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Final Report

COMMUNICATIONS EQUIPMENTS AND SYSTEMS TO SUPPORT INTRASTATE CIVIL DEFENSE OPERATIONS — CIRCA 1970

Prepared for:

OFFICE OF CIVIL DEFENSE
DEPARTMENT OF THE ARMY — OSA
UNDER
WORK UNIT 2211C

CONTRACT OCD-PS-64-201

STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

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By: DONALD R. CONE JAMES A. BAER ELMER B. SHAPIRO

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SUMMARY

Communications Equipments and Systems to Support Intrastate Civil Defense Operations—Circa 1970

By Donald R. Cone, James A. Baer and Elmer B. Shapiro. Stanford Research Institute, December 1965. Prepared for Office of Civil Defense, Department of the Army, Washington, D.C. under Contract OCD-PS-64-201.

This report provides a compilation of data covering both wire and radio communication systems and facilities of value for civil defense application. The general characteristics of the items are discussed and their potential application in a representative communications or command and control model is illustrated. Representative costs are provided. The discussion of the various communication systems and typical items of equipment generally identifies their salient operational strengths and weaknesses. A number of conclusions and recommendations relative to existing and potential CD communications systems and equipments are presented.

OBJECTIVES

(1) To assemble performance and cost data on potentially useful and available communications equipment for local civil defense emergency operations; and

(2) to postulate a representative communications model using such equipment to meet concurrently developed communication requirement. The orientation is towards communication capabilities for the period circa 1970.

SCOPE

1. Assembly of Performance and Cost Data

Communication equipments suitable for the requirements of local and state EOC's are investigated and operational and cost data assembled.

2. Development and Evaluation of Alternative Communications System Configurations

An evaluation is made of the ability of existing and potential communication capabilities to meet the representative communication requirements of the anticipated emergency civil defense situations in the 1970 time period. The emergency time periods of pre-attack, take shelter, in-shelter, brief and general emergence, and recovery are considered.

CONCLUSIONS

(1) No major breakthroughs in communication technology are foreseen that would revolutionize either the requirements or the implementation of an adequate local civil defense communication system for the 1970 time period. There are evolutionary trends, including more effective use of an increasing radio frequency spectrum, transistorization of communications equipment, and an increasing resource of radio operators and equipment, which can contribute substantially to the overall national potential for an effective and practical emergency communication capability.

(2) Radio- and/or wire-based systems represent the primary facilities widely available for the implementation of emergency CD communication systems.

(3) There exists throughout the country a tremendous reservoir of communications systems and equipment—public and private telephone and teletype systems; public safety, industrial and private citizen radio equipment; and the AM, FM, and TV broadcast (receiver) systems. The distribution of these equipments and facilities corresponds closely to the distribution of population throughout the country.

(4) During a nuclear emergency, where the widespread use of the fallout shelter system is required for survival, there will be substantial quantities of radio and wire communication equipment and channel assignments (especially commercial) not used for their normal functions. *With adequate prior planning*, these facilities could be used to supplement normal local government communication channels and to implement new channels, in order to provide an effective emergency system.

(5) Variations in local government size, operations, and anticipated attack situations prevent the development of a single optimized communication plan for all such organizations which would reflect adequate consideration of local conditions. The need is clearly indicated for study at and by each local governmental organization of: (a) an appropriate local civil defense organizational structure, (b) anticipated emergency communication requirements, (c) existing or potentially available communication resources, and (d) other important aspects of the local situation. This study should be followed by the development of the necessary emergency communication system (coordinated with higher, lower, and adjacent organizations) which satisfies the anticipated emergency requirements.

(6) The establishment of complete separate standby communication facilities solely for use in a nuclear emergency is neither operationally desirable nor economically practical. It is both feasible and necessary to effect an orderly improvement of existing local government communications facilities so as to achieve a realistic civil defense posture. Such facilities could provide for normal requirements, and be capable of rapid adaptation or expansion (using readily available auxiliary communication resources) so as to provide a coordinated emergency communications system responsive to the anticipated emergency.

(7) Use of a wire based system is generally more economical than the purchase of standard radio equipment for the implementation of a CD emergency communication system, particularly for urban areas. This should not mitigate against the desirability of providing complementary wire and radio communication channels between and among local government echelons to help ensure the availability of adequate communications during an emergency.

(8) The significant Civil Defense communication equipment needs in terms of numbers of units and potential cost are at the shelter and shelter complex headquarters echelons; hence it is in these areas that efforts toward the development of economical equipment and/or the use of low cost techniques responsive to CD communication requirements should prove most beneficial.

(9) Because of the proliferation of citizen band transmitters (both licensed and unlicensed) using the very limited channels available in the 27 MHz region, the minimal control possibilities for these equipments, and the increasing interference related to the sunspot cycle at these frequencies during the next 5-7 years, the planned widespread use of these radio equipments in a general CD emergency situation is undesirable.

(10) Radio antenna and exposed wire and cable lines are prime vulnerable components of communications systems exposed to nuclear weapon effects (other than fallout).

RECOMMENDATIONS

(1) Clarify the availability of RACES frequencies during a nuclear emergency. A prior study[12] mentions the probable pre-emption of amateur frequencies—including RACES—by the Armed Forces during a nuclear attack. The emasculation of RACES during the emergency for which it is constituted is inconceivable.

(2) Develop and implement alternative emergency radio (and telephone where needed) power supply facilities for shelters and SCHP's. Storage batteries, other chemical energy sources, hand or foot operated generators (either for direct power to equipment or for trickle charging storage batteries), and perhaps even solar and fuel cell possibilities should be explored.

The EOC's are more likely to have alternative electrical power sources for communications and other operational functions; the relatively modest requirements for shelter communications power, with consideration for the long-term storage and emergency activation problems, require attention.

(3) Develop economic modest-power radio equipment suitable for intra-city emergency communications. (Pertinent design criteria and references are presented in Sec. IV.) This should include consideration of the appropriate operating frequencies and the requisite licensing and other regulatory factors to permit realistic test and operational exercise of the equipment as well as utilization in its emergency function.

(4) Continue surveillance of developing communications techniques with potential for meeting present and anticipated CD requirements. These would include wideband random access multiple address techniques, telephone electronic switching and data transmission developments, community antenna and broadcast TV capabilities, and eventually satellite and laser communications.

(5) Develop and distribute a guide book for local CD communication system planners. This should include planning factors, aids for making a local communications inventory, a resume of significant technical factors effecting system design and implementation, weapon effect factors relating to communications, and examples of existing emergency CD communications systems.

(6) Develop improved capability for survivable communications components: hardened, dispersed or replaceable antennas, survivable wire links, emergency power sources, etc. Antennas and above ground wires exposed to effects other than fallout from nuclear weapons are prime vulnerable components of emergency communications.

ABSTRACT

This report provides a compilation of data covering both wire and radio communication systems and facilities of value for civil defense application. The general characteristics of the items are discussed and their potential application in a representative communications or command and control model is illustrated. Representative costs are provided. The discussion of the various communication systems and typical items of equipment generally identifies their salient operational strengths and weaknesses. A number of conclusions and recommendations relative to existing and potential CD communications systems and equipments are presented.

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I INTRODUCTION

A. BACKGROUND

Throughout the country, the National Fallout Shelter System has established a significant licensed, marked, and stocked emergency fallout shelter capacity which is rapidly expanding and improving. In any emergency, and particularly in the event of a widespread nuclear attack, adequate civil defense communication capabilities are imperative if effective use is to be made of available shelter and associated resources (food, water, sanitary and medical supplies, personnel, etc.). This is essential in order to minimize death and injury to citizens, help alleviate the discomfort and anxiety of the population during an enforced shelter period, and help prepare the people for emergence and the resumption of activities in a changed environment.

The current public attitude and political situation require that planning and implementation of emergency civil defense operations be done with relatively modest expenditures, drawing heavily on existing equipment and facilities to provide for the requirements of the emergency period. This will apply particularly to the communications system, because of the high cost of establishing a reliable standby system to be substantially unused until an emergency occurs.

Research in the civil defense communications field falls roughly into two areas: communications requirements and communications systems. Communications requirements research is defined as the study of the nature and volume of required or needed communications, in which the nature and volume are characterized by such factors as message length, message occurrence, mode of transmission, time urgency, and density of flow. Communications systems research is defined as the study of hardware, systems, and procedures that can be used to satisfy communications requirements. Under the present contract, Stanford Research Institute has prepared two reports on the subject of communications requirements--one on local requirements and one on state and regional requirements. This report is concerned primarily with communications systems.

B. OBJECTIVES

The objectives of this task are

(1) To assemble performance and cost data on potentially useful and available communications equipment for local civil defense emergency operations; and

(2) to postulate a representative communications model using such equipment to meet concurrently developed communication requirement. The orientation is towards communication capabilities for the period circa 1970.

C. SCOPE

1. Assembly of Performance and Cost Data

Communication equipments suitable for the requirements of local and state EOC's are investigated and operational and cost data assembled. Special consideration is given to the following types of communications and their applicability to civil defense.

(1) Landline commercial telephone systems operating through normal telephone exchanges and toll operators.

(2) Landline commercial telephone systems specially engineered to improve survivability.

(3) Private wire telephone or telegraph systems.

(4) Radio Amateur Civil Emergency Service (RACES).

(5) VHF radio systems operated on frequencies designated for local government services, police, and fire services.

(6) Citizen's band radio.

(7) Voice or telegraph circuits from extensions of local fire department voice and telegraph alarm systems.

(8) Microwave and VHF radio relay systems for exclusive civil defense use.

(9) Extension to local EOC's of state teletypewriter or radio systems presently installed in certain communities to provide service for such functions as law enforcement, motor vehicle registration, highway patrol, forestry, conservation and wildlife, and fire protection.

2. Development and Evaluation of Alternative Communications System Configurations

An evaluation is made of the ability of existing and potential communication capabilities to meet the representative communication requirements of the anticipated emergency civil defense situations in the 1970 time period. The emergency time periods of pre-attack, take shelter, in-shelter, brief and general emergence, and recovery are considered.

D. METHOD OF APPROACH

The initial portion of this study involved the acquisition and study of reports, articles, brochures, and other literature relating to the present and anticipated operational capabilities, and initial and recurring costs of pertinent communication equipments. This was followed by personal visits to manufacturers, system users, and operators to supplement the data and to fill gaps in published information.

A companion study - "Civil Defense Communications Requirements at the Local, State and Regional Levels,"[1*] Contract OCD-PS-64-201, concurrently performed at SRI (referred to throughout this report as the Requirements Study) has provided a detailed listing of anticipated communication requirements during a nuclear emergency situation at the local to state levels.

The final portion of this study has used the data base and has developed alternative communications configurations to satisfy the communications requirements generated by the Requirements Study.

The appropriateness of these communications configurations was evaluated, in part based on information obtained during visits to operating emergency organizations at state, state area, county, and city levels.

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*References are listed at the end of the report.

Much of the conceptual framework and other assumptions of the Requirements Study are adopted for the presentation of information and recommendations in this report. For instance, the organizational structure; shelters, shelter complex headquarters (SCH), city/county EOC and state EOC, is used, as are the emergency time phases and the community damage categories. These are useful concepts for presentation of this information, but are not intended to restrict the options available to the local planner. The similarity of concepts in these two related studies should make their combined use easier and more effective.

II CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

(1) No major breakthroughs in communication technology are foreseen that would revolutionize either the requirements or the implementation of an adequate local civil defense communication system for the 1970 time period. There are evolutionary trends, including more effective use of an increasing radio frequency spectrum, transistorization of communications equipment, and an increasing resource of radio operators and equipment, which can contribute substantially to the overall national potential for an effective and practical emergency communication capability.

(2) Radio- and/or wire-based systems represent the primary facilities widely available for the implementation of emergency CD communication systems.

(3) There exists throughout the country a tremendous reservoir of communications systems and equipment--public and private telephone and teletype systems; public safety, industrial and private citizen radio equipment; and the AM, FM, and TV broadcast (receiver) systems. The distribution of these equipments and facilities corresponds closely to the distribution of population throughout the country.

(4) During a nuclear emergency, where the widespread use of the fallout shelter system is required for survival, there will be substantial quantities of radio and wire communication equipment and channel assignments (especially commercial) not used for their normal functions. With adequate prior planning, these facilities could be used to supplement normal local government communication channels and to implement new channels, in order to provide an effective emergency system.

(5) Variations in local government size, operations, and anticipated attack situations prevent the development of a single optimized communication plan for all such organizations which would reflect adequate consideration of local conditions. The need is clearly indicated for study at and by each local governmental organization of: (a) an appropriate local civil defense organizational structure, (b) anticipated emergency communication requirements, (c) existing or potentially available communication resources, and (d) other important aspects of the local situation. This study should be followed by the development of the necessary emergency

communication system (coordinated with higher, lower, and adjacent organizations) which satisfies the anticipated emergency requirements.

(6) The establishment of complete separate standby communication facilities solely for use in a nuclear emergency is neither operationally desirable nor economically practical. It is both feasible and necessary to effect an orderly improvement of existing local government communications facilities so as to achieve a realistic civil defense posture. Such facilities could provide for normal requirements, and be capable of rapid adaptation or expansion, (using readily available auxiliary communication resources) so as to provide a coordinated emergency communications system responsive to the anticipated emergency requirements.

(7) Use of a wire based system is generally more economical than the purchase of standard radio equipment for the implementation of a CD emergency communication system, particularly for urban areas. This should not mitigate against the desirability of providing complementary wire and radio communication channels between and among local government echelons to help ensure the availability of adequate communications during an emergency.

(8) The significant Civil Defense communication equipment needs in terms of numbers of units and potential cost are at the shelter and shelter complex headquarters echelons; hence it is in these areas that efforts toward the development of economical equipment and/or the use of low cost techniques responsive to CD communication requirements should prove most beneficial.

(9) Because of the proliferation of citizen band transmitters (both licensed and unlicensed) using the very limited channels available in the 27 MHz region, the minimal control possibilities for these equipments, and the increasing interference related to the sunspot cycle at these frequencies during the next 5-7 years, the planned widespread use of these radio equipments in a general CD emergency situation is undesirable.

(10) Radio antenna and exposed wire and cable lines are prime vulnerable components of communications systems exposed to nuclear weapon effects (other than fallout).

B. RECOMMENDATIONS

1. Clarify the availability of RACES frequencies during a nuclear emergency. A prior study[12] mentions the probable pre-emption of amateur frequencies--including RACES--by the Armed Forces during a nuclear attack. The emasculation of RACES during the emergency for which it is constituted is inconceivable.

2. Develop and implement alternative emergency radio (and telephone where needed) power supply facilities for shelters and SCH's. Storage batteries, other chemical energy sources, hand or foot operated generators (either for direct power to equipment or for trickle charging storage batteries), and perhaps even solar and fuel cell possibilities should be explored.

The EOC's are more likely to have alternative electrical power sources for communications and other operational functions; the relatively modest requirements for shelter communications power, with consideration for the long-term storage and emergency activation problems, require attention.

3. Develop economic modest-power radio equipment suitable for intra-city emergency communications. (Pertinent design criteria and references are presented in Sec. IV.) This should include consideration of the appropriate operating frequencies and the requisite licensing and other regulatory factors to permit realistic test and operational exercise of the equipment as well as utilization in its emergency function.

4. Continue surveillance of developing communications techniques with potential for meeting present and anticipated CD requirements. These would include wideband random access multiple address techniques, telephone electronic switching and data transmission developments, community antenna and broadcast TV capabilities, and eventually satellite and laser communications.

5. Develop and distribute a guide book for local CD communication system planners. This should include planning factors, aids for making a local communications inventory, a resume of significant technical factors effecting system design and implementation, weapon effect factors relating to communications, and examples of existing emergency CD communications systems.

6. Develop improved capability for survivable communications components: hardened, dispersed or replaceable antennas, survivable wire links, emergency power sources, etc. Antennas and above ground wires exposed to effects other than fallout from nuclear weapons are prime vulnerable components of emergency communications.

III GENERAL DISCUSSION

A. DEFINITIONS AND ASSUMPTIONS

Because of the interdependent nature of the present study and the parallel Requirements Study, most of the assumptions and definitions outlined below have been drawn from the Requirements Study with little or no change.

1. Definitions

The following concepts are defined:

Local Government Organization--Any town, city, county, or similar entity that now has or could have its own civil defense organization.

Civil Defense Communication Requirements--Information flows necessary to support civil defense operations during nuclear emergency and the communication links required to transmit these flows.

Generalized Model of Local Civil Defense Organizations--The assumed organizational structure is that of a local government emergency operating center (EOC) providing the local command and control functions and linked to the county or state higher echelon. Within the local government area are shelter complex headquarters (SCH), each SCH in turn being the control point for a group of public shelters in close geographic proximity.

Time Phase--Segments of a time-consuming process, which terminates between two easily definable points. The time phases for the nuclear emergency are prewarning, take shelter, in shelter, brief emergence, general emergence, and recovery.

Functional Areas--Responsibilities and corresponding resources have been grouped into functional areas. No specific form of local government, size of community or formal CD organization structure is assumed by these functional areas; rather, the model is intended to be general and hence adaptable to a wide range of local situations. The specific functional areas considered herein include (a) mayor, city manager, or county supervisor; (b) civil defense director; (c) police; (d) fire; (e) rescue; (f) weapons effects; (g) medical; (h) health; (i) welfare; (j) utilities; (k) public works.

Attack Categories--It is possible to broadly categorize communities according to the worst attack case they might reasonably be expected to face as follows:

(1) Those communities that might be directly threatened by blast and fire, being themselves possible targets.

(2) Communities contiguous to the target communities of Category 1, wherein fallout dangers would be compounded with peripheral lower-order direct effects and where both capabilities and responsibilities to aid in the survival efforts of the target area should exist.

(3) Communities sufficiently isolated from potential target areas to make fallout from distant strikes the only danger and where distance makes short-term aid to stricken areas impractical.

2. Duration of Emergency Communication Requirement

This study has been directed primarily to the communication requirements during the time phases starting with take shelter, running through the in shelter and brief emergence phases, into the general emergence phase.

Except for drills or tests, the nuclear-emergency oriented CD communications structure would not be used prior to the issuance of the warning signal. Upon general emergence, the need for communications to the shelters and shelter complex headquarters would diminish drastically and the system configuration would either revert to the preemergency status or to some new configuration better adapted to the then-existing environment.

It is presumed that adequate priority of personnel and materiel would be allotted to the re-establishment and/or improvement of communications channels during the brief emergence phase to facilitate the operations requisite for the general emergence and recovery phase.

B. LOCAL GOVERNMENT OPERATIONS

Local government operations are conducted on a day-by-day basis using a variety of communications means, in a system adapted to the size and complexity of normal operational requirements. These activities include contacts with higher, lower, and adjacent governmental organizations, internal functions such as police, fire, rescue, medical health, welfare, public works, and utilities, as well as general administrative functions. Communication techniques may include telephone, teletype, radio, mail (both interoffice distribution and regular post office mailings), special messenger, and personal contact. This composite system benefits from the day-to-day continuity of operation, the familiarity of personnel with the overall structure and system, and by the establishment, either deliberate or implied, of standard operating procedures.

In the event of a nuclear emergency, the necessity for most of these functional activities would continue; in many cases their supporting communications requirements would be significantly increased. Superimposed on the normal functional activities would be the requirement for the effective management and control of a large proportion of the civilian population hurriedly assembled in temporary, unfamiliar shelters for a period of unknown duration. Unlike the normal city functions, the management and support of the shelter and shelter complex headquarters (or other equivalent organizational structures) has no parallel in normal local government operations, thus posing some additional and unusual requirements.

At the same time there is increased need for the collection and dissemination of weapons effects information, and more direct than usual tie-ins to local broadcast stations and nearby military facilities. Additionally, the possibility of receiving aid from nearby communities, which can be expected under other types of emergencies, is greatly decreased.

The communications problem is further compounded by the possibility--in many cases a high probability--of serious reduction in normal communication channels. There may be immediate destruction or damage due to nuclear blast, thermal effects, and possibly radiation. There may be delayed destruction or inoperability due to fire, excessive fallout radiation, loss of electrical power, lack of personnel at nonautomatic facilities, lack of maintenance, deterioration of equipment from overload, and other factors, possibly including panic, riot, looting, and sabotage. The mobility of people and vehicles may be severely curtailed or prohibited by damage to bridges, tunnels, roads, and by debris, fire, and/or radiation intensity.

The resultant increased and critical need for communications, at a time when there is a strong possibility of the loss or severe damage to many normal communication facilities, highlights the severe problem that must be faced.* This emphasizes the absolute necessity for providing

(1) Realistic evaluation of the anticipated local situation,

(2) Adequate planning for an effective emergency communications system,

(3) Timely implementation of the plan in terms of equipment, materiel and facilities, and emergency operational procedures, and

(4) Tests and exercises to ensure that the proposed system is adequate and effective in fulfilling the anticipated requirement.

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* There are a number of references that will be helpful in the study and development of the local communications system. The Systems Development Corporation of Santa Monica recently completed, under OCD contract, communication resources studies for eight specified communities.[2-11] Gautney and Jones, consulting engineering firm of Washington, D.C., has completed a number of studies including a comprehensive analysis of the Montgomery County, Maryland situation entitled "Fallout Shelter Communication Study."[12]

A recently completed study by the Electronic Industries Association (EIA) entitled "Report of EIA Land Mobile Section to the FCC Concerning Licenses Issued to the Land Mobile Radio Service,"[13] provides detailed information on geographic location of radio station licenses. In addition to emphasizing the problem of channel availability, this report clearly establishes a very high correlation between population and radio equipment distribution. The 1965 edition of Radio Registry, Volumes I through IV, provides additional information from FCC sources on Industrial, Transportation, Business and Public Safety Radio Systems, including frequency, call signs, and locations.[14-17]

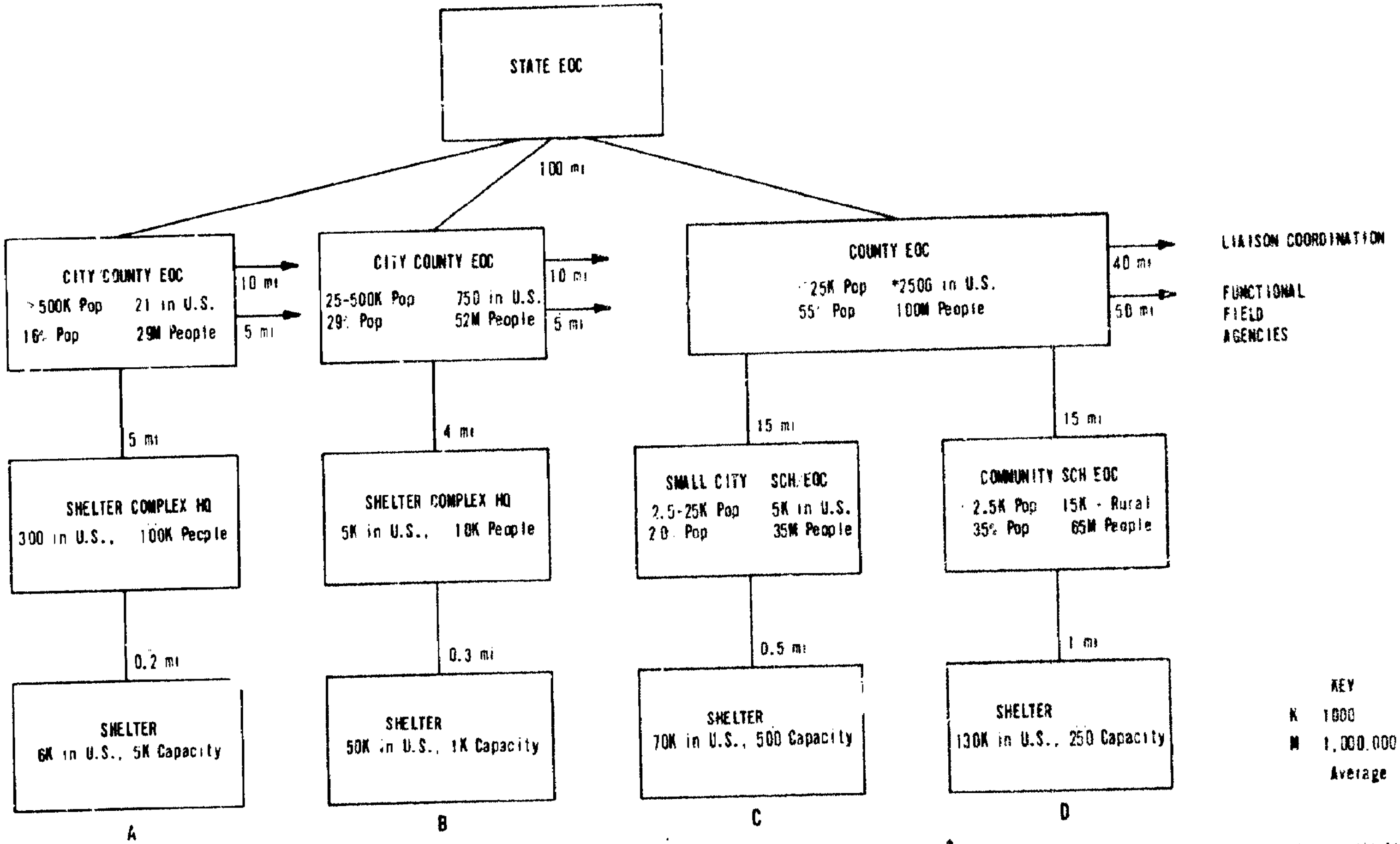
C. AREAS FOR LOCAL CONSIDERATION

Numerous variable factors will effect the development of the local civil defense structure and the related communications system. The more important items include

- Organization--the structure of the local governmental organization;
- Commitment--the degree of local commitment to civil defense planning and implementation (both philosophical and economic);
- Population--the density, distribution and mobility of the local population, and any day-to-night variation in distribution;
- Shelters--the number, size, distribution and adequacy of public and private shelters.
- Topography--the effect of local terrain features--such as rivers and hills--on mobility and radio transmission;
- Existing Communication Facilities--public/private telephone and telegraph networks; public radio networks--local government, fire, police, utility, etc.; industrial or commercial radio equipment; private amateur or citizen band equipment; etc.;
- Radio Frequency Utilization--the present and predicted usage of available radio frequency spectrum, and consideration of alternative use of local licensed channels, which might not otherwise be used during the shelter periods;
- Threat Appraisal--the estimated types and degree of damage anticipated for the community under a large-scale nuclear attack;
- External Factors--the requirements for communication with and possibilities of assistance from or to higher echelons of government, adjacent communities, nearby military installations, etc.

D. GENERALIZED COMMUNICATION SYSTEM MODEL

Figure 1 provides a generalized representative model of a state civil defense emergency organizational structure. Of necessity, it contains many assumptions and approximations, and will not necessarily meet the specific requirements of any individual state or community; however, it is a useful model in terms of providing a basis for displaying CD communication requirements. It presents a simplified model of the



* The balance of the 3100 total counties or county equivalents in the U.S. are included in groups A and B.

† Assumes 32M Rural Population not covered by Public Shelters.

FIG. 1 GENERALIZED CIVIL DEFENSE ORGANIZATIONAL CONFIGURATION

U.S. population by community size, with representative distances between and within the related local governmental structures.

It is recognized that in some areas a different number of organizational levels would be required or desired.* The postulated distances between organizational levels will differ significantly in some localities. The population and numbers and distribution of local government are based on 1960 census data.

The model groups local government populations into four sizes: very large (greater than 500,000), large to medium (25,000 to 500,000), small (2500 to 25,000), and very small and/or rural (less than 2500).

This model is considered in greater detail in Appendix A in terms of communications requirements and networks.

E. SURVIVABILITY

The survivability of an Emergency Communication System is a subject that is both important and difficult of solution. The possible range of nuclear weapon and corollary effects is extreme. In order to provide adequate post-attack communications, the emergency communications system must have a capability to resist or recover from the attack effects commensurate with the protection available for the local population subjected to the attack. The cost of the communication system designed to operate in an environment that is normal except for fallout is vastly less than the cost of a system designed to withstand the full extent of nuclear attack.

The survivability of the communication systems discussed herein has been an item of consideration, but the subject has not been dealt with in depth. For direct target areas it is presumed that if protection for the population from the thermal, fallout, and blast effects of nuclear weapons, is provided then provision will also be made for survivable communications system. Buried wire lines, protected radio and telephone

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* For instance, larger states may use state areas or similar entities between the state and county EOC's; similarly large cities may have intermediate EOC's.

equipment, re-erectable or protected raisable antennas, and adequate protected emergency power sources are major considerations. The cost of providing protection for the communication system will be substantial in dollars but will normally represent only a modest increment in the total cost of providing hardened population shelter facilities.

For fallout only areas, the primary communication problems are providing relatively conventional and generally available communication equipment and facilities at the shelter areas, providing for the continued operation of the telephone system, and ensuring adequate level and distribution of power for their operation.

The intermediate areas, those experiencing peripheral blast and thermal effects, fallout, and influx of survivors from and aid to direct target areas, present a number of challenging problems. The possible range of weapons effects is large; thus, the contingencies that must be considered in planning and implementing the requisite communication system are vast. Dispersion, hardening, or provision for re-establishment of antenna systems (including transmission lines) post-attack, together with adequate protection of the radio equipments and emergency power supplies, will permit establishment of radio links. Buried wire lines directly interconnecting shelter areas, or interconnections through adequately protected local exchange buildings, again with adequate provision for emergency power, will provide reasonable probability of a wire communication capability.

IV RADIO COMMUNICATIONS

A. FACILITIES OF GENERAL INTEREST

1. General

The bulk of radio equipment of interest to local Civilian Defense operations falls into the FCC category of Safety and Special Radio Services. This category includes the Amateur and Disaster Services (including RACES), Citizens Service, Industrial Services, Land Transportation Services, Public Safety Services, and Marine and Aviation Services. Table I lists the number of station licenses and number of transmitters in each of these services for the fiscal years ending June 1962, 1963, and 1964. The table also shows the increase in transmitters during these periods, to provide an indication of absolute and relative growth rates. A station license generally covers a base station and various mobile units. For the 1964 data, the average number of transmitters per station license, rounded to the nearest integer, is listed. This is an indication of the average numbers of units netted together.

Industrial services include business, forest products, industrial radio location, manufacturer, motion picture, petroleum, power, relay, press, special industrial, and telephone maintenance services. Land transportation services include automobile emergency, interurban passenger, interurban property, railroad, taxicabs, urban passenger, and urban property radios. (See Part A-4, this section.) Public safety services include fire, forest conservation, highway maintenance, local government, police, special emergency, and state guard. (See Part A-5, this section.)

Marine and aviation services are not particularly suitable or available for the general emergency CD communications requirements covered herein. Reference 12 (page 73) states that the frequency assignments for these services would be pre-empted in the event of nuclear emergency.

Table I

SAFETY AND SPECIAL RADIO SERVICES

	Fiscal 1962		Fiscal 1963			Fiscal 1964			
	No. of Station Licenses	No. of Trans-mitters	No. of Station Licenses	No. of Trans-mitters	Years Increase in Trans-mitters	No. of Station Licenses	No. of Trans-mitters	Years Increase in Trans-mitters	Average Trans-mitters per Station License
	← 1000's →		← 1000's →			← 1000's →			
Amateur and Disaster Service	252 Total	233	271	280	47	281	289	9	1
Amateur	237	230	255	247		264	256		1
Disaster	0.4	0.4	0.4	0.4		0.4	0.4		1
RACES	14	3	15	32		16	33		2
Citizens Service	305	973	447	1,443	470	682	2,197	754	3
Industrial Services	93	893	108	1,024	131	124	1,162	138	9
Land Transportation Services	13	369	14	388	19	15	396	8	26
Marine and Aviation Services	254	317	249	334	17	269	368	34	1
Public Safety Services	39 Total	440	43	491	51	47	510	19	12
Fire	7	87	8	101		9	113		13
Forest Conserv.	4	42	4	44		4	38		10
Hiway Maint.	4	46	5	51		5	54		11
Local Govt.	3	49	5	65		6	68		11
Police	15	196	16	208		17	214		13
Special Emerg.	4	18	5	21		6	22		4
Total	936	3,226	1,132	3,961	735	1,419	4,922	961	3

Source: FCC Annual Reports 1962, 1963 and 1964.

The citizens service is discussed in Part A-3, this Section.

The normal amateur service would in all likelihood be suspended during a nuclear emergency. The amateur operators should be utilized in implementing RACES. (See part A-2 of this section.)

The Disaster Communications Service (Part 20 of the FCC Rules and Regulations) was established for emergency operations. The only frequency band available to this service (1750 to 1800 kHz) is more suitable for longer distance communications, such as county-to-state, and is not generally appropriate for local communications requirements.

2. Radio Amateur Civil Emergency Services (RACES)

The Radio Amateur Civil Emergency Service (RACES) is established under FCC rules and regulations solely for the purpose of providing a basis for amateur radio operators to participate in civil defense emergency communication. They operate in specifically designated segments of the regularly allocated amateur frequency bands under the direction of authorized local, regional, or federal civil defense officials, pursuant to approved civil defense communications plans.[18,19] Reference 12 mentions "...the probable pre-emption of all amateur frequencies (possibly including RACES), by the Armed Forces" (p. 55). The emasculation of RACES during the emergency for which it is constituted is inconceivable. This situation needs prompt clarification.

Ham radio operators have repeatedly proved their value in providing emergency communications. The amateur operators' experience, training, and demonstrated willingness to provide a public service under emergency conditions is a valuable resource that should be utilized in CD plans and operations.

Reference 20, the OCD frequency communication plan for RACES, delineates the frequencies available and the levels of operation at which they may be used. The assignment and coordination of local communication channels within the RACES system is delegated to each state.

As of mid-1964 there were 16,000 RACES station licenses covering 33,000 transmitters.

The use of the RACES would appear to be most appropriate in the longer distance communications, i.e., city/county to state (in fact, RACES is essentially the only service within the Safety and Special Radio Services generally suitable for these longer-range radio communications), and in covering some of the communications requirements peculiar to the nuclear attack situation such as military liaison, communication with the EBS station, weapons effects monitoring, communication with adjacent communities, etc.

3. Citizen Band Service

The citizen band service is designated to provide private short-distance radio communications service for the business or personal activities of licensed citizens, with minimal licensing requirements.[21] There are four classes of stations: Classes A and B may be operated on 48 channels in the 460-470 MHz band, limited to input powers of 60 W and 5 W for Classes A and B, respectively. Class C, for control of remote objects or devices, is not of general interest for civil defense purposes. Class D stations are limited to 5 W input power and operate on 23 channels in the 27-MHz region. Class D service represents the great bulk (over 80 percent as of 1962) of citizen band equipment.

Class A and B station equipment represents an excellent supplemental source of potential emergency communication capability for shelter-SCH-city/county operations. The extremely widespread availability of Class D equipment and the limited number of channels available, together with the relatively long-range propagation characteristics of its frequency band, probably represent more of a problem than a solution to the CD communications requirement. Table I shows that almost 700,000 of the 1,400,000 station licenses in Safety and Special Radio Services are for citizen band stations and that almost 2.2 million of the 4.9 million transmitters are in this service, almost half of the total number of both stations and equipments. Furthermore, about 80 percent of the new transmitters licensed during fiscal 1964 were in the citizen band service, with the addition of over 750,000 units. Thus the present size of this equipment pool must be approximately 3 million transceiver units, about 2-1/2 million of which would be sharing the 23 channels in the Class D service. On top of this, the FCC license regulations permit unlicensed operation of 100 mW or lower power transceivers on the same 23 channels and vast quantities of such equipment, many in the $5 to $75 per set range, have been sold in recent years.* Thus the competition for channel space in this band is intense, and the possibility of reasonably interference-free communication is unlikely.

While one can predict reasonable control and usage in an emergency of the Amateur and Disaster, Industrial, Land Transportation, Public Safety, and Marine and Aviation Services equipment, the control during an emergency of the widely dispersed and individually owned citizen band equipment represents an almost insurmountable problem. Thus, planned use of the Class D citizen band equipment for nuclear emergency communications would not appear to be desirable.

During the next five years, the 11-year sunspot activity cycle will go through a maximum and markedly increase the possibility of reception of low power transmissions over long distances. This will result in further increasing the interference level in the 27-MHz band, due to longer range propagation characteristics attributable to sunspot activity.

4. Industrial and Land Transportation Services

These services represent a large potential source of commercial owned and operated radio communications equipment, portions of which would be useful for supplemental emergency communications. This would require voluntary cooperation on the part of the equipment owners, and thus realistic and effective preplanning of the proposed usage and requisite distribution of the equipment during the emergency period is essential.

5. Public Safety Services

The Public Safety Radio Service is the main basis for local government radio communications, and should be fully exploited in establishing

* Electronic News for Jan 3, 1966 reports a figure of 1.9 million CB transceiver imports from Japan during the first six months of 1965, four times the imports of the similar 1964 period.

emergency communications. The two largest users of these services--Police and Fire--will presumably be fully utilized in their established functions during an emergency (which might include weapons effects monitoring). Use of the local government radio service is increasing; this service provides an excellent base for a broad range of emergency communications, with the added advantage that it can be used for CD drills and exercises, a feature not permissible under most other Safety and Special Radio Services.

6. AM/FM/TV Broadcast

The need for battery-operated AM-FM broadcast radio receivers in all shelters is well covered in the existing literature. Recently, significant and increasing numbers of transistorized television receivers have become available, initially with smaller size screens, and particularly for battery-operated portable sets. Although adequate data for accurate prediction of numbers of such receivers is lacking, it appears reasonable to estimate that on the order of 1 million battery operated portable TV sets might exist throughout the country circa 1970, and even larger numbers of partially transistorized TV receivers, with resultant reduced operating power requirements. The information, educational and training, and entertainment potential from television service during a shelter period is tremendous and it would appear appropriate to look toward the implementation of this capability in future planning. This entails providing for the continuation or re-establishment of local TV broadcast capability, to include operator fallout protection, emergency power, and in some instances an erectable or hardened antenna as well as advance provision for suitable program material. At the shelters it would require providing suitable antennas and transmission lines, power source for the receivers, and either stocking of receivers in the shelter areas, or provision for bringing existing sets into the shelter at the advent of the emergency period.

7. Public Land-Mobile Radio Service

"Car telephone" service provides another potential communication channel for emergency service, although it is available only in specific areas throughout the country, and in limited numbers (less than 18,000 car phones as of mid-1964). The recently announced Improved Mobile Telephone Service (IMTS), capable of providing up to 11 channels of automatic dial service, should enhance the growth rate, and augments a trend toward automatic unattended operation, more appropriate for the anticipated emergency requirements.

8. Microwave Relay

The use of microwave relays for transmitting large volumes of information over both short- and long-distance paths is increasing. For the local traffic volumes predicted in the Requirements Study, the installation of microwave relays for CD emergency use alone is not indicated. In general, the cost would be one or more orders of magnitude greater than for single channel, point-to-point communication equipment. Where such microwave relay systems are available as part of existing communications systems, and where there appears to be a high probability of survival and continued operation throughout the emergency period, their incorporation into the emergency communications system would be desirable.

If the requirement for rapid transmission of displays, facsimile, or other high-information-content messages is established, the use of microwave transmission should be considered.

9. Broadband Multiple Random-Access Radio Communication System

Several recent studies of broadband, multiple-party-access, discrete-address communication systems based on new technology and operating procedures have resulted in new communication concepts. These are referred to in the literature variously as RADAS,[22] MADA,[23] and RADEM, etc. These communication concepts are oriented particularly to situations where users are randomly distributed geographically, with low usage requirements and where communications must be implemented quickly without regard to trunking, fixed networks, or switches. This approach involves the integration of message processing, message, and addressing information, and the sharing of a wideband channel.

Circuit complexity is increased several-fold over conventional communications equipment. However, the bulk of the incremental circuitry is digital in nature, and thus a prime candidate for the rapidly developing integrated circuit technology. This implies small size and weight, low power, economical, highly reliable circuit implementation.

This communications approach is still in a relatively early phase of development and is not expected to be in widespread use within the circa 1970 time period. It could be a significant factor in the communications field by 1975, but any plans for CD use of this potential communications medium should be preceded by further evaluation.

B. GENERAL TRENDS IN RADIO

There are a number of clear trends in the radio communications field which will generally prove beneficial to the CD emergency requirements.

Growth--The Safety and Special Radio Service licensing records indicate an annual growth rate of radio transmitters in service, in addition to the Class D citizen band equipment, of about 300,000 units per year. While some of these units are for replacement of worn out or obsolescent systems, there is a substantial net increase in available equipment. This growth rate will be curtailed by spectrum crowding unless additional frequencies are provided.

Transistorization--The use of transistors and other solid-state devices in these types of radio equipment goes back many years, starting first with the power units and receivers. In currently available equipment, portions (and in some cases all) of the transmitter circuitry are also transistorized. Generally, the higher frequency/or higher powered equipments still use vacuum tubes in the frequency multiplier, modulation, and final amplifier stages. Completely transistorized low- and medium-power mobile units are now widely available. This has resulted in reduced size and weight, and more significantly, in reduced power requirements and increased reliability, with resultant decrease in maintenance costs, and no significant increase in procurement costs.

Channel Availability--Channel splitting and the development of more economical equipment in the VHF and UHF bands have helped in providing additional communications channels. In spite of this, in most high-population-density areas, the limited number of available channels is, and will continue to be, a very significant problem.

Equipment Replacement--Manufacturers report a seven to ten year replacement cycle for communications equipment. This is occasioned by advances such as transistorization of equipment, availability of more suitable frequency and/or power capability economically, improved noise reduction and coded addressing circuitry, etc. Thus within the next few years, the majority of the operational equipment in the field will be at least partially transistorized, with the resultant benefits in terms of reliability and power requirement.

C. RADIO COMMUNICATIONS

This portion of the report is a review and evaluation of two-way radio communication suitable for use throughout a state, under emergency conditions. Factors considered include:

(1) Nuclear detonation effects upon emergency radio communication,
(2) Radio systems that are feasible for this type of operation,
(3) Radio engineering factors that need to be weighed,
(4) Cost and availability of suitable equipment,
(5) Pertinent FCC regulations, and
(6) Operator considerations.

Two-way radio can provide a back-up communication system that would be put into service in the event that the telephone system becomes unusable as the result of a nuclear attack or other emergency condition, or to supplement the telephone system if operating. Within a county, communication is needed between shelters and the shelter complex headquarters (a few tenths of a mile), between complex headquarters and the city/county EOC (4 to 15 miles), and between a city/county EOC and the state EOC (perhaps a distance averaging 100 miles). The assumed model for this communications network is shown in block-diagram form in Fig. 1.

The nature of the messages to be transmitted, viz., content, priorities, format, etc., is not of concern here.

1. Effects of Nuclear Detonation on Radio Communication

The energy produced by a nuclear detonation is divided into three components; nuclear radiation, thermal radiation, and blast and shock. The thermal and nuclear radiation energies are not of primary importance to radio communication in this review since electronic equipment has considerably greater tolerance to radiation than does a human. Radio equipment located in a shelter occupied by people will be adequately protected from radiation. Equipment outside a shelter may receive as much as 1000 times as much radiation as a human inside the shelter, but this amount still is below the threshold of damage for the equipment.* Furthermore, the effects of radiation upon the propagation of radio energy is negligible for the frequencies and distances we are concerned with.[24]

The effects of blast and shock upon radio systems need to be considered since a human can tolerate up to 45 psi overpressure, and electronic equipment and antennas can tolerate about 5 psi.[24-26] Existing structure shelters will have a wide variation in blast resistance. If the shelter can withstand more than 5 psi, then hardening the radio equipment is a reasonable step to take. (For reference purposes, houses are generally damaged beyond repair at an overpressure of 5 psi.[24])

Antenna towers present a special problem when one considers susceptibility to blast damage. In tests conducted in Nevada in 1955, an antenna tower that was guyed withstood 5 psi overpressure without sustaining damage, while an unguyed tower was damaged and unusable.[24] In many instances commercially available guyed antenna and antenna towers are adequate for shelter use. The fact that antennas are outside the building means that they could be damaged by missiles and falling objects, even though no direct blast damage is sustained. Furthermore, if the shelter is in the basement or inner rooms of a building that is of sturdy

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* Short-term exposure to 600 Roetgens of gamma radiation is lethal to man while most electronic equipment can tolerate 10^6 Roentgens (Teflon fails at 10^5).

construction, the shelter could withstand more overpressure than the antenna and antenna tower. This situation puts antennas in a rather unpredictable position as far as blast damage is concerned; in some cases they will sustain damage and in some they will not.

It is possible to harden antennas so that they can withstand high overpressures. This is expensive to do, and is generally not warranted. An intermediate approach has been proposed wherein quick-erect antennas are used.[27] These antenna structures are stored in the building and then quickly assembled and erected in the event of an emergency. This approach is applicable to a shelter that will withstand more than 5 psi overpressure, but must be considered in terms of the predicted fallout timing and level. Another type of erectable emergency antenna consists of an inflatable balloon supporting a length of wire. The gas for the balloon could be obtained from a pressure bottle, or a chemical gas generator, (such as Signal Corp. generator M-315-b) designed for this purpose. This latter system is used by the Navy as part of an emergency transmitter, designed AN/CRT-3 (Gibson Girl).

For the typical shelter, a well-constructed antenna is adequate, but it is prudent to consider an alternative unit (or units). This might take the form of several whip antennas placed at different locations on the shelter building; each antenna would have a separate lead-in transmission line. If one antenna were damaged, connection could be made inside the shelter to another antenna. If the main antenna structure is at all complex, it may not be economical to have identical redundant antenna units, but some emergency provision can be provided without excessive cost.

2. Radio Engineering Considerations

a. Frequency

The operating frequency of a transmitter/receiver system determines many factors in the design of the antenna and the electronic equipment. Two important factors, the amount of power required to operate the system and the cost of securing and installing the system, are strongly affected by frequency. The main frequency bands that merit evaluation for our purposes are the high-frequency (HF) band (3-30 MHz), the very-high-frequency (VHF) band (30-300 MHz), and the ultra-high-frequency (UHF) band (300-3000 MHz). The cost of two-way radio system designed for use above 3000 MHz or below 3 MHz is prohibitive for this application.

The HF band is currently used extensively for communication between points between 500 and 5000 miles apart. For these distances sky-wave propagation is required. In this mode of operation radio frequency energy from the transmitter is reflected back to the earth by the ionosphere.

The earth's ionosphere, an ionized region that surrounds the earth and comprises free electrons, positive ions and negative ions, is significantly influenced by the emission of solar radiations. These solar radiations have an observed correlation with the characteristics of the sunspots. The general level of sunspot activity varies with time and has peaks that occur at approximately 11 year intervals (the next maximum is expected in 1969-1970). Long distance sky-wave propagation is enhanced by sunspot activity, and in particular, there is a significant sky-wave component for 30-MHz wave propagation. The ionosphere is affected by nuclear detonation, and these detonations can disrupt communications that rely on this propagation mode.[24]

Most of the communication links that we are concerned with here are for comparatively short distances and therefore do not rely upon ionospheric reflections. However, even in short line-of-sight links these reflections cannot be ignored, as they can be a source of interference. Furthermore, it is conceivable that the reflections that result from an intended line-of-sight link could allow monitoring of messages by a foreign power, and thereby become a means for obtaining intelligence information. The effect of reflections and, in addition, the large antennas that are required by these frequencies make the HF band undesirable for use in local civil defense emergency communications except possibly for the upper end of the band.

The VHF and UHF bands appear to be the best ones for local civil defense purposes. The normal propagation mode for VHF and UHF is line of sight; the radiated energy that goes skyward normally penetrates the ionosphere and escapes from the earth. (In some systems, however, VHF is used for long-range propagation by relying upon the small amount of energy that is scattered back to earth by unusually intense regions of ionization.)

In the UHF region it is possible to communicate beyond the horizon (to 500 miles) by making use of tropospheric reflections. The troposphere is that portion of the earth's atmosphere that is within 10 miles of the earth's surface. Nuclear detonations that alter the ionosphere do not disturb the troposphere. A detonation located between radio transmitting and receiving stations could disrupt communications for a few seconds; except for this condition, tropospheric communication is immune to detonation effects.[24]

Within the VHF and UHF bands there is a considerable amount of freedom in frequency selection as far as propagation characteristics are concerned. In general, the higher the frequency the greater the propagation path loss.[28] This is caused by reflections and the resulting absorption and change in wave polarization. The surroundings, e.g., buildings, trees, brush and hills, all contribute to path loss, and for this reason it is impossible to give specific loss values without measurements on site. Furthermore, since the nuclear fallout conditions that we postulate could be near regions sustaining considerable blast damage, structures that cause reflections and absorptions under test conditions may not be present under actual use of the radio link. This fact along with others indicates that an emergency radio system should have a large margin of safety in signal level.* The price paid for this margin is higher initial dollar cost and greater power consumption. This trade-off must be evaluated for each individual network, and should also be studied in more general terms in future research.

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* However, it is important to use only the minimum necessary transmitted power for each communications channel, to minimize interference with other networks, and to reduce operating power requirements.

The question of noise level enters in the selection of operating frequencies because the noise present at a receiver input is a function of frequency. The sources of noise that we are concerned with are the same ones that are present in any communications link: man-made noise, electrical storms, interstellar sources, and the radio system itself. The noise received by an antenna generally decreases with increasing frequency; this occurs for two reasons, first because the higher the frequency the smaller the amount of energy returned to the earth from the ionosphere, and second, there are not as many sources that generate high frequencies as there are in lower-frequency regions.

A unique noise source that accompanies a detonation is designated EMP* (for electromagnetic pulse). EMP is present at the time of a chemical or a nuclear detonation, but fortunately it gives rise to only a brief noise signal at the receiver. The radio sensitive characteristics of EMP resemble those of "static" caused by lightning. Recently developed information on EMP is classified, and is not covered in this report.

Noise sources within the radio system itself that we consider briefly are cross-modulation and co-channel noise. The latter "noise" results from several transmitters using the same frequency. Reduction in the number of transmitters using the same frequency and appropriate radio operator procedures are obvious methods to reduce co-channel noise. To achieve reduction of the numbers of users of a frequency really means that more of the spectrum needs to be assigned by the FCC to mobile communications users. A recent study emphasizes this problem by making an analysis of channel usage throughout the nation.[13] From this study we have compiled Table II, indicating to some extent the channel crowding that exists today. This situation can only get worse unless significantly more channels are made available.

Cross modulation can occur when two received signals have carriers that do not differ greatly in frequency. The modulation of an undesired signal can become superimposed upon the desired modulation by the action

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* The EMP may also be sufficiently intense to damage radio components.

Table II

NUMBER OF LICENSED TRANSMITTERS PER MHz BANDWIDTH AS OF JUNE 1963

	FREQUENCY BAND		
Service	30-50 MHz*	150.8-162 MHz†	450-460 MHz§
Public Safety	1,810	39,336	1,974
Industrial	2,740	40,236	5,990
Land Transportation	189	35,114	2,033
Citizens	--	--	4,242
Common Carrier	1,228	54,725	7,794
TOTAL	5,967	169,411	22,033

* Includes a few transmitters between 25 and 30 MHz
† Includes a few transmitters between 162 and 170 MHz
§ Includes a few transmitters between 460 and 470 MHz

of nonlinearities within the receiver. Improved receiver design and greater spacing between assigned frequencies are solutions to this interference. A consideration bearing upon cross modulation as a noise problem is the fact that during fallout condition many of the communication links normally used by industry would not be operating. Likewise we anticipate that other man-made noise sources would be reduced or silenced in such an emergency situation (although the converse could also be true).

The noise that must be overridden by the desired signal is another factor, like path loss, that is variable from one location to another. A study of noise and path loss in New York City showed that noise level decreased as frequency increased from 100 MHz to about 600 MHz, while in a rural area the opposite was true. In the rural area the noise level was determined by internal noise generated within the receiver. In the New York area the combined effects of path loss and noise generation showed that the 500-MHz region was the optimum frequency.[28]

On the basis of the above discussion, channel availability, and other factors to be discussed later in this report, we conclude that frequencies between 50 and 500 MHz should be given first consideration, and that limited use can be made of frequencies as low as 27 MHz (citizens band) and as high as 1000 MHz.

b. Antennas and Transmission Lines

The antenna design characteristics that are important in the typical mobile communication system for police departments, fire departments, taxi companies, etc. are likewise important for a shelter communications network. The characteristics that we have in mind here are: gain, directivity, noise rejection, polarization, impedance, bandwidth, height, etc. In a shelter network, however, we see two distinctions that have importance: The transmitting and receiving stations are all stationary, and the displacement of the antenna relative to the transmitter/receiver may be considerably greater than in the normal vehicular installation.

Because all antennas are stationary, the use of an asymmetrical radiation pattern is possible (and probably desirable) for the lower organizational echelon portions of the radio link.* A directed radiation pattern reduces interference, reduces the required level of received RF power, and reduces the amount of RF transmitter power required. All three of these reductions result in a decrease in prime power required to operate the system. Prime power is an important factor for operation under emergency conditions when normal power sources may be inoperative.

Since the radiated energy in the UHF and VHF bands is propagated essentially in a straight line, the height of the antennas on both the transmitting and receiving end are important factors. As shown in Fig. 1 the average distance between a shelter and shelter complex headquarters varies from 0.2 miles to 1 mile. For the next higher echelon, the distances

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* The ability to restructure the lower echelon communication network during an emergency is limited if directional antennas are used. In this context it should be borne in mind that the radio link is only a backup in this system and not the primary means for communication.

vary from 5 miles to 15 miles, and for the highest echelon this average distance is estimated to be 100 miles. Table III, taken from Ref. 25,

Table III

DISTANCE TO RADIO HORIZON LINE FOR DIFFERENT ANTENNA HEIGHTS

Antenna Height (ft)	Radio Horizon Distances (miles)
5	3.2
10	4.5
25	7
50	10
100	14

shows the horizon distance as a function of antenna height for smooth earth. Note that for equal antenna heights the maximum transmission distance possible is twice the distance to the horizon. It is also significant to note that the radio horizon is somewhat greater than the optical horizon because of the slight bending of radio waves. This bending is caused by the gradient in the dielectric constant of the atmosphere.[29]

An estimate of the relationship of antenna height, power output, frequency and nominal range of transmission can be obtained from Table IV, taken from Ref. 30. In Refs. 31 and 32 a series of nomographs and other useful information are given relating height, power, distance, and frequency.

The tables indicate that the distances for communication between echelons are compatible with the VHF and UHF capability except possibly for the link between the state EOC and city/county EOC's. The use of a high tower and an antenna with gain on both transmitting and receiving ends of the line will increase the coverage beyond that indicated in Table IV. To get coverage in some state to city/county links* it may

* Some physically large states may insert state area organizations between state and city/county organizations, thus reducing the transmission distance requirements.

Table IV

NOMINAL MOBILE COVERAGE VALID FOR SMOOTH EARTH
USING DIPOLE BASE-STATION ANTENNA AND QUARTER-WAVE MOBILE WHIP

RF Power† (Watts)	Range (miles)* for Frequency Band and Antenna Height §											
	25-50 MHz				150-174 MHz				450-470 MHz			
	50'	100'	150'	300'	50'	100'	150'	300'	50'	100'	150'	300'
10	15	19	22	30	11	14	16	21	8	10	12	16
30	18	21	28	37	13	17	20	26	10	13	15	19
60	21	27	32	43	15	29	23	30	11	14	17	22
100	23	31	36	48	16	21	25	33	12	16	19	24
250	27	37	43	58	19	26	29	37	14	18	22	27

* Each dB gain adds about 5%; each dB loss subtracts about 5% from basic range.
† Doubling power adds 3 dB, a five-fold increase adds 7 dB, a ten-fold increase 10 dB.
§ Doubling antenna height adds 6 dB.

be necessary to use high-power transmitters and rely on tropospheric propagation, to use state microwave relays if they exist, or go to frequencies below VHF. As stated earlier, HF propagation can be temporarily interrupted by nuclear detonation.

The possible interception of messages transmitted in the HF band has additional significance in this instance, since we are considering the city/county-to-state EOC link. At this organization level the content of the messages is more likely to comprise intelligence information of value to the enemy than would messages between lower echelons, and the longer propagation characteristics may increase the opportunity for interception.

Other alternatives for beyond-line-of-sight propagation involve the use of different frequencies for day and night transmission, use of passive reflectors (perhaps balloon supported), use of unmanned repeater stations, and use of the city/county EOC's as relay points. The best system for this situation is highly dependent upon local conditions, e.g., topography, and will ultimately be made on the basis of economic factors.

As this discussion of state to city/county link indicates, Tables III and IV are useful for preliminary planning and estimating purposes, but on-site examination by qualified personnel is essential for any serious system planning.

The transmission lines problems to be solved are the standard ones. Nuclear radiation and blast effects are not detrimental to transmission lines in the fallout-only or low-blast regions (barring a direct hit by debris on an exposed section of line). The length of the transmission lines may tend to be longer in CD installations, and this is a disadvantage. The increase in length arises because a shelter is often located in a basement or other internal area rather than on upper floors or outer sections of the building. Also, in adapting mobile equipment for CD emergency operation, portions of the system will probably be removed from the vehicle and taken into the shelter as discussed subsequently. In some adaptions the antenna remains on the vehicle and the transceiver unit is removed to the shelter; this requires a longer than normal line. A long line has more radio frequency losses than a short one, and obviously costs more money. The cost of the transmission line can be a significant fraction of the total system cost (cost per foot varies from 5¢ to 40¢ depending on type, quality, and quantity).

For a given length of transmission line, the loss is dependent upon the type of line used. This loss is a design parameter that can be readily determined for each installation. As a rule of thumb it has been stated that transmission line length should not exceed 500 ft in the 25-50 MHz range, 250 ft in the 150-174 MHz range, and 125 ft in the 450-470 MHz range.[32A] In Fig. 2 the attenuation for several coaxial cables is given as a function of frequency.[34]

c. Modulation

Two methods of modulation are suitable for CD communications, frequency modulation (FM), and amplitude modulation (AM). Single-sideband modulation (SSB) is presently used in some amateur and RACES

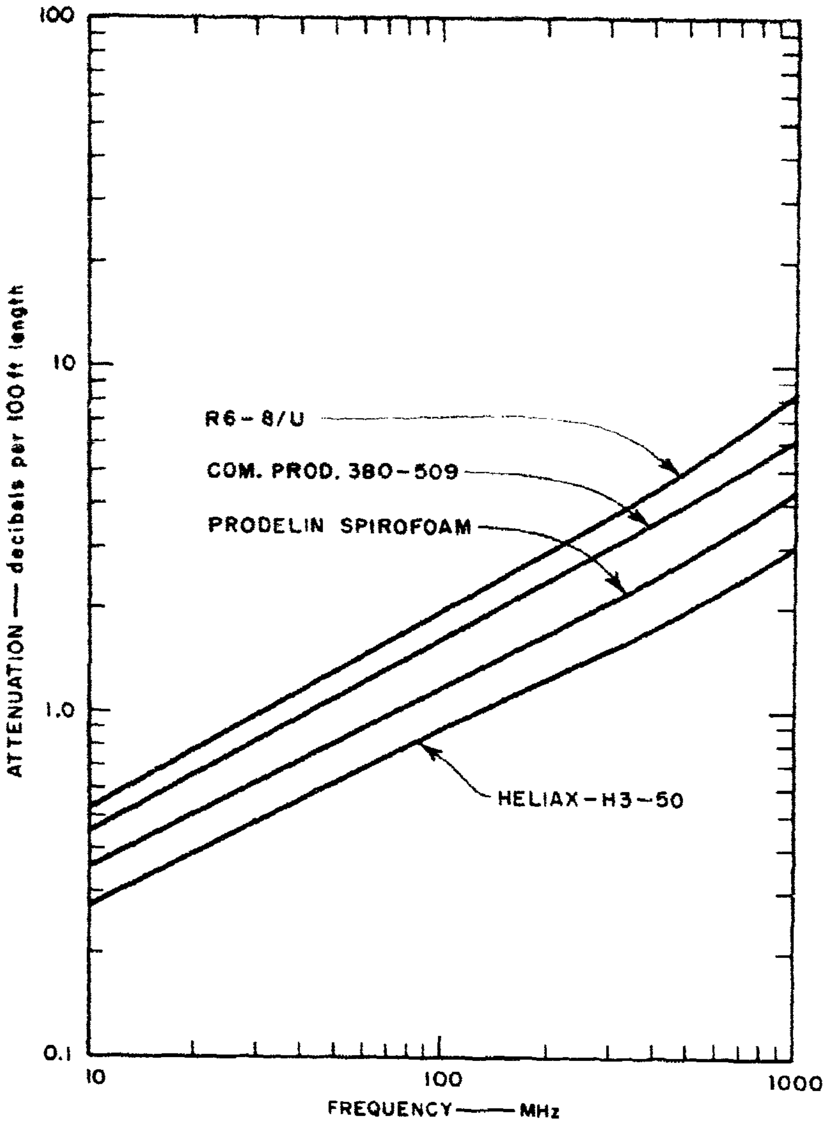

FIG. 2 ATTENUATION CHARACTERISTICS OF TRANSMISSION LINE

equipment, but is not considered generally suitable for the bulk of local CD communication requirements because of stability and cost factors, particularly in the frequencies of prime interest. Pulse modulation for Morse code transmission is not generally suitable because of the message capability limitations it imposes and the problems associated with operator training.

FM is widely used in mobile communication systems for industrial and government functions. By comparison with AM, FM has less flutter resulting from motion of a mobile unit, FM receivers have a better signal-to-noise ratio, and a "capture" effect, which aids in discriminating between two signals having the same carrier frequency. This capture effect increases the number of stations that can be in close proximity and more than offsets the somewhat greater channel width required by FM.[33] On the other hand, AM equipment is simpler and therefore less expensive and easier to maintain than FM. The CD requirements are primarily for fixed point-to-point links, the flutter elimination is of little consequence (except possibly in a region of frequent airplane traffic). The use of antennas having directed radiation patterns is possible in point-to-point links and desirable from several aspects as noted above. If such antennas are used, the desirability of the capture effect decreases. Lastly, the noise-limiting capability of AM circuitry has been increased in the past few years and will probably be further improved in the future.

The three main advantages that are typically attributed to FM are of reduced importance for CD emergency applications. These factors deserve further consideration, and other factors, such as compatibility with the present use of FM by most Safety and Special Service equipments should be brought into focus through further investigation, as a part of studies of CD radio equipment development.

d. Electronic Equipment Characteristics

There are several features of transmitters and receivers in addition to those already covered in other sections that need to be highlighted, namely, reliability, efficiency and power sources, operability, and adaptability of mobile equipment. Perhaps the most important of these is reliability because of the conditions that would accompany any need to use the communication link in a fallout emergency. This is particularly true for the postulated model shown in Fig. A-1, since only a single radio link is planned between lower level echelons. The fact that the links used in the upper echelons may be an integral part of normal nonemergency local government communication networks puts these stations in a different category than those between shelters and shelter complex headquarters. The pre-emergency use of these latter stations will probably be only in infrequent drills. An important feature of these drills should be to determine the performance status of this radio equipment. The equipment used for daily government functions will presumably be maintained in operating condition as a result of this daily use. However, it may be necessary in some cases to place more rigid requirements upon the maintenance of this dual-function equipment than are normally placed on this type of equipment. A specific aspect of this is the necessity for operation of the equipment when the normal electrical power sources have failed. The power sources intended for use in civil emergency situations probably would not be required for carrying ou nonemergency government functions and therefore routine provisions hould be made for their maintenance.

Reliability is a matter of concern not only for maintenance but also in the initial design of equipment. The use of transistors ir at least the low-level stages of the transmitter and throughout the receiver is a logical step in attaining high reliability. Conditions preva ing during storage are important and have reliability implications in ie initial design. In a basement shelter, for example, dampness can cause corrosion. Mechanical and electrical specifications of electroni equipment for fallout shelter use have been developed as a part of a recent study for OCD.[34]

Efficiency has greater emphasis placed upon it for this civil defense application than is often the case, because of limited energy available from emergency power sources. Here, as in the reliability considerations, the use of transistors is a logical stipulation. In the design of the transmitter a standby operational state is essential as a power savings means. For the receiver, a jack could be provided so that headphones can be used, with the output stage power disconnected.

Both the transmitter and receiver units should be capable of operation from direct current sources as well as 110 volt alternating current. Batteries of the type used in automobiles appear well suited for emergency purposes from several points of view, e.g., cost, durability, and availability. An interesting aspect of the availability is that there will undoubtedly be many batteries that can be removed from nearby autos when brief emergence from the shelter is possible, and also before taking shelter if sufficient warning has been given. It is possible to maintain a battery in a charged condition for the type of service anticipated through the use of a generator operated manually.[35] It is also possible to secure batteries with a built-in charging unit that operates from 110 Vac.[12] Still another attractive possibility is to use dry-charge batteries that are filled with an activator fluid before being put into service. A 10-year storage life has been estimated for batteries of this type that are sealed against dust and moisture.[34] Using these dry-charge batteries it is possible to supply power to a small (10 W RF) transmitter and receiver for the two-week shelter period without any recharging provision. We estimate that two or three high capacity batteries (70 Ah, 12 V) are sufficient for this purpose. For those shelter-to-shelter-headquarters links requiring only a few watts of RF power, one battery should be adequate. (Because of the heavy reliance we are suggesting on the use of auto batteries it is appropriate to note here that batteries have been tested and found apparently unharmed by a nuclear detonation causing 5 psi overpressure.)[24]

In an acute emergency situation requiring makeshift measures, it is possible to make batteries out of household chemicals. This and other improvised power sources have been investigated and are reported in Ref. 36.

The operation of electronic equipment, for the emergency conditions postulated here, must be simple and foolproof. This requirement is especially meaningful on the shelter level, where there is little assurance that a licensed operator or anyone with a technical background will be present. Tuning should be accomplished by a single channel selector switch. Two or three crystal-controlled channels seem adequate. All other controls should be simple and clearly labeled. Brief operating instructions should be permanently attached to the equipment itself. At the shelter complex headquarters level and higher echelons it is reasonable to assume a certain amount of operator training. At these higher levels, greater RF power is required, and, since the equipment is probably used for nonemergency government functions as well, we expect it to be more sophisticated than the simple units in the shelters.

The possibility of adapting existing mobile communication equipment for shelter communication networks has been studied (for a particular county).[35] A vehicle containing a mobile installation may be parked near the shelter and the transceiver controlled from the shelter via wire link. This is a feasible approach, and, in fact, the military has used this method for a number of years (e.g., the AN/GRC-3 through 8 series). Remote control is possible over five miles of field wire.

Another means of remote control is via a radio link. While this is technically feasible, it requires an additional low-power radio link and channel, and some re-transmission equipment at the mobile unit. This constitutes a "mobile" relay station, which is not permitted under many FCC licensing regulations. Again, this is a common capability in military equipment, such as that referred to above.

A third approach is to remove the transmitter/receiver/power unit* from the vehicle (leaving the dashboard control unit in the car). The transmitter/receiver/power unit is taken into the shelter area where an auxiliary control panel, antenna and power source would be connected. This method presupposes that the transmitter/receiver unit is reasonably accessible and does not require much time for removal, a reasonable assumption in many cases. The auxiliary set of controls could be a unit attached to the transceiver itself for this emergency operation,

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* This refers to the unit developing and distributing the appropriate voltages to different portions of the transmitter/receiver, but not to the energy source (i.e., battery).

or one pre-installed in the shelter. This type of operation for certain mobile stations licensed under Public Safety Services is apparently acceptable to the FCC, provided that the transmitter is under the control of the licensee.[37]

3. Equipment Cost and Availability

Quality citizens band equipment (class A, B) runs in the range of $100 to $300. Typical mobile transceiver equipment installed in vehicles might run $700 to $1200, and the associated base stations $1500 to $2500. Maintenance costs for a mobile station might approximate $7.00 per month per station with a trend toward $4.00 to $5.00 per month for the transistorized equipment. The mobile equipment indicated is for the VHF and UHF bands, using frequency modulation, with RF power ratings of 15 to 100 W. The cost of the higher-power units is greater than for the low-power units, and the cost of higher-frequency units is greater than it is for lower frequency. The citizen's band equ ment are generally lower power units than the other mobile units, and the citizen's band equipment makes use of amplitude modulation.

If one were to implement a CD network at this time using commercially available radio equipment, mobile FM units should receive serious attention. Alternative approaches are available, however, and they merit consideration. In the Gautney and Jones study that has been referred to several times, there are estimates of the cost for an FM transmitter/receiver specifically designed for CD use.[34] For an RF power of 1 to 3 W and a production quantity of 10,000 units, Gautney and Jones estimate a cost of $300 to $700, which is significantly less than the cost range for mobile equipment presently available. Because of the estimated cost saving per station, and because of the potentially large number of shelter-based stations throughout the nation, it appears desirable to establish a program to investigate this approach further (including the possibility of using AM) and, hopefully, secure prototype equipment.

A second alternative leads to a much less expensive per station outlay but has some conditions attached. This alternative comprises the assembly of low-power transistorized AM units by volunteer help. This alternative has been implemented in an actual working system in San Jose, California.[38] The cost for each set was $150. The transmitter has an output RF power of about one-half watt at 53 MHz, and has a three-mile coverage.

A third alternative is to make use of equipment available on the government surplus market. A brief investigation of this approach showed that a considerable cost savings is possible. (A 40-W AM transmitter can be purchased for less than $100.) Equipment from this market is available on a hit-or-miss basis, so this alternative is not generally applicable. Reliability and power required must be carefully evaluated in this alternative, since the equipment is second-hand and makes use of vacuum tubes.

A final alternative is to provide for remote control from a removal to the shelter, of mobile equipment installed in vehicles. The attractiveness of this alternative lies in the assumption that the major cost of the equipment will have been met from other sources and that the CD outlay will be for the additional remote/removal features only. An estimate of $145 per unit has been made for the auxiliary equipment and modifications required to permit the control of a mobile installation from a shelter.[35] For this system radio equipped vehicles would be furnished with a receptacle in the trunk or under the dash permitting rapid connection of a long cable (e.g., 100 ft). By means of this cable, the two-way equipment would be operated and the vehicular battery maintained in a charged condition from within the shelter. At the shelter end of the cable there would be battery terminals, a control unit, and a microphone and speaker, or handset.

V WIRE COMMUNICATIONS

A. TELEPHONE WIRE COMMUNICATIONS

Wire systems provide a primary means of satisfying the need for communication between shelters and other levels of the shelter organization hierarchy. Of the several modes of communication available on wire systems the telephone is most attractive when considered both in terms of ease of use and low cost. Only in situations involving distressingly poor or very costly transmission facilities need we consider teletypewriter or hand-keyed Morse transmission.

This section focuses attention upon telephone wire communication systems. Three major alternative implementation schemes are presented:

(1) The existing, commercial switched telephone network,

(2) A civil defense operated PBX-like facility, and

(3) A manual, locally powered facility.

In comparing these alternatives, factors of reliability, flexibility, feasibility, and cost are significant.

B. COMMERCIAL, SWITCHED TELEPHONE NETWORK

The commercial, switched telephone network serves all densely populated areas and is highly mechanized. Recent statistics (1 January 1964) show that for the United States overall there are 44.3 telephones per 100 people, while in the cities of 50,000 population (or more) the number of telephones rises to 52.5 per 100 people. Approximately 98 percent of all central offices are automatic (i.e., dial); these automatic offices serve 99 percent of all telephones. These factors make it worthwhile to consider this network for shelter communication.

1. Advantages

The widespread distribution of the telephone network in the urban and suburban areas indicate that telephone service should be readily extendable to shelters. A measure of the additional burden placed upon the telephone plant by the addition of shelter telephones can be estimated as follows: There are approximately 26.1 telephone lines (there are more telephones than lines) per 100 people. With an assumed average shelter population of 500 and one telephone line per shelter, the ratio is increased by 0.002 lines, requiring a net growth of wire and central office plant of less than 0.008 percent. With present plant growth of the order of 4.3 percent per year, there should be no difficulty in servicing shelters.

The high degree of mechanization implies continued, unmanned operation, as might be needed when telephone personnel are also in shelters.

The central offices can provide switching of calls, enabling ready telephonic communication between any two points of the shelter organizational structure.

2. Disadvantages

Though automatic, it is doubtful that all the telephone central offices can remain unattended for substantial periods of time (say in excess of seven days). Approximately 4.2 central office craftsmen (including test-board men, repeatermen, centeral office repairmen, and others) per central office work an average scheduled 40-hour work week to repair the minor faults that continually occur. Unattended offices are connected to attended offices by alarm circuits so that help can be dispatched to the unattended office when a fault occurs there.

The central office power system, typically 48 Vdc and 130 Vdc, is derived from the electric mains of the local power company. If the main power fails then batteries in the central offices assume the telephone load. Often a generator driven by some prime mover, all located in the central office, is available as an additional backup power source.

The batteries alone can usually support 3 to 4 hours of the central office load, though additional cells may need to be switched in to prevent a harmful drop in the dc voltages. This switching process might be manually effected in some cases.

The generators are not usually started until a main power failure has been sustained for more than 15 minutes or so. The startup of the prime mover and the loading of the generator is typically a manual operation.

It is doubted that more than a few days fuel supply is stored for the prime mover.

A remote possibility exists that abandoned telephones might be left accidentally off-hook in substantial numbers. In step-by-step dial central offices not equipped to dispose of "permanent" lines automatically, the capability of the office can be severely reduced. Step-by-step central offices constitute 68 percent of all central offices.

C. CIVIL DEFENSE PBX SWITCHES

The use of the commercial, switched telephone network makes all shelter communication dependent upon the proper performance of a power system and a complex switching mechanism that could well be unattended for a long period of time. A manual PBX switchboard in a shelter complex headquarters with lines only to its own shelters of responsibility and a few lines to other civil defense bodies is an alternate solution to these problems.

1. Advantages

The existence of ac power in a shelter complex headquarters is assumed. If this ac power will not be continuously available a battery supply (24 Vdc) may be employed as a backup. Such battery supplies are off-the-shelf items that are available from the telephone companies.

The use of small (40 lines or less), manual switchboards yields simple equipment which should achieve high levels of reliability.

2. Disadvantages

A switchboard cannot be properly operated by an untrained person; therefore, it is essential that one or more members of the shelter complex headquarters be a trained switchboard operator and also be in the headquarters when required.

Considering only the shelter complex headquarters, approximately 30,300 switchboards of 30 to 40 lines each are required. (See Fig. A-1 for derivation of quantities.) It is estimated that 227,000 switchboards are now in use at present. The headquarters boards, if new, would require a growth of 13.4 percent in the total number of boards. If it is further assumed that nominal switchboard production is geared to the average annual growth rate of the number of telephones (4.3 percent) then it is clear that a manufacturing bottleneck might be encountered.

Finally, loss of switchboard electric power at a shelter complex headquarters will disable all telephones associated with it.

3. Local Battery Operation

It is possible, of course, to operate a telephone plant without employing a large central power plant at the switchboard. Many early rural (and even a few present-day) telephone companies operate without the "common battery." Typically, a few dry cells are located at each telephone to power the carbon microphone. After a connection is established, the wire circuits carry only the talking currents--no direct current flows in the lines.

In common battery systems, a direct current flows when a telephone is "off-hook," and no current flows when a telephone is "on-hook." The flow of this direct current is employed to indicate (1) to the switchboard that a telephone is requesting service, (2) that a telephone is busy, (3) that a telephone has answered a ring, and (4) that a telephone is on-hook at the end of a conversation.

When "local battery" operation is employed instead of common battery operation, a different means of indicating these four conditions is necessary. A hand-cranked ringing magneto is used for some of these purposes. To call the operator when initiating a call, the magneto must be cranked. To indicate the end of a call, it must be cranked again. The operator must monitor a called line to determine if a party has answered. Seeing a plug in the switchboard indicates the line is busy.

Little is necessary to establish a wire communication system of this sort. Longer and poor quality wire circuits can be tolerated as there is no need to maintain adequate direct current flow in the line itself. Only a small battery supply (the order of a few flashlight cells) is required to operate the switchboard at the shelter complex headquarters.

Commercially available switchboards of the manual magneto variety are likely to be in very low production. (This does not apply to militarized equipment, however.) Special arrangements are required at both the telephone sets and the switchboards if compatibility with common battery operation is to be achieved--thus allowing use of existing commercial facilities.

The switchboard operator takes longer to complete a call on a manual magneto board, thus reducing the peak rate at which calls can be handled.

A fresh set of batteries must be maintained at all telephones and switchboards.

D. LONG-HAUL WIRE CIRCUITS

Wire circuits with a physical length of less than five miles typically consist only of a twisted pair of copper conductors, ranging in size from 19 to 26 gauge. Due to transmission losses, it is usually necessary to install amplifiers in the long haul (greater than five miles) circuits. To achieve high utilization of the physical circuits, multiplexing equipment is employed. This permits the superposition of several (typically 12) voice circuits on a single pair of conductors. The cost of this multiplexing equipment is low enough, at the present time, to justify its use on circuits as short as 20 miles.

The implication of amplifier (repeater) and multiplex (carrier) equipment use is that the long haul circuits are less reliable than short haul circuits. This follows from (a) the use of electronic equipment, and (b) their dependence upon a source of electric power.

Since the typical distances from shelter to shelter complex headquarters are of the order of 0.2 miles in large cities, one mile in rural areas, there is little concern here for the availability of telephone circuits. Between shelter complex headquarters and a city/county EOC, the average distances range between 4 and 15 miles (urban and rural cases), so circuit reliability becomes a matter of concern. With an average distance of 100 miles between state EOC's, circuit reliability should be a major concern.

E. LINE LOAD CONTROL

In those central offices equipped with "line load control" it is possible to prevent one or more groups of subscribers from originating telephone calls. The completion of telephone calls is not affected, however. A subscriber denied originating service can still be called by a subscriber not so denied.

The effect of line load control is to reduce the peak switching load on a central office, thereby eliminating the severe congestion that can hinder emergency or critical calls. When such peaks occur (usually at times of local emergency, such as at the onset of severe weather) the recovery of the central office from the severe congestion can be slow--line load control can be used to speed the recovery time.

Typically the activation of line load control is effected manually and may need to be imposed for only a few seconds at a time. The net effect to the subscriber who is affected is an increased delay in obtaining dial tone. At the central office, lines to critical subscribers (police, fire, doctor, hospitals, etc.) are specially identified and not included in those lines upon which line load control is exercised.

The use of line load control has two implications with respect to civil defense operations:

(1) It facilitates the service of critical calls

(2) It can extend the life of the emergency power supply of a central office.

With respect to this last point, it should be noted that the electrical load of a central office (considering the mechanical types as opposed to the extremely new electronic versions) increases with the calling load. If it becomes necessary to reduce the electrical load, then line load control can be employed to achieve this.

F. ELECTRONIC SWITCHING SYSTEMS

Electronic Switching Systems (ESS) for telephone use became commercially operational during 1965 when equipment was introduced into the telephone system by the Bell System and by Automatic Electric. These new forms of switching systems are based upon present day computer techniques employing solid-state electronics, and stored programs (as opposed to only wired programs).

The rate at which these new systems will be introduced into the telephone plant is dependent upon growth characteristics, operating company finances, and production facilities. It appears that by 1970 some 20 percent of all telephone lines might well be served by ESS's.

The significance of ESS upon CD operations is hard to assess at the present time, due to uncertainties regarding the exact nature of the ESS; however, the flexibility inherent in the stored program approach should make it possible for unusual CD requirements to be more readily accommodated. The use of solid-state circuitry should be beneficial in terms of reliability and power requirements.

G. LOCALLY IMPLEMENTED EMERGENCY TELEPHONE SYSTEM

One can conceive of situations where, because of unexpected developments, incomplete planning, communication equipment failures, etc., it becomes highly desirable to establish a local telephone connection between relatively closely spaced shelters, i.e., shelter-to-shelter, shelter-to-SCH, or from a private shelter to a nearby public shelter.

The over ninety million telephone instruments in the country provide a widely dispersed and readily available communications capability. Two standard commercial telephones connected directly together by a pair of wires, with as little as 1.5 Vdc in series with one of the wires can provide adequate communications over a mile or more. (Sound-powered telephones will also work over similar paths, without the power supply requirement, but are not normally readily available for emergency use.) The "old-fashioned" single-wire ground return system could also be used, again with a modest voltage source. The voltage required would be dependent on the path length, adequacy of ground connection, ground conductivity, etc.

The problem of stringing the interconnecting wires presents some interesting problems. If in a delayed fallout area, wires could be laid between locations subsequent to the warning but prior to taking shelter--either directly on the ground or overhead across roads, streets, paths, etc. In some cases ducts, culverts, or building crawl spaces might be used. Following the "take shelter" where vehicles were immobilized, a messenger going between shelter locations might pay out wire from a reel during the trip to establish a communications link.

In addition to the telephone instruments, such a system would require the necessary wire, (preferably on an easy pay-out reel or spool), the battery and connector, and if a single wire system, suitable grounding, i.e., water pipe, pre-emplaced ground connection, burying a length of bare wire in the ground, etc.

A number of different models of telephone instruments might be encountered. Some will have more than the two "line wires" in the connection cord, and other confusing situations can be anticipated. It would be desirable to provide information in the shelter on interconnection of various standard telephone models, including simplified circuit diagrams and the color coding or terminal designation of the correct contact points. The location and polarity of the batteries should also be established and standardized.*

* One of the authors briefly experimented with such a setup. Two standard telephone units were connected with 50 ft of wire and the resistance equivalent of an additional 2000 ft of No. 26 AWG pair, with 1.5 Vdc in series with one of the wires. This provided excellent communications. The effect of putting 1.5 V batteries

The suggested setup does not provide for signaling between instruments. Low-voltage buzzers, neon lights, magneto generators or other signaling facilities could be provided, or one could specify periodic checkins at both terminals.

H. WIRE EQUIPMENT AND FACILITY CHARGES

Typical commercial rates for installation and monthly rental, both standard telephone equipment and facilities, are listed in Table V. Table VI lists typical equipment purchase prices.

Users of large numbers of communication channels can, under certain conditions, obtain the use of telephone company facilities at reduced rental rates. This low-cost bulk communication service is known as Telpak. The Telpak tariffs (i.e., statement of services and rates offered) presently approved by various Federal and state utility regulatory agencies are being reviewed; it is possible that the rates will be raised or the series abolished.

Telpak A provides 48 kc/s of bandwidth channel (equivalent to 12 voice bandwidth channels) for a rental of $15 per mile per month. Typically a single voice bandwidth channel costs $3 to $4 per mile per month. Thus, if six or more voice bandwidth channels exist between a given pair of points, an economy can be achieved through the use of Telpak A. Wide-bandwidth channels can also be used for high-speed data transmission, (40.8 kilobits/second), facsimile, and teleprinter use. Larger bandwidths, up to 1 Mc/s from Telpak D, are available.

When considering problems of survivability it must be observed that the failure of a single wideband circuit can result in the loss of communication to all channels that are its components.

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at each end of the line was also studied. When the batteries were installed with opposing polarities, the performance, as expected, was vastly degraded, although the very faint message was still discernible. In fact, over modest distances, with <u>no</u> batteries, shouting into the receiver unit produces sufficient signal for an awkward but usable communications link.

Table V

TYPICAL RENTAL COSTS FOR WIRE COMMUNICATION EQUIPMENT

Equipment or Facility	Installation Charge	Monthly Rate
Switchboards (PBX)		
12-station manual*	$ 80	$12
60-station manual*	200	22
40-station dial	120	17
120-station dial	250	30
Remote Jack for Extension Phone	7.50	0
Telephone Instruments		
Extension phone with plug for jack	0	1
Telephone connected to PBX	4	1
Telephone connected to local exchange line	10	5+†
Wire Lines		
Trunk line to local exchange	10	2.50 + call charge
Private tie line between PBX's and/or telephone installations	10	4.00/airline mile§

* Availability of manual switchboards may be limited.

† Dependent on usage.

§ About 10 percent less for longlines beyond local exchange area.

Table VI

TYPICAL PURCHASE COSTS FOR WIRE COMMUNICATION EQUIPMENT*

Equipment or Facility	Cost Used	Cost New
Telephones		
Standard commercial instruments	$ 3 - 10	$16 - 30
Army field phones (EE-8)	17 - 28	40
Switchboards		
Military surplus, e.g., BD-71, 72, 89, 96, etc., 12-80 drop boards	30 - 700†	
Wire		
Army field wire, W 110 (surplus)	55/mile	
Twisted pair, WD-1	80/mile	

* These figures are derived from a limited number of sources and are believed to be representative, but are not the result of a detailed price survey. Where surplus equipment is involved, a widespread demand for significant quantities from the limited supply available would obviously affect the price structure. One California source indicated a stock of Army surplus field communications equipment including 10,000 magneto telephones, several thousand assorted switchboards, and 2000 miles of wire.

† Depending upon type, quantity, and condition.

I. OTHER WIRE SERVICES

1. Special Local Circuits

In some local government areas special wire circuits exist for voice, telegraph or other coded alarm message transmission. Depending on the nature of the circuits and the locations of terminals, these circuits may be useful--as is or with reasonable modification--as an additional communication capability for the CD emergency system.

For fire alarm box systems, a preferred configuration is a closed loop--or a number of loops--each connecting a group of fire alarm boxes with the central fire office in a continuous series circuit. This circuit may have a current flowing through it to provide indication of a line failure. While it is conceivable to superimpose a voice signal on such a circuit, it does not appear likely that the fire alarm boxes would be normally located in or near enough to shelter areas to be beneficial.

2. Data Communication

Data communications deals with the transmission of digital information, as opposed to analog information. (Analog transmission is in predominant use now in voice, video, program and facsimile applications.) Typically data communications involves the exchange of data between two machines, such as computers, displays, digital sensors, and keyboards.

No need for communication between machines (teleprinters are excluded here as they are usually treated as a separate communication mechanism) is apparent in the local civil defense requirements, circa 1970.

The future of data communications is destined to bring many changes, however. One change of particular interest here is the advent of the "touch-tone" or push-button telephone, now in operation in the present plant and certain to find increasing application. Ten pushbuttons (one for each digit 0 through 9) replace the familiar dial. Depressing a key causes transistorized oscillators to generate a unique pair of audio frequencies for detection at a distant point where the local central office interprets the tones to determine the number being called. Once a connection is established either voice or the pushbutton signals can be employed. Thus it is possible to use such a Touch-tone telephone to send data directly to a computer. The civil defense implications of this latter possibility are unknown at this time, but the potential usage of this capability is worthy of further consideration.

3. Community Antenna Television Systems

Community antenna television (CATV) systems were initiated to supply quality TV signals to areas shielded from direct TV reception, or beyond the range or in fringe (poor signal quality) areas. Recent trends show substantial continuing growth and actual and potential penetration into urban areas. This is credited in part to an increasing desire for improved TV signals, augmented by the current upsurge in color television sales. Another trend in CATV is an increasing number of channels; many of the newer installations can provide 12 independent video channels.

Data from a recent report to the FCC[39] provide the basis for the estimate of over 1500 CATV systems now in operation, with one and a half to two million subscribers. The same source shows that of 59 U.S. cities of 100,000 or more population, 15 have CATV systems operations, 4 are franchised but not yet in operation, and 40 have franchise applications pending.

Thus, there exists the growing capability for broadband information distribution throughout substantial portions of the country, both rural and urban. While designed as a one-way distribution system, the coaxial distribution cable is not unidirectional; with some supplemental design and equipment installation, a modest two-way communication capability might be added to a CATV system without interfering with its primary function.

Some communities, during their franchise discussions, have negotiated free CATV connections for churches, schools, and/or hospitals. Shelters might be an appropriate addition to this list, providing an inexpensive standby communication potential. Even if only the one-way distribution system were available it could have a substantial value during the in-shelter period in providing multichannel television inputs while eliminating the antenna requirements.

This subject is worthy of further study to establish the extent of and problems associated with its use for CD emergency communications.[40]

VI MESSENGER SERVICE

Although the great bulk of communications between CD organizations during the emergency period would be by wire and/or radio networks, there may be circumstances where by plan or because of equipment failure it becomes necessary to use messengers to carry messages from one location to another, such as from the shelter to the SCH. An SRI study developing Appendix E2 of the Federal Civil Defense Guide postulates a maximum of 1500 ft between shelters and their related shelter complex headquarters, in part to allow for messenger service.

If such messenger service were used, it would be necessary to know the approximate outside radiation intensity, and for the messenger to know the route to and location of this destination. It would be very desirable to have some concept of the obstacles and/or debris along the route and for the messenger to be provided with protective covering to minimize the attachment of radioactive material to his clothes or body. It would obviously be appropriate to assemble all available information for transmission to minimize the number of trips.

If one assumes a 7-1/2 mph rate (about three times normal walking speed and corresponding to an 8 minute mile), a 1500-ft trip would require 2-1/4 minutes. If the local radiation intensity at the time of the trip were 600 Roentgen per hour, this would entail a 23 Roentgen incremental dosage for the messenger.

Appendix A

GENERALIZED AND SPECIALIZED COMMUNICATIONS SYSTEMS MODES

Appendix A

GENERALIZED AND SPECIALIZED COMMUNICATIONS SYSTEMS MODES

1. EMERGENCY COMMUNICATION SYSTEM MODEL

Figure A-1 is an example of a generalized representative State CD emergency communications system, using the model and assumptions of Fig. 1. It is based on the primary use of wire communications, but provides for back-up radio communications between all echelons *

Three types of communication requirements are covered:

(1) Operational communication between echelons of government; i.e., shelter-SCH-city/county-state;

(2) Internal communications at any organizational echelon.

This has two aspects:

(a) Communication within the shelter, SCH, or EOC. These are presumed to be primarily by personal contact and messenger within a fallout protected area, thus not requiring significant amounts of equipment or facilities;

(b) Communication with field agencies of functional areas of local government, such as fallout-protected police precinct stations, firehouses, hospitals, corporation yards, motor pools, etc. (These communication links could be to personnel from such facilities occupying nearby shelters if the protection factor (PF) of the facilities is inadequate);

(3) Liaison and coordination--communication with the nearest emergency broadcast station (EBS), with any nearby military organizations, and with two or three adjacent communities.

The volume of communications between and amongst various echelons, the anticipated usage of channels--common versus sole users--and

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* In some instances, because of distances, topography, existing capability, or economics, greater use of radio in preference to wire communications may be indicated.

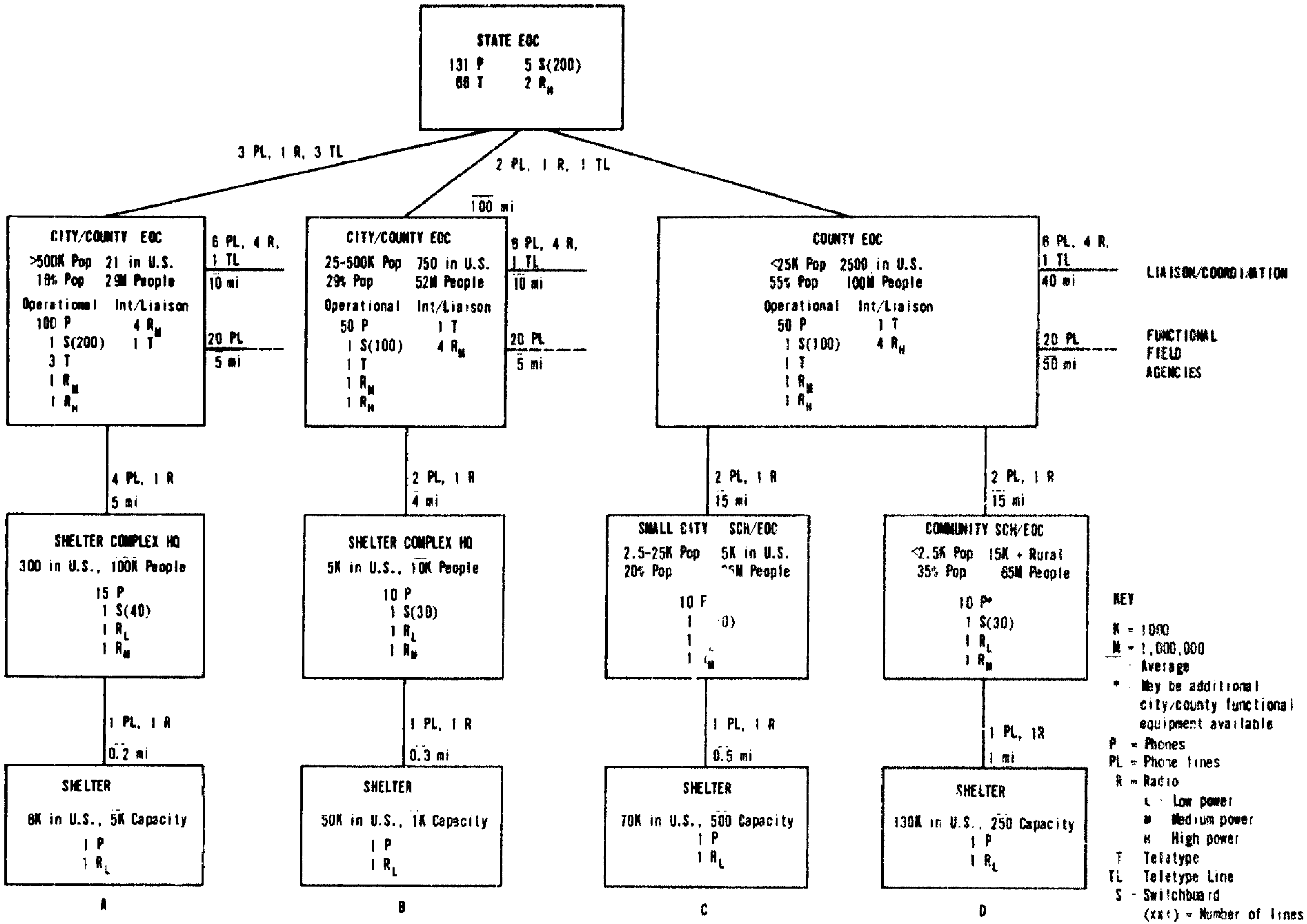

FIG. A-1 REPRESENTATIVE STATE-WIDE COMMUNICATION EQUIPMENT/REQUIREMENT MODEL special equipment requirements such as teletype links are drawn from the Requirements Study. These vary, depending on the size of the community involved and the target category.

Based on these channel requirements, and the organizational scale-up factors implied in the distribution of people and organizational echelons within the various community size groupings, representative numbers of communications equipments are developed for each echelon to implement the requisite communications capability.

Each shelter is allocated one telephone and one radio transceiver. Each SCH is allocated two transceivers, one for communication in the city/county net; the other is net control station for the assigned shelters. A 30-40 line switchboard and 10 to 15 telephones are indicated for the SCH communications center to handle the traffic with 10 to 25 shelters and two to four channels to the city/county EOC.

Similar considerations are involved in the equipments indicated for the city/county EOC's. It is recognized that the EOC set-up and requirements will vary widely, dependent on factors described in the body of the report. In many instances, the switchboards will not be physically located in the SCH or EOC, their function being fulfilled by local commercial dial offices. In fact, in many instances much of the communications equipment for the city/county EOC could and should be that used for normal operations. Some communities now operate with an EOC type structure in fallout and/or blast protected facilities. Other communities have established EOC's for use in emergencies, with alternative or spare communications equipment--both radio and wire--installed and periodically checked.

It is assumed that the existing radio equipment of the police, fire, public works, and other functional areas would be used at the EOC and the field sites to establish their respective radio communication links; hence, no separate communication facilities are included for this function, except the phone lines to functional field sites. This presumes that emergency plans call for timely distribution of mobile radios to functional field sites (and to the EOC if not equipped with the regular or alternative base station equipment*) at the onset of the emergency period.

In the city/county EOC equipment listing, two radios are included for the EBS network--one at the EOC, the other at the EBS station(s): one radio for adjacent community coordination, and one for the military liaison net. (The latter might be provided by the military organization concerned.)

No shelter-to-shelter or SCH-to-SCH direct links are shown on the chart. The backup radio nets provide a capability for direct lateral communication and either private or commercial switchboard interconnection is possible. There would be some advantage in having these installations connected directly by wire, particularly to provide alternative routings in case of line failures external to the sheltered areas.

Radio equipment has been arbitrarily divided into three power levels--low power (for communication parts up to and about three miles), medium power (for distances of three to fifteen miles), and high power (for distances up to 100 or more miles). Actually, other factors--described in Sec. IV, e.g., antenna height, operating frequency, interference and topography--will also be involved in establishing power requirements. The purpose of this rough division is to provide a first order feel for the cost and complexity of the radio equipment involved at the different echelons.

Figure A-2 expands these representative state requirements to a nation-wide scale. This helps to point up those organizational levels and communication channel requirements calling for substantial quantities of equipment and/or extensive facilities. It is apparent from this that the significant equipment requirements are found at the lower echelons--shelters and SCH's; whereas the major wire line (telephone and teletype) distances are at the city/county to state links.

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* In some cases, transmitter sites may be remote from both normal and emergency operating centers, with provision for operation of the base station remotely from either center.

ORGANIZATIONAL LEVEL		NATION-WIDE TOTAL OF ORGANI-ZATIONAL LEVELS	AVERAGE SPACING MILES	NO. OF LINES/ORG.		LINE MILES		NO. OF EQUIPMENTS/ORG.				EQUIPMENT TOTALS							
													SWITCHBOARD						
				P	T	P	T	P	S	T	R	P	200	100	30-40	T	R_H	R_M	R_L
State EOC		50	300					131	5	66	2	7K	250	0	0	3K	100	0	0
Lines Between	A	21	100	3	3	6K	6K	–	–	–	–	–	–	–	–	–	–	–	–
	B	750	100	2	1	150K	75K	–	–	–	–	–	–	–	–	–	–	–	–
	C, D	2.5K	100	2	1	500K	250K	–	–	–	–	–	–	–	–	–	–	–	–
			OPN/INT.																
City/County EOC	A	21	10/5	6/20	1/0	3K	200	100	1	4	6	2K	21	0	0	84	21	105	0
	B	750	10/5	6/20	1/0	120K	5K	50	1	2	6	38K	0	750	0	1.5K	750	3.8K	0
	C, D	2.5K	40/20	6/20	1/0	1.6M	800K	50	1	2	6	125K	0	2.5K	0	5K	12.5K	2.5K	0
Lines Between	A	300	5	4	0	6K	0	–	–	–	–	–	–	–	–	–	–	–	–
	B	5K	4	2	0	40K	0	–	–	–	–	–	–	–	–	–	–	–	–
	C	5K	15	2	0	150K	0	–	–	–	–	–	–	–	–	–	–	–	–
	D	20K	15	2	0	600K	0	–	–	–	–	–	–	–	–	–	–	–	–
S.C.H./Comm.	A	300	–	–	–	–	–	15	1	0	2	5K	0	0	300	0	0	300	300
	B	5K	–	–	–	–	–	10	1	0	2	50K	0	0	5K	0	0	5K	5K
	C	5K	–	–	–	–	–	10	1	0	2	50K	0	0	5K	0	0	5K	5K
	D	20K	–	–	–	–	–	10	1	0	2	200K	0	0	20K	0	0	20K	20K
Lines Between	A	6K	0.2	1	0	1K	0	–	–	–	–	–	–	–	–	–	–	–	–
	B	50K	0.3	1	0	15K	0	–	–	–	–	–	–	–	–	–	–	–	–
	C	70K	0.5	1	0	35K	0	–	–	–	–	–	–	–	–	–	–	–	–
	D	130K	1	1	0	130K	0	–	–	–	–	–	–	–	–	–	–	–	–
Shelter	A	6K	–	–	–	–	–	1	0	0	1	6K	0	0	0	0	0	0	6K
	B	50K	–	–	–	–	–	1	0	0	1	50K	0	0	0	0	0	0	50K
	C	70K	–	–	–	–	–	1	0	0	1	70K	0	0	0	0	0	0	70K
	D	130K	–	–	–	–	–	1	0	0	1	130K	0	0	0	0	0	0	130K

For description of symbols, see Fig. A-1.

FIG. A-2 SUMMARY OF REPRESENTATIVE NATIONWIDE EQUIPMENT/FACILITY REQUIREMENTS

2. SPECIALIZED COMMUNICATIONS SYSTEMS

Representative communication networks for a city of about 100,000 population have been prepared based on the established model to assist in the economic and operational analysis of different types of systems. Figure A-3 through A-5 illustrate, respectively, a private wire network, a public wire network, and a radio network. Each covers the echelons from individual shelter through the city EOC, and includes the local portion of the state-wide network.

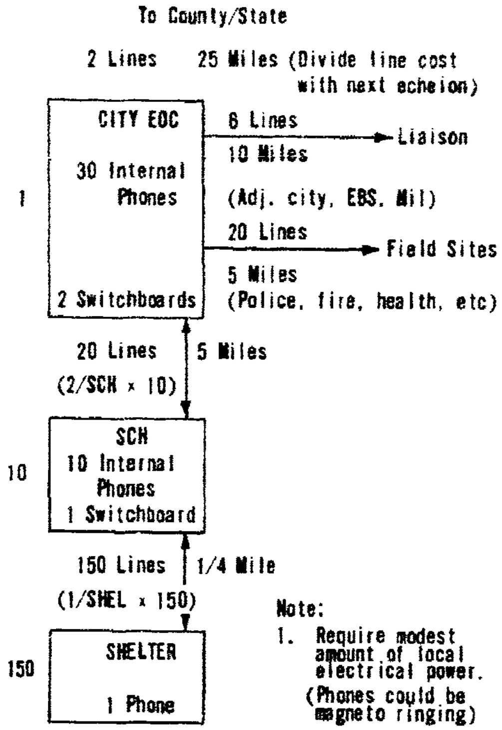
The networks are similar but not identical in terms of communication channels. For instance, the radio network provides one radio set at the SCH for each three shelters in its area, and two SCH radio sets for communication with the EOC--one on a sole-use basis and one in a net with all other SCH's and the EOC. The wire systems provide individual phone line connections between the various organizational levels.

The alternative plan indicated in Fig. A-4 suggests one approach to an economical emergency communication system implementation. It assumes that

(1) The local telephone system has a high probability of operating satisfactorily throughout the emergency period; and

(2) The public fallout shelters are located in buildings where telephones are installed for normal building usage, but not necessarily available in the shelter area.

Specified telephones in each shelter building (including SCH's) would be equipped with jacks and plugs at their normal location. From each such phone, a remote extension line would be run to the desired spot in the shelter area, terminating in a jack. This would entail a one-time installation charge of, typically, \$7.50 per line and jack, with no continuing monthly charge. To activate such a system it would be necessary to ensure that a telephone (preferably equipped with a matching jack, although most telephones could be readily adapted to a plug connection within the shelter if necessary) be brought to the shelter (10 for SCH's) at the onset of the emergency. This requirement



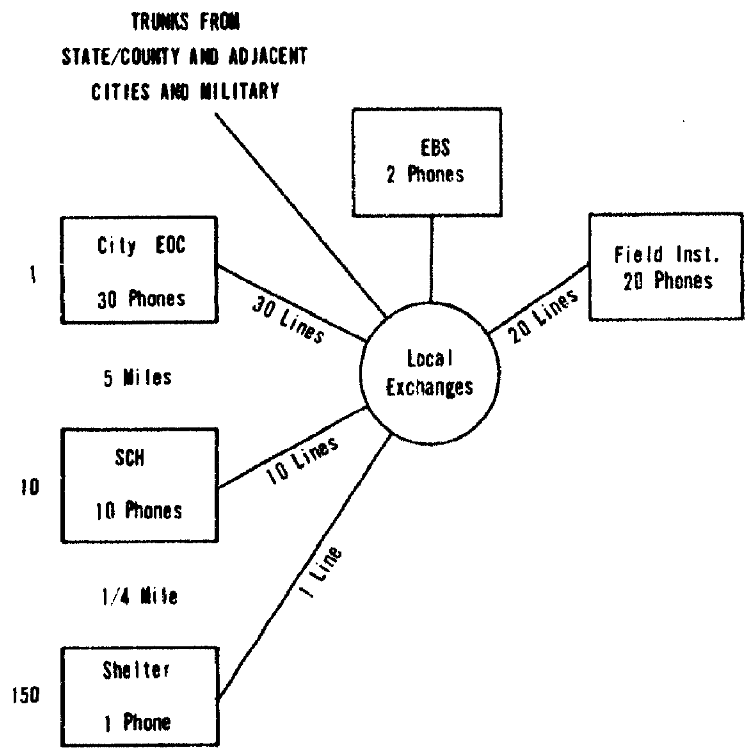
Note:
1. Require modest amount of local electrical power. (Phones could be magneto ringing)
2. Would probably want to interconnect to local dial system.

EQUIP.	LINES	LINE MILES	INSTALLATION CHARGES* Equip. $	Line $	MONTHLY CHARGES* Equip. $	Line $
	2	25	--	20	--	100
*2 PH	4	*40	8	40	2	160
30 PH	--	--	120	--	30	--
2 SWBD			400	—	44	--
20 PH	20	100	80	200	20	400
--	20	100	--	200	--	400
100 PH	--	---	400	--	100	--
10 SWBD			2000	--	220	--
--	150	38	--	1500	--	150
150 PH	--	--	600	--	150	--
			3608	1960	566	1216
			$5568		$1776	

* EBS Phones; adjacent cities and military provide own phones and ½ of line.
PH = $4
SWBD = 200
Line = 10

† PH = $1
SWBD = 22
Line = 4

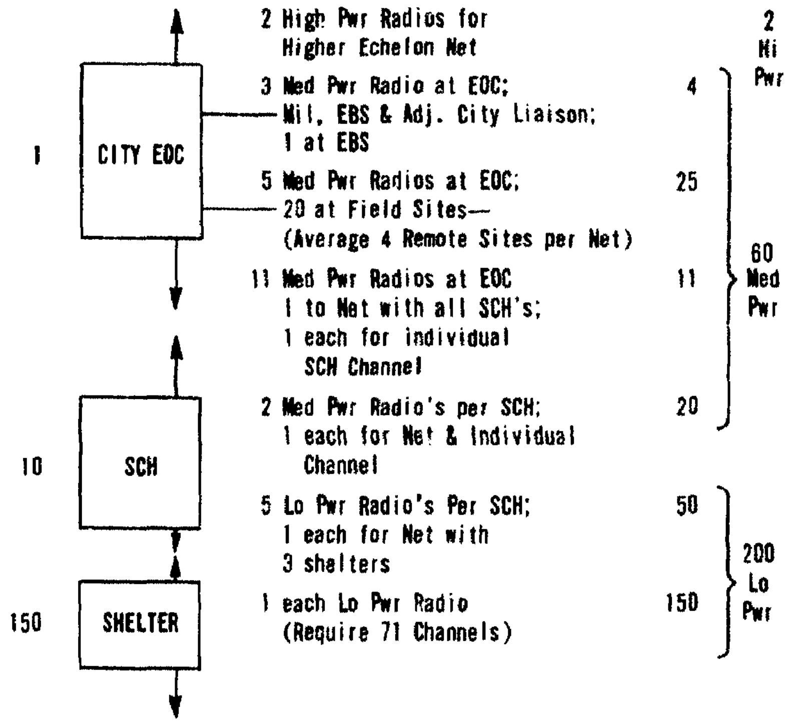
FIG. A-3 CD PRIVATE TELEPHONE NETWORK FOR COMMUNITY OF 100K POPULATION



CONVENTIONAL PLAN			ALTERNATIVE PLAN	
Phones	Inst. Charge $10.00/Ph.	Monthly Charge $5.00/Ph.	(Put in remote extension jacks at SCH and shelter locations from active lines in shelter buildings, and bring plug-in phones in during emergency period.)	
			Instal. Chg.	Monthly Charge
52	520	260	Use existing Facilities	
100	1000	500	750	*0
150	1500	750		
	$3020	$1510	$750	$*0

* Phones could be provided for these extension outlets at $1.00/month each.

FIG. A-4 CD PUBLIC TELEPHONE NETWORK FOR COMMUNITY OF 10K POPULATION



INITIAL COST EQUIP. & INST.		OPERATIONAL COST MAINTENANCE & POWER/MONTH	
@ $ 1,100	$ 2,200	@ $ 10	$ 20
@ 850	51,000	@ 8	480
@ 300	60,000	@ 6	1,200
	$ 113,200		$ 1,700

FIG. A-5 CD RADIO NETWORK FOR COMMUNITY OF 100K POPULATION could be eliminated by rental of an extra extension phone for each location at a charge of, typically, $1.00 per month, or by outright purchase of telephones at cost of $5.00 to $10.00 used and $30.00 to $40.00 new.*

If, in addition, arrangements were made with local commercial concerns having licensed mobile business radios, auxiliary radio nets at various echelons could be provided at minimum cost. This could be established by a prearranged plan whereby the radio-equipped commercial vehicles would move to prescribed shelter locations promptly upon receipt of the warning signal, perhaps prior to the general warning. Removal of the vehicular radio equipment to the shelter or provision for its remote control from the shelter, the antenna requirements, local power, operational frequency, license restrictions, operating personnel and other matters would have to be considered.

Table A-I provides a cost summary of the various communication networks postulated in Figs. A-3 through A-5, as well as a listing of some of the advantages and disadvantages of radio and wire systems for the indicated operations.

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* This purchase concept has a number of potential ramifications to be explored; particularly those relative to attachment of "foreign" equipment to commercial facilities.

Table A-I

SUMMARY OF COMMUNICATION NETWORKS
FOR COMMUNITY OF 100K POPULATION

Type System	Initial Cost-- $	Monthly Costs-- $	Five-Year Total $ (To Nearest $100)	Total Average Monthly $	Ref.
Radio	113,200	1,700	215,200	3,590	Fig A-5
Private Phone	5,568	1,776	112,100	1,870	Fig A-3
Public Phone					Fig A-4
Primary	3,020	1,510	93,600	1,560	
Alternative	750	0	750	12.50	

NOTE: Message capabilities of three systems are no identical, but are roughly comparable.

COMPARISON OF RADIO AND WIRE NETWORKS

Radio	Wire
Independent of wire system	Public system dependent on local exchange
Requires local power source	Lower power requirements
Requires 71 channels	No interference/interception problems
Requires trained operators	Except for switchboard, no operator training
Probably require people coming to radio to communicate	Equipment can be distributed conveniently
Except for antenna, relatively insensitive to blast and thermal effects	Overhead lines and other exposed facilities vulnerable to weapons effects
More likely to require skilled maintenance during use period, plus test equipment and spare parts	Minimal probability of maintenance problems
Radio circuit can broadcast to many receivers simultaneously.	Public system can provide additional connections through direct dialings. Private system restricted unless tied into public system.

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	Office of Civil Defense Department of the Army - OSA Washington, D.C.

13. ABSTRACT

This report provides a compilation of data covering both wire and radio communication systems and facilities of value for civil defense application. The general characteristics of the items are discussed and their potential application in a representative communications or command and control model is illustrated. Representative costs are provided. The discussion of the various communication systems and typical items of equipment generally identifies their salient operational strengths and weaknesses. A number of conclusions and recommendations relative to existing and potential CD communications systems and equipments are presented.

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UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Communications						
Communication systems						
Communication equipment						
Emergency Communications						

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