner) is sent out and the situation is classified as a false alarm. Thus all the calls for service may be classified either as real alarms, false alarms, or repair calls. Real alarms and false alarms are characterized by the fact that a guard is sent out immediately when the alarm is received. One major factor in the classification of false alarms are the situations in which a runner is dispatched and then recalled, because the central station has identified the alarm as not being valid. Depending on the criteria used, and this is a gray area, these situations may or may not be classified as false alarms. Compu-guard has considered both alternatives in computing parameters such as the false-alarm ratio. The choice of either alternative then rests with the reader.

False alarms may be caused by a number of factors. The seven primary causes of false alarms that were considered by Compu-guard are defined below:

a. User Error - An alarm caused by client neglect, carelessness, accident, or lack of knowledge of the system. This includes employees, family members, and pets.

b. Design Failure - Failure of the design to cope with environmental factors.

c. Equipment Failure - Any failure of installed equipment in operation.

d. Installation Error - Any failure because of improper installation or improper initial adjustment.

e. External - Failure of telephone lines or power lines.

f. Other - Cause known but did not fit into any of the above categories.

g. Unknown - Lack of data for positive identification.

There are some situations in which Fidelity may be unable to send its own guard or may consider it prudent to have the police respond immediately. The six month analysis shows that in 73 percent of the false alarms, the response agent was a Fidelity guard. Only in 42 percent of the situations was the response from the police. The sum of these two figures adds up to more than 100 percent, because in some situations both the guard and the police may respond.

It is interesting to look at the distribution of true alarms by type of crime. This is presented in Table 10.1. In terms of false alarms, about 97.5 percent were due to burglar systems and only 2.5 percent due to hold-up systems. The total number of false alarms and the distribution by type and by cause is given in Tables 10.2 and 10.3. These numbers must be viewed in conjunction with the fact that Fidelity had an average of 459 central-station alarm systems installed. As will be seen in Table 10.3, user error is the largest single known cause of false alarms, representing 33.5 percent of all false alarms. Given the sensitivity of the total false alarm rate to user error, this particular factor was examined in further detail. Given below are the nine primary reasons for the occurrence of "user-error false alarms," with details in Table 10.4

a. Early Opening - Going to day-setting before the usual time without notifying the central station (CS).

b. Late Closing - Staying on day-setting past the normal closing time without notifying CS.

c. Irregular Opening - Reentry into the building without notifying CS.

d. Improper Closing - Closing the building and neglecting to set the system for the night.

e. Exterior Door or Window Open - User left the building and neglected to close either an exterior door, window, or the garage door.

TABLE 10.1: TRUE ALARMS BY TYPE

Types of Crimes	Number of Crimes	Percentage of Total
Burglary	15	16.7
Holdup	5	5.5
Parking Lot Violations	12	13.4
Fire	6	6.7
Vandalism	24	26.7
Attempted Burglary	15	16.7
Arson	3	3.3
Medical/Accident	2	2.2
Other	8	8.9
	90	100.00

Table 10.2

CLASSIFICATION OF FALSE ALARM, BY TYPE

Type	Number of False Alarms A	Number of False Alarms B	% of Total
Burglary	921	1064	97.5%
Holdup	24	27	2.5%
TOTAL	945	1091	100.0%

A = excludes situations in which runners were recalled

B = all situations

Table 10.3

CLASSIFICATION OF FALSE ALARMS, BY CAUSE
(A: 1091 False Alarms, all situations)

1	Unknown	58.4%
2	User Error	33.5
3	Weather/Environment Susceptibility	3.1
4	Equipment Malfunction	1.6
5	Installation	0.1
6	Transmission Line (external)	0.2
7	Other	3.0
	TOTAL	100.0%

TABLE 10.4
DISTRIBUTION OF FALSE ALARMS DUE TO USER ERROR
(A: all situations)

Cause	%
Unknown	4.1
Early Opening	0.8
Late Opening	0.3
Irregular Opening	7.4
Improper Closing	13.4
Unauthorized Personnel	1.6
Door Or Window, Exterior Left Unlocked	18.3
Accidental or Malicious	31.7
Improper Opening	14.3
Door, Interior, Unlocked	4.4
Other	1.6
User Threshold	1.9
TOTAL	100.00

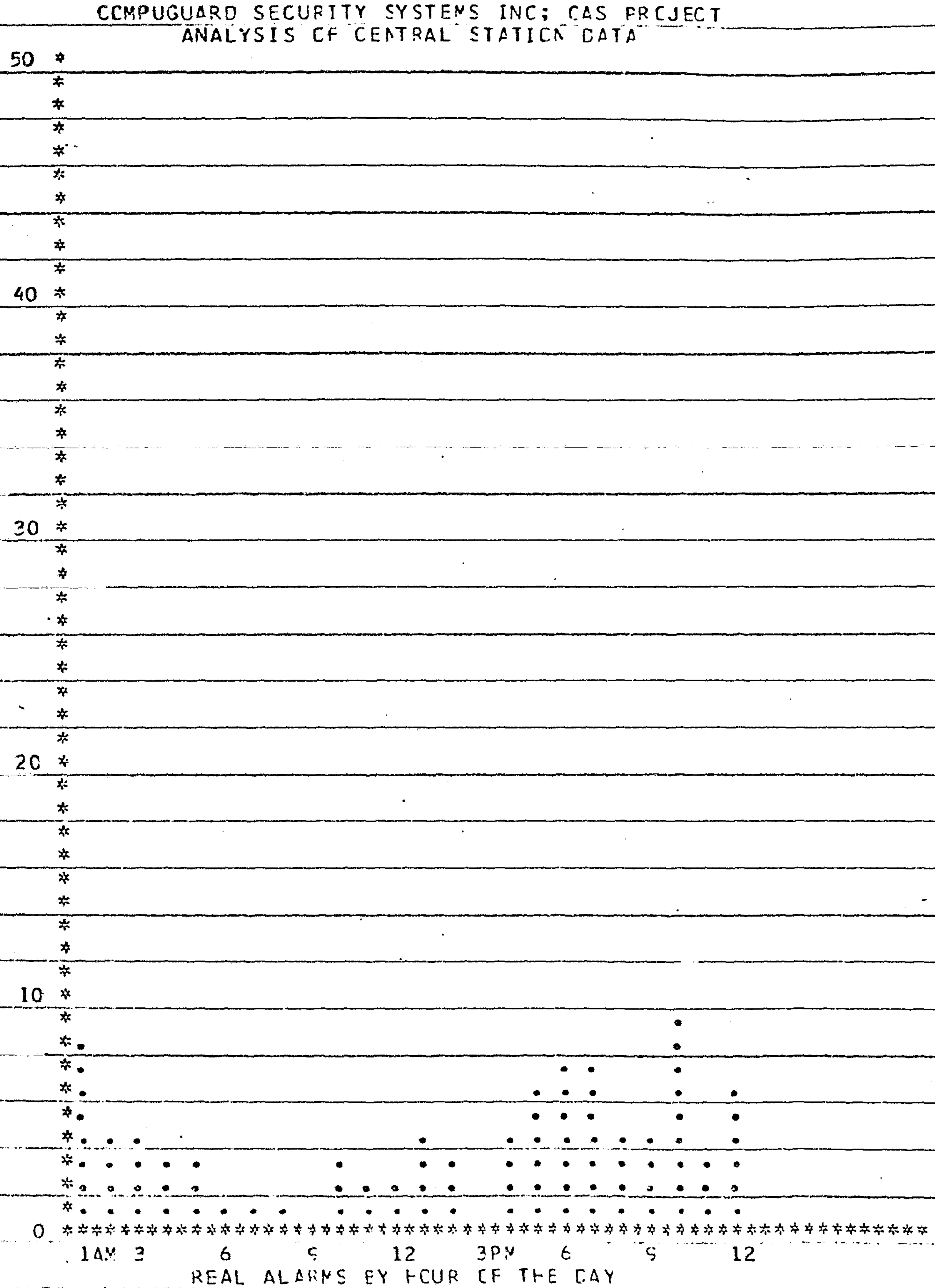
f. Accidental - Any accidental act that results in an alarm condition.

g. Improper Opening - Entering the building at the normal opening time but neglecting to set the system for day.

h. Interior Door Open - User left the building and neglected to close an interior door.

i. Threshold of Emergency - This in reference to the hold-up alarms and is an alarm triggered by an employee who feels, incorrectly, in imminent danger of a hold-up attempt.

The distribution of real alarms, false alarms (A: all situations), and repair calls by hour of the day is shown in Figures 10.1, 10.2, and 10.3. Similar distribution by day of the week is shown in Figures 10.4, 10.5, and 10.6. Monthly distribution is given in Figures 10.7, 10.8, and 10.9. A number of interesting observations may be made from these graphs. Most of the real alarms occurred in the evening or night. This is expected since most of the premises protected are small businesses. The false alarm rate tends to peak between 6 and 8:00 p.m. at night, suggesting that irregular closings are a significant contributor to the false alarm rate. Also, the total number of false alarms between 4:00 p.m. and 4:00 a.m. is substantially greater than the number between 4:00 a.m. and 4:00 p.m. The distribution of alarm calls by day shows that Sunday is the big day for real alarms. The number of real alarms on Sunday is almost twice that on any other day and is followed by Saturday and Thursday. The variations in the false alarms by day are not quite as significant. The month-by-month analysis shows that there has been a steady increase in the number of real alarms received between January and June 1973. The behavior of the false alarm rates per month is more erratic. In addition to the figures presented for real alarms and false alarms, information



CCMPUGUARD SECURITY SYSTEMS INC; CAS PRCJECT
ANALYSIS CF CENTRAL STATICN DATA
50
40
30
20
10
0
1AM 3 6 9 12 3PM 6 9 12
REAL ALARMS BY HCUR CF THE DAY

Figure 10.1

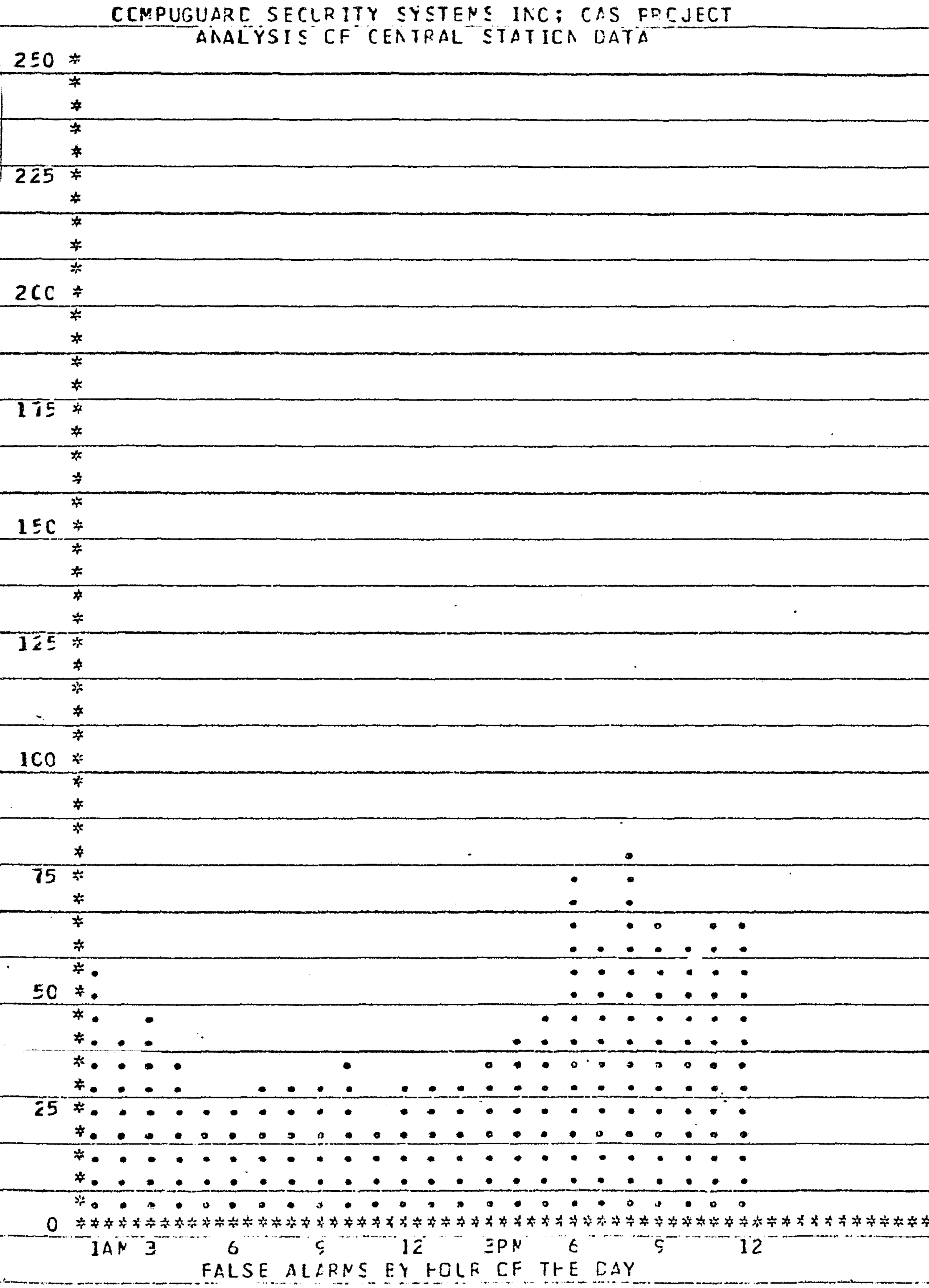

COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA
250
225
200
175
150
125
100
75
50
25
0
1AM 3 6 9 12 3PM 6 9 12
FALSE ALARMS BY HOUR OF THE DAY

Figure 10.2

COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA

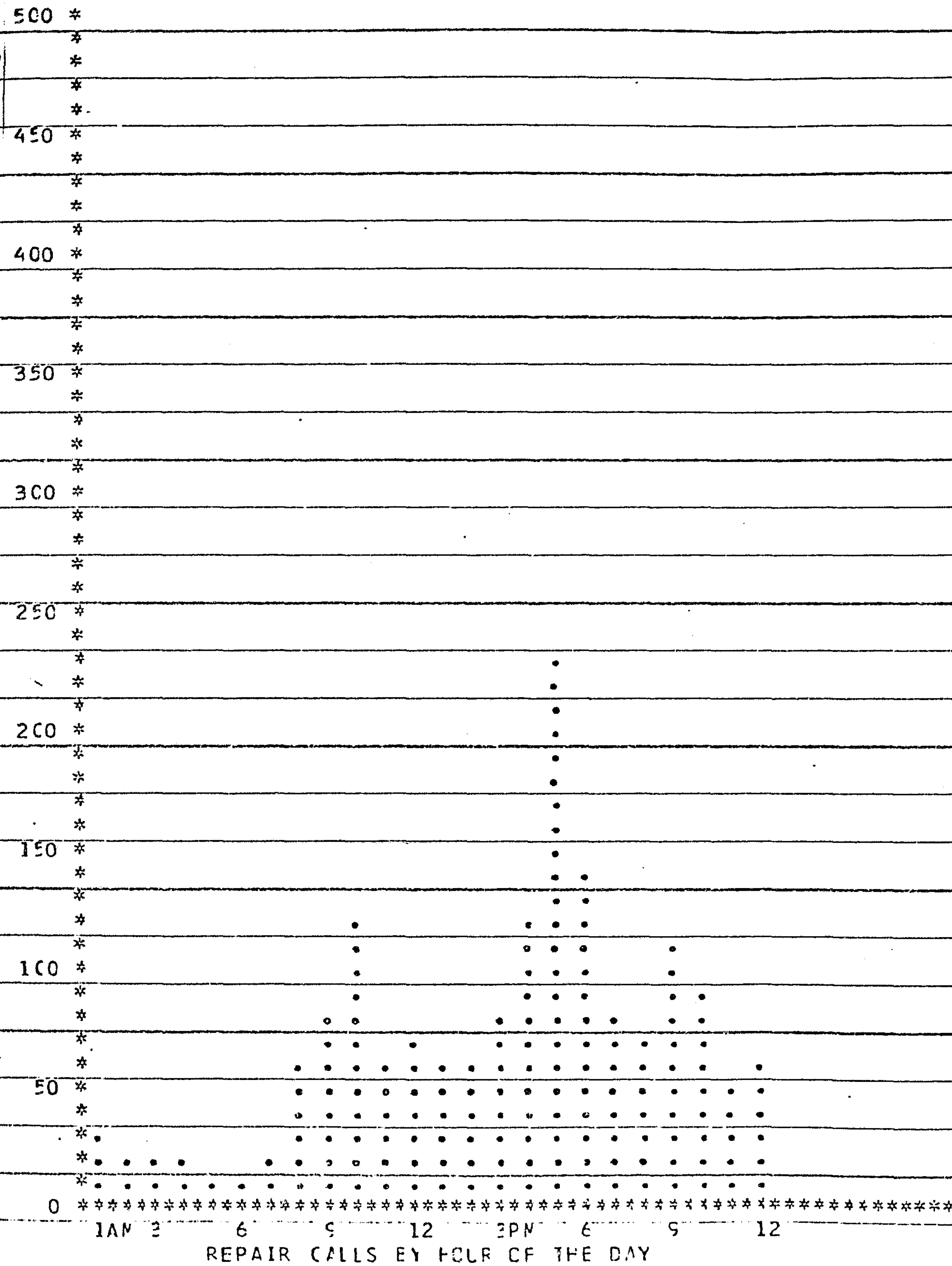


Figure 10.3

COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA

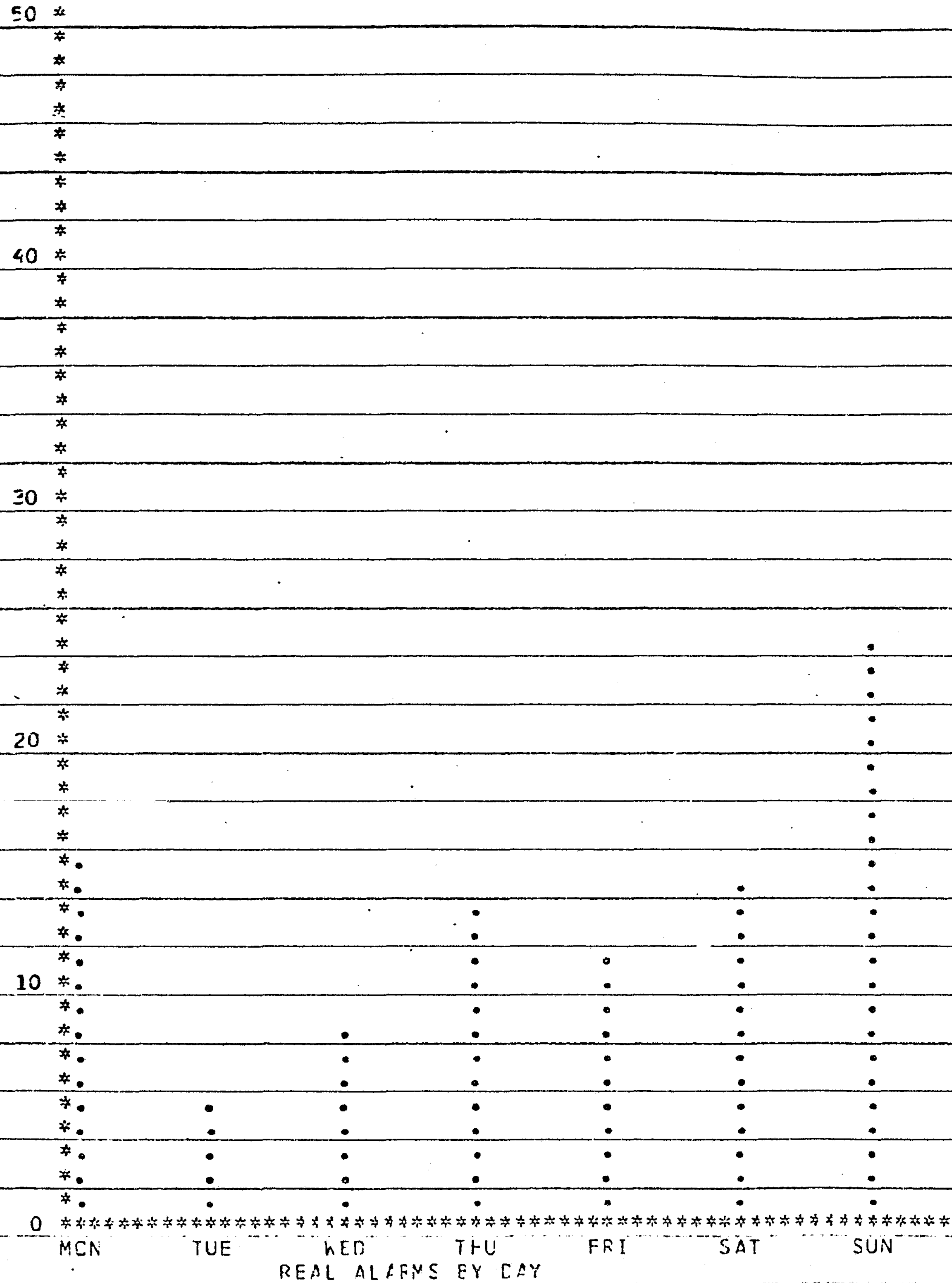


Figure 10.4

COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA

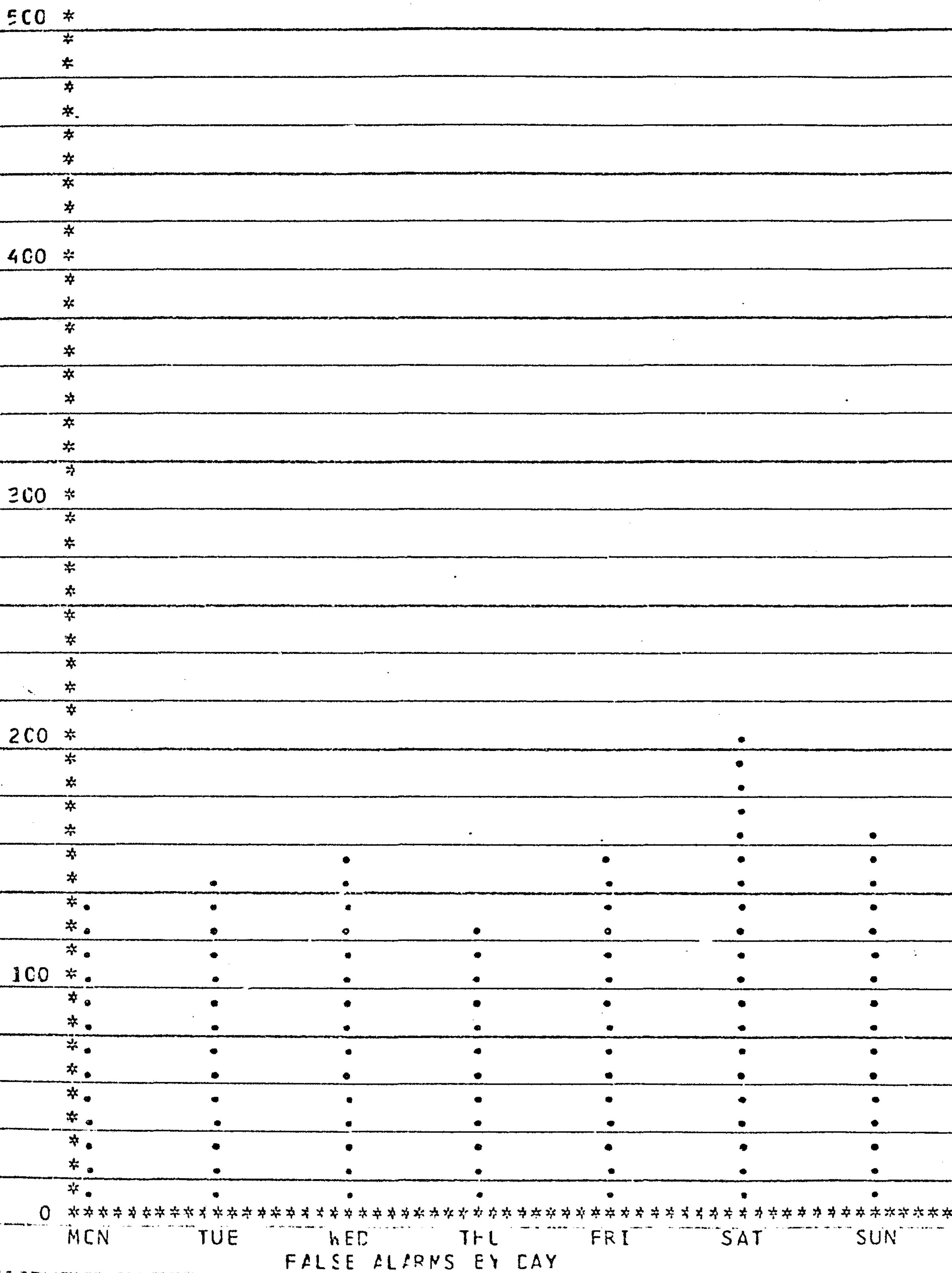


Figure 10.5

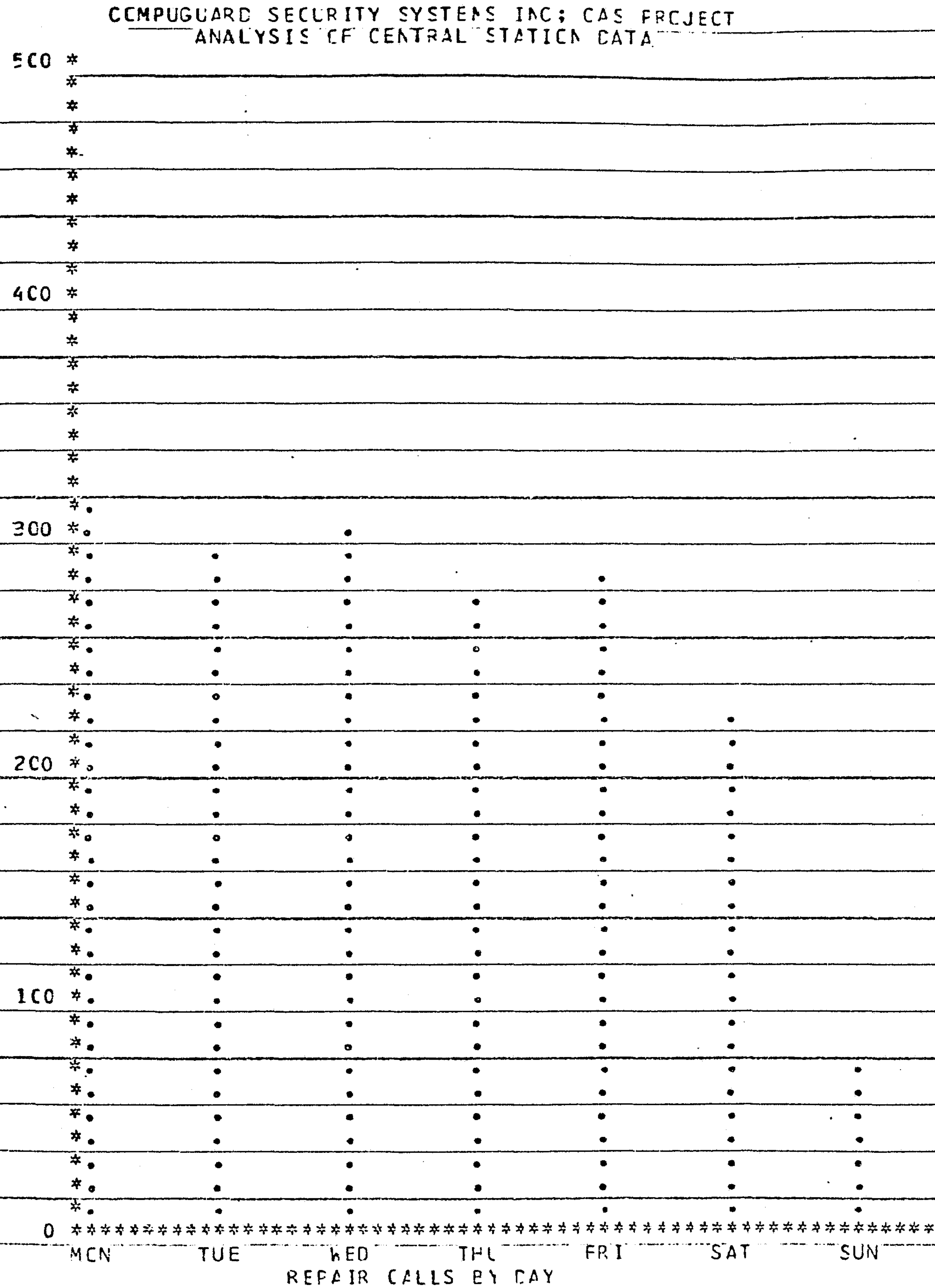
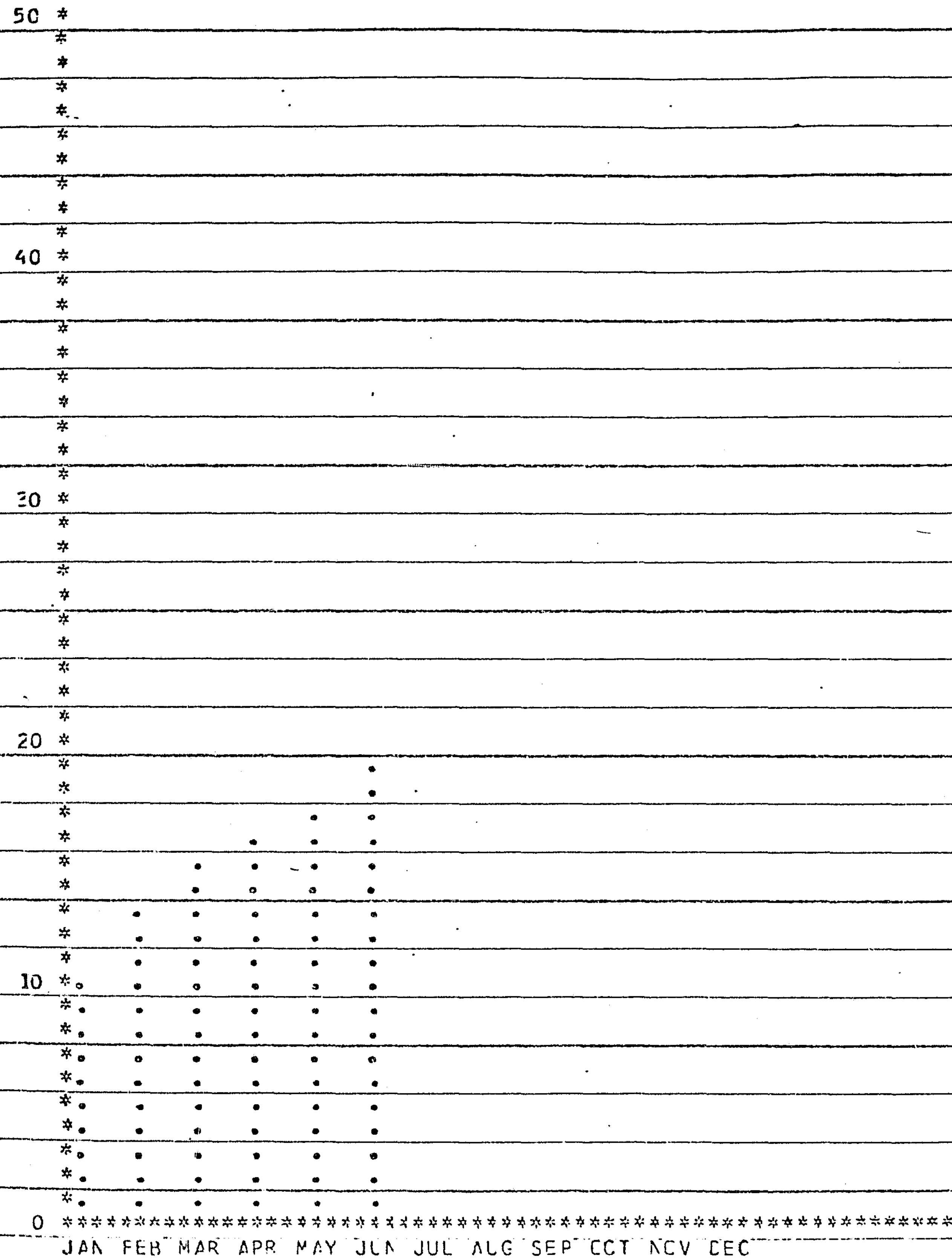

COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA
500
400
300
200
100
0
MON
TUE
WED
THU
FRI
SAT
SUN
REPAIR CALLS BY DAY

Figure 10.6

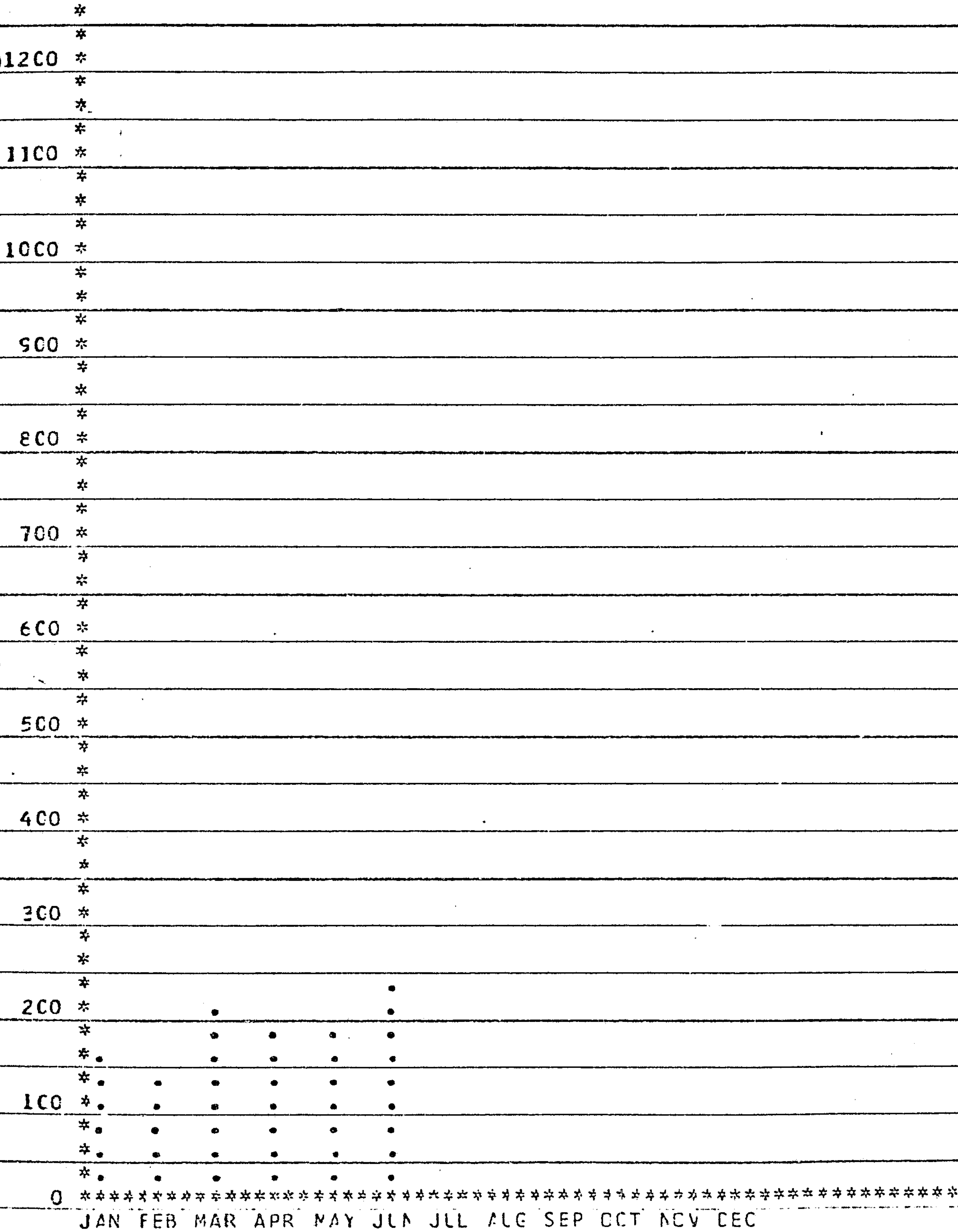
COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA



REAL ALARMS BY MONTH

Figure 10.7

COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA



FALSE ALARMS BY MONTH

Figure 10.8

COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA

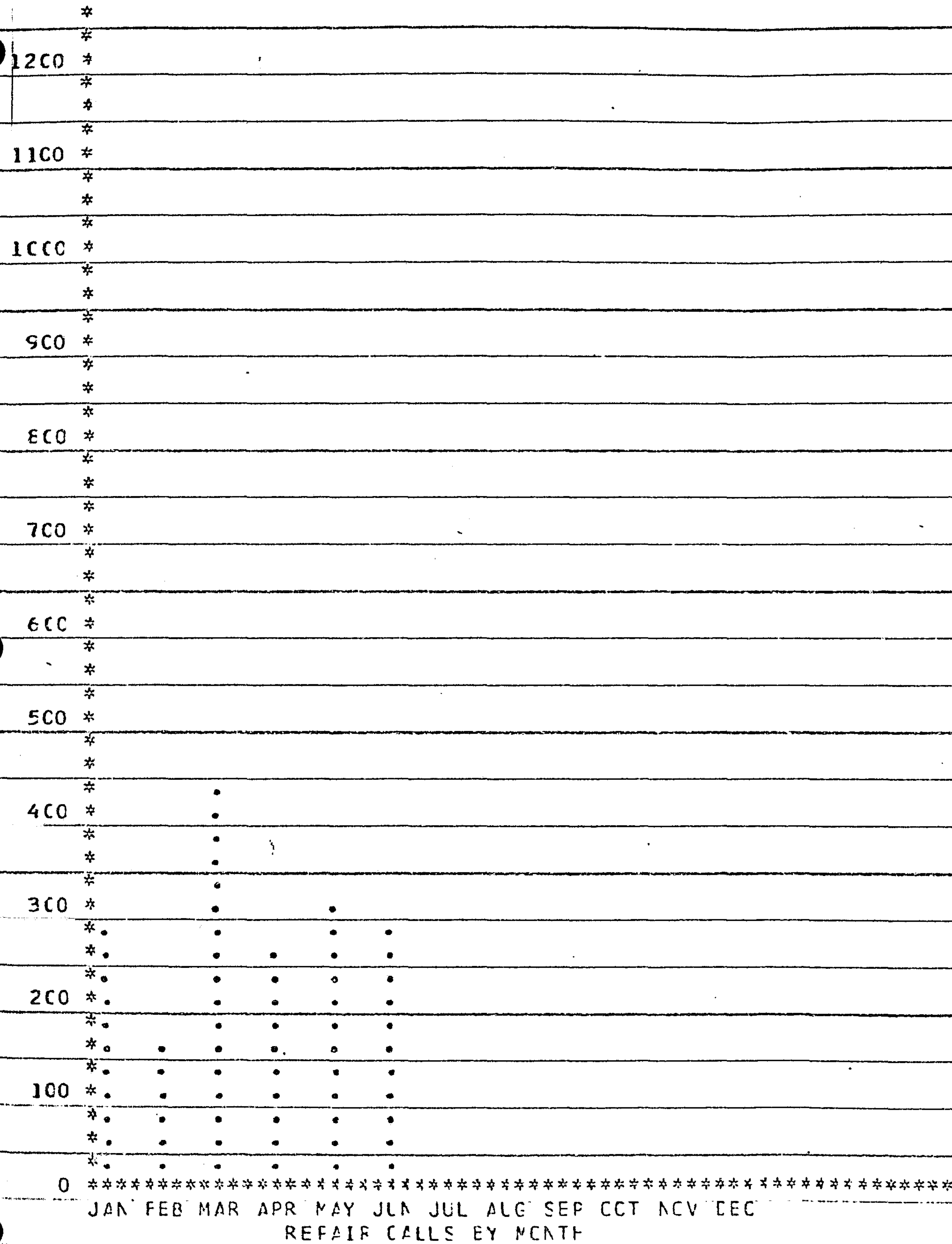


Figure 10.9

has also been provided on the number of repair calls as a function of temporal variables. Presently no direct application has been made of this information on repair calls. However, it is expected that such information will lead, in the future, to an analysis of the reliability of the devices and components installed and in operation.

One very significant fact does emerge from the observations discussed above. The variations in the false alarm rate as a function of hour of day, day of week and month of year, indicated that MTBFA is also a function of these temporal parameters. In fact, this six month analysis shows that the MTBFA may vary by a factor of two or three, depending upon the point in time (see Table 10.5). It has been suggested that MTBFA can be used directly as a measure of the performance of a burglar alarm network. This would be valuable if the MTBFA was a static parameter, more or less independent of time. As the analysis of Fidelity data shows, this is not the case. The very fact that the MTBFA may change by a factor of two or three because of non-network variables suggests that any actual change in a static MTBFA parameger would be difficult to attribute to any one particular cause, i.e., changes due to network variables from changes due to non-network variables such as the temporal parameters.

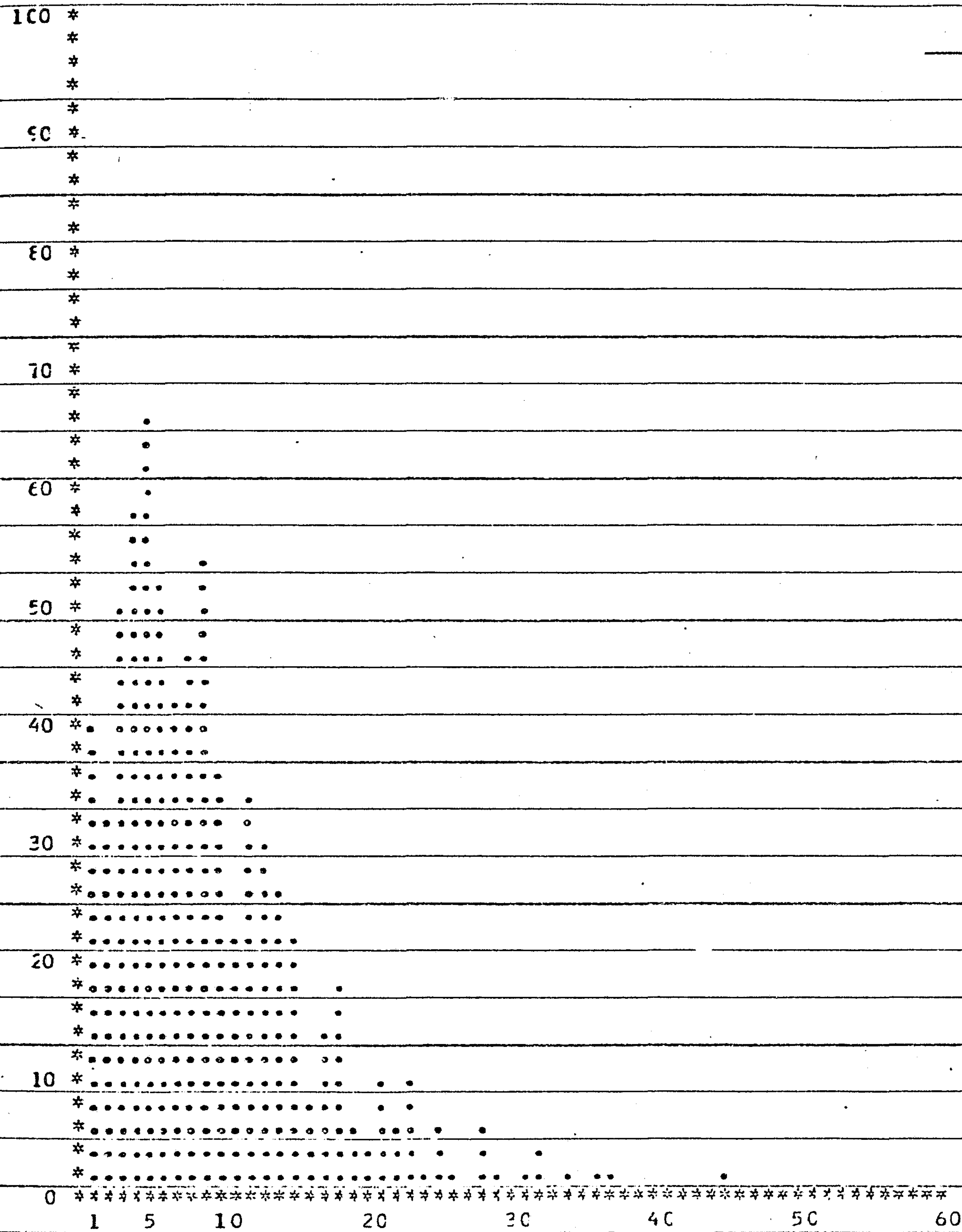
For the six months of data collected, the calculated average mean-time-between-false-alarms in any given month is presented in Table 10.4. In addition, Compu-guard has developed graphs of the MTBFA as a cumulative probability distribution function. Three such curves for the months of January, February, and June arepresented as Figures 10.10, 10.11, and 10.12 respectively. Curves of this kind may be more representative of the MTBFA function than a single pseudo-deterministic parameter. Additional research must be conducted to help identify the best representation of all the parameters relevant in the characterization of an alarm system network.

TABLE 10.5

DISTRIBUTION OF ALARMS BY CAUSE
(AICCC Study)

Cause	Percent
1. Internal Any alarm initiated at the protected premises caused by other than intruders, property damage, or equipment malfunction. This category includes user error at the protected premises	41%
2. Alarm Installation Equipment Malfunction Any alarm initiated by malfunction of the alarm equipment installed on the premises	23%
3. Unknown	19%
4. External Any alarm initiated in a place other than the protected premises	9%
5. Intruder or Property Damage Alarms caused by actual or attempted entry by an intruder or by damage to property detected by the alarm installation.	8%
	100%

COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA

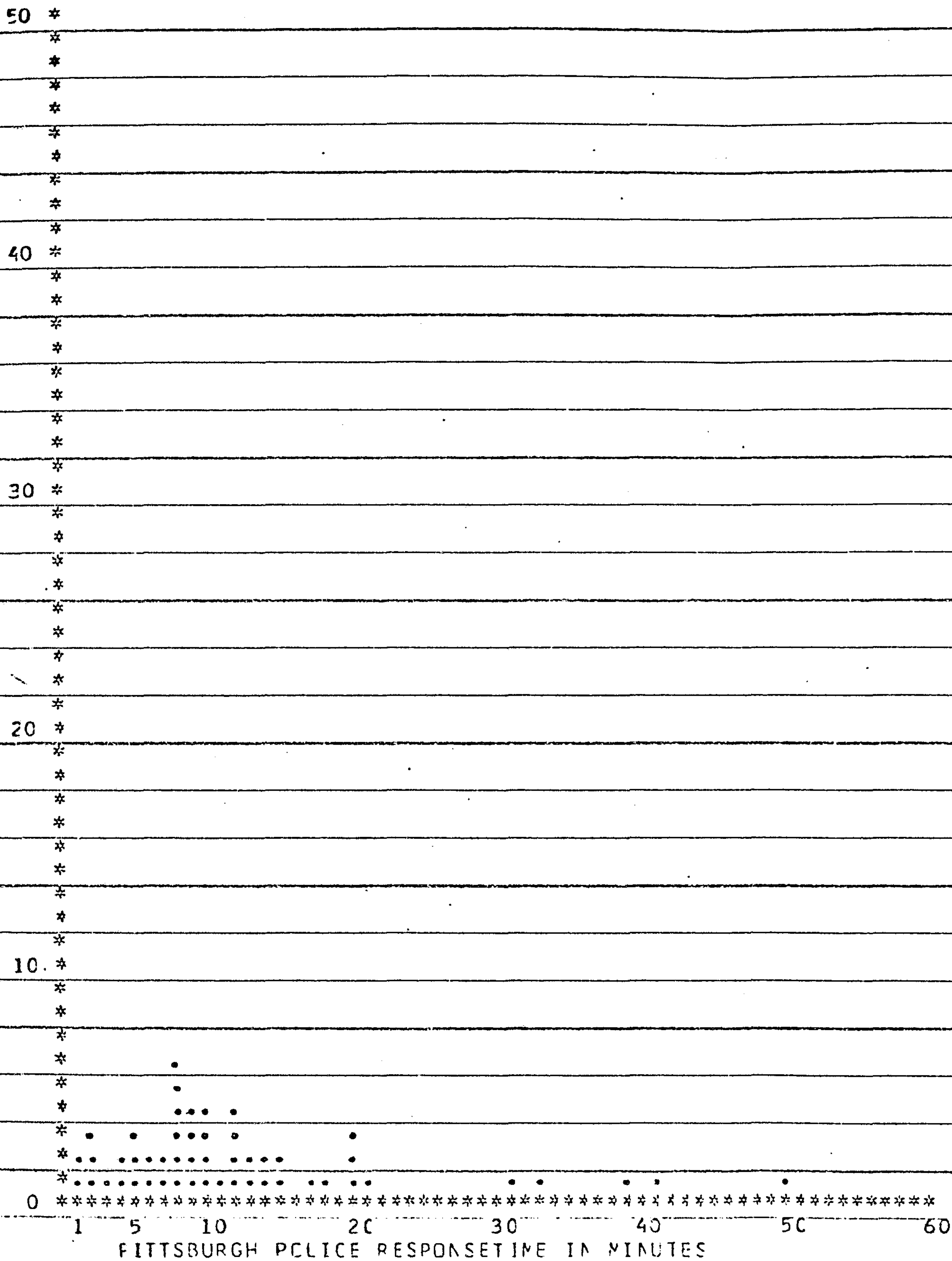


FIDELITY GUARD RESPONSE TIME IN MINUTES

NUMBER OF DATA POINTS= 745 AVERAGE RESPONSETIME= 10.16 MINUTES

Figure 10.10

COMPUGUARD SECURITY SYSTEMS INC; CAS PROJECT
ANALYSIS OF CENTRAL STATION DATA



N[illegible]ER OF DATA POINTS= 51 AVERAGE RESPONSETIME= 12.49 MINUTES

Figure 10.11

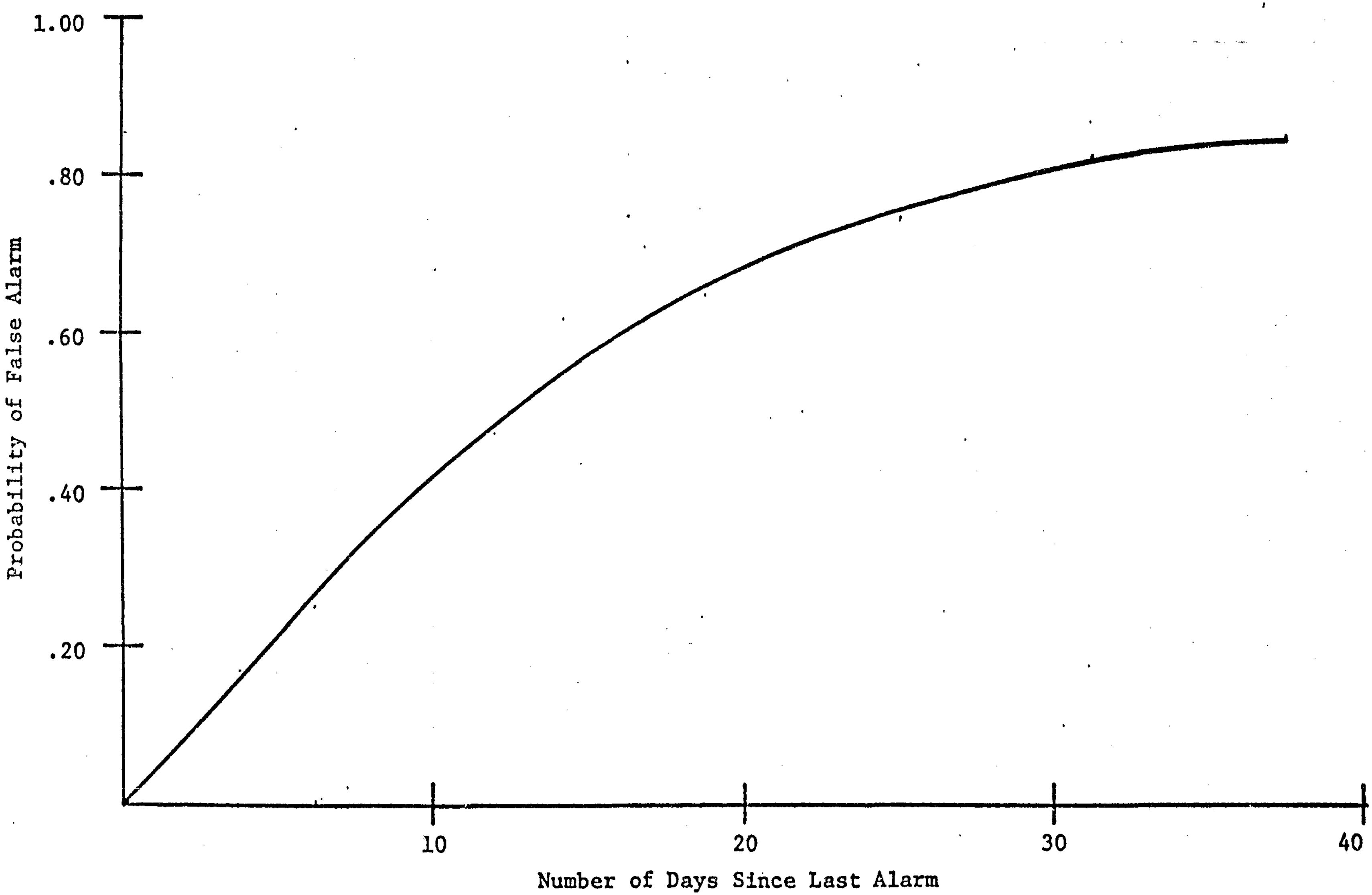


FIGURE 10.12 MTBFA AS A CUMMULATIVE PROBABILITY FUNCTION
FOR MONTH OF JANUARY

The analysis of Fidelity's data included a study of the response time of Fidelity guards and that of the Pittsburgh Police. The distribution of response time for these two response agents is shown in Figures 10.13 and 10.14. It is seen that the average response time for the Fidelity guards, from the time of notification of the central station of an emergency, to the time of the guard's arrival at the scene of the emergency, is a little over ten minutes. The corresponding response time of the Pittsburgh Police is 12.5 minutes. It is also interesting to look at the plot of the arrival time as a cumulative probability distribution function. These curves are presented as Figures 10.15 and 10.16.

10.3 FALSE ALARMS ANALYSIS OF OTHER DATA

Compu-guard conducted a thorough investigation of the false alarms data available from other sources. This data is very sparse and unreliable. Compu-guard does not place any great emphasis on this for specific analytic purposes, but some observations are presented below since these may be of general interest.

10.3.1 AICCC False Alarm Study.

The Alarm Industry Committee for Combating Crime recently conducted a survey of the cause of false alarms. They defined four major causes of false alarms: actual alarm, external alarm, internal alarm and equipment alarms. A distribution of these alarms by cause is presented in Table 10.5. These results were based on an analysis of 178 central stations with a total of 152,425 systems. Over a one month period, these systems resulted in a total of 38,898 alarms of which 2906 were actual alarms, leading to 634 captures. Since the internal alarms represent such a large percentage of the total causes of false alarms, the distribution of these causes of internal alarms is presented in detail, below:

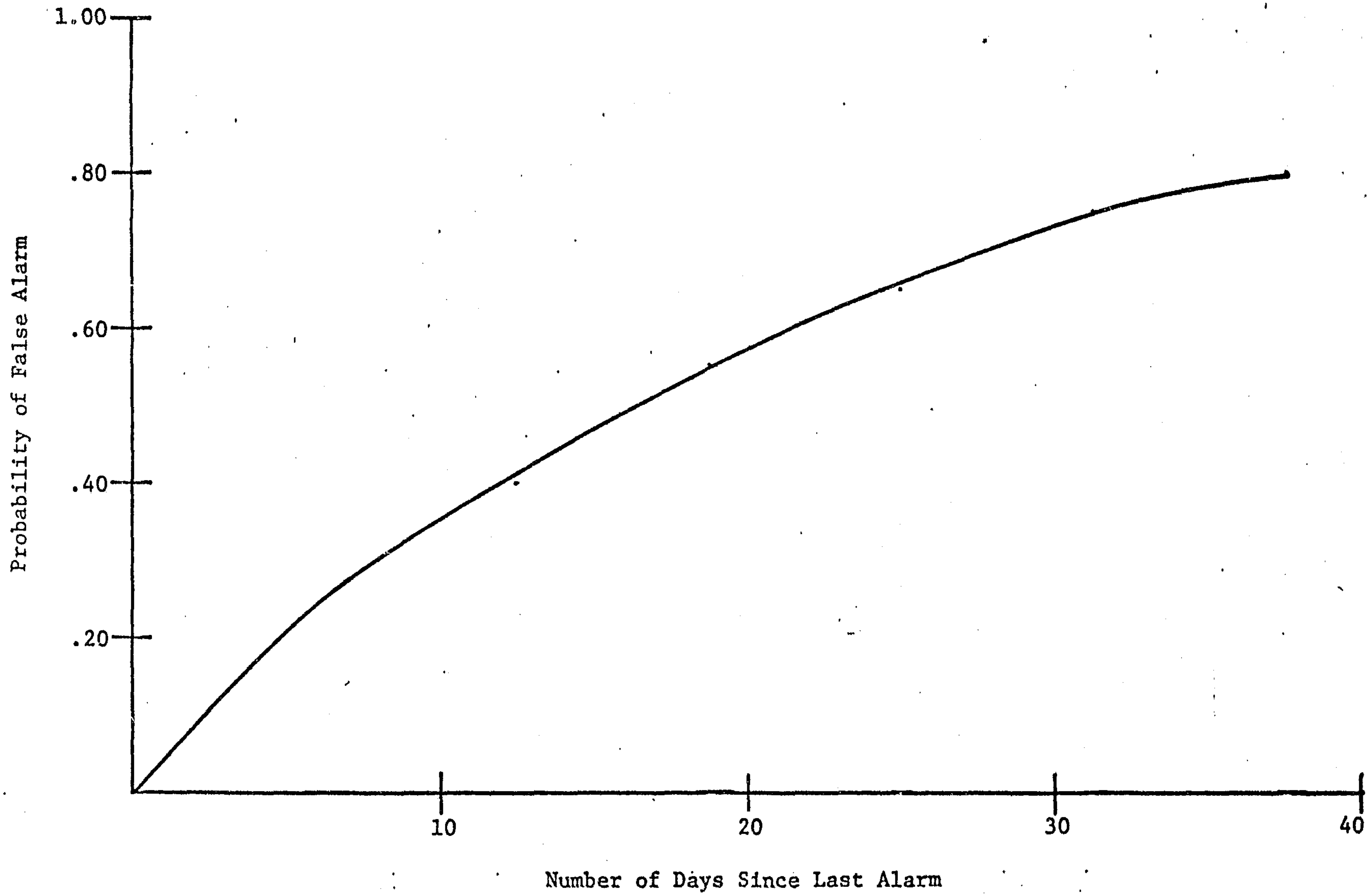


FIGURE 10.13: MTBFA AS A CUMMULATIVE PROBABILITY FUNCTION
FOR MONTH OF FEBRUARY

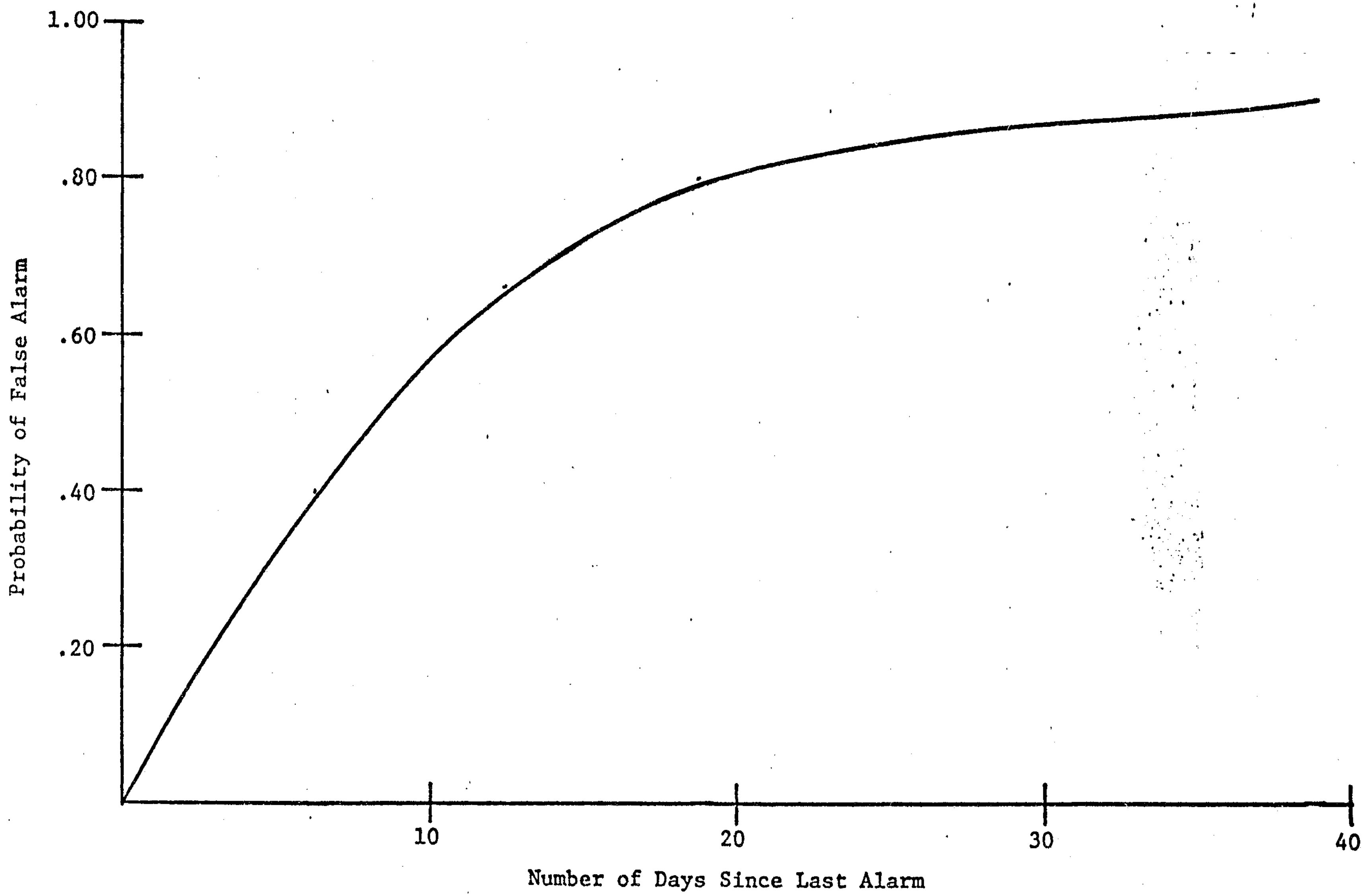


FIGURE 10.14: MTBFA AS A CUMMULATIVE PROBABILITY FUNCTION
FOR MONTH OF JUNE

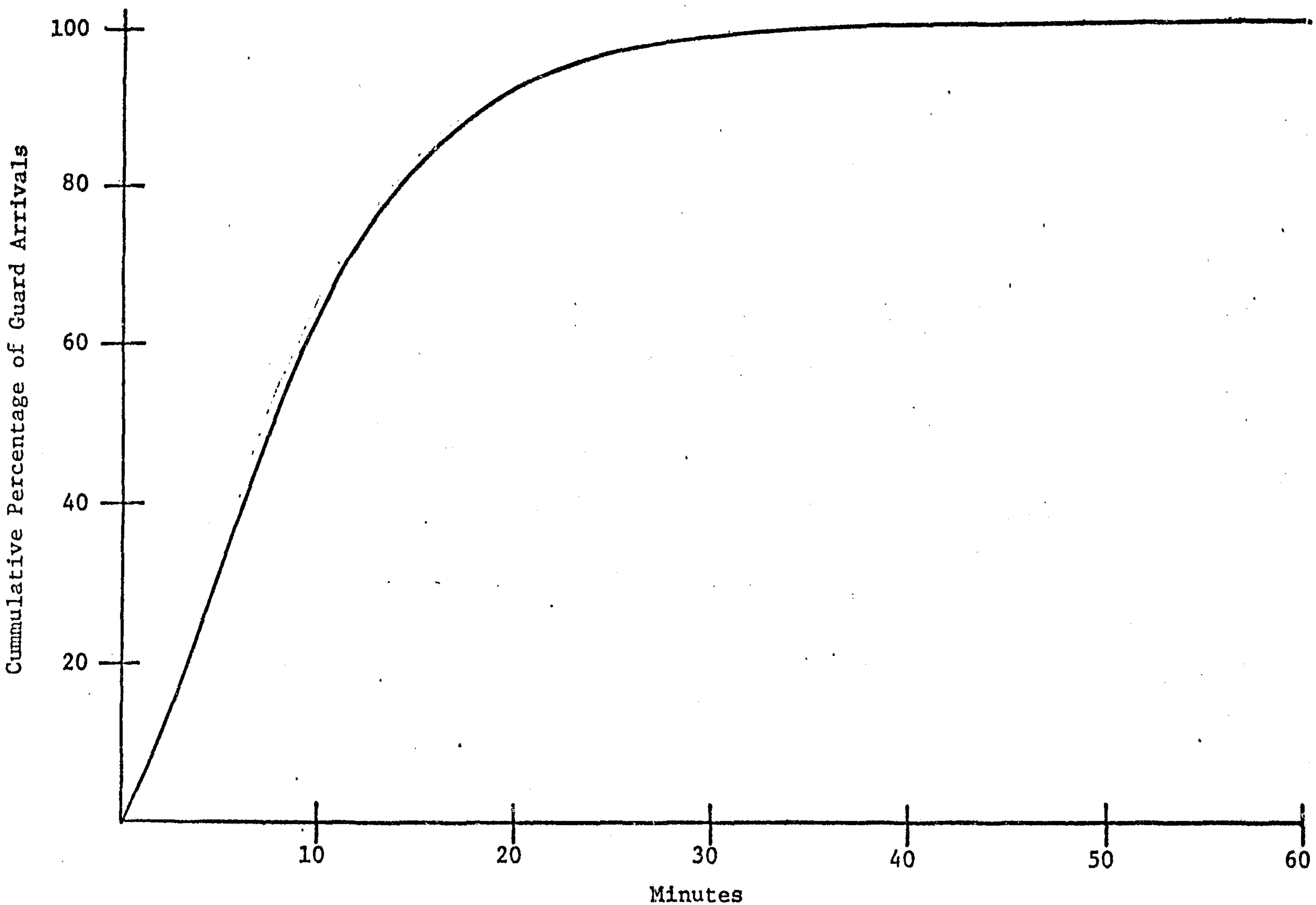


FIGURE 10.15: CUMMULATIVE ARRIVAL TIME
BY FIDILITY GUARDS

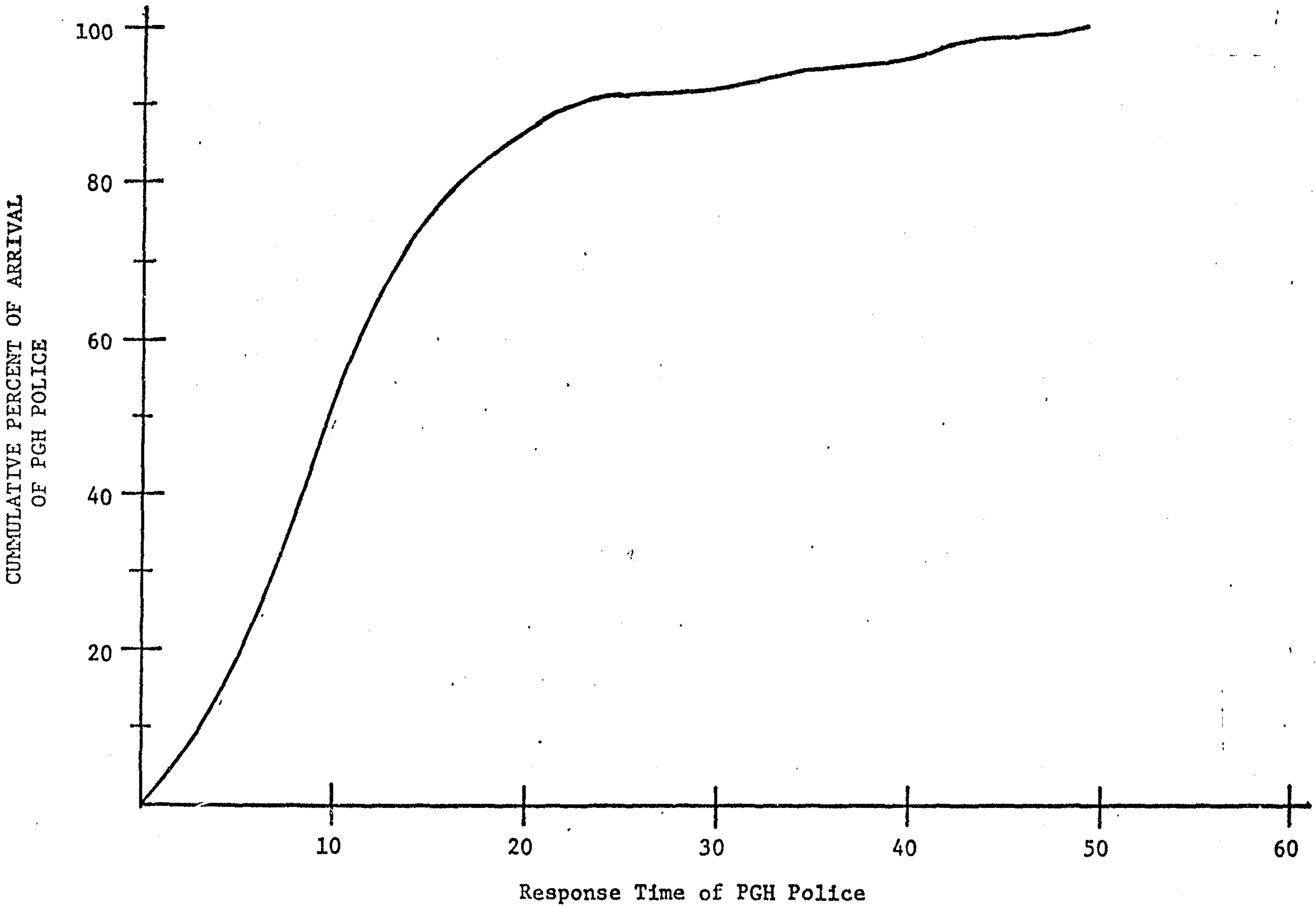


FIGURE 10.16: CUMMULATIVE ARRIVAL TIME
FOR PITTSBURGH POLICE

a.	Failure to lock doors or windows	21.2%
b.	Custodial or other personnel improperly entering secured areas	17.8%
c.	Improper operation by user	14.8%
d.	Failure to notify alarm company of change in procedure	12.7%
	TOTAL	66.5% of internal causes

10.3.2 All Other Data.

Figure 10.17 is a copy of a false alarm study conducted by the Crime Prevention Squad for the City of New York. Figure 10.18 is a copy of a false alarm report issued by the Seattle Police Department. Table 10.6 gives additional central station data issued by Underwriters Laboratories, Inc. which relates the number of captures to the number of attempts and the elapsed time in minutes since the triggering of central station alarm system. This can easily be converted into a plot of the probability of capture as a function of elapsed time in minutes.

10.4 CONCLUSIONS

A number of significant conclusions can be drawn from the data and the analyses presented in this section.

a) Available false-alarm data suffers from the problems of inaccuracy, inconsistency of formats, and the limited duration of the data-collection period. These factors make the use of such data for any sophisticated analyses questionable.

b) The analysis of Fidelity data, as presented, answers these three problems but is obviously limited for other reasons:

i. It is influenced by the topography and other factors unique to Pittsburgh.

ii. It is based on a relatively small number (457) of installed systems connected to the Fidelity central station.

Table 10.6

CENTRAL-STATION - NR CAPTURED / ELAPSED TIME

ELAPSED TIME (IN MINUTES)	NUMBER OF ATTEMPTS	PERCENT OF TOTAL	NUMBER CAPTURED	PERCENT OF TOTAL
1	26	0.7	10	1.2
2	58	1.7	29	3.4
3	103	3.0	32	3.7
4	137	3.9	55	6.4
5	177	5.1	57	6.6
6	202	5.8	40	4.7
7	241	6.9	61	7.1
8	243	7.0	48	5.6
9	226	6.5	42	4.9
10	346	10.0	68	7.9
11	201	5.8	45	5.2
12	178	5.1	48	5.6
13	158	4.6	41	4.8
14	129	3.7	31	3.6
15	128	3.7	37	4.3
16	92	2.7	21	2.4
17	83	2.4	11	1.3
18	66	1.9	28	3.3
19	72	2.1	16	1.9
20	55	1.6	23	2.7
21	40	1.2	7	0.8
22	38	1.1	14	1.6
23	38	1.1	8	0.9
24	32	0.9	7	0.8
25	34	1.0	12	1.4
26	22	0.6	1	0.1
27	20	0.6	4	0.5
28	21	0.6	8	0.9
29	19	0.5	3	0.3
30	20	0.6	7	0.8
OVER 30	215	6.2	33	3.8
UNREPORTED	46	1.3	9	1.0
TOTALS	3,470	99.9	860	99.5

POLICE DEPARTMENT
CITY OF NEW YORK

CRIME PREVENTION SQUAD

INFORMATION-TRAINING
BULLETIN NO. 6
FEBRUARY 21, 1972.

SUBJECT: FALSE ALARM RATE OF ALARM SYSTEMS.

1. The National Bureau of Standards maintains a " Law Enforcement Laboratory ", which works closely with the Law Enforcement Assistance Administration and tests various security devices and systems. At present, the laboratory is working in the following areas:

Protective devices - i.e. helmets, armor vests, etc.

Communications - police computers.

All types of alarm systems.

Intrusion Alarms.

Security Hardware, i.e. locks, screens, etc.

2. A prime problem of security alarms and devices is the false alarm rate. In a recent one month test of 170 central stations alarm systems, 38,000 alarms were received with only 8% being an actual alarm condition. A breakdown of false alarms revealed the following:

a) 44% were due to internal procedures, i.e. careless employees, failure to follow instructions, etc.
b) 25% were due to equipment malfunctions.
c) 11% were due to external failures i.e. telephone lines, power failures, etc.
d) 12% unknown causes.

3. Responding to false alarms creates not only a loss of police manhours, but can also result in a " cry wolf." attitude on the part of some police officers. The crime prevention officer should therefore alert the businessmen and residents within their precincts of the importance of following correct procedures for alarm conditions in order to reduce the false alarm rate.

Figure 10.17

D.I. Emile E. Racine
Commanding Officer,
Crime Prevention Squad

EO.

SUMMARY OF SEATTLE POLICE DEPARTMENT FALSE ALARM REPORT

Seattle police respond to 550-700 false burglar and robbery alarms monthly. An average of 80 are bank alarms. Departmental studies indicate that over 97% of alarms are false. The number of false alarms is growing as more citizens seek greater physical seucrity for their homes and businesses. The Seattle Police Department Annual Report recorded 7,443 total alarms requiring police response in 1970.

Bank and alarm companies estimate that employee errors account for one-half of all false alarms. The increase in bank alarms is the result of an increased number of bank branches and the fact that banks are installing more sophisticated alarm devices.

Accidental tripping of "bill-traps" and janitors' sweeping of floors after hours trigger many false alarms in banks.

Analysis of causes of false alarms in Seattle:

50% subscriber or owner error.

21% installation.

11% equipment failure.

9% weather.

9% other.

The study recognizes that it is likely that many alarms are triggered by burglars who have fled before police arrive.

The conclusions of the Report were as follows:

> "Police officers ... are becoming complacent in procedures for handling alarms because they expect them to be false. The Communications Center is unnecessarily burdened with dispatching cars to alarms and coordinating units to perform valid police services at the same time. Lack of coordination among responding units is actually resulting in a lower suspect apprehension rate than is possible, and is thus making more alarms appear to be 'false' than would otherwise be true.

Figure 10.18

iii. It is influenced by the specific equipment, components, and devices used by Fidelity in their installations.

This implies that a far more comprehensive study is necessary, for definitive conclusions, However, the methodology developed by Compu-guard should be valid.

c) The current use of parameters such as False Alarm Ratio and False Alarm Rate to describe the performance of an alarm system is a gross oversimplification, and is undesirable as it may be misleading and even wrong.

d) The Mean Time Between False Alarms (MTBFA) is a more representative measure of system performance. However, the analysis presented in this section suggests that the MTBFA should not be considered as a static, deterministic parameter. It varies significantly with time, and its sensitivity to non-network variables (for an alarm network) such as time of day and month of year may be greater than to network variables such as the type of system, coverage ratio, etc. Thus, the MTBFA should perhaps be treated as a probabilistic parameter that must be compensated or normalized with respect to time and time-related and other non-network variables.

e) Some effort must be given to the standardization of the definition of commonly used parameters such as false-alarms, real alarms, etc.

f) The relevance of such false-alarms analysis of burglary alarm systems to CAS is quite limited. This is because the significant causes of false alarms in the use of CAS are likely to be both different and differently distributed than for burglary alarm systems. For example, one of the major expected causes of CAS false alarms is the triggering of the CAS actuator at a threshold of emergency perception that is too low, e.g., in response to the noise of a tree-branch rattling against a window pane. On the other hand, CAS false alarms will never be due to improper openings or closings. The direct extrapolation of burglar-alarm system data to the use of CAS is likely to be dangerous.

g) Extensive discussions with criminologists, sociologists, and others indicate that there is no reliable way to simulate the response behavior of a potential CAS user in an emergency, as a means of determining the expected threshold of CAS usage for different types of users. Since this simulation is not possible, and since user-threshold is a critically important factor in the determination of the expected CAS False Alarm Rate and MTBFA, a large-scale field test of CAS seems to be a necessity. This test is necessary with a large enough number of field systems so as to be representative of the range of scenarios, the types of users, the types of emergencies, and the types of non-emergencies in which the actuator may be triggered. This large-scale field test of CAS may be the only reliable way to determine CAS false-alarm parameters.

SECTION 11

FALSE ALARMS MODELING

11.1 INTRODUCTION

The previous chapter is a description of a study performed on false alarm data. In this chapter an attempt is being made to define some theoretical basis for the false alarm question.

The first model shown is a false alarms model, which seeks to describe false alarm occurrences as a function of several causes. The model can be used both as a predictive model and as a sensitivity check. An alternative to the MTBFA (mean time between false alarms) measure is suggested.

The second model deals not with the causes of false alarms, but their effect on the workload and effectiveness of the police. Specifically, a technique for measuring the acceptability of the CAS system to the police is suggested.

11.2 FALSE ALARM MODEL

One purpose of developing a false alarm model is to describe the incidence of false alarms in terms of the causes. Such a model would obviously describe the relative importance of the various causes, and could allow an analysis of the sensitivity of the false alarm rate to changes in the effect of the various causes. From a policy standpoint, such information would be desirable in deciding where and how much effort should be expended in attacking each cause. The model could be used to analyze the false alarm problem as a function of time of day. For instance, one may want to know how significant the peak load is, and which causes are important at that time. The model might also have some predictive applications. For instance, having some prior knowledge of the situation in the various causal dimensions, it might be feasible to estimate the false alarm rate for a proposed situation.

The model itself is very straightforward. Let r be the false alarm rate per system (false alarms per year) in the field. Then:

$$r = r_1 + r_2 + \ldots + r_i + \ldots + r_n$$

where r_i is the false alarm rate due to cause <u>i</u>. There exist <u>n</u> types of causes. If R is the aggregated false alarm rate for all N units in the field, then:

$$R = Nr = N(r_1 + r_2 + \ldots + r_n)$$

To see how this relates to the MTBFA, set

$$\frac{1}{\text{MTBFA (years)}} = N(r_1 + r_2 + \ldots + R_n)$$

$$\text{MTBFA} = \frac{1}{N} \cdot \left(\frac{1}{r_1 + r_2 + \ldots + R_n}\right)$$

This represents the MTBFA for the entire system of units.

11.3 POLICE WORKLOAD FALSE ALARMS MODEL

Any system designed to detect criminal activity and produce an alarm will inevitably produce a certain number of false alarms. The occurence of false alarms will most likely bear a certain relationship to real alarms. Frequently, the occurrence of false alarms is stated as a percentage of total alarms. For example, for a system with an 80 percent false alarms ratio, 80 percent of all alarms sent will be false.

But the false alarms percentage figure is of little use by itself in deciding whether to use the system. The acceptance of the system by the police is one of the most critical factors. In analyzing the direct effect on the police, a major trade-off will be made between the additional workload imposed upon the police and the performance of the system in combatting crime.

The police will probably be willing to accept a higher workload if it results in a sufficient increase in performance.

Within the framework of the analysis indicated above, false alarms become important because the level of false alarms is one of the most important factors in determining police workload.

11.3.1 The Model.

The model is designed to compare a measure of police effectiveness calculated before the CAS system is in use to the same measure calculated assuming CAS systems are in use by citizens. The effectiveness measure used will be the ratio of total police patrol time plus detective time to the total number of arrests (to be defined later) over a given period. The patrol and detective time is simply the number of active patrolman and detective times the average hours worked by one individual in the period (say, 2,080 hours per year). The measure is thus in units of man-hours per arrest, and the lower the number the higher the indicated efficiency.

A very similar index was utilized by the Operations Research Task Force of the Chicago Police Department[1] in their study of resource allocation in the Department. The specific measure used there was the ratio of felony arrests to assigned manpower.

The present effectiveness index of the police (without CAS) is relatively easy to calculate from manpower and arrest data. Projecting the index for

1 Allocation of Resources in the Chicago Police Department, U.S. Department of Justice, Law Enforcement Assistance Administration, March 1972, pp 22-30.

CAS situations is somewhat more difficult. The technique employed is to determine the incremental arrests and additional workload caused by CAS, add these to the present baseline, and recalculate the index. There is, however, a certain amount of uncertainty concerning just how CAS will operate. Although further understanding should come from field testing, the present calculations are performed for a number of different assumptions, falling basically into three categories:

A. False alarms - false alarms ratios for CAS of 95 percent, 90 percent, 70 percent and 50 percent were used.

B. Coverage of CAS - three coverages were chosen, assuming the following percentages of the population to be protected by CAS: 2.5 percent, 5 percent, and 10 percent. Coverages greater than 10 percent will probably not materialize for many years.

C. Crimes reported - two extreme possibilities exist. One is that all crimes reported by CAS would not have been reported, thus leading to new arrests. The other is that they would have been reported anyway, but that CAS offers a lower response time and thus a higher arrest probability for these crimes. A third situation is studied assuming the more realistic situation that the crimes reported are a mixture of the two above categories.

The mathematical formulation is presented below. For convenience, all terms are defined in Table 11.1.

Assume that the present annual arrests by police are X_p. In addition, the present annual manpower usage of patrolmen and detective is W_p. Then the present effectiveness index for police, E_p, is $E_p = \frac{W_p}{X_p}$.

<u>TABLE 11.1</u>

P - The population of the city.

v - The probability of any citizen being victimized in personal crimes during the period of one year.

c - Coverage. This is the fraction of the population using CAS systems.

t - The average time (man-hours) spent by police on an emergency call. As these are generally two men in a car, this time will be twice the time spent by the patrol car.

p_o - This represents the probability of an arrest being made as a result of a true alarm from a CAS system, assuming the alarm would <u>not have been sent</u> without CAS.

p_m - Given a true alarm from CAS, and assuming that the call would have been made even without CAS, p_m represents the marginal probability of arrest with CAS. In other words, since the probability of an arrest with CAS is larger than without it due to the faster response time, this additional probability over the normal or present probability of arrest is taken as p_m. In this manner the effects of CAS are separated.

f - CAS false alarms ratio.

Three CAS situations are developed.

CASE I. CAS signaled crimes would not have been signaled otherwise.

If X_c are the total expected CAS arrests, then

$$X_c = cPvp_o.$$

The additional police workload (man-hours) spent servicing both the real and false alarm calls is W_c, where

$$W_c = \frac{cPvt}{(1-f)} \quad .$$

With these factors, a term could be defined to represent a sort of incremental effectiveness related to the marginal arrests and workload due to CAS. Let this term be M, then

$$M = \frac{W_c}{X_c}$$

$$= \frac{cPvt}{(1-f)} \Big/ cPvp_o$$

$$= \frac{t}{(1-f)p_o}$$

With CAS, the overall effectiveness of the police becomes E_c, where

$$E_c = \frac{W_p + W_c}{X_p + X_c}$$

Therefore, $$E_c = \frac{W_p + \frac{cPvt}{(1-f)}}{X_p + cPvp_o} \qquad \text{———— (1)}$$

CASE II. All CAS signaled crimes would have been signaled, but CAS provides higher arrest probability.

Here the terms X_c , W_c , M, and E_c have the same meanings as in (I), then

$X_c = cPvp_m$, representing the marginal arrests caused by CAS.

$W_c = \frac{cPvt}{(1-f)}$, which has not changed.

$$M = \frac{W_c}{X_c}$$

$$= \frac{t}{(1-f)p_m}$$

$$E_c = \frac{W_p + \frac{cPvt}{(1-f)}}{X_p + cPvp_m} \quad \text{———— (2)}$$

CASE III. The calls are split 50/50 between I and II above. In this case the probability of an arrest becomes $(p_o + p_m) / 2$.

$$X_c = cPv(p_o + p_m) / 2$$

$$W_c = \frac{cPvt}{(1-f)}$$

$$M = \frac{W_c}{X_c}$$

$$= \frac{2t}{(1-f)\ (p_m + p_o)}$$

$$E_c = \frac{W_p + \frac{cPvt}{(1-f)}}{x_p + cPv(p_m + p_o) / 2} \quad \text{———— (3)}$$

11.3.2 Sample Calculations.

In order to see what sort of results are obtained from the model, a realistic example had to be analyzed. It became apparent that the best city and police department to base this example on was Pittsburgh, mainly because the Pittsburgh Bureau of Police Statistical Report, prepared annually, contains most of the information required. Good information on any other major metropolitan police department would have been good also.

The various parameters inthe model must be set. Brief explanations follow.

1. As Pittsburgh has a population of close to 600,000, P = 600,000.

2. The average service time for a call by Pittsburgh police is 30 minutes. This was calculated from the Police Weekly Vehicle Report, which gives the total number of calls and the total service time. Since there are two men per car, the total man-hours spent is 2 x 30 minutes or 60 minutes. Thus t = 1, or one hour.

3. Several coverages were analyzed, .025, .05, and 0.1. It will realistically be a number of years before coverages greater than this are obtained.

4. Several CAS false alarms ratios were analyzed, .95, .9, .7 and .5.

5. The probability of a person being victimized by murder, rape robbery, assault, or burglary while at the scene is roughly 0.015 or 1.5 percent[2]. Thus v = 0.015.

6. The probability of an arrest being made, given a crime has occurred, is expected to be higher when CAS is present than without. Roughly 40 percent of all known offenses are cleared by arrest. For part one crimes this figure is only 20 percent. Since CAS is only expected to be used for murder, rape, robbery, assault and burglary if the victim is on the scene, which are part one crimes, the arrests made due to CAS will be for these crimes.

1

2 In the UNIFORM CRIME REPORTS-1971, U.S. Government Printing Office, rates of murder, rape, robbery, assault and 13 percent of burglary were reported to be 542 per 100,000 or .542 percent. The NORC Criminal victimization study estimates that over twice as much crime occurs as the police are aware of (p. 9). Thus the true victimization rate is at least 1.084 percent. Assuming also that CAS will be generally used more often by people susceptible to crime, the number of 1.5 percent was chosen.

In the <u>Task Force Report: Science and Technology</u>[3], a graph was presented showing the probability of an arrest given a response time less than so many minutes. From the graph in Figure 11.1 it appears that for response time of less than 15 minutes the probability is over 40 percent. As the CAS notification is to be in seconds, the total delay will be communication center and field response times, which have been averaged at 1.40 and 3.43 minutes respectively[4] for emergency calls. As CAS calls will be emergencies, in general the response should be within 15 minutes. To be conservative in evaluating CAS, an arrest probability of 40 percent was chosen.

As the arrest probability for Part I crimes is 20 percent, and as p_o = 40 percent, then the "marginal" probability of CAS where the alarm would have been sent anyway is .40 - .20 = .20. Thus p_m =.20.

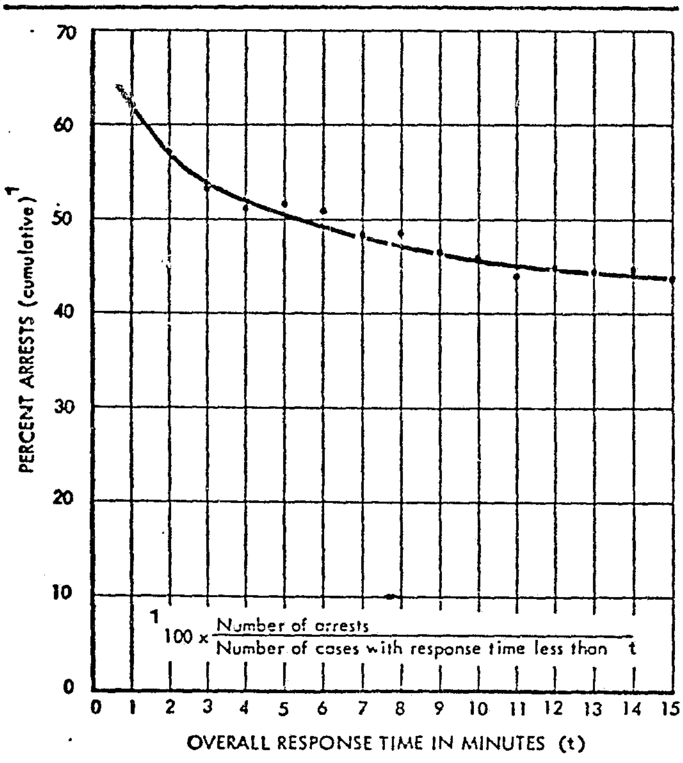
7. The serious crimes which CAS will be instrumental in affecting include the following:

- murder
- rape
- robbery
- assault
- 13 percent of all burglaries

The inclusion of 13 percent of burglaries represents the fact that, on the average, 13 percent of burglaries occur while the victim is actually at the scene, and thus able to use a CAS system to call for assistance. Obviously, a majority of burglaries occur when the victim is away from the scene.

3 <u>Task Force Report: Science and Technology</u>, The Institute for Defense Analyses, U.S. Government Printing Office, 1967. p. 93.
4 Ibid, pp. 92, 93.

FIGURE 11.1 PERCENT OF ARRESTS IN RELATION TO OVERALL RESPONSE TIME



Sample calculations were carried out. The resulting effectiveness factors are in Table 11.2. The calculations were performed for various false alarm rates, coverages, and the three situations concerning the originality of CAS calls. Figures 11.2, 11.3, and 11.4 show the output graphically in plots of man-hours per arrest vs. the false alarms ratio. Figure 11.2 is for the situation where the CAS calls would not have been reported otherwise. Figure 11.3 is the results assuming the crimes would have been reported anyway, and Figure 11.4 shows the 50/50 split between the two assumptions.

11.3.3 Limitations of the Model.

The model developed here represents a very useful and potentially powerful framework for analyzing the effects of false alarms. False alarms are not intrinsically important in themselves, but in the manner in which they affect the response agent. It is of little practical use to compare false alarm rates, false alarm ratios or MTBFA unless the numbers are translated into terms having operational significance. It was shown by this model that the relationship between effectiveness and false alarms is highly non-linear in the critical region, which is not immediately obvious without the model. However, although the approach utilized here is basically sound, the actual model developed has several limitations. The important ones are indicated below.

a. The actual index of effectiveness used is imperfect. This index combines different types of crimes and different categories of police time into one index. At least at this stage of the game, one index is preferred for simplicity as the human mind can only handle a small number of simultaneous factors. But throwing everything into one figure tends to overlook the fact that different crimes have different arrest probabilities, require different amounts of police time, and assume different degrees of importance.

TABLE 11.2 CAS CONTRIBUTION TO POLICE EFFECTIVENESS

EXPECTED MAN-HOURS PER ARREST* FOR VARIOUS POTENTIAL CAS SITUATIONS

		PERCENTAGE OF FALSE ALARMS											
		95%			90%			70%			50%		
		CASE I[1]	CASE II[2]	CASE III[3]	CASE I	CASE II	CASE III	CASE I	CASE II	CASE III	CASE I	CASE II	CASE III
	Present Police	127.5	N/A	N/A	127.5	N/A	N/A	127.5	N/A	N/A	127.5	N/A	N/A
C = 0.025	CAS Incremental Effectiveness	50	100	66.7	25	50	33.3	8.3	16.7	11.1	5	10	7.5
	Total Arrests CAS Included	123.8	127	125.1	122.5	125.5	124.0	121.5	124.5	123	121	124	122.5
C = 0.05	CAS Incremental Effectiveness	50	100	66.7	25	50	33.3	8.3	16.7	11.1	5	10	7.5
	Total Arrests CAS included	120	126	123	118	1,235	121	116	122	119	115.7	121	118.5
C = 0.1	CAS Incremental Effectiveness	50	100	66.7	2.5	50	33.3	8.3	16.7	11.1	5	10	7.5
	Total Arrests CAS Included	114.5	125	119.5	110	120	115	107.5	117	112	106.5	116.5	111

* See explanation in test

1 This category assumes that all crimes reported via CAS would not have been reported were CAS not available

2 This category assumes that all crimes reported via CAS would have been reported anyway. CAS simply allows quicker response and a higher arrest probability.

3 As both of the above categories represent extremes, a 50/50 split between new and substituted calls is assumed here.

FIGURE 11.2 MAN HOURS PER ARREST FOR NEW ALARMS i.e. Those Which Would NOT Have Been Sent Without CAS

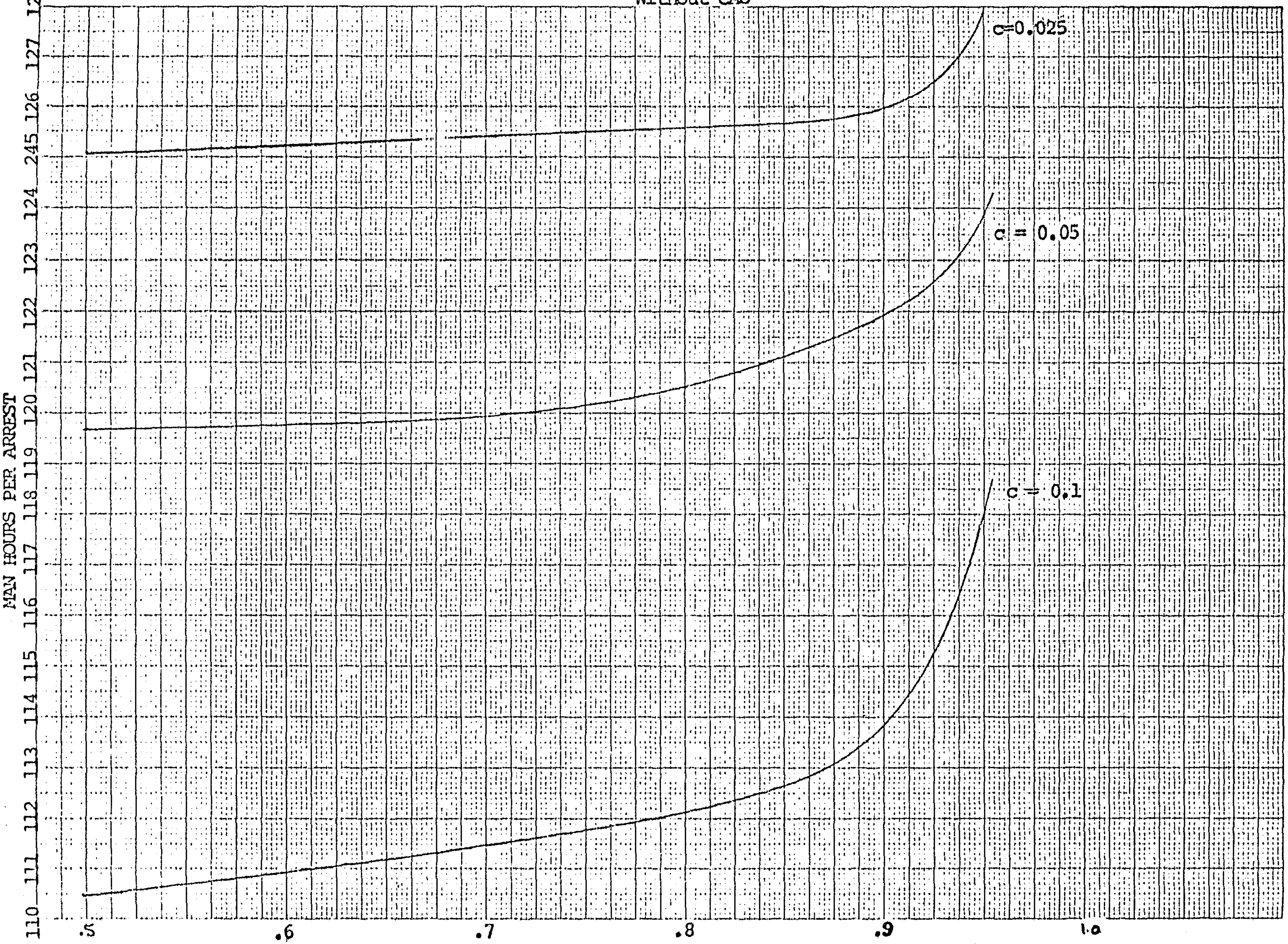
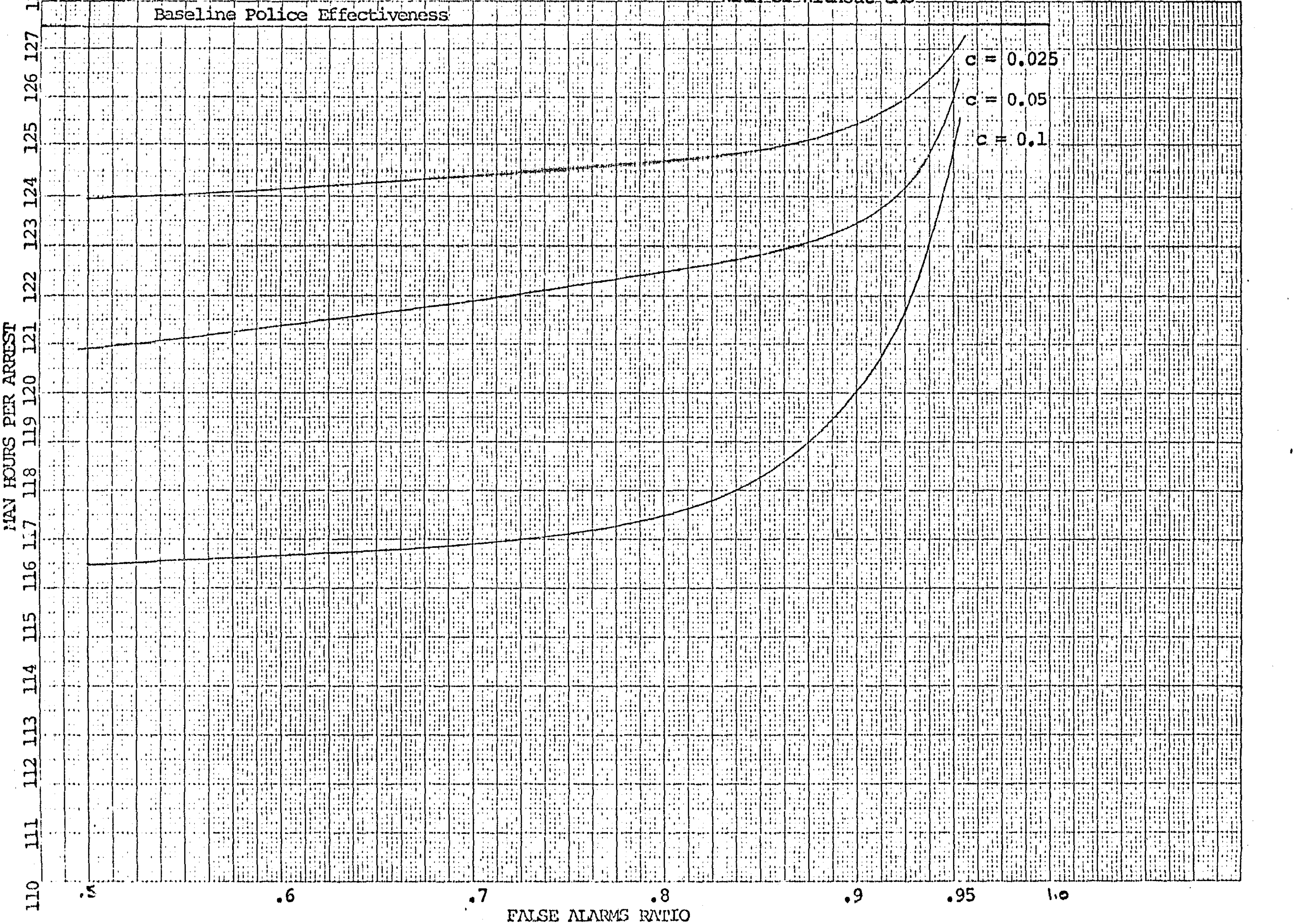


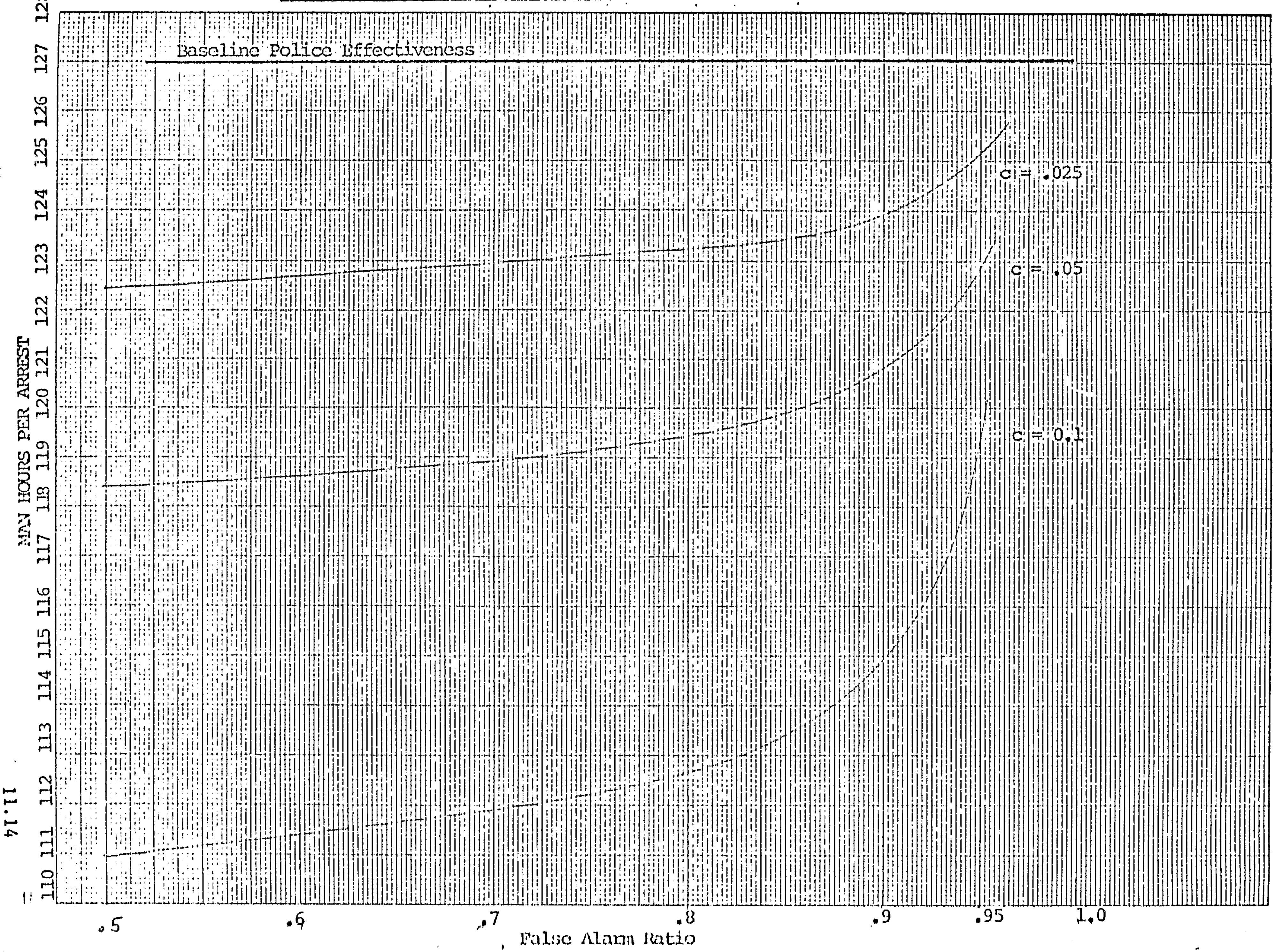
FIGURE 11.3 MAN HOURS PER ARREST FOR SUBSTITUTION ALARMS, i.e. Those That Would Have Been Sent With or Without CAS



CONTINUED

3 OF 5

FIGURE 11.4 MAN HOURS PER ARREST 50/50 Split Between New Alarms and Substitution Alarms



In addition, the index is one of efficiency. It does not recognize the actual level of arrests. For example, the inhabitants of a city may be willing to accept lower overall efficiency just to achieve a higher level of clearances.

b. At present, at least, some difficulty is encountered because the data available in the field is not generally structured for this purpose. Thus it was not possible to estimate all parameters with the same degree of accuracy.

c. As this represents a new approach, the results of previous work cannot be easily translated for the purposes here. And, of course, there are many areas in which insufficient work has really been performed. One of the biggest problems of this type encountered was in estimating arrest probabilities. Separate arrest probabilities for different crimes would have been useful, but only aggregate data was available.

d. As there is no existing system with which to compare CAS significant difficulty was encountered in modeling and projecting exactly how CAS would operate. Thus some projections are based only on theory or hypothesis: for example, the question of whether all the calls made via CAS would have been made otherwise. Also, it is virtually impossible to predict the false alarm ratio. In these situations seeral possibilities were assumed in order to observe the sensitivity to these factors. The model can be focused and fine-tuned as real data become available.

e. The model itself is very simple compared to the actual situation, which exhibits many complicated interrelationships which cannot be modeled in closed form. Thus significant room is available for making the model more closely resemble the true situation.

11.4 CONCLUSIONS

Several important points concerning the results should be noted.

a) In general, it appears that the use of CAS systems will offer significant reductions in man-hours per arrest, or an increase in the effectiveness of the response agent.

b) The false alarms ratio is important in that it determines to a large extent the additional police workload. However, as can be seen in the graphs, the effect of false alarms on the total police effectiveness is only of great significance above rates of roughly 80 percent. The reason for this is that as the ratio increases, the ratio of false to real alarms increases at an accelerating rate. At a false alarms ratio of 50 percent, there is .5/.5 or only 1 false alarm for each real. At 80 percent there are .8/.2 or 4. At 90 percent is becomes .9/.1 or 10. At 98 percent it is .98/.02 or 49. Thus, if field testing indicates ratios above 80 percent or 90 percent it will be critical to determine the true ratio accurately, as the effectiveness is very sensitive to the ratio in this region.

As can be seen from the curves, there will exist a false alarms ratio, somewhere between 95 percent and 100 percent where CAS will fail to enhance police effectiveness, due mainly to the high workload caused by answering false alarms. However, for a CAS false alarm ratio below 95 percent, it should significantly enhance the performance of the police.

c) Higher coverage ratios significantly increase the effectiveness of CAS and hence help improve police performance.

d) From observing the curves in the three figures, it can be seen that different effectiveness levels are achieved depending on whether or not CAS-signaled calls would have been sent without CAS. If all the calls are assumed to be new calls, i.e. they would not have been signaled without CAS, then the man-hours per arrest turn out to even lower. As it is difficult to predict the distribution between such new calls and substituted calls which CAS will generate, this can only be observed in a large-scale field test. Also the distribution of these calls will depend significantly on whether CAS is complemented by an outdoors alarm system as well.

e) Regarding the model itself, although it has several limitations, it represents potentially the most useful approach to analyzing the important effects of false alarms. It must be noted that this is a first cut at this type of modeling. Further work coupled with expected information from field testing and actual usage will allow significant improvements in the model.

SECTION 12

EFFECTIVENESS MODELING

12.1 THE DEFINITION OF EFFECTIVENESS

The selection of the specific structure and components of a CAS system will be based largely on a trade-off between system cost and some measure of effectiveness. The system will of course have to meet various constraints, such as cost limitations, minimum required performance levels, etc. Defining effectiveness presents problems in that a definition is required which is compatible with the way in which effectiveness can presently be measured, otherwise the definition is of no use to the system designer. A qualitative, non-operational definition of the effectiveness of CAS would be "the degree to which the system inhibits or decreases the level of victimization."

A very generalized goal of CAS is to provide maximum security against crimes involving victims for given levels of expenditure. This goal will be transformed to the extent possible into a set of operational requirements.

CAS is really only an alarm agent; to operate it must be in a system including one or more response agents and may operate in parallel with other security agents, such as locks, door alarms, etc.

In attempting to analyze the effectiveness of a CAS type system, the same types of problems are faced that exist in any effectiveness modeling of complex systems. At present, the state-of-the-art in this type of analysis is not well developed. The main difficulty stems from the fact that effectiveness is in actuality a multi-dimensional function, and that attempting to produce a one dimensional index of effectiveness requires dealing with the problem of relating non-commensurable variables quantitatively.

12.2 CRITERIA FOR COMPARISONS

The analysis of security system effectiveness should depend on some set of general criteria. The most important of these are listed below.

Deterrence capability: The effect of system in deterring criminal activity. This may be effected by physical barriers, increased probability of capture, increased difficulty associated with thwarting system, etc.

Detection Capability: The probability that the system will detect criminal activity.

Intelligence of System: This covers several points:

a) The ability of the system to discriminate real from false alarms.

b) The ability to define the type of emergency.

c) The ability to describe (to response agent) the emergency location.

Communication capability: Ability of system to reliably and quickly transmit information.

Response capacity: Quickness and adequacy of responding agent.

Reliability: Freedom from system failure.

Generality: Applicability of system to a variety of different threats.

Vulnerability: Susceptibility of system to incapacitation.

12.3 RANKING SCHEME FOR ALTERNATIVE SYSTEMS

A system has been developed to allow a quantitative ranking of alternative systems.[1] The developers found it necessary to design the system to

---

[1] Improving Public Safety in Urban Apartment Dwellings: Security Concepts and Experimental Design for New York City Housing Authority Buildings, William Fairley and Michael Liechenstein, The New York City Rand Institute, New York 1971.

accommodate both objective and subjective information, as it is simply not possible at present to obtain objective data on all variables.

The mathematical formulation of the model is developed below:

1. It is important to separate the major crime types which exist. Such a list would include burglary, robbery, assault, rape, larceny, etc. It is also possible to categorize these crime types into two major types: crimes involving victims and those not involving victims. For instance, burglary is not considered a victim-related crime, whereas robbery is. In the former case the person affected by the crime is not subject to danger from the criminal.

   Every crime type, labeled C_i, is assigned a factor c_i which represents the "cost" or disutility of the particular crime type to society. For c_i we have:

$$\sum_{i=1}^{N} c_i = 100,$$

   Where N = the total number of crime types. If we have two crime types, for example, victim and non-victim related crimes, then:

$$c_1 + c_2 = 100$$

   The estimates c_i's may be $c_1 = 80$, $c_2 = 20$. This indicates that society places four times the importance on c_1 (victim related crimes).

2. Security systems can be described by a set of features or abilities to perform various tasks. Examples might be the prevention of building access, the detection of criminal activity, rapid response, etc. Obviously these features are closely related to the system evaluation criteria mentioned earlier. The features are labeled F_{ij} for each crime type C_i. For each crime type, the total number of features required is M_i, thus $j = 1, 2, \ldots, M_i$. Each feature f_{ij} will have

a particular effectiveness in combating each crime type C_i. This effectiveness can be labeled f_{ij}, where:

$$\sum_{j=1}^{M_i} f_{ij} = 100, \; i = 1, 2, \ldots, N$$

The sum above represents the total effectiveness of having all desired characteristics, which of course is 100. The f_{ij} represents the percentage contribution to total effectiveness of each feature F_{ij}.

3. Realistically, of course, it will not be possible to provide the F_{ij} in the quantities or strengths desired. This is why effectiveness will not be complete. Each basic security system alternative will be able to provide the F_{ij}'s in varying amounts. System alternatives might be a burglar alarm, a guard, locks, CAS, or a combination of these and other factors. If there are k system alternatives, then a factor r_{ijk} can be defined, where

$$-10 \leq r_{ijk} \leq 10.$$

Each r_{ijk} represents the relative ability of alternative A_k to provide F_{ij} to combat crime C_i. Negative r_{ijk} represent detrimental effects. Two effectiveness scores can then be computed. The first represents the effectiveness of A_k against C_i, labeled E_{ik}

$$E_{ik} = \frac{1}{10} \sum_{j=1}^{M_i} r_{ijk} f_{ij} = E_{ik} = \sum_{j=1}^{M_i} r_{ijk} f_{ij}$$

The factor $\frac{1}{10}$ normalizes the E_{ik} to the interval (-100, 100). If the E_{ik} are summed over i and the crime types weighted by their disutility factors c_i, then a measure of the effectiveness of A_k against all M_i crime types, E_k, is developed.

$$E_k = \frac{1}{100} \sum_{i=1}^{N} c_i E_{ik} + \frac{1}{1000} \sum_{i=1}^{N} \sum_{j=1}^{M_i} r_{ijk} c_i f_{ij}$$

The factor $\frac{1}{1000}$ normalizes the E_k to the interval (-100, 100). Obviously the E_k are not intended to be general definitions of effectiveness. Their usefulness lies in a comparative analysis of different systems. As will become evident, there are a number of areas where the model may be expanded and improved; however, it represents possibly the best methodology available at this stage of the game.

12.4 ESTIMATING RANKING SCHEME FACTORS

To use the model obviously requires estimation of the various c_i, f_{ij}, and r_{ijk}. The determination of the c_i, or importances of preventing certain crimes, will depend on the frequency of the various crimes in the neighborhood where the system will be used and the relative aversion to each crime type of the inhabitants. Considerable subjective judgment will be required here. The determination of the f_{ij} and r_{ijk}, although allowing more room for objective analysis, will still require some expert judgment.

The above-mentioned report, which suggested the basic model used here, also described a large set of alternative security systems. Most of these were combinations of various components, such as alarm locks, local guards, television cameras, burglar alarms, etc. The model was then used to compare these various systems by calculating the effectiveness factors. To do this it was necessary to estimate the f_{ij} factors for each system. No objective method existed to estimate these factors, so the original designers used a subjective technique. The collective judgment of numerous select people was used to estimate the factors. These people included security experts, police department personnel, manufacturers of security system equipment, installers, consultants, housing authority officials, various tenant groups, engineers and many others. Although this represented the major approach to this type of question, it was a significant effort, and the figures represent the best available today.

12.5 EXTENSION OF MODEL TO ACCOMMODATE CAS

Starting with the results of the study described above, several extensions were made to develop a technique for evaluating CAS, and to compare CAS alternatives with the systems described in the previous report. The major concern in the present project is to describe and identify various CAS alternatives. An example might be CAS hardware and a local guard. Another might be CAS plus a remote guard. The baseline is CAS hardware transmitting an alarm directly to the police. However, it is both useful and necessary to be able to relate the cost effectiveness of CAS alternatives to other type systems, and for this reason the results of the study mentioned above were used as a starting point. Additions and changes were then made to expand the technique to accommodate CAS.

The study under discussion dealt with public housing projects, yet it is felt that it can be made sufficiently general to be applied to other possible scenarios. Eight desired security features were identified there:

1. Prevent building access
2. Prevent apartment access
3. Detect by patrol or surveillance
4. Increase crime duration & visibility
5. Transmit alarm rapidly
6. Respond rapidly - police/guard
7. Prevent escape or concealment
8. Provide identification evidence

For the analysis of CAS, some additional features were deemed important and were added to the above list. These are:

9. Discriminate between various types of emergencies
10. Provide accurate information

The ability to discriminate between emergencies is very important. Fire and medical emergencies are feasibly handled by the system, and identification and discrimination of the type of emergency will make it possible to signal the appropriate response agent. In addition, within the realm of criminal activities alone, discrimination capability will provide police with information on the type of threat: assault, robbery, etc. The police will then be able to decide on the most appropriate type of response. Another addition felt to be necessary to the model is somewhat different from the other ten, it is

11. Restrict false alarms

False alarms have detrimental effects in several areas:

Increasing police workload
Producing police complacency--thus endangering officers
Decreasing user confidence

The problem of false alarms is very complex and little good work has previously been performed in the area of finding solutions. Yet it is a significant aspect of alarm systems, and is addressed in greater detail in Chapter

The factors described so far have all been analyzed as additions to the security feature vector. However, the original approach as a whole was found to contain a major deficiency in that it did not address itself specifically to the question of system reliability: the probability that the system will, in fact, work. Reliability cannot be simply added as an additional desired characteristic, as it is not independent of the other features. In actuality, the reliability affects the performance of the system in providing the various required characteristics. It was decided to add reliability to the model in the following fashion. For each r_{ijk} (the effectiveness of A_k in supplying F_{ij} to C_i) define a factor p_{ijk} ($0 \leq p \leq 1$) representing the probability that the system component providing F_{ij} will be operative. E_{ik} and E_k can therefore be redefined:

$$E'_{ik} = \frac{1}{10} \sum_{j=1}^{M_i} r_{ijk}\, p_{ijk}\, f_{ij} \qquad \text{and}$$

$$E'_{k} = \frac{1}{1000} \sum_{i=1}^{N} \sum_{j=1}^{M_i} r_{ijk}\, p_{ijk}\, f_{ij}\, c_i$$

The definitions of E'_{ik} and E'_k are really no different from E_{ik} and E_k, except that system reliability has been integrated into the formal model. One further change was necessary. The study used here as a starting point employed two crime types, burglary and robbery. The basic concern in CAS is crimes involving victims. It was thus decided to categorize the crime types as either burglary or victim related crimes (robbery and assault), as victim related crimes have similar characteristics.

12.6 PRESENTATION OF VARIOUS CAS ALTERNATIVES

Descriptions of various CAS system alternatives are given below. It should be noted that the baseline CAS is the CAS hardware with the police as response agent. In addition, in all the systems below the police are automatically notified. These systems represent expected common applications of CAS.

System 1. CAS linked only to police.

System 2. CAS and a local guard. This system involves an on-site guard who can receive messages from CAS. An example would be a building guard in an apartment complex.

System 3. CAS and a regional guard. This is similar to No. 2, except that the guard covers a much larger area. An example would be a guard for an entire housing project of say, ten buildings.

System 4. CAS and a property protection alarm system.

System 5. CAS plus a property protection alarm system <u>and</u> a local guard.

Table 12.1 presents performance ratings r_{ijk} for several CAS and non-CAS alternatives. Tables 12.3 and 12.4 indicate the basic components of each system, as well as the system costs.

The non-CAS alternatives (labeled S_a through S_f) were taken from the earlier study described, as were the performance ratings for features 1 through 8. The ratings from 1 to 8 had to be renormalized when the additional three features were added. Note that the ratings are given for both victim and non-victim related crimes. For features 9, 10 and 11 no previous ratings existed, as the features had not been identified. Thus it was necessary to estimate ratings for the non-CAS systems for the categories of discrimination between emergencies, provision of accurate information, and restricting false alarms. Complete ratings had to be developed for the CAS system alternatives, and the ratings had to allow comparison to non-CAS systems. Conveniently, one of the systems described in the earlier study contained components similar to those proposed for CAS. This provided a base line for developing CAS ratings. In addition, the CAS systems described contain components found in other systems, such as police, guards, burglar alarms, etc. (As mentioned earlier, CAS itself is only a signaling device.) The effectiveness of these other components has already been indirectly estimated in the other non-CAS systems, which greatly assisted in the rating of CAS. Therefore, the ratings developed for CAS systems are logical and consistent with the previous work performed.

Reliabilities were developed for each system in combating both crime types. Although there will exist some differences in reliability in providing the various security characteristics for any given system, it was felt that the differences were not in general significant to the

Table 12.1

PERFORMANCE RATINGS (rijk) FOR ALTERNATIVES

BURGLARY

	S_a	S_b	S_c	S_d	S_e	S_f	S_1	S_2	S_3	S_4	S_5
1. Prevent building access	4	0	6	8	10	10	0	8	0	0	9
2. Prevent apartment access	8	0	7	9	9	7	0	0	0	9	10
3. Detect by patrol or surveillance	7	3	0	4	10	0	4	4	0	6	8
4. Increase crime duration & visibility	8	0	7	9	9	5	0	0	0	4	5
5. Transmit alarm rapidly	2	0	5	8	10	9	3	3	3	5	8
6. Respond rapidly (police/guard)	0	5	3	5	10	10	0	10	5	8	10
7. Prevent escape or concealment	2	3	2	6	10	10	0	8	1	4	9
8. Provide identification evidence	2	1	3	6	10	8	0	2	0	4	8
9. Discriminate between emergencies	3	3	5	5	5	5	5	10	8	10	10
10. Provide accurate information	0	0	0	0	0	0	5	10	8	10	10
11. Restrict false alarms	0	0	0	1	2	3	2	5	4	2	8

ROBBERY & ASSAULT

	S_a	S_b	S_c	S_d	S_e	S_f	S_1	S_2	S_3	S_4	S_5
1. Prevent building access	4	0	6	8	10	10	0	8	0	0	8
2. Prevent apartment access	2	6	2	3	3	2	0	0	0	0	0
3. Detect by patrol or surveillance	0	3	1	3	5	4	8	8	8	8	8
4. Increase crime duration & visibility	2	0	3	4	5	5	2	2	2	2	3
5. Transmit alarm rapidly	1	0	5	8	9	9	8	8	8	8	8
6. Respond rapidly (police/guard)	0	5	3	5	10	10	10	10	5	0	10
7. Prevent escape or concealment	1	3	2	3	10	10	1	9	2	1	9
8. Provide identification evidence	2	1	3	6	8	8	3	5	3	3	5
9. Discriminate between emergencies	0	2	3	5	5	5	10	10	10	10	10
10. Provide accurate information	0	2	2	0	0	0	10	10	10	10	10
11. Restrict false alarms	0	0	0	1	2	2	5	5	5	5	5

Table 12.2

EFFECTIVENESS VALUES FOR SELECTED SYSTEMS

CRIME IMPORTANCE FACTORS c_i	NON-CAS ALTERNATIVES						CAS - ALTERNATIVES				
Burglary/Robbery & Assault	S_a	S_b	S_c	S_d	S_e	S_f	S_1	S_2	S_3	S_4	S_5
80/20	16	11	32	53	67	55	16	51	27	46	77
50/50	13	11	28	42	61	54	25	60	36	45	76
20/80	11	11	23	36	55	52	35	68	44	43	75
10/90	10	12	21	33	53	52	38	71	47	43	75
05/95	10	12	20	32	52	51	39	73	49	42	75

Table 12.3

COST BREAKDOWN
NON-CAS SYSTEM ALTERNATIVES

Note: Total costs are defined as dollars per user per month

S_a	Intercom call-up system		$ 1.15
	Building exit alarm		.02
	Apartment alarm locks		.41
	Total		$ 1.58
S_b	Full-time patrolman for 2500 users (1000 apts):		
	Minimum base pay per patrolman	$ 8,874	
	Eleven paid vacation days	374	
	Uniform allowance	185	
	Security benefit	190	
	Annuity	260	
	Social Security	374	
	Health plan	250	
	Pension	2,457	
	Compensation	92	
	Total cost of one patrolman for one year	$13,056	
	Annual cost of five men to cover one post full time	$65,280	
	Cost per user per month		$ 2.17
S_c	Full-time private guard for 2500 users:		
	Annual cost per guard	$10,000	
	Four guards for three posts	40,000	
	Cost per user per month		$ 1.33
	Call-up intercom		1.15
	Lobby and rear exit TV cameras		.25
	TV monitoring cost		.19
	Total		$ 2.92
S_d	Call-up intercom		$ 1.15
	Building exit alarm		.02
	One-shift lobby guard for each 100 apartments		3.49
	Apartment alarms and remote panel		.34
	Lobby TV camera		.11
	Total		$ 5.11
S_e	Three shift lobby guard for 100 apartments		$ 9.00
	Call-up intercom		1.15
	Building exit alarm		.02
	Lobby TV camera		.11
	Total		$10.28
S_f	Three-shift patrolman in lobby		$21.76
	Exit alarm		.02
	Lobby TV camera		.11
	Call-up intercom		1.15
	Total		$23.04

Table 12.4

COST BREAKDOWN
CAS-SYSTEM ALTERNATIVES

	Low Cost (Minimum Estimate)		High Cost (Maximum Estimate	
S_1 Basic CAS	System cost*	$0.60	System cost**	
	Service charge	3.00	Service charge	4.00
	Total	$3.60		$4.90
S_2 CAS plus local guard full time	S_1	$3.60	S_1	$4.90
	Annual cost of 4 guards: $40,000		Full-time guard for 500 apts	2.66
	Cost per user (500 apts)	2.66		
	Total	$6.26	Total	$7.56
S_3 CAS plus regional guard	S_1	$3.60	S_1	$4.90
	Full-time guard for 1000 apts	1.33	Full-time guard for 1000 apts	1.33
	Total	$4.93	Total	$6.23
S_4 CAS plus burglar alarm	S_1	$3.60	S_1	$4.90
	Low cost apt burglar alarm	1.60	Low cost apt burglar alarm	1.60
	Total	$5.20	Total	$6.50
S_5 CAS plus burglar alarm plus local guard	S_1	$3.60	S_1	$4.90
	Burglar alarm	1.60	Burglar alarm	1.60
	Local guard	2.66	Local guard	2.66
	Total	$7.86	Total	$9.16

Notes: All costs in dollars per user per month
*System cost is equipment cost of $50 amortized over 7 years
**System cost is equipment cost of $75 amortized over 7 years

purposes here. Very accurate reliability figures await actual field testing of a CAS system, but some minimum expectations, or "worst case" figures, can be given. The reliabilities are listed in the following chart:

	S1	S2	S3	S4	S5
Burglary	.90	.95	.925	.90	.95
Robbery & Assault	.90	.95	.925	.90	.95

One special note is made. The problem of estimating at this time the reliabilities of non-CAS systems was very difficult, as little work had been done in this area previously, so they were assumed to all have reliability equal to 0.9. This will overstate the reliability in many cases, but will provide a harder test for CAS. Should CAS prove superior to this test, it will definitely prove superior in an actual situation.

It was felt that the importance attached to each crime type (c_i) might influence the selection of systems in various ways. Therefore, the effectiveness comparison of the various sytems was performed for different sets of importance figures. The results are shown in Table 12.2 The CAS systems have already been described (S_1 - S_5). The other alternatives (S_a - S_f) each contain components designed more for property protection than personal protection. This is so because most present security systems in existence today are highly property oriented. Brief definitions are given in Table 12.3

12.7 RESULTS AND IMPLICATIONS OF EFFECTIVENESS VALUES

The important figures will be the effectiveness/cost ratios calculated from Table 12.5 and expected costs per user. These effectiveness/cost ratios are found by dividing the effectiveness figure from the model by the cost (dollars per user per month). Obviously a high ratio is desired. However, several interesting observations emerge from the table

Table 12.5

EFFECTIVENESS-COST RATIOS FOR SELECTED SYSTEMS*

CRIME IMPORTANCE FACTORS c_i Burglary/ Robbery & Assault	S_a	S_b	S_c	S_d	S_e	S_f	S_1		S_2		S_3		S_4		S_5	
							**Low Cost	High Cost	Low Cost	High Cost	Low Cost	High Cost	Low Cost	High Cost	Low Cost	High Cost
80/20	10.00	5.06	10.90	10.37	6.51	2.39	4.44	3.26	8.14	6.74	5.48	4.34	8.84	7.07	9.79	8.40
50/50	8.12	5.06	9.62	8.21	5.93	2.34	6.94	5.10	9.58	7.93	7.31	5.78	8.65	6.92	9.66	8.29
20/80	6.87	5.06	7.90	7.04	5.35	2.25	9.72	7.14	10.86	8.99	8.94	7.07	8.26	6.64	9.54	8.18
10/90	6.25	5.52	7.21	6.45	5.15	2.25	10.50	7.75	11.34	9.39	9.55	7.55	8.26	6.61	9.54	8.18
15/95	6.25	5.52	6.87	6.26	5.05	2.21	10.80	7.95	11.66	9.65	9.95	7.87	8.07	6.46	9.54	8.18

* Costs are defined as dollars per month per user.
** Low cost and high cost refer to minimum and maximum cost estimates for CAS-alternatives.

of effectiveness ratings relating to the problem of system selection. In addition, as the observations agree with prior expectations, there exists some qualitative validation evidence for the technique. These points are discussed briefly below.

In general, non-CAS systems S_a through S_f were basically conceived of as both personal and property protection systems; however, a majority of the hardware is property protection related, and important personal protection features are weak or missing. Consequently, in general these systems have higher effectiveness ratings against property related crimes (burglary) than victim related crimes. When the disutility scheme (c_i's) is applied to the alternatives, the total effectiveness of each alternative (E_k) will decrease as the scheme places a higher and higher importance on victim related crimes. It becomes obvious from the figures that the effectiveness for an 80/20 scheme is quite different than for a 20/80 scheme. Thus the importance attached to crime types is critical in system selection. The question of whether robbery and assault is five or six times more important than burglary is not significant; however, the question of whether R & A and burglary are of equal importance or if one is five times more important is significant.

For CAS alternatives the opposite effect tends to occur, since these systems will present a relatively high effectiveness against victim related crimes. Several systems, such as S_a, S_f, S_4, and S_5 have roughly equal effectiveness ratings in both categories, as they combine roughly equal proportions of both person and property protection equipment.

In a majority of cases users will be looking for a system which combines both personal and property protection capability. Most systems with more than one component will have a mixed capability, and even systems designed specifically for one purpose will have spillover. The significance of Table 12.2 is that in using the effectiveness model under discussion, a very key factor in system selection is the relative importance attached to crime types. This indicates that system selection will tend to vary for different user classes, i.e., homeowners, small business owners, apartment dwellers, those living in high crime areas, etc.

12.8 SYSTEM COSTS

Tables 12.3 and 12.4 show the cost calculations for both the non-CAS systems and the CAS alternatives. The costs for non-CAS alternatives were basically taken from the original study in which they were defined.[2] In this study the costs were given in dollars per apartment per month. In the report, information on the New York Housing Authority occupancy indicates an average of 2.5 people per apartment. Therefore, the cost figures for non-CAS systems are divided by 2.5 to convert the costs to dollars per user per month. As no figures exist presently for CAS, these figures were given as targets which appear to be feasible. Due to the uncertainty, however, high and low estimates were given for these costs. To maintain comparability with the non-CAS alternatives, hardware costs for CAS were amortized over a seven year period. The low and high estimates are explained below:

Low estimate -- System cost of $50

Amortized (7 yrs)	.60/mo.
Service cost	3.00/mo.
TOTAL	$ 3.60/mo.

High estimate -- System cost of $75

Amortized (7 yrs)	.90/mo.
Service cost	4.00/mo.
TOTAL	$ 4.90/mo.

---

2 Ibid., pp. 58-61.

The costs shown obviously represent average costs over a large number of applications. However, to try to define and analyze every possible situation at this point would be a huge task.

12.9 EFFECTIVENESS-COST ANALYSIS

In Table 12.5 is presented the results of the effectiveness-cost analysis. For each system alternative examined, the ratio of effectiveness to cost ($ per mo. per user) was calculated. This was done for the various schemes of attaching importance to crime types. In addition, the CAS alternatives received two ratios, one each for the low and high cost estimates.

Several points should be mentioned concerning the table:

1. In the first category, where burglary is given an importance rating of 80, several of the non-CAS alternatives seem to be the best, specifically, S_a, S_c and S_d have very high E/C ratios. CAS alternatives do not do as well. S_4 and S_5 are fairly cost-effective here, but both of these systems also have a burglar alarm, which is essentially a property-protection component.
2. As the importance shifts to personal-protection systems, in general the cost-effectiveness of non-CAS systems decreases, while CAS gains a substantial advantage. Even the basic CAS system S_1, where only the police are notified, has a higher E/C ratio than any non-CAS system. This holds for both the high and low cost estimates.
3. CAS systems mixed with property protection systems such as S_4 and S_5 change in E/C as the prime importance factors change.
4. In general, systems exhibit wide variations in both effectiveness, cost, and E/C.
5. The relative importance assumed for the different crime types is

a critical factor. Quite different systems will be chosen under different utility schemes. For users interested in only personal or only property protection do not present a serious problem in choosing systems, as they are either at one end of the spectrum or the other. Those users with limited resources wanting protection in both areas present a problem in that they must quantify their utility for the various types of protection.

Various types of institutional users exist for CAS systems. Each of these institutions will have its own protection preferences. These should be determined accurately, however. Table 12.6 is a possible classification of these institutions by their crime importance factors.

If we assume that the user types in Table 12.6 use a CAS type system, then Table 12.7 gives the most appropriate (cost effective) CAS systems for each user type.

The selections in Table 12.7 were not made solely on the basis of the highest E/C ratio. Other considerations were taken into account. For example, for small businesses, S_5 has the highest E/C ratio. Yet S_5 calls for a local guard which not all small businesses can afford. Thus S_4, which has a high rating yet only requires CAS and a burglar alarm, was also included.

Hospitals and schools are another case, as they need capabilities on both ends of the spectrum. In one area a personal protection system is needed for nurses, teachers, patients, etc. On the other hand, dangerous drugs, expensive equipment, books and so on must be protected from burglary.

The table shows the best areas of application for each CAS-type system. However, the most important factor here is not so much the specific information contained in Table 12.7, but the techniques indicated.

Table 12.6

USER CATEGORIZATION BY CRIME IMPORTANCE FACTORS

CRIME IMPORTANCE FACTOR Burglary/Robbery & Assault	Homes	Hospitals*	Prisons	Apartments	Small Businesses	Schools*
80/20		X			X	X
50/50					X	
20/80	X			X		
10/90	X	X		X		
5/95	X	X	X	X		X

* Schools and hospitals will have two important separate needs. One is to protect staff (nurses, teachers, etc.), and the other is to protect valuable equipment and materials (movie projectors, books, medical equipment, drugs, etc.)

Table 12.7

MOST APPROPRIATE CAS-SYSTEMS FOR EACH USER CLASS

USER CLASS	S_1	S_2	S_3	S_4	S_5
Home	X	X			
Apartment	X	X	X		
Hospital	X	X			X
School	X	X			X
Small Business				X	X
Prison (for guards)	X				

It presents a workable method for assisting in the decision of which basic alternative components are best for particular applications. Conceivably any type of system can be analyzed in the above fashion.

12.10 CONCLUSIONS

Below are presented two sets of conclusions. The first set concerns the model itself and its usefulness as a tool for evaluation security systems. The second consists of the results of the model with respect to the effectiveness of CAS systems.

12.10.1 The Model.

a) In general, the effectiveness model presented here offers a highly useful methodology for evaluating security systems. In fact, it appears to be the most practical technique in that it attacks the problem in several dimensions, which is essential in a problem of this complexity. In addition, the technique allows the combination and simultaneous evaluation of both subjective and objective information. At the present state-of-the-art in effectiveness modeling, models which cannot handle subjective data are of little use in practical applications, as a major portion of the available information will be subjective. In addition, the technique presents no computational problems.

b) The model defines the security systems in operational terms. For instance, a lock represents a certain deterrent capability, while larger components might represent a combination of operational dimensions. Such an approach forces the analyst to describe the manner in which a system works against crime, thus leading to a separate analysis in the various operational dimensions and hence a more accurate result.

c) While the model is internally multi-dimensional, the output is a single dimensional value, the effectiveness/cost ratio. Thus the technique simplifies the complex information and provides a usable decision vehicle.

d) Various types of sensitivity analysis are possible with the technique, which is extremely important in these early stages of effectiveness modeling. For instance, Table 12.5 indicates that the choices made will depend heavily on the relative importance placed on various crime types (i.e., the crime importance factors c_i). Therefore, it is obvious that the area of user utilities must receive considerable attention. Another important consideration stems from the significant estimation problems exhibited by this technique. Estimates must be made for all of the performance ratings (r_{ijk}) shown in Table 12.1 These ratings, to reiterate, measure the ability of the various systems to provide crime-fighting features (F_{ij}) such as "prevent building access," "respond rapidly," etc. Error in estimating the r_{ijk} will have the most significant effect for those r_{ijk}'s relating to important features (those for which f_{ij} is high). Thus more effort should be expended in estimating ratings for the most important features, and the mode can identify the critical areas. Thus, in general, the technique is useful in directing additional effort.

e) The model is a very general approach; it can be used to analyze many other types of security systems or techniques, and will even have applications outside the security field.

f) Being new, and dealing with an extremely difficult problem, the technique is far from perfect. One of the most significant problems lies in estimating the various f_{ij} and r_{ijk} required. The F_{ij} categories, mostly having just been defined, have not been subject to close study or statistical analysis. Conceptually, however, the categories are generally ones for which benchmarks can be established against which systems can be compared. However, some of the dimensions will remain somewhat subjective for some time.

g) As much of the information used is subjective, it is difficult to validate the model.

h) Although the structure proposed by the model appears good, the particular dimensions or security system features proposed may not be the most appropriate. Some improvement is possible here.

12.10.2 Implications for CAS.

a) From the analysis performed, it appears that in general a Citizens Alarm System will be a cost effective approach to victim related crime. From the results given in Table 12.5 it can be stated than when personal assault and robbery are considered more serious than burglary (20/80, 10/90, and 05/95 schemes), which appears to be the case for most people, CAS systems in general provide a higher degree of cost effectiveness than non-CAS. For the 10/90 and 05/95 schemes, this advantage becomes quite significant, even for the CAS high-cost estimates. It should also be remembered that CAS is a complex solid-state device. The production costs of such devices in recent years have shown a strong downward trend.

But E/C ratios are not the only figure to observe. The base CAS system will cost between $3.60 and $4.90 per month, yet deliver (Table 12.2) considerably more effectiveness than non-CAS systems except those costing over $10 per month per user ($S_e$ and S_f). By paying between $4.93 and $6.23 per month (S3, CAS and a regional guard) it is possible to get a system effectiveness closely comparable to the most expensive non-CAS system. And for a maximum cost of $7.56/mo., ($S_2$, CAS and local guard) a level of effectiveness far in excess of <u>any</u> non-CAS system is obtainable.

b) It has been demonstrated that CAS has applications not only in residences and apartments, but in various institutions (schools, prisons, hospitals, businesses) as well. In addition, CAS technology can easily incorporate property protection components to provide full protection for the institutional needs.

c) Various types of CAS system alternatives are possible, and a technique for decision making was presented. However, the E/C ratio cannot be used exclusively. Budgets will exist as well as minimum effectiveness requirements; thus the selected system should provide the highest E/C within these constraints and any others which might be imposed.

d) One point is very key and should be brought out. Excluding present hold-up alarms, CAS is the only real active system relating to users. Most systems are passive, such as burglar alarms, and must await triggering by the criminal. This is a drawback in personal protection systems. For instance, an apartment door alarm will not help the victim attacked in an elevator. Even victim triggered devices (holdup alarm) are useless if the victim cannot reach it. It is in providing to the user the capability to send an alarm regardless of the situation or location that CAS demonstrates its effectiveness.

e) The CAS technology conceived, micro-computers and digital information transmission, is so powerful and flexible that the system can be easily made to assimilate and control any number and variety of security components simultaneously, in the areas of personal protection, property protection, equipment monitoring, etc.

12.11 FUTURE DIRECTIONS FOR CAS

The requirements for CAS hardware and information processing software have necessitated the use of highly sophisticated micro-computer and digital information processing technology. Having been developed, however, a system exists with capabilities far in excess of those necessary for a Citizens Alarm System for homes and institutions. It is obvious that this technology, which already exists, will in a very short period of time proliferate a host of varied and complex applications. Some of the next steps are quite apparent, and this section will briefly indicate two of the more important.

It was indicated earlier that CAS can be augmented by property protection devices. It is also important to note that the CAS technology can make a standard burglar alarm (say, perimeter protection devices) more effective by providing information on location, type of emergency, etc. And with any significant number of alarms in the field, the user cost due to monitoring equipment will be lower for CAS technology than for conventional hard-wired systems.

With these facts in mind, the effectiveness analysis performed above studied two CAS systems with burglar alarm components. The first, S4, containt CAS and a burglar alarm. The second, S_5, also incorporates a local guard. The results are summarized below.

1) The marginal cost of a burglar alarm is low, about $1.60 per user per month.

2) Total monthly costs for CAS and the burglar alarm will be between $5.20/mo. and $6.50/mo. With a local guard it will range from $7.86/mo. to $9.16/mo. Other combinations (regional guard) are possible.

3) From Table 12.5, it can be seen that the cost-effectiveness of these alternatives is quite high.

4) The provision of both property and personal protection in one system gives an alternative exhibiting little sensitivity to the crime-importance factors, providing high effectiveness everywhere.

5) From Table 12.2 it can be seen that the pure effectiveness of the combined CAS-burglar alarm systems (S4, S5) under the 80/20 scheme

(high importance on burglary) is comparable to the best non-CAS systems (S_d, S_e, S_f). The non-CAS systems S_a and S_c offer high cost-effectiveness but low absolute effectiveness. Thus CAS-burglar alarm systems offer both high effectiveness and cost-effectiveness over the entire range of user utilities, which cannot be said for any non-CAS alternative studied.

6) Comparing S_1 to S_4 it can be seen that introducing a burglar alarm also increases the personal protection effectiveness. Note the 10/90 and 05/90 schemes.

7) The performance described in (5) above is possible because the combination CAS-burglar alarm system is fully integrated. The control devices provide a generalized security system with the capacity to handle any variety of personal or property protection actuators. It is not a collection of individual systems.

It was mentioned earlier that one of the most important factors contributing to the high effectiveness of CAS is that the user is always in a position to trigger an alarm. The victim does not have to reach a panic button or holdup alarm, nor wait until the criminal himself sets off an alarm. It is a highly active and mobile system. The actuator is worn on the person and requires only a single simple action to trigger it. Only the receiver-relays are fixed in location, and the user is free to move about in any area covered by receiver-relays. The present scenarios under study involve structures such as homes, apartment buildings, schools, etc.

The information processing ability of the controller and central station equipment would allow for easy expansion of the system. Basically, by increasing the number of receiver-relays and expanding the area covered, the CAS system as it stands could be expanded to cover whole communities, industrial parks, campuses, or even cities. The only major additional problem would be to design packaging to allow receiver-relays to be placed outside of buildings and to plan the most appropriate communications network between the receiver-relays and the central station.

The concept is inviting: an entire city-wide network of receiver-relays (there presently exists a network of police call boxes) allowing people to move about the city, both within buildings and on the streets, with the ability to signal an emergency (criminal, medical, etc.) describing the nature of the emergency.

SECTION 13

RELIABILITY MODELING

13.1 DESCRIPTION OF THE OVERALL MODELING APPROACH: SOFTWARE AND HARDWARE

An important element in the design of a Citizens Alarm System (CAS) is the choice of techniques that gives the maximum reliability for given cost. Systems can be designed for highly reliable information transmission in microminiature packages; this is obvious from the fact of weather satellites, deep space probes, earth resources satellites and so on. But the cost of their reliability is far beyond the means of the average citizen.

The purpose of this chapter is to show how the CAS reliability problem can be solved through state-of-the-art techniques in software and hardware. Alternatives in the design of both will be discussed and weighed according to cost and reliability tradeoff. A block diagram of the CAS system is shown in Figure 13.1.

The system consists of several components, starting with the actuator--a radio-frequency transmitter (C_1) worn by the user. This sends an alarm message via the radio link (L_1) to a non-error correcting internal receiver-relay (C_2), i.e., the relay transmits the message exactly as it is received, and no errors are corrected by it. Prior to re-transmission, the relay adds on the location code which identifies each specific receiver-relay.

The message is then sent along L_2, the local 110V power line. It is picked up by the external receiver-relay, at some central location, and error correction techniques are applied before it is retransmitted on link L_3. L_3 may be:

a) Switched telephone line

b) Leased telephone line

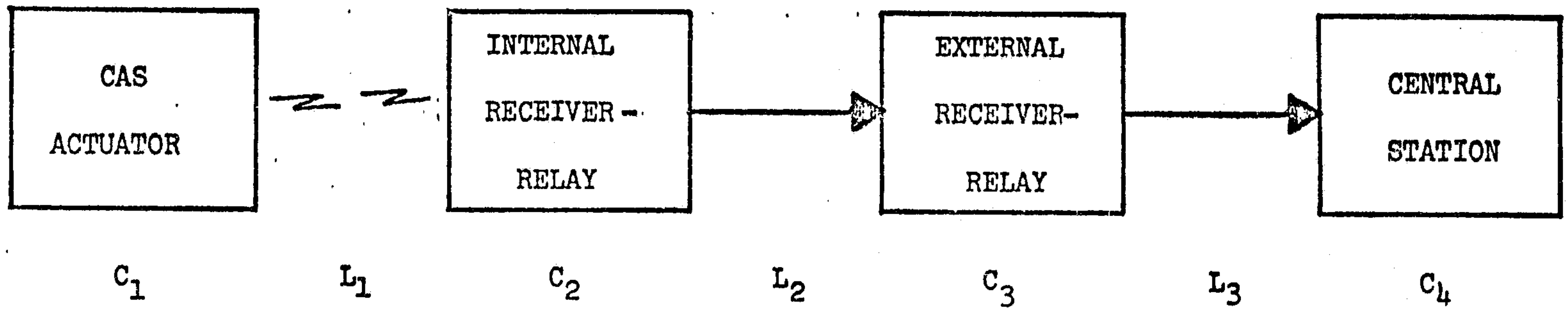


Figure 13.1: Block Diagram of CAS System

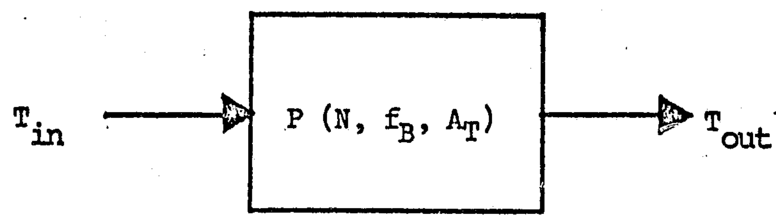


Figure 13.2: Example Of A Probabilistic Transfer Function

From the graph it is seen that the system transfer function is:

$$T = C'_4 \; L_3 \, C'_3 \, (L_1 \, L_2) \quad . \; . \; . \; . \; . \; (2)$$

A similar diagram, Figure 13.5, shows the selections related to the other model for component reliability. For this model, ignore the L_n's and $C^1{}_n$'s, since only hardware items are of interest. This graph gives the component reliability transfer function:

$$R = C_1 \, C_2 \, C_3 \, C_4 \quad . \; . \; . \; . \; . \; . \; (3)$$

The remainder of this section will be devoted to studying the detailed structure of Equations (2) and (3).

13.2 DESCRIPTION OF THE SUB-MODELS

13.2.1 Overview.

Each of the models can be broken into a set of analytically tractable sub-models, each one being equivalent to a term in the reliability equations. All the reliability models depend on certain underlying environmental models which will be taken from the literature, based on factors such as noise and component reliability. The outline of the approach is shown below:

I. Message Transmission Reliability Model (MTRM)

- A. RF data link
  - 1. Error and noise sub-model
- B. Hardware data links
  - 1. Error and noise sub-model
- C. Error correcting codes and software
  - 1. Bit by bit voting
  - 2. Message by message voting

II. Component Reliability Model (CRM)

- A. Component failure sub-model

Under IC, the error correcting codes, it is seen that there are two phases. Each of these requires a slightly different approach in modeling, and they will be discussed separately.

c) External power line

d) Coaxial cable (CATV)

The destination of the CAS alarm message is C_4, the central station, where error correction is again applied and the result is displayed on a teletype or similar output unit.

A more useful diagram from an engineering standpoint is a directed graph, with the subsystem transfer functions. Since the models considered here deal with component reliability and transmission reliability, the transfer functions will be functions relating probabilities. An example is shown in Figure 13.2 for a typical block in the transmission model, where n, the length (of each alarm message) in bits per word; f_B, the bandwidth in Hz; A_T, the total number of words transmitted; and BER, the bit error rate; are parameters of the subsystem. T_{in} is the probability a message or word is correct at the input, T_{out} is the probability it is correct at the output. In general, the form for the probabilistic transfer function is:

$$P_{out}/P_{in} = H\ (a,b,c, - - - -) \quad . \ . \ . \ . \ . \ (1)$$

where P_{in}, P_{out} are the input and output success probabilities, and a, b,c,- -, etc. are the system hardware parameters.

It is now possible to introduce the model in general form (Figure 13.3). Items such as L_n represent transmission links. C_n's are hardware components and C'_n are software, program components. A basic assumption in this methodology is the statistical independence of errors (or malfunctions) in each block.

Now for the message reliability model the hardware error is of such inconsequential magnitude that the C_n terms cans be ignored. This model is diagrammed in Figure 13.4.

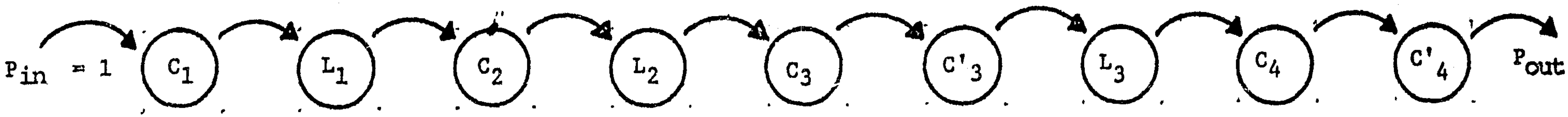


FIGURE 13.3: DIRECTED GRAPH OF CAS SYSTEM

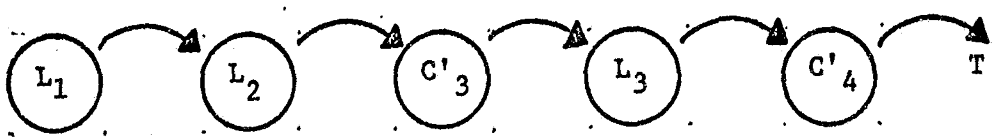


FIGURE 13.4: THE TRANSMISSION RELIABILITY MODEL

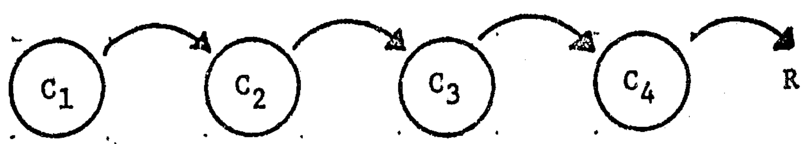


FIGURE 13.5: THE COMPONENT RELIABILITY MODEL

13.2.2 Description of the Message Transmission Reliability Model.

13.2.2.1 Bit-by-bit Error Correction Sub-Model.

The bit by bit voting sub-model approaches the task of error correction as a signal averaging of bits with a threshold of $(A_T/2)+1$ bits, where A_T is the number of messages. Implementation is proposed on an MCS-4 micro-computer, which would receive and process each of the A_T words. It stores the number of times a one or a zero occurs at each bit position. A resultant, output word is built by the micro-computer by selecting a resultant one in each bit where at least $(A_T/2)+1$, the majority vote, are ones. Otherwise, zero is selected.

Now the probability that a word is correct is the probability of there being $(A_T/2)+1$ or more bits correct, up to the maximum of A_T. One further effect can also be included. Assume that noise bursts will totally destroy Y out of the A_T messages transmitted. Then at most, A_T-Y identical bits may be found. The validity of this approach will be examined in greater detail in another subsection.

The probability of bit n being in error is statistically independent of the probability of an error in bit n+1. Further, the event (an error), is a binary choice event. These two factors imply a binomial distribution model. This says that the probability that an event occurs at least k_1 times and not more than k_2 times is found by letting x take on each of the values:

$$k_1,\ k_1+1,\ k_1+2 \ldots\ldots\ldots\ldots,\ k_2$$

Now p is the probability of success on any one trial, so p^x is the probability of having a total of x successful trials, and $(1-p)^{k_2-x}$ is the probability of having k_2-x unsuccessful ones. Also, $\frac{k_2!}{x!(k_2-x)!}$ is the number of ways in which x items can be selected from total of k_2. So the probability of P(x), of finding a trial where x are successful and k_2-x are unsuccessful is:

$$P(x) = \frac{k_2!}{x!\,(k_2-x)!}\; p^x (1-p)^{k_2-x}$$

Solving the equation for each allowed value of x:

$$P(k_1 \leq x \leq k_2) = \sum_{x=k_1}^{k_2} P(x)$$

so the binomial distribution is, in general form:

$$P(k_1 \leq x \leq k_2) = \sum_{x=k_1}^{k_2} \frac{k_2!}{x!\,(k_2-x)!}\; p^x\,(1-p)^{k_2-x}$$

Now for the MTRM the following applies:

$$(A_T/2)+1 \leq x \leq A_T-Y$$

So the probability of a particular bit in a message being correct at the output:

$$P\quad (A_T/2)+1 \leq c \leq A_T-Y \quad = \sum_{(A_T/2)+1}^{A_T-Y} \frac{(A_T-Y)!}{x!\,(A_T-Y-x)!}\; p^x (1-p)^{A_T-x-Y} \quad \ldots \quad (4)$$

And if the message is n bits long, the equation for the probability of the output message being correct is, where T is throughput:

$$T = \left[\sum_{(A_T/2)+1}^{A_T-Y} \frac{(A_T-Y)!}{x!\,(A_T-Y-x)!}\; p^x (1-p)^{A_T-Y-x}\right]^n \quad \ldots\ldots \quad (5)$$

13.2.2.2 <u>A Message-by-Message Model</u>.

An alternative error correction technique attacks the problem by voting on the entire message rather than on individual bits of the message. Thus the micro-computer needs to find between $(A_T/2)+1$ and A_T identical messages. The MCS-4 system would once again be used. In this case it would store a copy of each different word received, compare each new word with all of the old ones. Whenever two words match, it increments a count. If any word has sufficient weight (i.e., has occurred sufficiently often) it is selected and transmitted. If no such word exists, i.e., several words have occurred, but none with a frequency equal to or more than $(A_T/2)+1$, an error detection occurs. Such a system would require an additional parity checking code or a means for asking for retransmission if such errors are likely to occur.

As before, a binomial distribution model is applicable. The limits are the same:

$$(A_T/2)+1 \leq x \leq A_T-Y$$

Now for this model, the probability of interest is that of having x entire words correct. The probability that any one of these n-bit words is correct is:

$$p' = p^n$$

The probability for x words correct is just $(p^n)^x$ and for $(A_T-Y)-x$ being incorrect, $(1-p^n)^{A_T-Y-x}$. This gives the binomial distribution model in the form:

$$T = P(A_T/2)+1 \leq x \leq A_T-Y = \sum_{(A_T/2)+1}^{A_T-Y} \frac{(A_T-Y)!}{x!\,(A_T-Y-x)!} (p^n)^x (1-p^n)^{A_T-Y-x} \qquad (6)$$

13.2.2.3 Modeling Hardwire Transmission Lines.

Line noise is modeled as a two component function: bursts which destroy several bits in close proximity, i.e., a high correlation between adjacent bit errors, and single bit errors which destroy only one bit and have zero correlation with neighboring bits. Now it is known from information theory that all noise can be modeled as an ergodic (random) process. The key point, however, is the duration of a given noise element. If it is short, less than the width of a bit, it is random noise and the bit is in error. If it is longer, it is seen as a burst that covers several bits. Noise

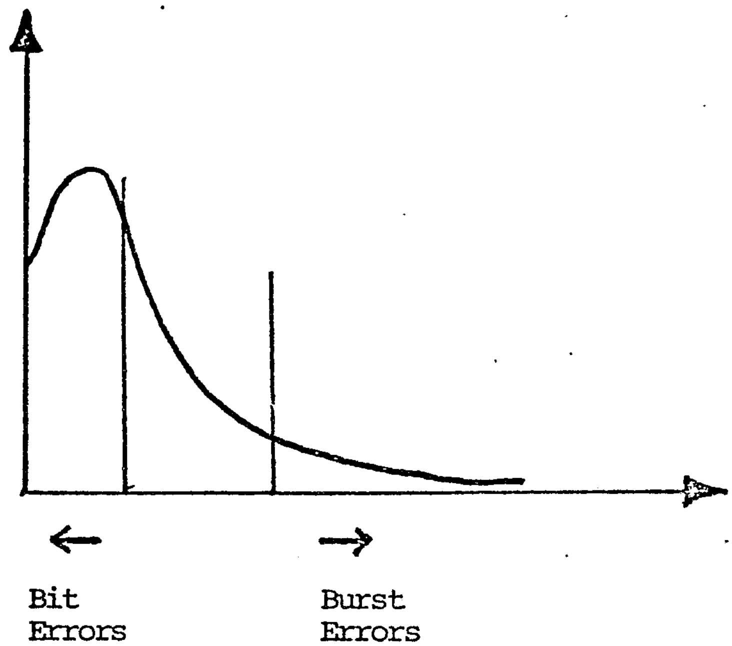


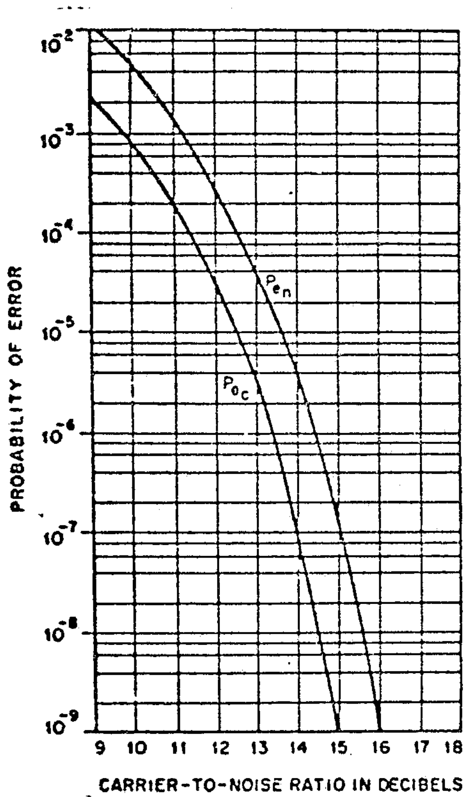
FIGURE 13.6: DIAGRAM OF RANDOM NOISE ENERGY DISTRIBUTION

energy plotted as a probability distribution (see Figure 13.6) will give a normal curve, with the higher energy, longer duration bursts occurring at the tail. This means that a few high energy bursts, wiping out a number of bits; and a much larger number of low energy bursts, which destroy only one bit each, will occur. Since the occurrence of either effect is random, each can be examined as a separate distribution. This will of course leave an uncertain region in between, but the region of inapplicability is not important to the CAS analysis, as will be shownin Section 13.3.2. Since it is known that the frequency distribution of gaussian noise has constant amplitude, so that noise intensity varies only with bandwidth and not withthe absolute frequency, this effect will be seen regardless of the bandrate. The analytic power of these assumptions makes an otherwise difficult problem tractable.

13.2.2.4 Radio Data Link Model.

The model of radio frequency data transmission is based on the literature. It has already been stated that wider bandwidths encompass more noise, so it is known that error rates will be, in part, a function of frequency bandwidth. The most important variation for CAS, however, is the variation with the carrier-to-noise ratio. That is to say, if the attenuation is such that the signal energy falls, how will the error rates react? As the CAS user moves about, he will necessarily be continuously changing this C/N ratios, and it will be important to know if this function will cause an unacceptable level of errors.

Examination of the error rate versus C/N graph on pages 21-25 of the Reference Handbook for Radio Engineers gives the above information for coherent and noncoherent FM detection. This shows that C/N levels as low as 10dB will still give bit error rates better than 10^{-3}, which will be more than sufficient to insure proper reception (Figure 13.7).



Reference Data for Radio Engineers

FIGURE 13.7

This model is a worst case approach, for a complete model for the modulation system being proposed has not been completed. Since one of the components is an FM modulation, the CAS can expect to have error rates not greater and probably substantially less than those of the model.

The radio link can be modeled by:

$$P_e = \tfrac{1}{2}\left[1 - \text{erf}\ (\tfrac{1}{2}C/N)^{\frac{1}{2}}\right] \quad \ldots\ldots \quad (7)$$

which for Figure 13.4 means the transfer function of L_1 is

$$T_{out} = T_{in}\ P_e\ (C/N) \quad \ldots\ldots \quad (8)$$

where P_e is as shown in (7) above.

13.2.3 Component Reliability Model.

It is known from the literature that equipment failures over time can be represented by decaying exponentials, so each of the blocks in the directed graph of Figure 13.5 can be represented by this form of distribution:

$$P(t) = A\ e^{-t/\tau}$$

where the condition for a distribution function;

$$A\ e^{-t/\tau} = 1$$

implies that if the function is equal to zero for t less than zero:

$$A = 1/\tau$$

Now the available information is in terms of failures in 10^6 hours. If we take hours per failure, the reciprocal, we get a more useful figure, the Mean Time Between Failures (MTBF), or the time at which half of a given component type have failed,

$$\int_0^{MTBF} A\ e^{-t/\tau} = .5$$

which implies;

$$\tau = -\frac{\ln(.5)}{MTBF}$$

Now the probability functions can be multiplied together;

$$R(t) =$$

$$\left[\frac{-MTBF_1}{\ln .5}\exp\ (-t).\frac{-MTBF_1}{\ln .5}\right]\left[\frac{-MTBF_2}{\ln .5}\exp\ (-t).\frac{-MTBF_2}{\ln .5}\right] - - - \left[\frac{-MTBF_n}{\ln .5}\exp\ (-t).\frac{-MTBF_n}{\ln .5}\right]$$

simplifying,

$$R(t) = -\frac{(MTBF_1 + MTBF_2 + - - - MTBF_n)}{\ln .5}\exp\left[(+t)\ \frac{(MTBF_1 + MTBF_2 + - - - MTBF_n)}{\ln .5}\right] \quad (9)$$

which shows that the system MTBF is simply the sum of the component MTBF's.

Information sources in industry (1,2) gave the following failure rates for electronic components, assuming that a burn has been carried out. This is necessary to avoid the high infant mortality rates at the beginning of a failure probability curve.

ITEM	FAILURE RATE IN 10^6 HOURS
CMOS IC's	5 to 6
TTL IC's	2 to 5
INTEL MCS-4 Chips	10
Transistors	.5 to 1
Passive components	.5
Mechanical components	2
Double Clad PC	1
Crystal	.5
Card connector (male)	.05
(female)	.005

As shown in (9) above, the equation for modeling reliability is simply the number of each component class (N_i) times its failure rate (F_i) with a sum taken over all component type.

$$\text{Failure rate} = \sum^{i} N_i F_i$$

Now a worst-case composition of components for the proposed CAS system would be as follows:

Information provided by 1. Scope Electronics, Inc.
2. Intel Corporation

C1-Actuator Components

- 4 CMOS IC's
- 2 Transistors
- 10 Passive Components
- 1 PC Board

C2-Internal Receiver/Relay Components

- 10 CMOS IC's
- 10 Transistors
- 100 Passive Components
- 1 PC Board

C3-External Receiver/Relay Components

- 15 CMOS IC's
- 10 INTEL MOS IC's
- 10 Transistors
- 5 TTL IC's
- 150 Passive Components
- 1 PC Board

C4-Central Station

Similar to external receiver/relay

So the failure rates are:

DEVICE	FAILURES IN 10^6 HOURS
Actuator	22.5
Internal Receiver/relay	61
External receiver/relay	200
Central station	200

The system failure rate is thus:

R = 483 failures in 10^6 hours, or System MTBF = 2800 hours

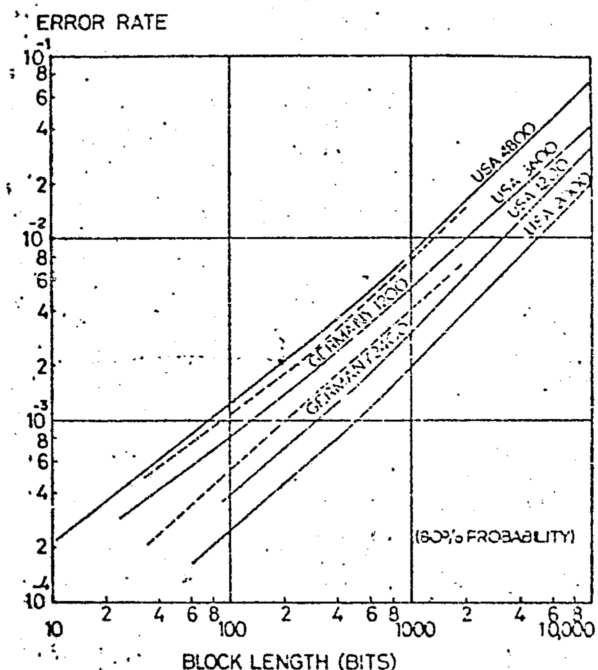
13.3.2 Relationship between Theoretical CAS Transmission Reliability and Empirical Data.

In the literature, such as Lemon & Evanowsky (1973) and Stuttard (1972), there is empirical data showing a striking bimodal response of word error rate to word length. It is stated in Stuttard that for long word lengths, this relationship is approximately linear. This can readily be seen in Figure 13.8. A similar linearity can be seen for short block lengths in Lemon et al. (Note that Lemon's work is graphed by T, word success rate, and Stuttard's by Qw, word failure rate).

Another important point is the empirical proof of the division of noise into single-bit random errors and multi-bit error random bursts. A plot of frequency of occurrence of various error-free intervals, i.e., the distribution function of intervals between successive bit errors, is shown in Lemon. From this plot it is seen that if a word is shorter than 60 bits, the chance of an error burst crossing a word boundary is high, so the error rate "seen" by a word is close to the actual bit error rate. This is of great interest to CAS, for due to limitations on such items as cost, transmission time, and so forth, the word length preferably is under 60 bits. Conversely, if the word is larger than 250 bits, the effect of clustered errors in the bursts is effectively hidden, for a burst of n errors can usually cause only one word error, thus the effective error rate is less than the actual bit error rate. This validates use of bit error rate in modeling, since the worst case is what will actually be seen. Further, it validates the parameter Y, messages lost, since a burst of noise will wipe out several messages, as assumed.

Since the range of values, 60 to 250 bits, that falls between the two noise modes, is also the same range for the breakpoints on the graphs of word error rates, it seems fairly safe to assume a correlation and to attempt the derivation of a linear model in terms of the bit error rate and the effective bit error rate.

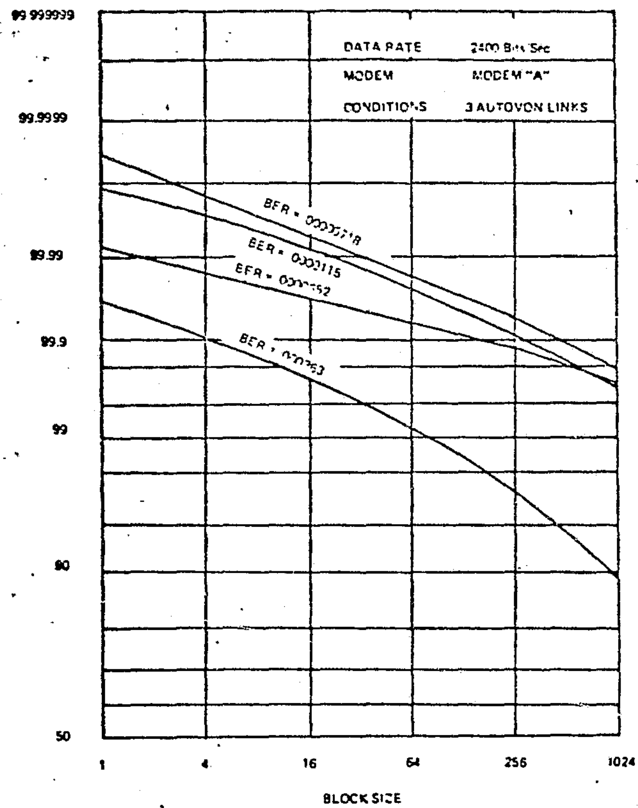
It is also of interest to note that the assumption of Section 13.2.2.3 predicted an inapplicable region between the single bit and burst error types.



Variation of Error Rate With Block Length.

Stuttard, 1972

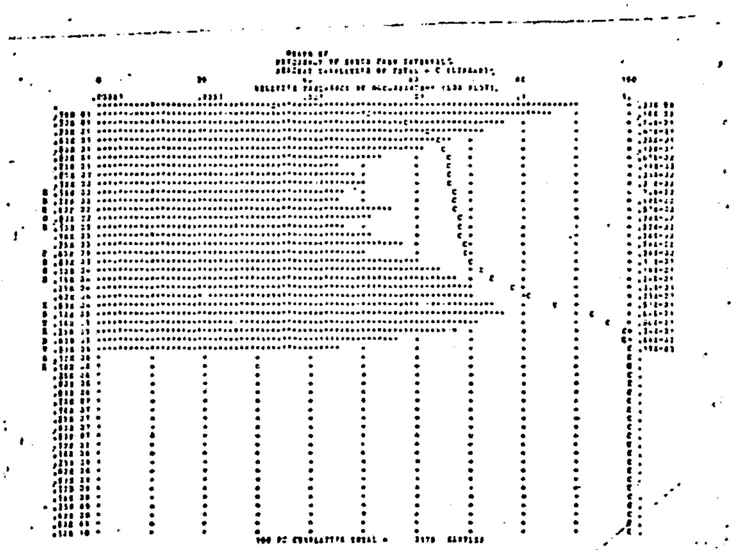
FIGURE 13.8



Percent throughput versus block size:
four one-hour tests during AUTOVON evaluation.

Lemon & Evanowsky, 1973

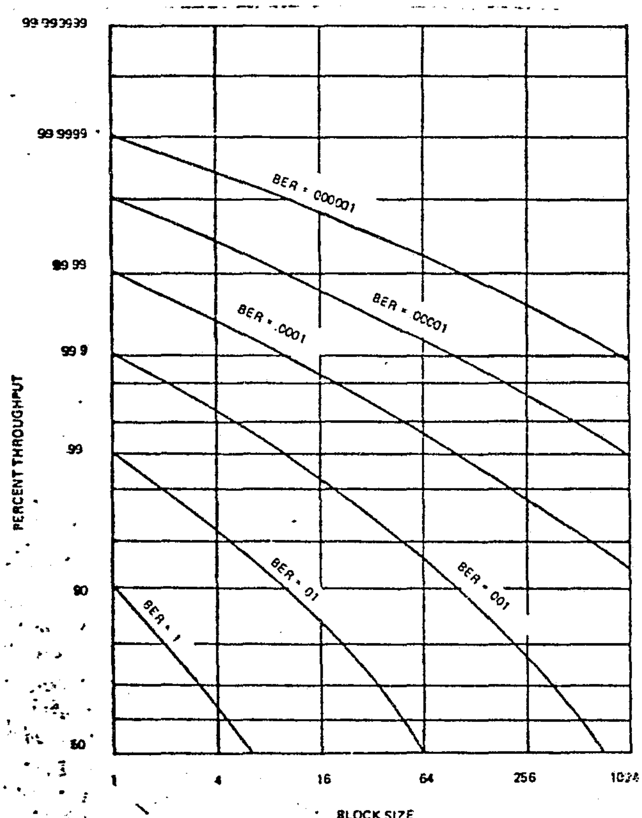
FIGURE 13.9



Graph of frequency of error-free intervals:
cumulative percent of total = C (linear);
relative frequency of occurrence = * (log plot).

Lemon & Evanowsky, 1973

FIGURE 13.10



Percent throughput versus block size: randomly-distributed errors.

Lemon & Evanowsky, 1973

FIGURE 13.11

13.3.2.2 A Linear Approximation.

In the general mathematical case, if the probability of a binary choice event, such as a bit being correct, is p, then the error probability is:

$$q = 1-p$$

The probability, T, that no errors occur in n successive trials, where one bit represents a trial is:

$$T = p^n$$

if the events can be assumed to be independent. Since the errors discussed are caused by random noise, this restriction is fulfilled.

Now if information is discussed in terms of words, the smallest group of bits that is a unit of coding, i.e., the probability of an n-bit word being incorrect is:

$$Q_W = 1-T = 1-p^n$$

so

$$n \log(p) = \log(1-Q_W)$$

Applying the series expansion for a logarithm:

$$n\left[(p-1)-\tfrac{1}{2}(p-1)^2+1/3(p-1)^3 \ldots\right] = -\left[Q_W-\tfrac{1}{2}Q_W^2 + 1/3Q_W^3 \ldots\right]$$

Since it is known that in most practical cases the error rate is under 10^{-3}, assume p to be near unity, and since a small number to a power is even smaller, the higher order terms of p can be neglected. Similarly, for the right-hand side, if p is nearly one, $1-p^n$ is very small so the same simplification applies and

$$Q_W = n(1-p) \quad \ldots\ldots \quad (10)$$

which is the desired linear approximation, valid if p is close to one.

Now, examine this approximation in the light of the studies mentioned earlier. The BER, bit error rate, defined as the ratio of the total incorrect bits to the total number of bits transmitted:

$$BER = E_T/B_T \quad \ldots\ldots \quad (11)$$

where E_T is the total errors and B_T is the total bits sent. It is important to note that E_T is the sum of random errors and burst errors occurring within a burst:

$$E_t = E_R + E_B \quad \ldots\ldots \quad (12)$$

It is safe to assume that bursts are ergodic (random) events and that there is little if any correlation between succeeding bursts. Thus for wordlength n and burst width N_B,

$$\text{if } n \gg N_B$$

then effective bit error rate, R, is:

$$R = \frac{BER}{E_B/N_B} \quad \ldots\ldots \quad (13)$$

where N_B is the total number of noise bursts.

Plugging in equations (11) and (12):

$$R = \frac{E_T/B_T}{E_B/N_B} = \left[1 + \frac{E_R}{E_B}\right]\frac{N_B}{B_T} \quad \ldots\ldots \quad (14)$$

Therefore if n is large, p = R, so the information throughput equation is:

$$T = R^n, \quad \ldots\ldots \quad (15)$$

the effective probabily that an error will not occur within the n bits of a long word. Also:

$$Q_w = 1-R^n,\ n \gg N_B \quad \ldots\ldots \quad (16)$$

Examining the converse:

$$n \ll N_B$$

it is seen that it becomes unlikely that bursts are confined between word boundaries. So the word error rate in this range is very close to the BER and is equal to it, of course, when n = 1.

It is noteworthy that the CAS system is constrained by cost parameters, bandwidth limitations and limitations on maximum allowed transmission time such that the block lengths of interest are all within the range of validity of the approximation:

$$Q_W = n(BER) \ldots\ldots (17)$$

or:

$$T = 1 - n(BER) \ldots\ldots (18)$$

13.3.2.3 Transmission Efficiency versus Frequency.

Another parameter of interest is the transmission bandwidth. It has been stated that the probability of burst events and single bit error events are gaussian, so both BER and R become monotonically increasing functions of frequency bandwidth:

$$BER = h(f_B), \quad \frac{d\,h(f_B)}{df} \geq 0 \ldots\ldots (19)$$

$$R = g(f_B), \quad \frac{d\,g(f_B)}{df} \geq 0 \ldots\ldots (20)$$

Defining the system efficiency, E, as the number of good words transmitted in unit time:

$$E(f_B) = \frac{A_G(f_B)}{t} \ldots\ldots (21)$$

where A_G is the number of good words, A_T, the number of total words.

Now the total words per unit time:

$$\frac{A_T}{t} = \frac{f_B}{K.n} \ldots\ldots (22)$$

where n is the number of bits in a word, K is the number of hertz per bit, and f_B is the transmission bandwidth in hertz per second. From the equations for Q_W:

$$T = p^n$$

Now from the above and the definition of T:

$$A_G = A_T p^n \ldots\ldots (23)$$

so that the system efficiency,

$$E(f_B) = \frac{A_T}{t} p^n = \frac{f_B\, p^n}{K.n} \ldots\ldots (24)$$

so:

$$E(f_B) = \frac{f_B}{K.n}\left[1 - BER(f_B)\right]^n \qquad n < 60 \ldots\ldots (25)$$

$$E(f_B) = \frac{f_B}{K.n}\left[1 - R(f_B)\right]^n \qquad n > 250. \ldots\ldots (26)$$

These theoretical derivations quantitatively show the empirical results of Stuttard, that is, even though error rate increases with bandwidth, the efficiency of transmission improves. The reason is that more good messages are arriving in each unit of time. Although message transmission efficiency is greater, CAS performance would still be degraded. The concept is that of averaging A_T repetitions of one message, so that even though the throughput per second may be better, the probability of the word being correct is degraded.

13.4 SYSTEM RELIABILITY

13.4.1 The System Models.

Overall evaluation of the models is simply a matter of bringing together the appropriate transfer functions for each item in equations (2) and (3) in Section 13.1. This defines the system equations for message transmission and for component reliabilities in terms of the appropriate parameters. The relevance of this for CAS is in the precise definition of design and environmental parameters that affect the models. This is especially important for the transmission model. Knowledge of these factors shows where the weak points lie and how they can be compensated for, if possible.

Interaction of the two models is minimal. The transmission reliability asks the question, "Will a set of messages sent at time t arrive at the central station intact?" The component reliability model asks only if a system will be operable after some time interval from the manufacture date. Any small interaction that does occur is one way: if the components are inoperable, the transmission model is obviously invalid. The converse is not true, since the question, "Will the component reliability change if the message transmission fails?" is meaningless.

13.4.2 The Message Transmission Reliability Model.

In building the system model it is necessary to combine a number of the equations derived previously. A summary of these are listed below in transfer function format. The convention is used that B is a bit reliability, T is a word reliability, inputs and outputs are subscripted.

A. L_1 the RF link"

$$B_{out} = B_{in}(1 - \tfrac{1}{2}\left[1 - \mathrm{erf}(\tfrac{1}{2}C/N)^{\frac{1}{2}}\right])$$

B. L_2 and L_3, the power line and external links:

$$T_{out} = T_{in}(1 - BER)^n$$

$$B_{out} = B_{in}(1 - BER)$$

C. C'_3 and C'_4, the external receiver relay and central station software for bit by bit

$$T_{out} = \left[\sum_{(A_T/2)+1}^{A_T-Y} \frac{(A_T-Y)!}{x!\,(A_T-Y-x)!} B_{in}(1-B_{in})^{A_T-Y-x} \right]^n$$

and for message by message:

$$T_{out} = \sum_{(A_T/2)+1}^{A_T-Y} \frac{(A_T-Y)!}{x!\,(A_T-Y-x)!} (T_{in})^x (1-T_{in})^{A_T-Y-x}$$

D. Additionally a dummy block of the form:

$$B_{out} = T_{in}^{1/n}$$

is used to interface terms with differing inputs and outputs, i.e., message reliability output, bit reliability input.

The B_{in} to the RF link is equal to one since this is the message source. So L_1L_2 becomes:

$$T_{12} = \left[\frac{1}{2} - \frac{1}{2}\,\mathrm{erf}(\tfrac{1}{2}C/N)^{\frac{1}{2}}\right]^n (1 - BER)^n$$

which is the input T_{in} for C'_3 if it is a bit by bit model For the message by message:

$$T_{12} = \left[\frac{1}{2} - \frac{1}{2}\,\mathrm{erf}(\tfrac{1}{2}C/N)^{\frac{1}{2}}\right] (1 - BER)$$

The output of C'_3 we will call T_{123} if the central station C'_4 is bit by bit, the input to C'_4 will be in the form:

$$B_{1234} = \left[T_{123}(1 - BER)^n\right]^{1/n}$$

If it is of the message by message type:

$$T_{1234} = T_{123}(1 - BER)$$

The actual plugging in of these terms would produce an equation longer than the page permits. It is possible, though, to examine its response with respect to CAS by plugging ballpark figures into the various equations.

Choose some typical sets of conditions and evaluate the total system message reliability, the T_{out} of C'_4, the central station. Then calculate the parameters suggested for CAS, n = 32, and bit by bit analysis.

Case 1. The RF channel has 12dB C/N ratio, and the hardwire lines have a 10^{-4} bit error rate. Assume that one of twenty messages is lost due to burst noise.

Case 2. The RF channel has 9dB C/N ratio, the hardwire lines have a 10^{-3} error rate. Assume three of twenty due to burst noise.

Now plugging values in for Case 1:

$$B_{12} = (.99996)\ (.9999) = .99986$$

This roughly .99990 which can be checked in the computer generated table. The output of C'_3 is thus .9997 for the word reliability. The input to the central station is then

$$B_{in} = \left[.99997\ (.9999)^{32}\right]^{1/32} = .999899$$

For the second case, B_{12} = .9981, so the external receiver/relay outputs a .9999 reliability, and the output of the central station has a reliability of .99991.

These figures show that the proposed CAS system has sufficient transmission reliability, even under the poor conditions of Case 2.

Plugging values for Case 1 gives:

$$B_{12} = (.99996)\ (.9999) = .99986$$

This is roughly .99990, which can be checked on the computer generated table for bit by bit reliabilities. The output of C'_3 is thus found to be a .99997 reliability. The central station input is

$$\left[.99997\ (.9999)^{32}\right]^{1/32} = .999899$$

so the central station reliability is .99991.

For the second case:

$$B_{12} = .9986$$

The external receiver/relay outputs a .9999 reliability, so the central station output is .99991.

These figures show that the proposed CAS system has sufficient transmission reliability, even under the poor conditions of Case 2.

13.5 SPECIAL CONSIDERATIONS RE SOFTWARE/PROGRAMMING

The IBM 360/67 high speed digital computer at Carnegie-Mellon University was chosen to calculate the values for the model equations of the bit by bit and message by message error correcting techniques. Representative portions of the output are included in the appendix of this chapter.

Since the process to be studied was entirely mathetmatical, Fortran IV was chosen due to its high speed and efficient compiling for iterative calculations.

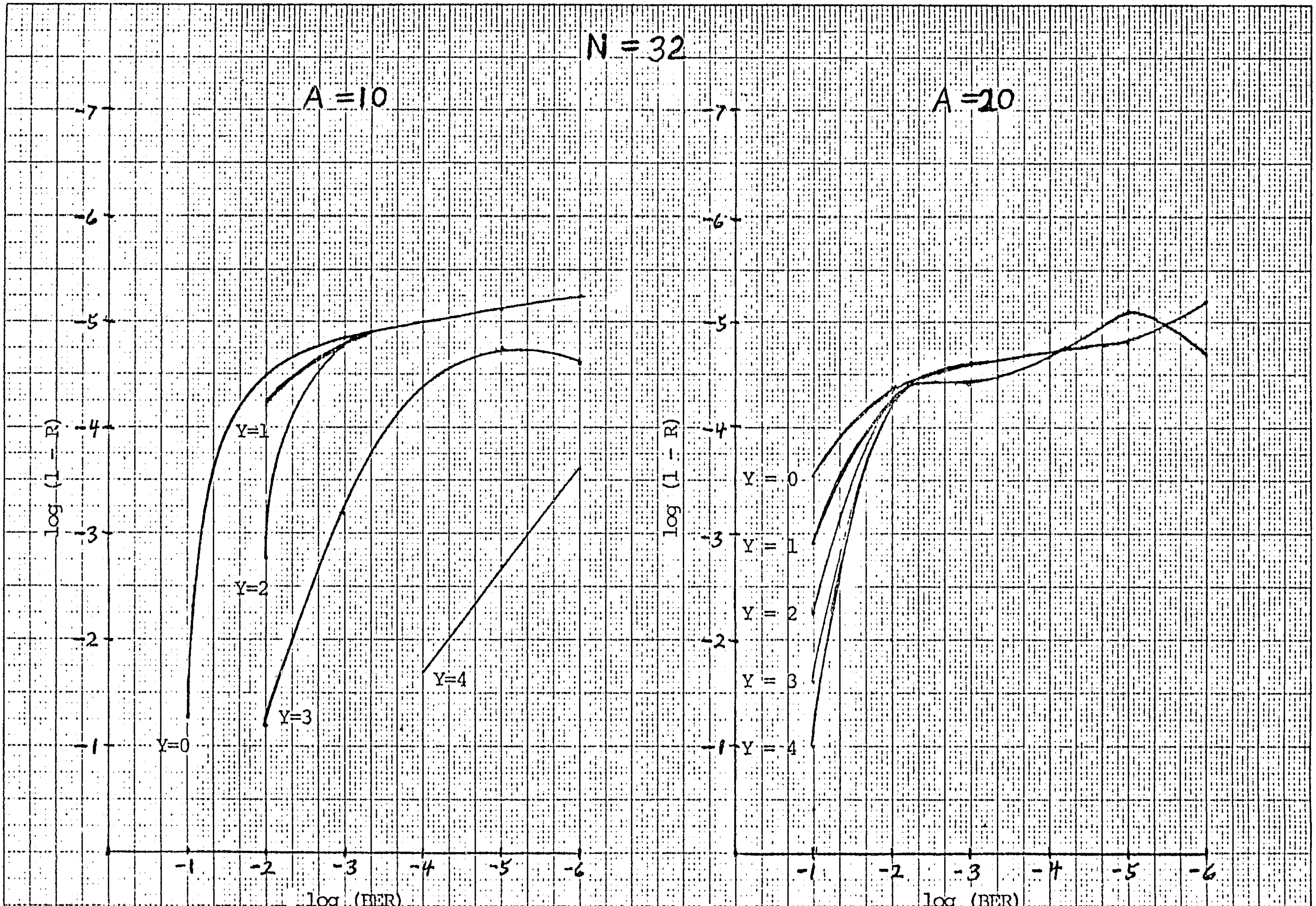


Figure 13.12
Message Interpretation Logic

MESSAGE INTERPRETATION LOGIC: EXAMPLE 13

32= BITS PER MESSAGE

.900000 PROBABILITY OF RANDOM NOISE NOT AFFECTING ANY ONE BIT

A = TOTAL NUMBER OF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO TRANSIENTS AND NOISE BURSTS

R=RELIABILITY (PROBABILITY) OF CORRECT INTERPRETATION OF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.11790139E-02	2	0.00000000	2	0.00000000
4	0.15776382E-03	4	0.40483530E-04	4	0.00000000
6	0.19721934E-04	6	0.67594410E-05	6	0.13900735E-05
8	0.24501514E-05	8	0.94582532E-06	8	0.27818919E-06
10	0.30544311E-06	10	0.12587486E-06	10	0.43229001E-07
12	0.38270684E-07	12	0.16439042E-07	12	0.61627112E-08
14	0.48188120E-08	14	0.21300921E-08	14	0.84501672E-09
16	0.60943095E-09	16	0.27511105E-09	16	0.11354789E-09
18	0.77370485E-10	18	0.35492678E-10	18	0.15084725E-10
20	0.98553258E-11	20	0.45787506E-11	20	0.19904434E-11

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.47730630E-07	8	0.00000000	8	0.00000000
10	0.11134759E-07	10	0.16389157E-08	10	0.00000000
12	0.19060244E-08	12	0.43667425E-09	12	0.56275068E-10
14	0.29052871E-09	14	0.81727750E-10	14	0.16859916E-10
16	0.41844236E-10	16	0.13285319E-10	16	0.34271717E-11
18	0.58387947E-11	18	0.20089043E-11	18	0.59245214E-12
20	0.79918201E-12	20	0.29122006E-12	20	0.93960918E-13

MESSAGE INTERPRETATION LOGIC: EXAMPLE 14

32= BITS PER MESSAGE

.990000 PROBABILITY OF RANDOM NOISE NOT AFFECTING
ANY ONE BIT

A = TOTAL NUMBER OF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO
TRANSIENTS AND NOISE BURSTS

R=RELIABILITY (PROBABILITY) OF CORRECT
INTERPRETATION OF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.52559328E 00	2	0.00000000	2	0.00000000
4	0.69542956E 00	4	0.38104391E 00	4	0.00000000
6	0.78909147E 00	6	0.58014560E 00	6	0.27624857E 00
8	0.84870619E 00	8	0.70289451E 00	8	0.47567278E 00
10	0.88920522E 00	10	0.78454393E 00	10	0.61540693E 00
12	0.91774684E 00	12	0.84123117E 00	12	0.71476924E 00
14	0.93833619E 00	14	0.88167155E 00	14	0.78657705E 00
16	0.95343184E 00	16	0.91106373E 00	16	0.83917207E 00
18	0.96462917E 00	18	0.93271679E 00	18	0.87811059E 00
20	0.97300971E 00	20	0.94883066E 00	20	0.90718579E 00

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.20027423E 00	8	0.00000000	8	0.00000000
10	0.38478404E 00	10	0.14519441E 00	10	0.00000000
12	0.53083861E 00	12	0.30790967E 00	12	0.10526282E 00
14	0.64250469E 00	14	0.45201081E 00	14	0.24421549E 00
16	0.72714192E 00	16	0.57046854E 00	16	0.38057536E 00
18	0.79124397E 00	18	0.66490227E 00	18	0.50083530E 00
20	0.83988613E 00	20	0.73912382E 00	20	0.60173124E 00

MESSAGE INTERPRETATION LOGIC: EXAMPLE 16

32= BITS PER MESSAGE

.999900 PROBABILITY OF RANDOM NOISE [NOT] AFFECTING ANY ONE BIT

A = TOTAL NUMBER OF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO TRANSIENTS AND NOISE BURSTS

R=RELIABILITY (PROBABILITY) OF CORRECT INTERPRETATION OF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.99361706E 00	2	0.00000000	2	0.00000000
4	0.99993861E 00	4	0.99044144E 00	4	0.00000000
6	0.99999881E 00	6	0.99989831E 00	6	0.98727542E 00
8	0.99999964E 00	8	0.99999815E 00	8	0.99984753E 00
10	0.99999940E 00	10	0.99999958E 00	10	0.99999785E 00
12	0.99999946E 00	12	0.99999928E 00	12	0.99999940E 00
14	0.99999881E 00	14	0.99999905E 00	14	0.99999946E 00
16	0.99999928E 00	16	0.99999905E 00	16	0.99999881E 00
18	0.99999899E 00	18	0.99999917E 00	18	0.99999928E 00
20	0.99999899E 00	20	0.99999893E 00	20	0.99999899E 00

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.98411989E 00	8	0.00000000	8	0.00000000
10	0.99978703E 00	10	0.98097396E 00	10	0.00000000
12	0.99999690E 00	12	0.99971724E 00	12	0.97783822E 00
14	0.99999928E 00	14	0.99999559E 00	14	0.99963725E 00
16	0.99999905E 00	16	0.99999940E 00	16	0.99999404E 00
18	0.99999905E 00	18	0.99999881E 00	18	0.99999899E 00
20	0.99999917E 00	20	0.99999928E 00	20	0.99999905E 00

MESSAGE INTERPRETATION LOGIC: EXAMPLE 17

32= BITS PER MESSAGE

.999990 PROBABILITY OF RANDOM NOISE NOT AFFECTING
ANY ONE BIT

A = TOTAL NUMBER OF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO
TRANSIENTS AND NOISE BURSTS

R=RELIABILITY (PROBABILITY) OF CORRECT
INTERPRETATION OF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.99935913E 00	2	0.00000000	2	0.00000000
4	0.99999875E 00	4	0.99903832E 00	4	0.00000000
6	0.99999946E 00	6	0.99999863E 00	6	0.99871926E 00
8	0.99999958E 00	8	0.99999934E 00	8	0.99999791E 00
10	0.99999946E 00	10	0.99999952E 00	10	0.99999958E 00
12	0.99999946E 00	12	0.99999934E 00	12	0.99999946E 00
14	0.99999928E 00	14	0.99999911E 00	14	0.99999946E 00
16	0.99999869E 00	16	0.99999893E 00	16	0.99999928E 00
18	0.99999893E 00	18	0.99999881E 00	18	0.99999869E 00
20	0.99999881E 00	20	0.99999887E 00	20	0.99999893E 00

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.99839854E 00	8	0.00000000	8	0.00000000
10	0.99999720E 00	10	0.99807841E 00	10	0.00000000
12	0.99999952E 00	12	0.99999672E 00	12	0.99775851E 00
14	0.99999934E 00	14	0.99999946E 00	14	0.99999589E 00
16	0.99999911E 00	16	0.99999946E 00	16	0.99999934E 00
18	0.99999893E 00	18	0.99999928E 00	18	0.99999911E 00
20	0.99999881E 00	20	0.99999869E 00	20	0.99999893E 00

COMPU-GUARD SECURITY SYSTEMS INC; CAS PROJECT
RELIABILITY ANALYSIS FOR CITIZENS ALARM SYSTEM

MESSAGE INTERPRETATION LOGIC: EXAMPLE 18

32= BITS PER MESSAGE

.999999 PROBABILITY OF RANDOM NOISE NOT AFFECTING
ANY ONE BIT

A = TOTAL NUMBER OF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO
TRANSIENTS AND NOISE BURSTS

R=RELIABILITY (PROBABILITY) OF CORRECT
INTERPRETATION OF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.99993515E 00	2	0.00000000	2	0.00000000
4	0.99999994E 00	4	0.99990273E 00	4	0.00000000
6	0.99999982E 00	6	0.99999994E 00	6	0.99987030E 00
8	0.99999988E 00	8	0.99999982E 00	8	0.99999982E 00
10	0.99999982E 00	10	0.99999982E 00	10	0.99999988E 00
12	0.99999934E 00	12	0.99999982E 00	12	0.99999982E 00
14	0.99999976E 00	14	0.99999976E 00	14	0.99999934E 00
16	0.99999976E 00	16	0.99999946E 00	16	0.99999976E 00
18	0.99999982E 00	18	0.99999934E 00	18	0.99999976E 00
20	0.99999970E 00	20	0.99999946E 00	20	0.99999982E 00

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.99983788E 00	8	0.00000000	8	0.00000000
10	0.99999982E 00	10	0.99980533E 00	10	0.00000000
12	0.99999982E 00	12	0.99999988E 00	12	0.99977291E 00
14	0.99999982E 00	14	0.99999982E 00	14	0.99999976E 00
16	0.99999976E 00	16	0.99999934E 00	16	0.99999982E 00
18	0.99999946E 00	18	0.99999976E 00	18	0.99999976E 00
20	0.99999934E 00	20	0.99999976E 00	20	0.99999946E 00

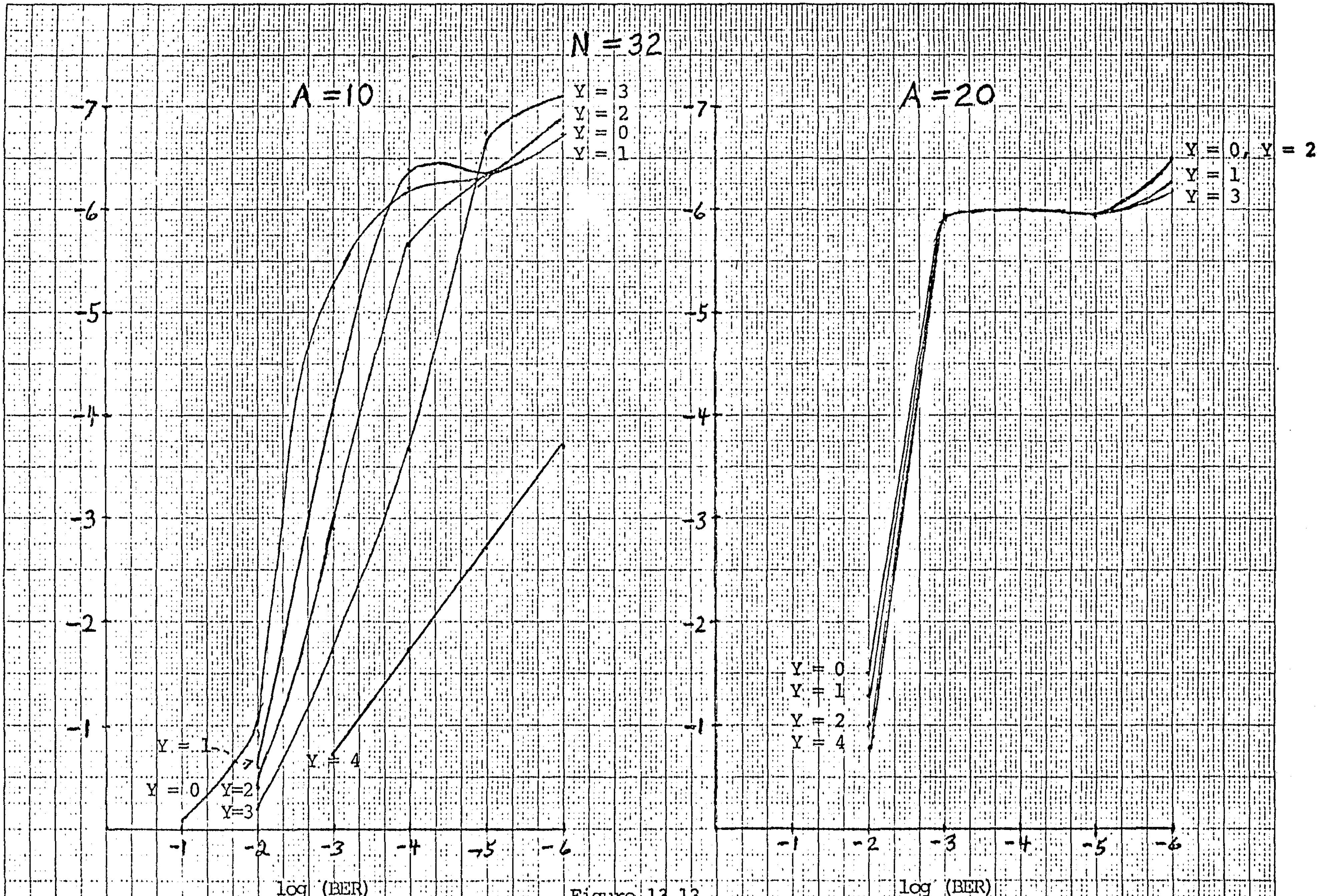


Figure 13.13
Bit Interpretation Logic

BIT INTERPRETATION LOGIC: EXAMPLE 13

32= BITS PER MESSAGE

.900000 PROBABILITY OF RANDOM NOISE NOT AFFECTING ANY ONE BIT

A = TOTAL NUMBER OF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO TRANSIENTS AND NOISE BURSTS

R=RELIABILITY (PROBABILITY) OF CORRECT INTERPRETATION OF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.11790139E-02	2	0.00000000	2	0.00000000
4	0.17925149E 00	4	0.40483166E-04	4	0.00000000
6	0.59972340E 00	6	0.65937340E-01	6	0.13900653E-05
8	0.85111862E 00	8	0.43479097E 00	8	0.20592581E-01
10	0.94895923E 00	10	0.76511496E 00	10	0.28858137E 00
12	0.98279995E 00	12	0.91559905E 00	12	0.66224736E 00
14	0.99416190E 00	14	0.97093260E 00	14	0.87034541E 00
16	0.99799323E 00	16	0.99005461E 00	16	0.95384461E 00
18	0.99927342E 00	18	0.99657375E 00	18	0.98393422E 00
20	0.99970627E 00	20	0.99877787E 00	20	0.99440688E 00

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.47730186E-07	8	0.00000000	8	0.00000000
10	0.55769086E-02	10	0.16388866E-08	10	0.00000000
12	0.17522681E 00	12	0.13325398E-02	12	0.56274679E-10
14	0.54952425E 00	14	0.97406983E-01	14	0.28496701E-03
16	0.81266201E 00	16	0.43555999E 00	16	0.49659606E-01
18	0.93041545E 00	18	0.74320054E 00	18	0.32880390E 00
20	0.97517353E 00	20	0.89967787E 00	20	0.66383660E 00

BIT INTERPRETATION LOGIC: EXAMPLE 14

32= BITS PER MESSAGE

.990000 PROBABILITY OF RANDOM NOISE NOT AFFECTING
ANY ONE BIT

A = TOTAL NUMBER OF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO
TRANSIENTS AND NOISE BURSTS

R=RELIABILITY (PROBABILITY) OF CORRECT
INTERPRETATION OF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.52559072E 00	2	0.00000000	2	0.00000000
4	0.98121285E 00	4	0.38104385E 00	4	0.00000000
6	0.99935919E 00	6	0.96909946E 00	6	0.27624601E 00
8	0.99996567E 00	8	0.99889416E 00	8	0.95429325E 00
10	0.99997711E 00	10	0.99994659E 00	10	0.99826157E 00
12	0.99998093E 00	12	0.99997330E 00	12	0.99991417E 00
14	0.99995804E 00	14	0.99996567E 00	14	0.99997902E 00
16	0.99996758E 00	16	0.99997330E 00	16	0.99995804E 00
18	0.99996376E 00	18	0.99996567E 00	18	0.99996758E 00
20	0.99996567E 00	20	0.99996567E 00	20	0.99996376E 00

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.20027387E 00	8	0.00000000	8	0.00000000
10	0.93699372E 00	10	0.14519328E 00	10	0.00000000
12	0.99741822E 00	12	0.91739905E 00	12	0.10526180E 00
14	0.99987411E 00	14	0.99633980E 00	14	0.89570111E 00
16	0.99961185E 00	16	0.99983215E 00	16	0.99501395E 00
18	0.99997330E 00	18	0.99995232E 00	18	0.99975204E 00
20	0.99996567E 00	20	0.99996567E 00	20	0.99996376E 00

BIT INTERPRETATION LCGIC: EXAMPLE 16

32= BITS PER MESSAGE

.999900 PROBABILITY OF RANDCM NOISE NOT AFFECTING ANY ONE BIT

A = TOTAL NUMBER CF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO TRANSIENTS AND NCISE BURSTS

R=RELIABILITY (PRCBABILITY) CF CORRECT INTERPRETATION CF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.99360996E 00	2	0.00000000	2	0.00000000
4	0.99997902E 00	4	0.99044043E 00	4	0.00000000
6	0.99999046E 00	6	0.99999046E 00	6	0.98726076E 00
8	0.99999237E 00	8	0.99997520E 00	8	0.99998474E 00
10	0.99998665E 00	10	0.99998665E 00	10	0.99999237E 00
12	0.99998856E 00	12	0.99998856E 00	12	0.99998665E 00
14	0.99998474E 00	14	0.99998665E 00	14	0.99998856E 00
16	0.99997711E 00	16	0.99998856E 00	16	0.99998474E 00
18	0.99998474E 00	18	0.99997711E 00	18	0.99997711E 00
20	0.99998283E 00	20	0.99997711E 00	20	0.99998474E 00

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.98411822E 00	8	0.00000000	8	0.00000000
10	0.99996758E 00	10	0.98097032E 00	10	0.00000000
12	0.99998665E 00	12	0.99998283E 00	12	0.97782004E 00
14	0.99998856E 00	14	0.99998665E 00	14	0.99997520E 00
16	0.99998665E 00	16	0.99998856E 00	16	0.99998856E 00
18	0.99998856E 00	18	0.99998474E 00	18	0.99998665E 00
20	0.99997711E 00	20	0.99997711E 00	20	0.99998856E 00

BIT INTERPRETATION LOGIC: EXAMPLE 17

32= BITS PER MESSAGE

.999990 PROBABILITY OF RANDOM NOISE NOT AFFECTING
ANY ONE BIT

A = TOTAL NUMBER OF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO
TRANSIENTS AND NOISE BURSTS

R=RELIABILITY (PROBABILITY) OF CORRECT
INTERPRETATION OF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.99935919E 00	2	0.00000000	2	0.00000000
4	0.99999309E 00	4	0.99903888E 00	4	0.00000000
6	0.99998856E 00	6	0.99999619E 00	6	0.99871874E 00
8	0.99999619E 00	8	0.99998283E 00	8	0.99998856E 00
10	0.99999237E 00	10	0.99999237E 00	10	0.99999619E 00
12	0.99999428E 00	12	0.99999428E 00	12	0.99999237E 00
14	0.99998474E 00	14	0.99999428E 00	14	0.99999428E 00
16	0.99999237E 00	16	0.99997902E 00	16	0.99998474E 00
18	0.99999046E 00	18	0.99998665E 00	18	0.99999237E 00
20	0.99998474E 00	20	0.99999237E 00	20	0.99999046E 00

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.99839675E 00	8	0.00000000	8	0.00000000
10	0.99998283E 00	10	0.99806911E 00	10	0.00000000
12	0.99999237E 00	12	0.99999619E 00	12	0.99774379E 00
14	0.99999428E 00	14	0.99999237E 00	14	0.99999237E 00
16	0.99999428E 00	16	0.99999428E 00	16	0.99999428E 00
18	0.99997902E 00	18	0.99998474E 00	18	0.99999428E 00
20	0.99998665E 00	20	0.99999237E 00	20	0.99997902E 00

COMPU-GUARD SECURITY SYSTEMS INC; CAS PROJECT
RELIABILITY ANALYSIS FOR CITIZENS ALARM SYSTEM

BIT INTERPRETATION LOGIC: EXAMPLE 18

32= BITS PER MESSAGE

.999999 PROBABILITY OF RANDOM NOISE NOT AFFECTING ANY ONE BIT

A = TOTAL NUMBER OF MESSAGES TRANSMITTED

Y = NUMBER OF MESSAGES LOST DUE TO TRANSIENTS AND NOISE BURSTS

R=RELIABILITY (PROBABILITY) OF CORRECT INTERPRETATION OF RECEIVED MESSAGES

Y = 0		Y = 1		Y = 2	
A	R	A	R	A	R
2	0.99992371E 00	2	0.00000000	2	0.00000000
4	0.99998474E 00	4	0.99989700E 00	4	0.00000000
6	0.99999619E 00	6	0.99999619E 00	6	0.99985695E 00
8	0.99999619E 00	8	0.99997520E 00	8	0.99999619E 00
10	0.99999428E 00	10	0.99999619E 00	10	0.99999619E 00
12	0.99999237E 00	12	0.99999428E 00	12	0.99999428E 00
14	0.99999428E 00	14	0.99997711E 00	14	0.99999237E 00
16	0.99997711E 00	16	0.99999619E 00	16	0.99999428E 00
18	0.99997902E 00	18	0.99999237E 00	18	0.99997711E 00
20	0.99999428E 00	20	0.99998093E 00	20	0.99997902E 00

Y = 3		Y = 4		Y = 5	
A	R	A	R	A	R
0	0.00000000	0	0.00000000	0	0.00000000
4	0.00000000	4	0.00000000	0	0.00000000
6	0.00000000	6	0.00000000	6	0.00000000
8	0.99983597E 00	8	0.00000000	8	0.00000000
10	0.99997520E 00	10	0.99980354E 00	10	0.00000000
12	0.99999619E 00	12	0.99999619E 00	12	0.99975014E 00
14	0.99999428E 00	14	0.99999428E 00	14	0.99999619E 00
16	0.99997711E 00	16	0.99999237E 00	16	0.99999428E 00
18	0.99999619E 00	18	0.99999428E 00	18	0.99997711E 00
20	0.99999237E 00	20	0.99997711E 00	20	0.99999619E 00

13.6 CONCLUSIONS

13.6.1 Technical Observations (Figures 13.12 and 13.13).

The computer simulation of message by message and bit by bit voting models showed the following:

a) Both techniques had a "plateau" region and a critical breakdown point.

b) For a small number of bursts, neither model was greatly affected in the plateau region. However, the rate of fall of reliability with BER beyond the critical point was proportional to the number of messages lost due to bursts.

c) The "plateau" for message-by-message logic was at 99.9999 percent reliability versus 99.995 percent for bit by bit.

d) The critical point for bit-by-bit logic was at a bit error rate of one percent, that of message by message at 0.1 percent.

e) Bit-by-bit transmission logic is far superior to message-by-message logic, if the BER is greater than about 0.3 percent.

f) If the number of burst errors is large, both systems are roughly equivalent (the Y = 4, A = 10 curves for both methods are nearly identical).

g) If the number of bursts is large, the critical point is moved to lower bit error rates and the plateau level decreases.

h) Since CAS will be functioning in a noisy environment, the high reliability of bit-by-bit voting in the 0.2 percent to 1 percent BER range is decisively in its favor.

13.6.2 General Conclusions.

a) Using bit-by-bit interpretation logic, the reliability of transmission along both power lines and voice-grade telephone lines can be expected to be very high (better than 99.9 percent), even at high bit-error-rates. This reliability model therefore suggests not only the reliability of hardware but also the preferred software and programming to be used for error correction.

b) The model develops a theory that is applicable to the empirical data found useful for CAS component design.

c) The estimated failure rates for components suggest that a CAS network with one component of each kind is likely to have an MTBF of 2800 hours. With a network of 100 actuators, 50 internal receiver-relays, one external receiver-relay, and a central station, the system MTBF drops to 180 hours. This suggests the need for improved electronic packaging of both the actuator and the internal receiver-relay. Once the actuator is on a hybrid chip, its failure rate should go down to about 10 per 10^6 hours. Similarly, if the internal receiver-relay goes onto one or two special-purpose integrated circuit chips, its failure rate should go down to perhaps 20 in 10^6 hours. Thus, with these improvements the network MTBF rises significantly to 420 hours. This points up the importance of improved electronic packaging for the internal receiver-relay prior to building a large number of units, such as for a large scale field test. This reliability is, of course, predicated upon the use of commercial components rather than the more expensive MIL-spec components.

SECTION 14

SCENARIO EVALUATION AND SELECTION

14.1 SCENARIO SELECTION

One of the major tasks in Phase I is the evaluation of alternative scenarios for the feasibility demonstration of CAS and the selection of two scenarios which provide the broadest possible base for the test of the system. The diversity and range of potential environments within which CAS must operate is so large that specific factors relating to the environments must be itemized and considered as a structural basis in the selection of desirable scenarios for feasibility demonstration. These factors are now considered.

14.1.1 User Demographic Factors.

Within the physical structure, a wide range of potential users must be considered. Users may differ in terms of age, sex, income and profession. Their perception of crime will be an important factor in determining the threshold at which they will be likely to trigger the actuator. This perception will be a function of a number of factors, including the crime rate, the perceived responsiveness of the police, etc. Users will also differ in terms of the relationships which they enjoy both with their families and with the community around them. Generally, the closer the social relationship, the lower the fear of victimization.

14.1.2 Human Factors.

A number of human factors will significantly affect the manner in which CAS is used. These factors are of several types.

To take an example, the physical coordination of the user will be a primary consideration in designing thephysical actuator package. People with various handicaps should be able to use the system with minimum difficulty.

Along other lines, various user characteristics will influence the threshold for various emergencies. For example, to a cardiac patient a suspected seizure may assume far greater importance than suspected situations of criminal attack. A person's general level of insecurity will also be important.

Another area which will quite possibly be important is the general intelligence or level of sophistication of the user. Along these lines also would be the user's sense of responsibility.

14.1.3 Physical Environment.

A number of different factors must be considered in determining the range of physical environments in which CAS will have to perform. There are factors such as the exterior dimension of the structure, the number of floors, the layout of each floor, the external appearance and finish, the susceptibility to weather and changes in weather and the landscape around the physical structure. Within the building there are factors such as the location of elevators, hallways, stairwells, closets, light fixtures, etc. The nature of the entrance to the building and the total number of possible points of ingress and egress, the level of lighting, both outside and at all points inside, are all important factors. There will exist different types of apartments exhibiting different crime-related characteristics. The type of occupancy in the building is a very important factor. Key dimensions here are the general level of income and education, and so on. Finally, consideration must be given to the physical plant facilities. This includes the location of the heating and air conditioning systems, the telephone system and the power utility system. Facts of importance here are the age of the physical plant, the quality of the maintenance of physical plant facilities throughout the structure, and the level of abuse by residents.

14.1.4 The Crime Environment.

Another important set of facts to be considered in the choice of scenarios is the frequency and distribution of criminal activity. Also important are the type of response agents available in the event of an emergency, and the response time and the quality of the response for each of these agents. User perception of victimization is of course important and has been discussed in detail in Section 2.

14.1.5 Choice of Scenarios.

After a very careful investigation of all the factors listed above, Compu-guard concluded that both scenarios should preferably be apartment complexes rather than professional institution, (schools, hospitals, etc.). Professional institutions were investigated in detail, and some observations were given in Section 7; however, the use of CAS in such institutions would be restricted to highly selected groups of people and to a highly specialized physical environment. It was therefore felt that this kind of environment would not represent a wide enough cross-section, given the limited number of systems to be installed in Phase III of this project. In addition, such a specialized test would have only limited applicability to the bulk of expected usage. The use of homes for feasibility demonstration was excluded again because of the problem associated with the most effective demonstration of a small number of ssytems and a large number of possible environmental situations. As a result, it was decided to choose two apartment complexes representing a very broad cross section of environmental factors.

One of the scenarios chosen is a public housing project administered by the Public Housing Authority of the City of Pittsburgh. The city has ten projects in different locations. The one chosen is the Arlington Heights Housing Complex, a situation representing perhaps a high level of

CAS usage. The second scenario chosen is the Amberson Apartment Complex. This complex is relatively new, and is occuped by residents most of whom are working and financially self-supporting. These two scenarios should be representative of a very broad range of possible CAS applications, and further description of the scenarios is presented below.

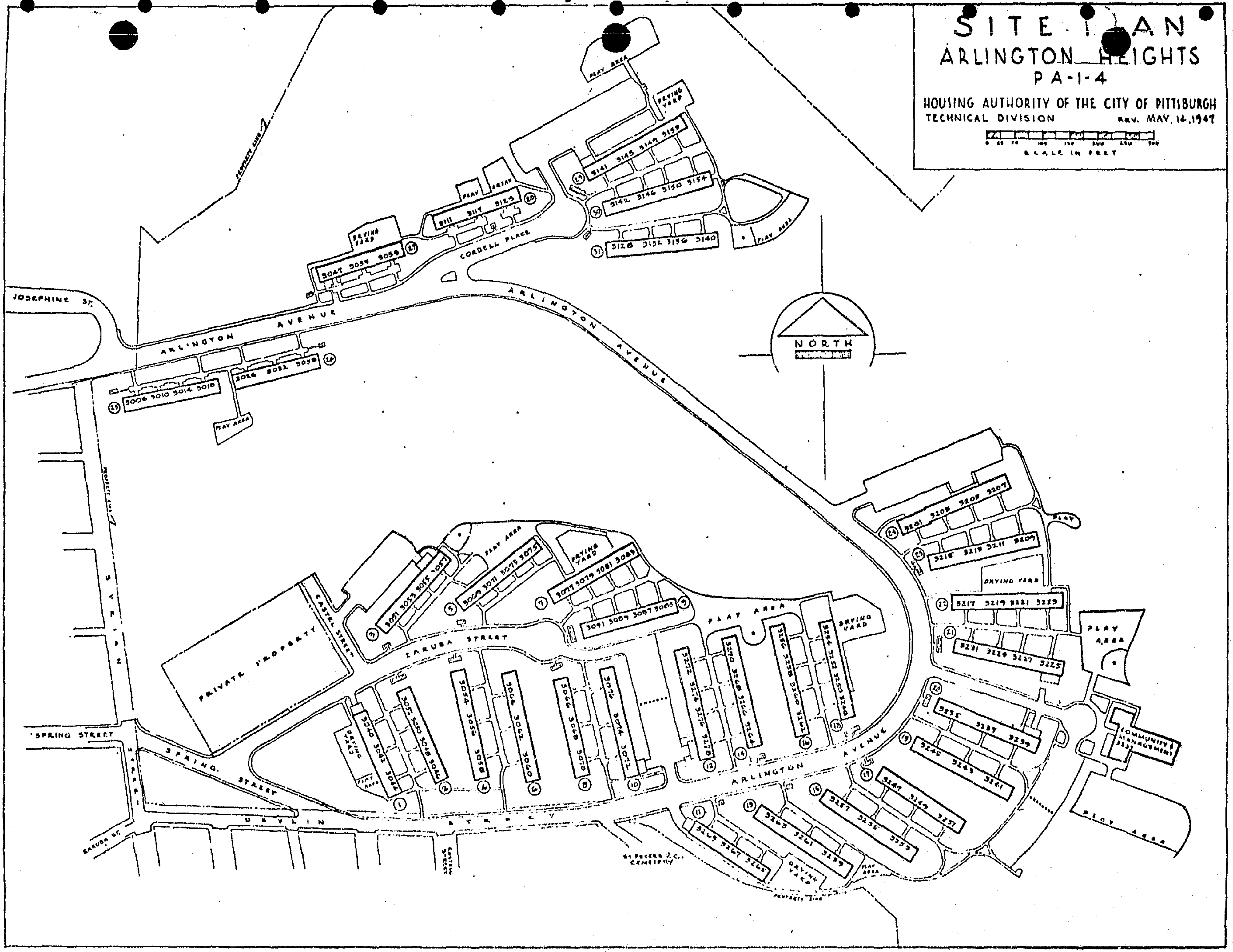
14.2 THE ARLINGTON HEIGHTS PUBLIC HOUSING COMPLEX

Arlington Heights is a 31 building complex of public housing, covering a total area of 82.5 acres. It is accessed from Syrian Street by means of Arlington Avenue, Spring Street, and Zaruba Street, located on Pittsburgh's Southside. The parking facilities for the buildings are situated in front of each building. The complex is serviced by one central management office adjacent to a community center. This and designated play areas provide the only recreation facilities provided by the complex. For a better understanding of the layout, please refer to Figure 14.1.

The buildings are 32 years old and in very poor repair. The wiring and telephone lines are in bad condition. Each building is serviced by either three or four entrances, each allowing access to six apartments located two per floor. All of the buildings are three stories high, and there are no elevators in any of the buildings. The apartments themselves range from one bedroom to four bedroom, and each has a living area and kitchen. The rents for DPA families are $32, $43, $52, and $56 per month, depending on the number of rooms. Working families pay $90-$99 per month with the number of rooms making no difference in the rent.

Arlington Heights is in census tract 1604, and according to the Annual Report of Major Crimes by Census Tract, 1972, there were no murders, two rapes, fourteen robberies, sixty-one assaults, twenty-one burglaries and twenty-five cases of larceny. These figures are derived from the reports of the Pittsburgh Police and include only clear-cut cases. Arlington is

Figure 14.1


SITE PLAN
ARLINGTON HEIGHTS
PA-1-4
HOUSING AUTHORITY OF THE CITY OF PITTSBURGH
TECHNICAL DIVISION
REV. MAY. 14, 1947
SCALE IN FEET
NORTH
JOSEPHINE ST.
ARLINGTON AVENUE
CORDELL PLACE
ZARUBA STREET
CASTLE STREET
SPRING STREET
ORVLIN STREET
PRIVATE PROPERTY
PLAY AREA
DRYING YARD
COMMUNITY & MANAGEMENT
ST. PETERS R.C. CEMETERY
PROPERTY LINE
ZARUBA ST.

considered to be in a high crime district, and the population density is greater than average for the city. The occupants of Arlington Heights are mainly poor and black. About 85 to 95 percent of the families are supported by DPA and 5 to 15 percent are working. The average income is 6,000 dollars per annum for the working families; only three families earn more than $8,000 per annum. Eighty-five percent of the occupants are black. In terms of age, about 18 percent are elderly, 70 percent are under the age of 30. There are also disabled and handicapped persons residing in this complex.

Compu-guard has developed excellent working relationships with the administration of the Public Housing Authority. In particular Mr. Rupert West, the manager of the Arlington Heights Housing Complex, is taking a very active role in the coordination of Compu-guard activities, and will provide preliminary assistance in the selection of the actual test sites of the feasibility demonstration. Appendix 14.1 is the unedited report of Rupert West concerning the relevance of CAS to the Arlington Heights Complex.

14.3 AMBERSON APARTMENTS COMMUNITY

The Amberson Apartments Community is a development of six high-rise buildings consisting of Amberson Gardens (4 buildings), Amberson Towers, and Amberson Plaza, located on 8½ acres in the Shadyside section of Pittsburgh. This grouping is easily accessed by road from Morewood Avenue, and has a private entrance on Bayard Road. There is a centrally located management office in the Towers and a private guard station.

The Plaza has 98 one bedroom apartments, and 41 bedroom and den units. Each apartment has a kitchen and living area, and is equipeed with appliances, air conditioner, carpeting and curtains. The floor plans and general layout are shown in the enclosed brochure. The Gardens are about 20 years old, the Towers, 5 years old, and the Plaza has just been occupied. The Towers is the most luxurious of the grouping, including many special features which are listed in the enclosed brochure. The Gardens are the least expensive of the grouping, but still offering many comforts such as laundry facilities and storage lockers. All buildings have elevators and satisfactory physical plant facilities, telephone lines, and power lines. For all three, parking is available in enclosed garages and a swimming club is offered for a fee to any occupant of the Community.

Amberson Apartment Community is located in 0701 census tract, and according to the Annual Report of Major Crimes by Census Tract, 1972, there were no murders, 2 rapes, 24 robberies, 4 assaults, 51 burglaries, and 58 cases of larceny. Amberson is considered to be located in a good area of Pittsburgh, with a normal to high crime rate.

The occupants of this community are generally in the middle to upper income brackets, mainly white. There are a number of elderly tenants with various physical and mental disabilities. Compu-guard is co-ordinating this effort with Mr. Fleming, the Manager of the community.

14.4 CONCLUSIONS

Some general conclusions and comments should be made concerning the scenarios selected for testing.

a) These two scenarios are expected to provide the broadest range of environmental, crime-related, and human factors of possible scenarios available in Pittsburgh.

b) They provide excellent potential for the demonstration and testing of other systems compatible with CAS. For example, both complexes are highly suited for the installation and testing of burglar alarms which are compatible with CAS.

c) The Arlington Heights complex covers a large area, and a significant amount of outdoor activity occurs. For this reason Arlington Heights offers a good opportunity to test a CAS-compatible system meant for the outdoors environment.

d) The Arlington Heights scenario lends itself as an excellent site for a large-scale field test of CAS, either by itself or in conjunction with other compatible protection systems.

APPENDIX 14.1

THE RELEVANCE OF CAS TO ARLINGTON HEIGHTS COMPLEX

SECURITY IMPLICATIONS

PHYSICAL STRUCTURE

a) The three story walk up building causes heavy traffic through entrances, and the common unlocked entrance door affords loitering space for purse snatchers, burglars, etc.

b) First floor apartments are easily accessible to burglars. Many windows are only a few feet from the ground. In addition, no protective screens can be placed over the windows--health department and fire regulations prohibit this.

c) The flat roofs can be climbed onto by any astute climber, e.g., by forcing his way through a window opening at the top of a stairway, someone can pull himself onto the roof which is only a few feet up.

d) Locks can be broken by someone intent on entering an apartment. Screws on the outer casing can be easily removed.

POPULATION - INCOME - EMPLOYMENT

A significant proportion of the population is elderly. The greater proportion is under 35 (1,589) and many are unemployed (85.6%).

This leaves many to roam the street, and the elderly become easy prey for con-men and burglars alike. Crowds loiter around corners and bus stops, and the elderly are especially afraid to move around the community.

Over the years Urban Renewal has caused a great influx of all types into public housing. Screening policies are unpopular and sometimes impractical, and the trend toward housing bad and insecure families seems destined to continue. At the same time it is impossible to relocate families to other areas, as the demand for units far outweighs the supply, e.g., over 100 transfers approved for Arlington, but no more than about a dozen would be relocated for all of 1973.

CRIME STATISTICS

The statistics available which supposedly show the level of crime in this community would, I estimate, reflect only about 20% of the actual cases. People tend after a while to "live" with the problem either because of fear of reprisals from offenders, or because of the lack of a proper deterrent by law enforcement agencies. My office receives dozens of calls per month on purse snatchings, burglaries, assaults, etc., but residents refuse to report to police because of fear of reprisals. In other cases they were unable to summon help in time, before the act was completed.

OTHER SECURITY PROBLEMS

HEALTH

Arlington houses a significant number of elderly, many of whom are unable to properly take care of themselves because of severe medical problems Every year one or more of the residents can be found dead in their apartments, many of whom could have been helped if aid could have been more easily reached.

The latest case in point was Lulu Griffin, Apt. 152. This resident suffered from an illness that caused dizzy spells. For two days she was not heard from by her relatives. A sister came from Cleveland Ohio to investigate. The evidence revealed that Ms. Griffin had attempted to reach someone by phone but did not succeed. She was taken to the hospital but died a few days later from resultant complications. Obviously times was of the essence here.

In other instances residents recall hours of suffering and anguish because of sudden illnesses which prevented them from reaching the phone or opening the door for help.

FIRE

This community has on the average about six severe fires per year.

CONTINUED

4 OF 5

The severity of losses suffered is in many cases due to the time lag between recognizing the problem and contacting and receiving help. Losses run on the average of about $1000 per apartment. Residents interviewed after incidents recall being unable to dial, due to anxiety, or not having a telephone, or not being able to reach the phone for smoke or flames. Many have been trapped on 3rd floors and have been hurt by smoke inhalation, etc. In times like these, easy accessibility to a communication system and quick responses by protective agencies are of the essence.

RELEVANCE OF THE CAS SYSTEM

In view of the problems outlined above, it is highly recommended that citizens be given some added protection that would make for more effective communication with secuirty agencies. On reviewing the attributes of the CAS system I am convinced that it would provide the answer to the security problems that plague this community. Below would be presented some cases (which are typical of security problems in the community) that in my opinion could have been averted, substantially reduced, or at least the assailants could have been apprehended and punished had the CAS system been in the possession of the resident.

CASE A - BURGLARY - STAIRHALL

Ms. Williams came home one evening after dark and entered her stairhall. After she was inside she was stopped by a young man who demanded money and all other valuables. She then proceeded to empty her purse, take her bracelets and watch off, and gave these to the assailant. The entire encounter lasted over one minute, after which the robber calmly walked outside after threatening Ms. Williams not to call neighbors or the police. Ms. Williams did not, and so the offender was let off free.

In this incident, CAS could have been easily activated, and the local patrol would have had ample time to reach the dwelling and arrest the suspect.

CASE B - BURGLARY - HOME

Mrs. Bronaugh was asleep at her home one night. She was awakened by the shattering of glass in her livingroom. She got up to investigate, but was forced back into her bedroom by a burglar who had gained entrance through her front window. She was forced to stay in her bedroom while the apartment was ransacked for valuables. The entire encounter lasted well over five minutes, at the end of which time she was threatened with physical violence if she reported the incident to the police. She did not. Here again is a case where CAS could have been easily activated and the law would have had ample time to react effectively.

CASE C - HEALTH

We may recall Mrs. Griffin's case, where she was left alone in her apartment for two days after being severely ill. It can be assumed that her life could have been saved if CAS was in her possession when she first became ill. One thing is certain: she could have received help two days earlier and the chance for her survival would have been substantially greater.

CASE D - FIRE

Mrs. Dyer was at home one morning when she was awakened by the smell of smoke. She rushed to the living room to investigate but was stopped by the smoke and heat coming from that area. At the same time she was unable to reach her telephone which was also in the livingroom. She could not jump from her apartment to safety. It was located on the third floor. Hence she opened her window and shouted for help. Later she told of the agonizing minutes spent shouting for help before neighbors recognized her problem, and the fire department was summoned. Ms. Dyer was later rescued by the fire department. She later suffered from shock and severe smoke damage, and lost well over $2000 of her personal possessions.

We can well imagine what could have happened here had Ms. Dyer been unable to wake her neighbors. We can also imaging the precious minutes that could have been saved for her had she been able to quickly summon help with her CAS system, not to mention the possessions that could have been saved had the fire department been summoned before.

The above represent actual cases, some more severe, others less, and many more could be recalled where CAS could have helped. Generally speaking we may say that CAS is ideally suited to communities such as this one for the following reasons:

a) Buildings cannot be made absolutely secure from burglaries, e.g., first floor apartment windows cannot be secured by iron mesh, etc., due to health department rulings. However, in cases where forceable entry is made, an effective communication system can be triggered without revealing the location or intention of the user.

b) The need for public housing continues to grow, and there seems no alternative to housing people of various age groups together. Low incomes of families will undoubtedly foster the birth of those who must sometimes steal to make a living for themselves and families. Gullibility and physical disability of the elderly would continue to make them easy victims for those who are bent on preying on them. High rates of unemployment and large numbers of young people housed together leaves many people idle to crowd the public ways and make walking through the community a difficult and often a painful task. Sickness and accidents often comewithout notice, and as isolated as so many of these communities are, help is often too little or too slow.

Many of the conditions above we cannot alleviate or even hope to appreciably change, but we can put in the hands of responsible citizens a system which would not only help them to feel more secure, but one that would enable them to receive the swift and effective attention needed to combat many of the adverse conditions under which they must live in this and other public housing communities.

c) Many of these communities do not carry the political clout that the middle class and richer communities do. It is a fact that services, police, fire, medical, to these areas are often less efficient and often not enough of anything is done to correct the imbalance. Citizens of this community have complained for years about poor ambulance, police, and fire service. Many times the fault, when pinned down, may be due to lack of effective communication by victims to the agency required to deliver the service.

Introduction of this service will among other things help narrow the communication gap, to speed up service needed to protect the people of this and other socially and economically deprived areas.

SECTION 15

REVISED STATEMENT OF REQUIREMENTS, CAS PROJECT, (ANNEX B, SOW)

15.1 THE SYSTEM: CONFIGURATION

a) The system shall consist of actuators, internal receiver-relays, external receiver-relays, and a central station.

b) The central station shall include annunciator/display panels.

c) The central station may be situated locally (i.e. within the same building as a CAS network) or remotely (e.g. a police station).

15.2 THE SYSTEM: TRANSMISSION

a) From actuator to internal receiver-relay by radio, at frequencies above 70 MHz.

b) From internal receiver-relay to external receiver-relay or to a local central station, by internal power lines (e.g. 110v AC).

c) From external receiver-relay to a remote central station, by leased telephone line (voice-grade).

d) The actuator will transmit a user-identification message of at least 20 bits, BCD coded, or 5 BCD characters. This will allow at least 100,000 different combinations.

e) The user-identification message will be transmitted repeatedly, with at least 5 repetitions.

f) The internal-receiver-relay will receive all messages from the actuator, and add on a location code with a length of at least 8 bits or 2 BCD characters. This will allow up to 100 internal receiver-relays per external receiver-relay or local central station.

g) The external receiver-relay or the local central station will receive repeated messages from the internal receiver-relays and display them for use by an operator or dispatcher.

h) The actuator will have a range of at least 50 feet from an internal receiver-relay.

i) The system will minimize the effects of interference due to simultaneous or near-simultaneous transmissions of information from the actuator, or from the receiver-relay.

15.3 THE SYSTEM: RESPONSE

a) Any system will be connected to a single response agent, e.g. police or a local guard force, depending on the location and the special features of the system.

b) The actuator will have only one option, i.e. a single triggering mechanism for sending a call for assistance to the single response agent of a) above.

c) Response times within the CAS system will be as follows:

Actuator to Internal Receiver-Relay: 1 second

Internal Receiver-Relay to External Receiver-Relay: 4-5 seconds

External Receiver-Relay to Central Station (remote): 5-8 seconds

d) The response time of the response agent, after information is displayed at the central station, cannot be determined by CAS. In the Phase I report, procedures have been identified to allow the minimization of this component of response time, if these are adopted by the response agent. However, the CAS hardware does not have any direct control over the response agent.

15.4 THE SYSTEM: DESIGN FEATURES

a) The actuator will be packaged in the form of a miniature device, with aesthetic appeal, that can be worn on a watchband or a waist belt, or as a pendant. Its size will be about the same as that of an average watch worn by a male.

b) The actuation mechanism will be a pincer-movement requiring simultaneous actuation of two buttons, or a rotating dial mechanism. This will allow ease of use by a miximum portion of the population.

c) The central station will provide a clear and easy-to-interpret display, together with an audible indication.

d) The system will be modular to allow for integration with some other specifically-designed systems, compatible with CAS, for protection in an outdoors environment and for protection against burglary.

e) The receiver-relays are such that the system will be usable in a wide range of environments. With suitable modifications related to packaging and size, it will be applicable in both homes and institutions

f) The internal receiver-relay will be small enough that it can be plugged directly into the 110v socket (wall receptable), with aesthetic appeal. This is preferable to fitting it inside the wall receptable for two reasons: installation cost and electrical codes.

g) CAS components will operate satisfactorily in a normal range of physical and EMI environments.

h) The components will be resistant to tampering and abuse.

i) The system will not be susceptible to power failure.

j) The system will withstand most kinds of efforts to jam its operations or to maliciously cause system malfunction.

k) The self-test capability will be provided in terms of user procedures rather than any specific hardware or software built into the system.

15.5 THE SYSTEM: RELIABILITY

a) The actuator will be such as to minimize the probability of inadvertent triggering.

b) Reliability of transmission, for the power line and telepho ne line combined, will exceed 99.9 percent.

c) Reliability of transmission on the radio link between the actuator and internal receiver-relay cannot be specified deterministically, as this is a probabilistic function of environmental and other parameters. However, the expected value of the reliability of this link, for a predefined set of standard conditions, should be in excess of 98 percent.

d) Component reliabilities should be better than the limits set below:

Component	Figures in 10^6 Hours
Actuator	40
Internal Receiver-Relay	100
External Receiver-Relay	300
Central Station	300

e) Response reliability cannot be determined by CAS design, hardware, or software.

15.6 THE SYSTEM: FALSE ALARMS

a) False alarms due to equipment failure or malfunction will be controlled as indicated in 15.5.

b) The actuator will be such as to minimize its inadvertent triggering.

c) There is no way that the number of false alarms due to user error, user negligence, or very low user threshold, can be estimated. Thus the false alarms ratio can only be estimated after a large-scale field test is conducted. This is because these factors will be primary in causing CAS false alarms, but cannot be controlled by CAS design, hardware, or software. They can be controlled by appropriate user procedures, but the testing of alternative procedures cannot be conducted on a small scale.

d) Given a large scale field test of CAS, it should be possible to develop user procedures and penalties such that the false alarm ratio does not exceed 70 to 80 percent. However, the validity of this estimate can only be determined in such a test.

15.7 THE SYSTEM: COST

The cost of components will be within the limits established, as follows:

	Production Quantity		
Component	Low	Medium	High
Actuator	$60	$30	$20
Internal Receiver-Relay	$80	$50	$30
External Receiver-Relay	$350	$250	$200
Central Station	$3,000	$2,000	$1,500

END